FINAL ASSEMBLY, TESTING AND PROCESSING OF THE RIGIDIZABLE INFLATABLE GET-AWAY-SPECIAL EXPERIMENT (RIGEX) FOR SPACEFLIGHT QUALIFICATION

THESIS

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AFIT/GA/ENY/07-S02

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Abstract

The purpose of this research is to complete the building, testing, verification, and qualification of the Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) for spaceflight. The process of qualifying a payload for spaceflight is discussed, specifically addressing the issues of operability and survivability verification of a general payload. The spaceflight qualification process is then applied to the RIGEX payload at the Air Force Institute of Technology (AFIT) and at the Johnson Spaceflight Center (JSC) in Houston, TX, capstoning the work of 12 masters' students and 3 summer interns that has already gone into the RIGEX project over the last 7 years.

The culmination of this effort is the necessary documentation required to turn the RIGEX payload over to the National Air and Space Association (NASA) in preparation for its launch in February 2008.

This work is dedicated to my family whose sacrifice made this effort possible.

Acknowledgements

I would like to express my sincere appreciation to all the previous and present researchers on the RIGEX payload, without whose early work and down the line thinking, would have made my research more time consuming and difficult.

I would like to thank Dr. Richard Cobb, whose patience and inspiration helped to get me through this excellent learning experience. To the Space Test Program Office, thank you for all your support and knowledge. You did not help me to be a better student, rather a better engineer.

Finally, to anyone who utilizes this work in their research. Thank you for making all my work and effort count for something other than a degree.

Jeremy J. Owens

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List of Symbols

Symbol		Name	Meaning as used Here
A	………	A	Unit of current known as Ampere
psia	………	Absolute Pressure	Measure of Total Pressure
atm	………	atmosphere	Unit of Pressure (= 14.7 psia)
©	………	Copyright	Copyright exists for the word immediately next to it.
I	………	Current	Used to indicate current. Measured in Amps
dB	………	Decibel	Measure of Power
ft	………	feet or foot (unit of measure)	Unit of Length
psig	………	Gage Pressure	Measure of Pressure via a Gage which measures the difference between what it sees at the source and the gages local atmospheric pressure (usually 14.7 psia)
g	………	g	Gram- unit of mass
Hz	………	Hertz	Unit of Cycles per Second
in	………	inch	Unit of Length
kHz	………	kilo Hertz	10E3 Hz
ksi	………	kilo pound force per square inch	Force per unit Area (Pressure)
Kb	………	Kilobyte	Unit of Computer Memory (10E3 Bytes)
kg	………	kilograms	Unit of mass (10E3 grams)
MHz	………	Mega Hertz	10E6 Hz
m	………	meter	Unit of Length
μV	………	micro-Volt	10E-6 V
mA	………	milli-Amp	10E-3 A

Symbol		Name	Meaning as used Here
mm	………	milli-meter	10E-3 m
ms	………	milli-seconds	10E-3 s
NEG.	………	Negative	Used to indicate negative electrical lead
Ω	………	Omega	Unit of resistance known as ohms
POS.	………	Positive	Used to indicate positive electrical lead
lbf	………	pound force	Unit of Force
psi	………	pound force per square inch	Unit of Force per Area
lbm	………	pound mass	Unit of Mass
P/S	………	Power Supply	Used to indicate the emulator
®	………	Registered trademark	Used to indicate word to the right is a registered trademark of someone
R	………	Resistance	Used to indicate resistance measure in ohms
s	………	second	Unit of Time
~	………	tilde	Approximately
V	………	V	Used to indicate Voltage measured in VDC
VDC	………	Volts - Direct Current	Unit of Voltage with Direct Current
VAC	………	Volts Alternating Current	Unit of Voltage with Alternating Current

List of Abbreviations

ASD	……	Acceleration Spectral Density
AFIT	……	Air Force Institute of Technology
AFRL	……	Air Force Research Lab
CAPE	……	Canister for All Payload Ejections
CHUG	……	CAPE Hardware Users Guide
CMP	……	CAPE Mounting Plate (p/n RIGEX-2006-1-P)
C.G.	……	Center of Gravity
CDR	……	Critical Design Review
DoD	……	Department of Defense
EMI	……	Electro-Magnetic Interference
ERB	……	Engineering Review Board
EVA	……	External Vehicular Activity
FRF	……	Frequency Response Function
Tg	……	Glass Transition Temperature
KSC	……	John F. Kennedy Space Center (Located in Cape Canaveral, FL)
LED	……	Light Emitting Diodes
JSC	……	Lyndon B. Johnson Space Center (Located in Houston, TX)
MDP	……	Maximum design pressure
MSC	……	Marshal Spaceflight Center
MSDS	……	Material Safety and Data Sheet
Hg	……	Mercury
NASA	……	National Aeronautics and Space Association

NRL	……	Naval Research Lab
P/N	……	Part Number
PDR	……	Preliminary Design Review
PI	……	Principal Investigator
RAM	……	Random Access Memory
RITF	……	Receiving Inspection Test Facility
RD	……	RIGEX Document
RIGEX	……	Rigidizable, Inflatable Get-away-special Experiment
RTD	……	Resistive Thermal Device
STP	……	Space Test Program Office
STS	……	Space Transportation System
SVP	……	Structural Verification Plan
SWG	……	Structures Working Group
TPS	……	Task Performance Sheet (NASA JSC Form 1225)
TVAC	……	Thermal Vacuum
VTF	……	Vibration Test Facility
VDC	……	Volts, Direct Current

FINAL ASSEMBLY, TESTING AND PROCESSING OF THE RIGIDIZABLE INFLATABLE GET-AWAY-SPECIAL EXPERIMENT (RIGEX) FOR SPACEFLIGHT QUALIFICATION

I. Spaceflight Qualification of a Payload

Background

Spaceflight is a risky business. Losses of national and global resources, and most unfortunately, human life, remind us of the expense faced as we set out to explore the heavens or enhance our understanding. Fortunately, along the broken road man has been smart enough to develop checks to minimize the occurrence of such tragedies. In general, spaceflight missions are designed to deploy assets in space. Manned missions have the added capability to perform missions that retrieve, repair or re-supply space assets. It is the job of each individual component of the mission to ensure its overall success. Payload verification (according to NASA) is considered a primary step toward certification of that payload for flight [15]. In verifying the payload, one must complete:

Structural Verification – The payload is strong enough to handle the loading.
Thermal Verification – The payload will survive and operate within the thermal extremes it will be subjected to.
System Compatibility Verification – The payload mechanically has the proper form, fit, and electrically does not interfere with the overall systems operating ability.
Mission Safety Verification – Ensure that in every instance that a human being is involved that the utmost care is taken to preserve human life. The Science always comes second.

Spaceflight qualification of payloads both within the Department of Defense (DoD) and commercially is a dynamic compilation of best practices used to validate system models, fit and functionality of the system, and to ensure mission success. With manned spaceflight, extra care and concentration are rightfully placed on the safety of the personnel aboard, which only further restricts the margin for error when validating the payload. It is the responsibility of the payload organization to ensure that their payload conforms to all regulations, safety policies, and National Air and Space Association (NASA) [15]. The following is a very brief overview of the challenges that need to be overcome for spaceflight and should not be considered a complete listing.

Challenges to Overcome for Spaceflight

Unlike systems designed for use on the ground, spaceflight systems must be designed and tested to withstand the environmental elements of space, which come from both the Space Environment and Launch.

Space Environment

The space environment alone is one of the most brutal environments that our systems are subjected to. On any given orbit, a spacecraft is subjected to a variety of external forces, some of which are noted in Table 1. In general, space environment conditions are a complex set of phenomena involving the Sun and Earth [7]. A spacecraft must be built to withstand these elements and overcome there effects. Additionally, all components used on the spacecraft must withstand the effects of the space environment. Further design considerations must be made for use in space.

Table 1. Space Environmental Elements of Earth Satellites [7]

Element	Effect	Primary Source
Magnetism	**Varying strength and direction interacts with electron flow through the spacecraft**	**Earth**
Thermal (Solar Radiation)	**Half the orbit about the Earth, the spacecraft is warmed by the direct radiation from the sun. Once the radiation is blocked by the planet, the spacecraft is cooled.**	**Sun**
Debris	**Space junk. Micrometeoroids and micro-debris environments cause significant risks for manned and unmanned spacecraft**	**Many**
Upper Atmospheric Drag	**Results in a net orbital decay as the spacecraft is slowed**	**Earth**
Plasma	**Electrostatic charging of spacecraft parts or affects scientific instruments.**	**Sun**

Launch

The violent 6-minute ride to space can be just as detrimental to a system as its prolonged operational life on orbit [15]. Severe and unpredictable dynamic forces, which vary between launch systems, conditions and flight path, can literally tear apart the satellite if it is not designed properly. The satellite's main structure must be designed to withstand these dynamics loads.

Challenges to Overcome for Manned Spaceflight

A great advantage for the United States is the ability to send people into space. An advantage that, over time, has led to the ability to put payloads in orbit and then bring them back to Earth for study, data collection, or if desired, full refurbishment. In order to become spaceflight qualified utilizing the manned space vehicle commonly known in the United States as 'the Space Transportation System (STS)', the payload design, building, and testing must follow special strict guidelines set forth in NSTS_1700_7B [38]. The primary concern of this document is the safety of the human beings on board the shuttle and these guidelines have been established for their protection and safe return.

Unlike other launch vehicles, payloads designed to fly in the shuttle must also be proven to sustain loads seen during re-entry and landing. The thermal tiles on the underside of the STS protect the cargo from the extreme heating of re-entry, so thermally no further assessment is required, as the most significant thermal loading will be seen on orbit. Additionally, the landing impact loads that could be produced because of a very heavy shuttle emergency landing need to be evaluated adding additional loading cases for the structural strength verification of the payload [1].

NASA has a general flow of events that takes place prior to the launch of a system on the shuttle and is shown in Figure 1. This process can take years to accomplish. Each item must be accomplished or waived prior to the shuttles' use.

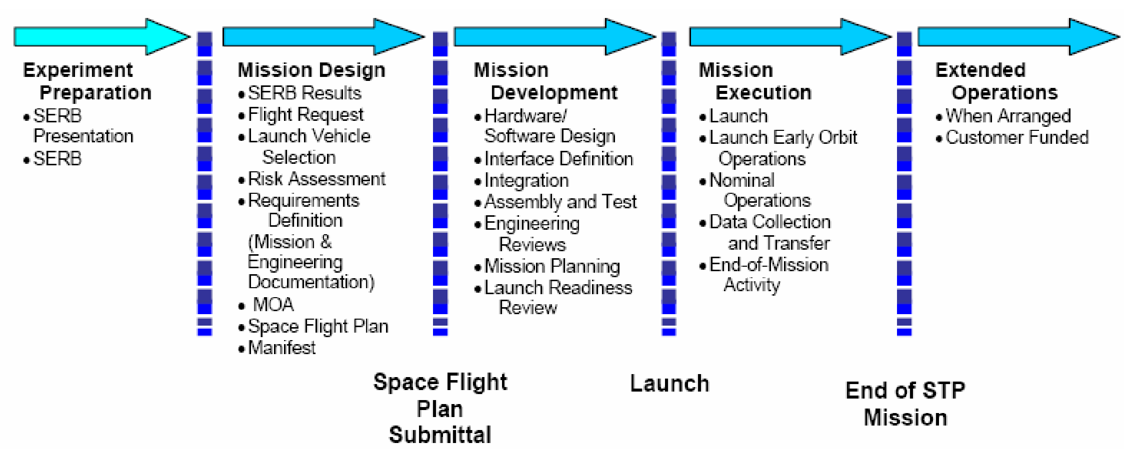


Figure 1. Mission Life Cycle Activities [11]

Considerations for Mission Success

Mission success is not defined by NASA, but by the mission planners. Every space mission starts with a technical objective - a science, technology, political, or any combination of the three. Most missions have more than one objective. Success of the mission is dependent on the extent to which the objective has been achieved. The success criteria of the mission should be completely defined before pen is placed to paper on the design of the spacecraft.

Summary of Thesis

With the above understanding of the challenges to be overcome for spaceflight qualification, this thesis work will explore the efforts of an Air Force Institute of Technology (AFIT) designed and built payload, called *Rigidizable Inflatable Get-Away-Special Experiment (RIGEX)* to become spaceflight qualified, while keeping in mind the mission success of the payload. Upon the conclusion of this work, the RIGEX payload will be ready to fly aboard the shuttle *Endeavor* on mission STS-123 currently scheduled for launch 14 February 2008.

Chapter II will explore the background of the payload, highlighting the specific work of individuals who made previous contributions to the spaceflight qualification or the mission success of RIGEX. A quick look at the individual components and sub-systems of the payload will be taken in order to verify the components spaceflight worthiness. If a component is found to be not within, the required specifications for spaceflight qualification it will be identified for the component level qualification testing that will be documented through Chapter III. Once the components are verified to be within the specifications for qualification the complete system, will tested for conformance to NASA regulations in Chapter IV. Additionally, any safety related testing that is to be done will also be documented in Chapter III if the concern is for a component or in Chapter IV if for the system or a subsystem of the payload. In Chapter V, the status of the payload will be discussed and a scheduled of the events to come for the RIGEX payload capstoning the efforts of 12 masters' students and 3 summer interns over the last 7 years.

Deliverables

The deliverables of this work are:

- Reports of testing completed by AFIT to support various NASA needs
- A complete drawing package of the as-built configuration of RIGEX
- Documentation of the as built configuration to include the consolidated Acceptance Data Package that is to be presented to NASA when the payload is handed over for integration

II. RIGEX Payload

Background, A quick look at the past of RIGEX

A great deal of effort and emphasis has already been placed on the past work that has been written and published during the evolution of RIGEX over the last 7 years. A condensed timeline summary is shown in Figure 2.

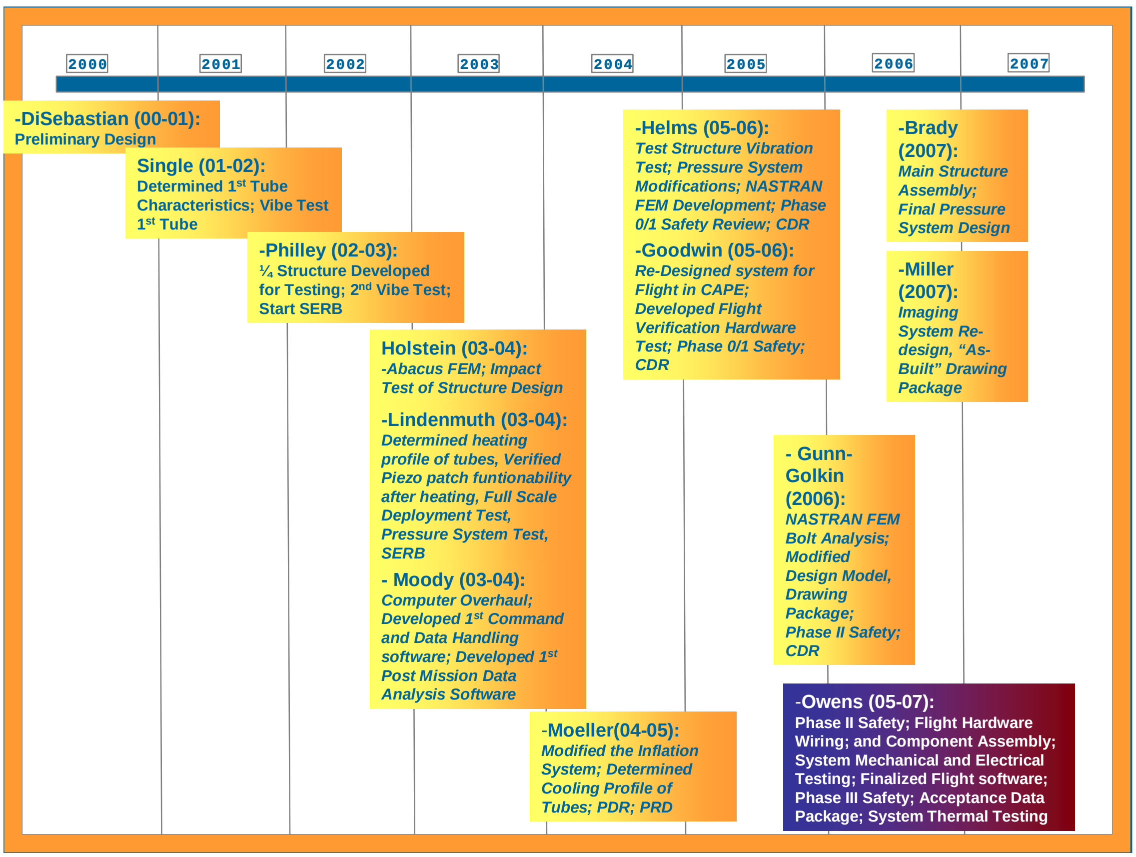


Figure 2. RIGEX Student Activity History

RIGEX – The Science

The RIGEX payload experiment was originally started by DiSebastian [5] in 2000 to investigate the plausibility of utilizing rigidizable, inflatable tubes as a type of "space lumber" for building large radar aperture support systems or other large truss systems.

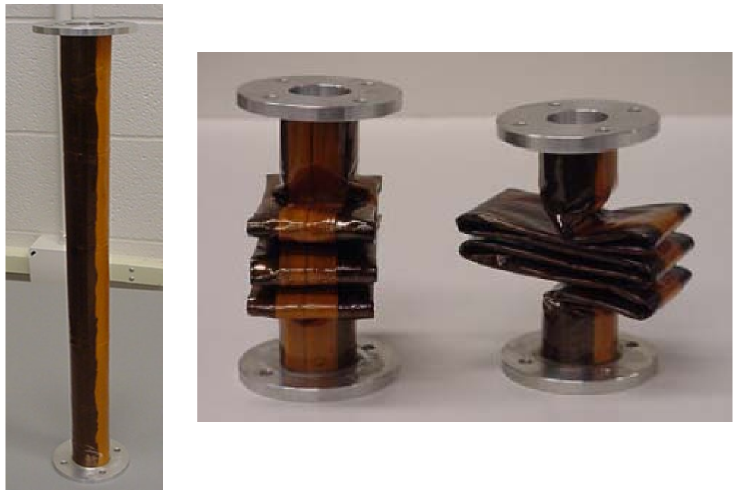


Figure 3. Rigidizable Inflatable Sub-Tg Tubes (20" long deployed) [14]

The major physical characteristics of the rigidizable, inflatable tubes supplied by L'Garde Inc [14] are as follows:

- Thermoplastic composite inflatable tubes
- Carbon fibers with polyurethane-based resin
    - o 125 °C glass-transition temperature (Tg)
    - o Tubes are rigid below Tg and pliable above
- Tube caps made of machined 6061 aluminum
    - o Base Cap = 74.02 g
    - o Tip Flange = 74.6 g
    - o Tube Material ≈ 94 g
- Wrapped in Kapton

Initially, significant ground work was done on establishing the Sub-Tg tubes structural characteristics, through vibration testing comparisons and modal analysis through frequency response functions (FRFs) by both Single [36] and Philley [34] (see Figure 4).

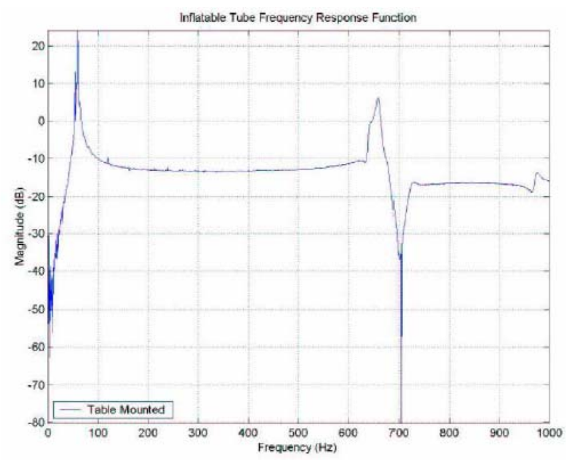


Figure 4. Sub-Tg Modal Analysis via 3-D Laser Vibrometer by Philley [34]

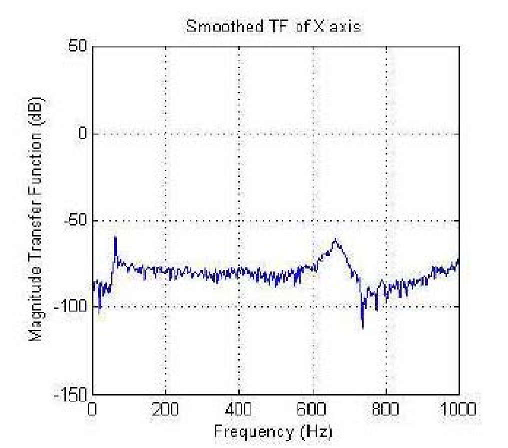


Figure 5. Sub-Tg Modal Analysis via Kionics Tri-axial Accelerometer by Goodwin [9]

Originally, the flight experiment design included a "heavy" accelerometer on top of the tube, introduced another mode that was identified by Goodwin [9] at 300 Hz. His change to the current "lightweight" accelerometer (shown in Figure 6) eliminated the mode and gave a better match to what Philley was able to determine with a laser 3-D laser vibrometer (see Figure 5).

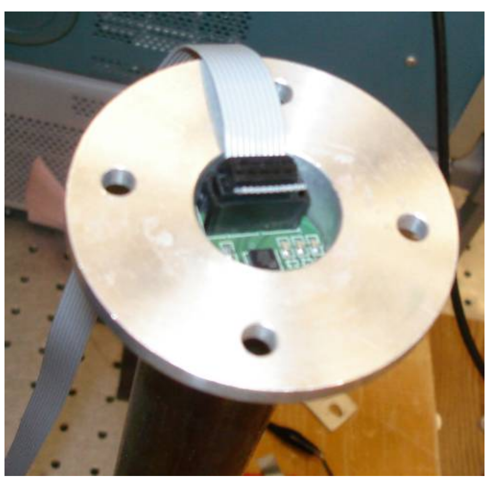


Figure 6. Lightweight Accelerometer (Kionics KXPA-4 shaped to fit into the end cap of each tube) NOTE: Shown without staking compound

Both Philley's [34] and Goodwin's [9] data was collected using separate equipment. Since RIGEX will be the test bed on orbit, a ground test using the actual flight hardware must be done to further verify the accelerometer data to have an actual direct comparison of the flight data to ground data for the modal characteristics of the tubes.

RIGEX – Support Structure

Since conception, RIGEX was originally designed for the Get-Away-Special (GAS) payload project and was re-designed as a self-contained experiment for the Canister for All Payload Ejections (CAPE) (see Figure **7**). The CAPE platform was originally developed to fill the role vacated when the shuttle program de-activated the GAS program after the Challenger incident of 2003. CAPE is owned and operated by the Space Test Program (STP) office located on Johnson Space Center (JSC) in Houston, TX. Due to the high personnel turnover rate in the RIGEX program, STP has agreed to provide technical oversight of the project and acts as AFIT's liaison to NASA.

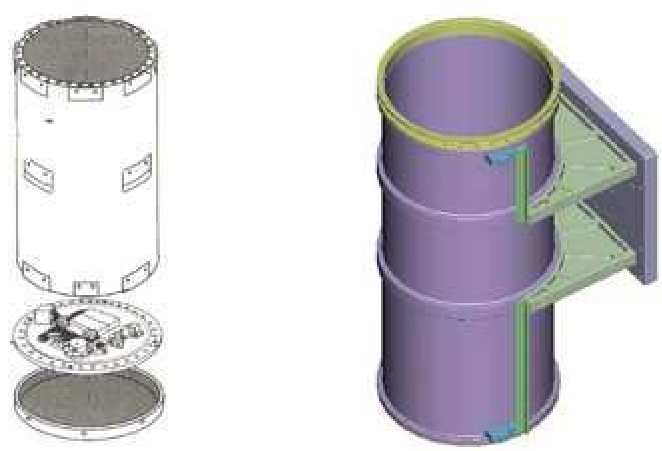


Figure 7. RIGEX Mechanical Attachment to Shuttle Comparison (GAS Can (left) and CAPE (right)) [9] NOTE: Not to scale

Initially, RIGEX was designed for flight in the Get Away Special (GAS) can provided by NASA-Goddard Spaceflight Center (GSFC). DiSebastian [5] developed the original structural concept, which was later modified by Philley [34] to fix the pressure system obstruction of the tubes that was observed in his deployment testing. Holstein [12] showed through FEM analysis in ABAQUS, later verified by Helms [11], that the ribs and fasteners were undersized for the anticipated loading during launch. In the detail design of RIGEX, Goodwin [9] made significant strides to adapt the concept to the different parameters that came from the carrier system change from GAS to CAPE (see Figure 7). Later, Gunn-Golkin's [10] bolt analysis resulted in the final placement of the structural fasteners and determined that the main structure would support the payload through launch.

RIGEX—Support Systems

Initially, DiSebastian [5] separated RIGEX into subsystems shown in Figure 8.

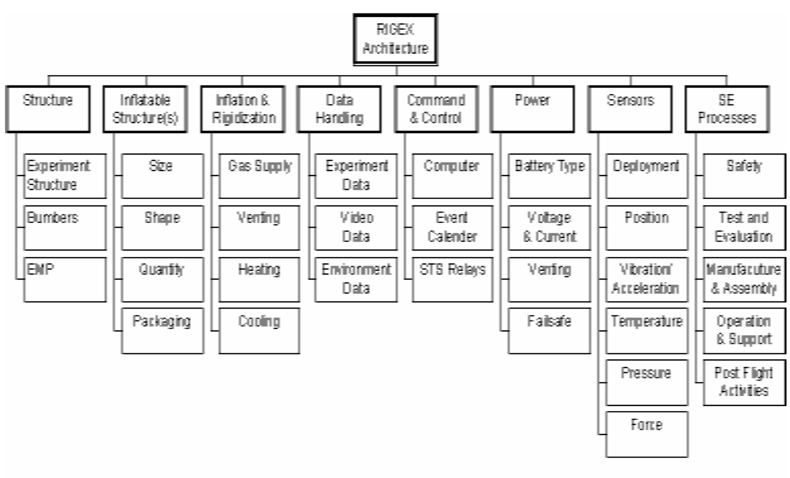


Figure 8. DiSebastian's RIGEX System Architecture [5]

Figure 8 has changed significantly over the life of this project. The final component layout can be seen in subassembly drawings RIGEX Document-5 (RD-5)

RIGEX "As Built" Drawing Package provided in Appendix I of this document. For further reference in this document, the nominal configuration of RIGEX is shown in Figure 9. From a system operation standpoint the final timeline of events for the RIGEX payload is provided in Appendix J.

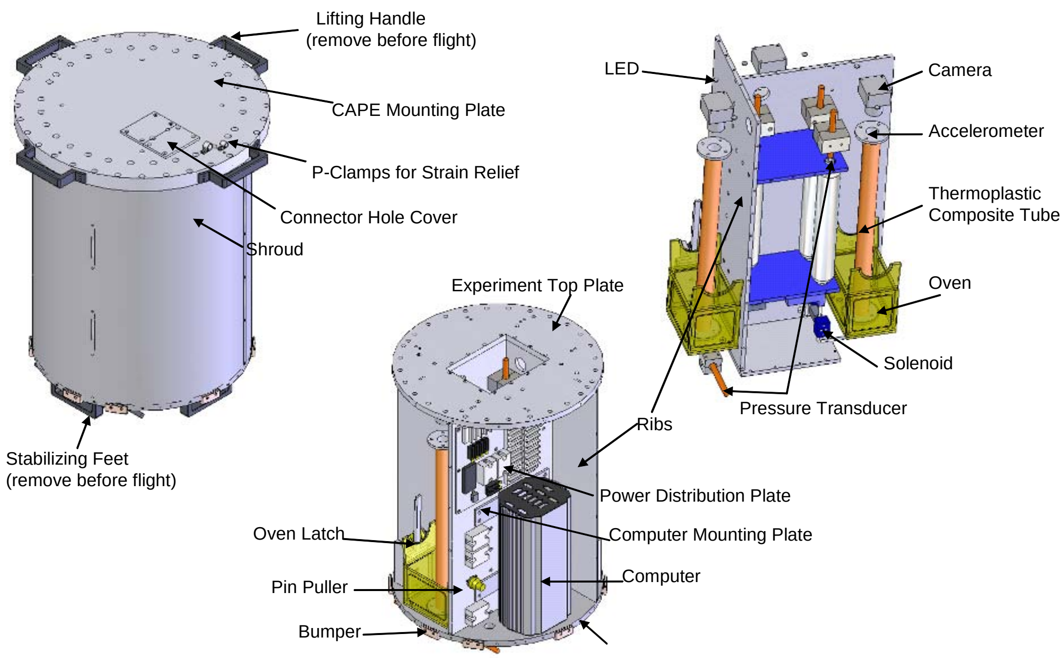


Figure 9. Notional Configuration of RIGEX as defined by Goodwin [9]

Qualifying RIGEX for Spaceflight

Table 2 is a tabulated form of requirements dictated in the Canister for All Payload Ejections Handbook and Users Guide (CHUG) [6]. In order to become spaceflight qualified, the RIGEX system must be proven through analysis and demonstrated through NASA defined testing listed in Table 3 to comply with each requirement listed in Table 2. The requirements in Table 2 have been color coded as follows to correspond with the verification testing identified in Table 3:

- **Mechanical –** colored yellow
- **Environmental** –colored blue
- **Electrical**- colored green

Table 2. Requirements for Flight as defined by CHUG [6]

	Requirement	Description	
1	Vibration Environment	The CAPE/Payload will meet the random vibration flight levels specified in the Structures Verification Plan, with an analysis to the appropriate levels for flight.	
2	Thermal Environment	The CAPE/Payload shall meet the following conditions without heaters for the cold case and with runaway heaters for the hot case if heaters are used for each category.	
		Operating Temperature	–40 deg C to +55 deg. C.
		Survival Temperature	–60 deg C to +80 deg C.
3	Depressurization / Pressurization	Meet the design requirements specified in NSTS 21000-IDD-SML in paragraph 10.6.1.2 for depressurization. The system shall meet the pressurization rate as defined in paragraph 10.6.1.3 of NSTS 21000-IDD SML.	
4	Radio Frequency Transmission	The overall system must meet the following table for RF transmissions. As specified in NSTS 21000-IDD-SML, paragraph 10.7.3.	
5	Electromagnetic Compatibility	The overall system must meet the EMI emissions specified in NSTS 21000-IDD-SML Paragraphs 10.7.3.2.2.2 and subs. Exceedance of these values may be negotiated on a case-by-case basis.	
6	Payload Avionics Compatibility	If the payload requires Orbiter services, then avionics compatibility are required per, NSTS 21000-IDD-STD paragraph 10.7.4 is required.	
		The Payload must be grounded to the CAPE canister with a resistance as specified in NSTS 21000-IDD-SML paragraph 10.7.4.2.	
7	Natural Frequency	The CAPE/Payload system shall have a natural frequency above 50 Hz. Test verified structural models are required for Payload Elements for incorporation into the CAPE System model.	
8	Design Loads	The CAPE/Payload system shall meet the design loads specified in Table 4.0.4.2.4-1 of NSTS 21000-IDD-SML with the following adjustment to the table. The following rotational accelerations will be substituted:	
		Rotational accelerations:	Compares w/ the IDD values :
		Rx = +/- 195 rads/sec^2	Rx = +/- 75 rads/sec^2
		Ry = +/- 60 rads/sec^2	Ry = +/- 20 rads/sec^2
		Rz = +/- 75 rads/sec^2	Rz = +/- 55 rads/sec^2

Table 3. Spaceflight Qualification of RIGEX via Analysis and/or Testing to be Completed as of CDR

Subsystem	Qualification Issue	Analysis Required	Test Required
Mechanical			
	Mass Properties	x	x
	Structural Strength	x	
	Structural Stiffness	x	x
	Fracture	x	
	Pressurization/ Depressurization	x	
	Containment	x	
	Thermal	x	x
	Random Vibration		x
Electrical			
	Interface Verification Test		x
	Electromagnetic Interference Test		x

Table 3 tabularizes the deliverables expected for spaceflight qualification preliminarily based on NASA's review of the RIGEX payload following the Preliminary Design Review (PDR) that was later refined following the Critical Design Review (CDR). The color code associates the test or analysis back to the spaceflight qualification requirement identified by Table 2.

Requirements for Spaceflight Qualification

The majority of the analysis requested in Table 3 has since been completed. Analysis is obviously the preferred method for verification as experimental testing is time consuming, costly, and if done incorrectly, can be detrimental to the overall system. However, not all requirements can be properly analyzed, or the analysis needs to be substantiated through testing. To negate the risk of physical testing, the following process was employed using the standards of NASA's JPG8080.5 JSC Design and Procedural Standards Manual [28].

- Identify what will be performed, what equipment is needed, and the methodology to what needs to be conducted. Put this into a "Plan"
- Identify what is to happen during the test. Write this up as a "Procedure"
- Perform procedure with a witness

This method ensures significant thought is placed into what has to be done and how the task is top be performed. Additionally, this provides the means for test repeatability, substantiality and verification. Employing this philosophy, the RIGEX team with the help of STP, wrote several plans, procedures and documents to properly document the progress from design through build to testing and flight. A listing of all procedures and documents for the RIGEX program is listed in Table 4. All documents, and procedures where verified by the RIGEX Principal Investigator (PI), Dr. Richard Cobb.

Table 4. RIGEX Documents and Procedures

Document #	Title
RD-1	Memorandum of Agreement Between The USAF Space and Missiles System Center (SMC) Space Test Program (STP) and the Air Force Institute of Technology (AFIT) for the Rigidizable Inflatable Get-away-special Experiment (RIGEX)
RD-2	RIGEX Program Requirements Document (PRD)
RD-3	Power Scheme (ICD)
RD-4	RIGEX Electrical Architecture
RD-5	RIGEX Drawing Package
RD-6	RIGEX Parts and Materials List (Living Document)
RD-7	Mishap Reports
RD-8	RIGEX Acceptance Data Package
RP-1	Mechanical Assembly Procedure (Wave #1)
RP-1A	Mechanical Assembly Procedure (Wave #2)
RP-1B	Mechanical Assembly Procedure (Wave #3)
RP-2	Electrical Ground Support Check-out Procedure
RP-3	Mechanical Integration with CAPE Procedure
RP-4	RIGEX Launch Prep Procedure
RP-5	Mechanical Ground Support Check-out Procedure
RP-6	Electrical Assembly Procedure Electrical Component Mechanical Assembly
RP-6A	Electrical Assembly Procedure Electrical Component Inter Connection Assembly
RP-6B	Electrical Assembly Procedure RIGEX to Orbiter Pigtail Build Procedure
RP-7	Mishap Incident Report Procedure
RP-8	Handling Procedure
RP-9	NITROGEN Re-fill procedure
RP-10	Functional Verification Test Procedure
TP-1	Insulation Test Procedure
TP-2	Runaway Heater
TP-3	Vacuum Chamber Operation Procedure
TP-4	RIGEX Operation During EMI Test Procedure
TP-5	Thermal Vacuum Test Procedure

Note: The documents listed here are retained on AFIT's internal server due to size, number and quantity and are available upon special request to AFIT/ENY

The following document nomenclature was used in titling each document in Table 4.

- **RD**- RIGEX Document
- **RP**- RIGEX Procedure
- **TP**- RIGEX Test Procedure

This nomenclature was developed as a means to organize the individual documents and give an initial indication of what each document describes. Similarly, the drawings of RIGEX's parts and assemblies needed to be organized as they had been developed by Goodwin [9], Gunn-Golkin [10], O'Neal [33] and Miller [19]. Some of these drawings required additional modification and are available in Appendix I. The drawing were organized in a drawing tree as shown in Figure 10

The results of the experimental testing that RIGEX will undergo are described in detail later in Chapters III and IV. In order to mitigate any risk of integrating a component in the overall system that will not operate or survive in the space environment, as defined in Table 1, each component will be verified to meet or exceed the defined operability and survivability limits of Table 2. The tabulation of all current RIGEX components and their operating requirements and limits is provided in Appendix A of this document. If a component did not meet the specification, a suitable replacement was sought and in most cases found. The replacement was then incorporated into the system with little to no change in the overall system.

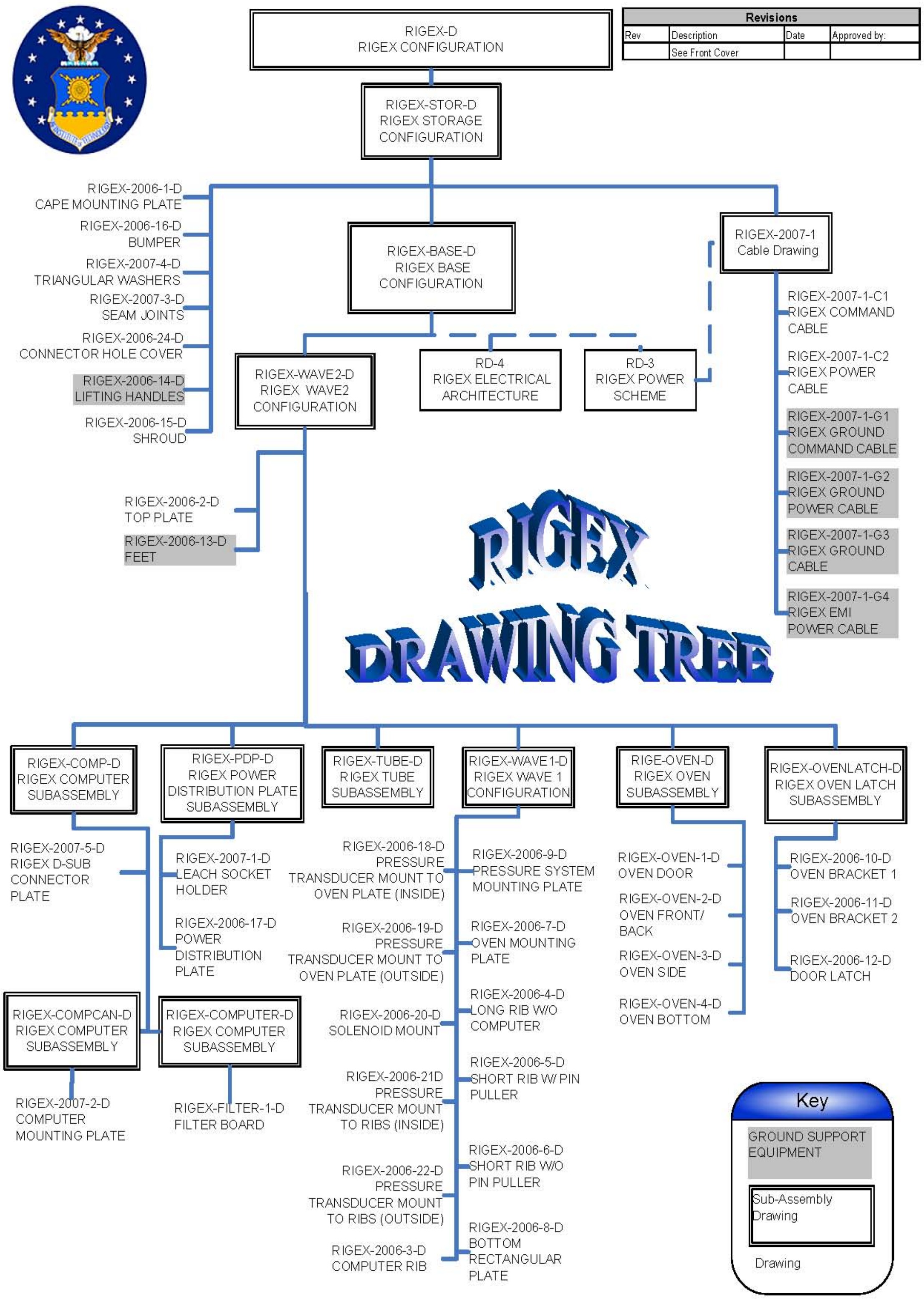


Figure 10. RIGEX Drawing Tree

Flight Hardware Changes since Critical Design Review

There have been, however, some significant changes to that payload are not related the survivability of the payload and directly affect its operation. As other RIGEX team members finished their work on the project, they would leave suggestions about how they would have liked to better the system if a solution were available, or if given more time, the options they would have investigated. Where practical some time and thought was given to these suggestion and in some cases the changes were made to the over all system. Other changes, however, came about because of unforeseeable circumstances that will be addressed and are discussed below. Where the changes have already been documented, the reference is provided.

- Cameras [19]
- Computer
- Experiment Top Plate [33]
- Shroud Hardware [33]
- Pigtails
- Oven Design
- Wire Selection

Figure 11. Depiction of EyeC Camera [19]

1. Camera

The imaging system had originally been identified and acquired by DiSebastian [5] in 2000. The cameras required control using PC-104 boards and most importantly space on the system hard drive to store the acquired images (Note: Moody [22] divided the computer into two separate computers to allow the control computer to gather the experiment data and the imaging computer to gather the images.) The Electrim camera system proved to be complex and difficult to work with, and an easier to incorporate replacement was recommended. The Tern Inc EyeC standalone camera system was identified as a possible solution to this issue. Although no data existed to show that the camera was suitable for spaceflight, it had the following characteristics that made it attractive.

- **On Board Data Storage –** Captured pictures stored on separate Compact Flash Disks which come in various storage sizes, including 1 and 2 GB!
- **Programmable –** Can be customized to take pictures at various rates and store the pictures in various formats. In addition, able to continually capture pictures once power is applied to the camera.
- **Low Power –** Requires a voltage of 9-30 VDC. The cameras each consume milliamps to operate.

For details on the configuration and setup of the cameras, see Miller [19]. As a direct result of implementing these cameras into the imaging system, the computer setup was re-worked to accommodate the change.

2. Computer

The computer had the following shortcomings that needed to be addressed:

- Components not specified for operation in the space thermal environment
- Integration of the cameras into the system
- 24 VDC Power source required for solenoid activations
- Inability to extract the data or load programming to the computer without completely disassembling it.

Upon initial inspection of the computer component specifications, the following components were found to not meet the specifications for the space operating environment:

- Butterworth filter chip located on the filter board (minimum operating temperature rating of 0^{o}C)
- Pearl-MM 16 Relay Board (minimum operating temp rating of 0^{o}C)
- MSI-P440 Thermocouple board (maximum operating temperature rating of 70^{o}C)

Ideally, from a configuration control standpoint, the best thing to do would be to find a component that has the same interface as the component that needs to be replaced, to avoid further configuration changes. Fortunately, we were able to find a Butterworth filter chip from the same company with a -40^{o}C to 80^{o}C operating range. The new chip was bought and integrated into the system, and the configuration documentation was updated to reflect the different component.

Unfortunately, the same solution was not possible for the Pearl-MM 16 relay board. In this case, a completely new PC-104 relay board needed to be identified in order to meet the environmental operability requirements. The Parvus® 24 Form C Relay Board (Part number PRV-0728) was identified by Goodwin [9] but it required integration into the system and testing. The new board had an additional eight relays from which the ovens, imaging system, pressure system, and shuttle displays could be controlled. This proved to be beneficial for the camera change mentioned above, as now there was a method for delivering 12 VDC from the HE104 12 VDC power source to the cameras, as well as new way to control the shuttle display relays mentioned by Goodwin [9]. Lastly, the MSI-P440 Thermocouple board is only rated to 70^{o}C. The decision was made to qualify this components operation and functionality in the component suitability test as no suitable alternative could be identified.

Initially the RIGEX computer was broken down into two separate computers by Moody [22] (The primary computer dubbed the "DAQ" Computer and the second computer for imaging) and used the "Quartz Timer/Counter" boards to communicate between them. The second computer was dubbed the "imaging computer", because as stated previously, the Electrim Cameras required both the PC-104 controller board and space on a hard drive to store the captured pictures. With the incorporation of the standalone Tern EyeC cameras and the Parvus® Relay board (mentioned earlier) there was no longer a need for the Imaging Computer. However, the components that the Imaging Computers HE104 supply were powering was found to draw too much current for the "DAQ" computers power supply. Thus, the imaging computers power supply remained being dubbed "AUX" power supply. All components whose operation relied on power being routed to it by the relay board were re-routed to receive power from the AUX power supply, alleviating the power burden on the "DAQ".

Power also became an issue when it came to the solenoids, which control the flow of nitrogen gas from the storage tanks to the tubes. At some point, the on-hand solenoids had been configured to use a 24 VDC power source consuming 500 mA when active. Currently, there was no power source capable of directly providing 24 VDC to any of the components.

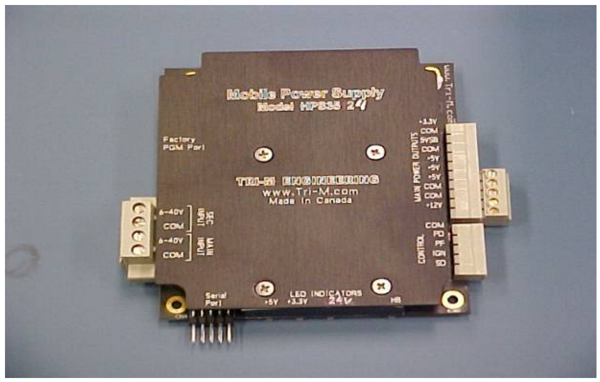


Figure 12. Tri-M Engineering Modified HPS 3512 to HPS 3524

The solution was to have Tri-M Engineering provide a modified HPS 3512 power board, shown in Figure 12, which they renamed HPS 3524. Once received at AFIT, the output of this power board was confirmed to be 24 VDC and was then incorporated into the computer stack, solving the power to the solenoid issue.

Once the computer was ready, there was an issue with its configuration. To get data from the computer, reset the command and control software, or to load new software, the computer would need to be completely disassembled, as there was no user input/output built into the system. Obviously, this would be a significant amount of work to make the smallest changes, so we needed an interface to communicate with the computer that did not require a significant amount of disassembly. Luckily, the user input boards already used by previous students with the PC-104 development kits included a keyboard and mouse interface as well as a USB port, which is now used to add and extract data. The interface board, dubbed “utility board”, was integrated with the MZ104 cabling that accompanied the development kit. This created an unexpected issue, however, in that the material that insulated one of the cables could not be identified. The wires label “AWM 2651 E169626” indicated that it was comprised of strands of 28AWG ribbon cable and after reaching the number was found to be an industry wide standard appliance cable that could be insulated with any of 5 different insulations. To alleviate this, the wire was wrapped in Kapton tape, as shown in Figure 13, at the direction of STP after consulting NASA material directorate.

Figure 13. Kapton wrapped wire between user input board and processor board

Now, the user could communicate to the computer and extract data, but the computer could not report input/output to the user. A monitor is a common choice and therefore a video graphics adapter (VGA) board was purchased and incorporated into the system (see Figure 14). A cable was made to connect the output of this board to a standard monitor port so that any monitor could be attached.

Figure 14. Video Graphic Adapter card. NOTE: Conformal Coated as described by Miller [19].

Because of the addition of the port and the removal of imaging computer, the computer D-sub plate was modified to use fewer D-subminiature connections and use more of the pins in each D-subminiature (see Figure 15) than what Goodwin [9] indicates. The reduction in the number of D-subs allowed the ability to have flight spares of this expensive part as the D-subs selected for use are copper, plated in pure gold, and use gold pins and sockets. The spares allowed for the *possibility* of having a flight worthy replacement in the event that anything may happen to the attached cabling during manufacturing or pre-flight processing. See the Electrical Architecture in Appendix D for a detailed depiction of the current pin-out for each sub-miniature.

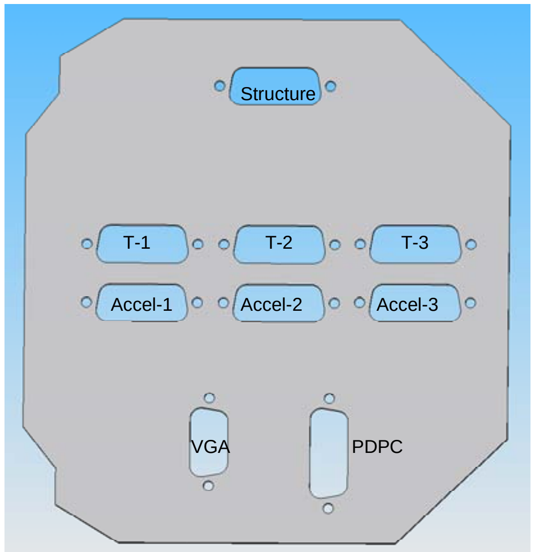


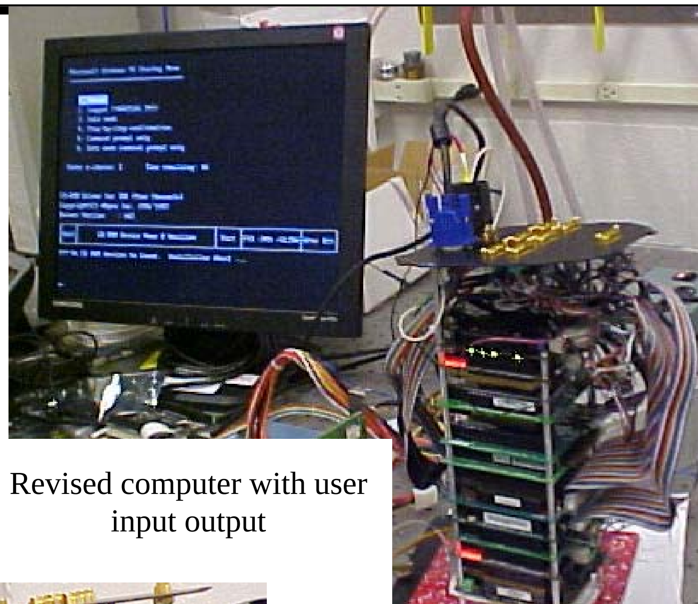
Figure 15. D-Sub Plate Configuration

While these changes where being made to the computer, Gunn-Golkin [10] added helical inserts at the computer attach points to the main structure. This allowed the computer to be removed and replaced back on the structure repeatedly. For AFIT in house testing the bottom plate of the computer housing is removed and extension cables to the keyboard, mouse, and USB port exposed allowing the computer to stay connected to the structure and the user to interact with the payload as needed for various testing. An example of instructions for activating various components through the relay boards supplied DIOtest software is supplied in Appendix D.

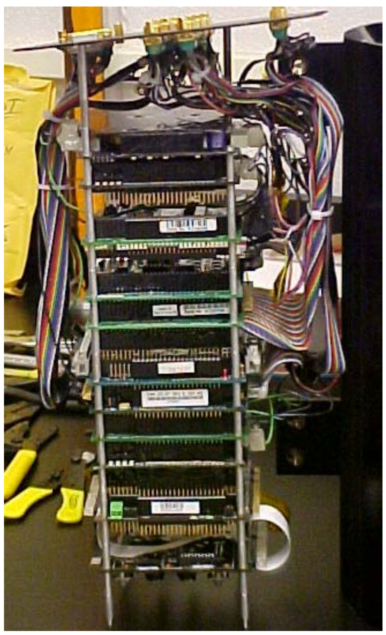
The RIGEX computer saw not only physical changes (see Figure 16) but setup changes as well. Originally, Moody [22] had envisioned the system running on a 32-bit Windows environment, where the command and control executable would be loaded into the system startup files and then automatically executed while Windows booted. This worked fine while the computer PC-104 stack was still attached to the MZ104+ development board as shown in Moody's [22] configuration, (see Figure 16). Once the flight computer stack was finished and removed from the development board, a problem was encountered.

The problem was that the Windows98SE operating software requires a monitor to be attached to the computer in order for Windows to startup properly. When the embedded, non-optional, hardware check programs were executed by the Windows98SE operating software, the startup would not be allowed to get past the hardware BIOS check at power up. To fix this, we needed to either trick the operating software into *thinking* the monitor was attached or change the operating software. A 15-pin VGA sub miniature schematic was found that worked for personal computer systems. A quick comparison of the VGA boards output schematic to personal computers showed that the VGA boards return signal connections and chassis ground were at the same potential where personal computers VGA signals are isolated from chassis ground. With the signals of the boards VGA being tied to chassis ground, the decision was made to convert to a 16-bit DOS operating system, but this came with a new set of problems.

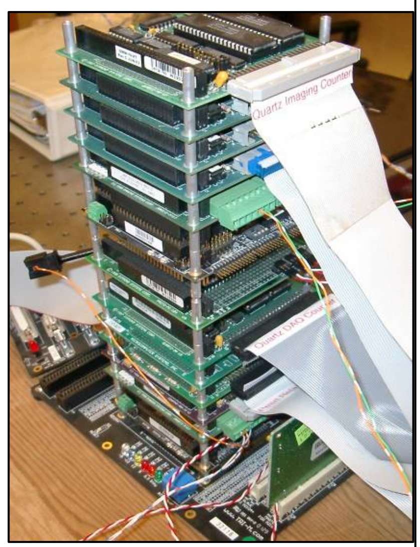
After the conversion of the operating system to 16-Bit DOS, the flight experiment code needed to be completely converted to execute in a 16-bit executable. A Watcom C/C++ complier was acquired to convert the command and control code into a 16-Bit executable. This allowed the code to execute in the DOS environment, but unfortunately while running the executable, multiple run time errors were encountered.



Revised computer with user input output



Revised computer stack 11 boards



Moody's [6] two computer stack with 14 total PC-104 boards

Figure 16. Computer comparison and current configuration

The runtime errors were a result of the system running out of physical memory. Physically, Moody [22] had 64 Kilobytes (Kbs) extended memory attached to the system, which already had 512 Kbs of random access memory (RAM) embedded in the hardware, all of which must have been consumed by the executable. To fix the runtime errors, the memory consumed by the executable needed to be reduced. After consulting the computer programming experts at AFIT, it was determined that memory management practices needed to be applied.

Memory management practices are as follows as defined by Gaddis [8]:

- Declare every variable only as large as needed
- Declare as a constant when the variable will not change value
- Declare large variable arrays early and use pointers to allocate enough memory for the large array reuse for large data sets.
- Reuse changeable variables to keep the number of variables down

Once the code was adjusted to use less memory, there were no more runtime errors. A copy of the finished flight code can be found in Appendix C of this document. To ensure that adjusting the parameters of the code was enough however, steps were taken to adjust the hardware startup settings of the computer in order to allow the executable to utilize as much of the lower memory (64Kbs) as possible.

By changing the operating system to DOS, the use of the Windows HIMEM.SYS system program was lost. The Windows HIMEM.SYS is the primary Windows memory utilization controller program, and losing it meant having to manually control the memory usage of the computer. Specifically, this meant commanding the computer to execute the DOS operating system in the "high" memory region. This was accomplished by adding the following text to the CONFIG.SYS file:

```
DOS=HIGH
```

This freed up more low memory usage in the system that then guaranteed the system to function as expected. As of the date of this publication, the computer has performed as expected through multiple activations. The computer is expected to perform nominally during flight.

3. Experiment Top Plate

The next major change since CDR was to the experiment top plate (P/N RIGEX-2006-2-P). STP is charged with the complete RIGEX/CAPE structural certification and was completing a RIGEX/CAPE system level analysis in accordance with the Structural Verification Plan (SVP) [1]. During this analysis, STP had determined that we had negative margins of safety on the bolts that mate the Experiment Top Plate to the four ribs. Note: A negative margin of safety means that *analytically*, a possibility of a structural failure. Originally, the top plate was to be attached to the ribs with NAS1189 [32] series bolt that are made of corrosion resistant steel with a maximum axial load capacity of 160 ksi. STP's recommendation was to change the bolt to a NAS1351 [31] series screw which is made of heat resistant steel and has a maximum axial load capacity of 180 ksi and to add a washer. Replacing the bolts resulted in positive margins, however, the top plate needed to be counter bored a depth of 0.34" instead of being counter sunk to accommodate the new bolt and washer. O'Neal [33] captures this change in detail (see Figure 17 and Figure 18).

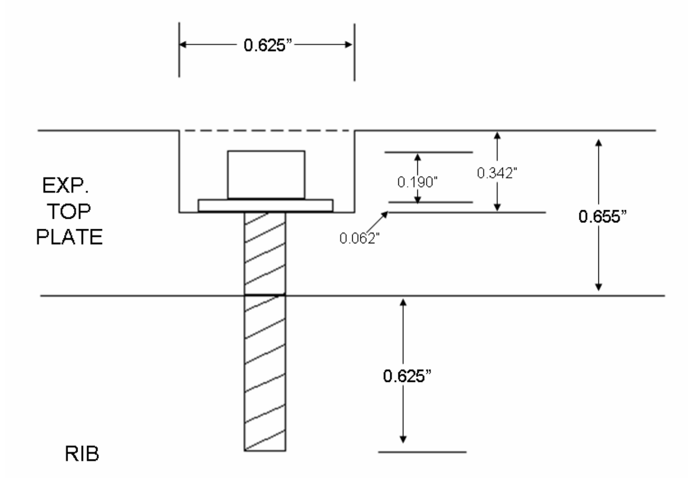


Figure 17. O’Neal’s [33] depiction of experiment top plate to ribs interface

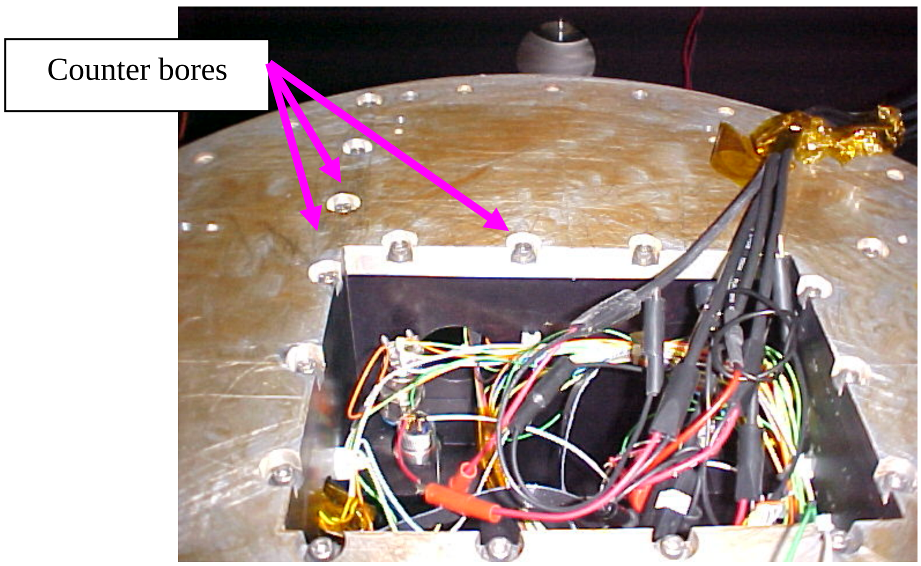


Figure 18. View of Top plate during pressurization test where counter bores are visible

4. Shroud Hardware

Even before manufacturing began, the shroud had been identified as one of the more intricate parts to make. It had originally been determined by Goodwin [9] to have a 1/8” overlap of material at on a rib interface. This proved to be difficult not only for manufacturing, but for manipulating the shroud onto the structure. It was decided to butt the two ends of metal together and make seam bars to join the two ends. The structure connections were rotated slightly and the seam joint was placed in the computer bay where it would not obstruct the deployment of any of the tubes.

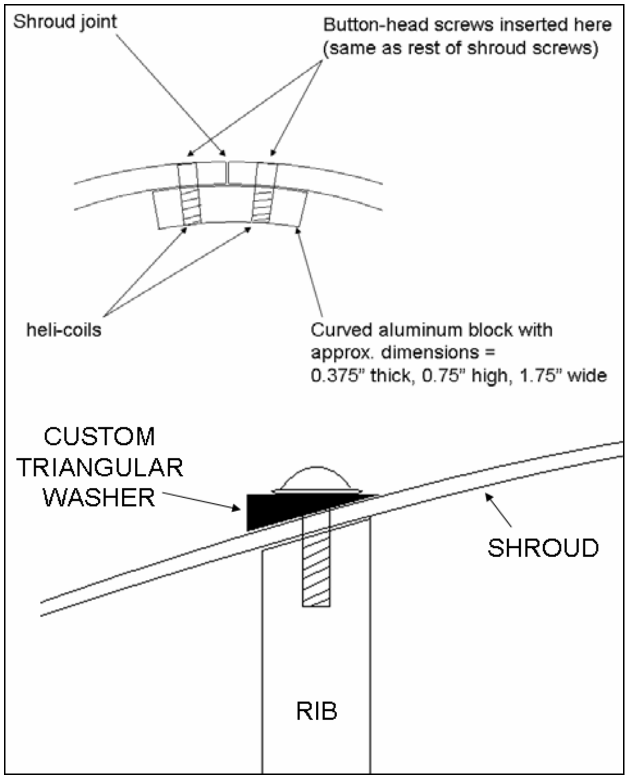


Figure 19. O'Neal's [33] Shroud attachment scheme

Attaching the shroud to rib ends was also a challenge. The button head flange screws (NAS 8402 series) would stop once the edge of the flange touched the shroud, which made the area grabbed by the screws head very, very small due to the curvature of the shroud. To counter this, triangular shaped washers were developed to go between the screw and the shroud, which allowed the thread grip of the screw to be distributed as originally intended. Both the seam bars and the triangular washers design, implementation, are laid out in detail in O'Neal [33] and are shown in Figure 19.

5. Pigtails Cables

At the CDR, the pigtail cables – the primary and only means of electrical connection to the shuttle – had merely been conceptual and not discussed at full length or designed. The need also arose to have specialized ground cabling that closely resembled flight cabling for the Electromagnetic Interference (EMI) test, which will be discussed Chapter IV. On top of which, extra cabling interface with the flight pigtails and the emulator were required. (Aside: the emulator was designed by Gunn-Golkin [10], and built by Mr. Wilbur Lacy to provide power to RIGEX and simulate shuttle commands and indicators on the ground, (see Figure 20). For a physical and operational description of the emulator, see Appendix H). The schematic and drawings of the six cables manufactured for RIGEX are provided in Appendix B of this document. The cables final lengths and weights are provided in Table 5 while each is shown in Figure 21 (except –G3 and –G4).

Figure 20. RIGEX Emulator

Table 5. RIGEX pigtails (weight and length)

Pigtail	Weight kg (lbm)	Length(in)	Purpose
RIGEX-2007-1-C1	0.545 (1.2)	107*	Command cable to turn RIGEX 'ON', and relays display signal to the Astronauts
RIGEX-2007-1-C2	1.17 (2.57)	102*	Main Power Cable
RIGEX-2007-1-G1	0.72 (1.58)	~169	-C1 interface to the emulator
RIGEX-2007-1-G2	1.76 (3.88)	176	-C2 interface to the emulator
RIGEX-2007-1-G3	N/A	157.5	Direct command cable to the emulator, performs same function as C1 on ground
RIGEX-2007-1-G4	N/A	98.4	Direct power cable to the emulator, specifically for EMI test, performs same function as C2 on ground

**NOTE: Length listed is the length outside of RIGEX*

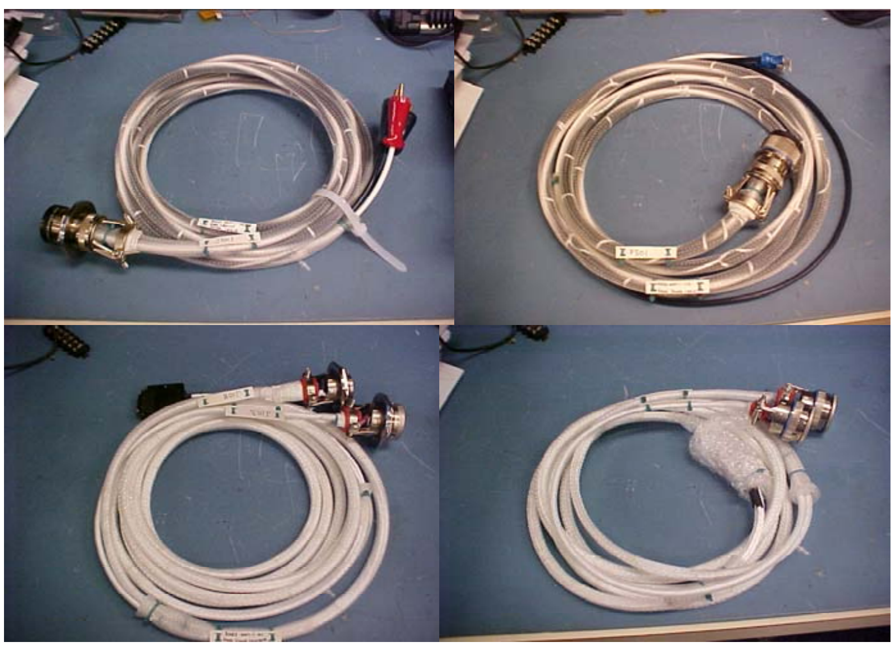


Figure 21. RIGEX Pigtails*

**NOTE: Clockwise from top left RIGEX-2007-1–G2, –C2, –C1, and –G1 (–G3 and –G4 not shown)*

The pigtails were built in accordance with NASA STD 8739.3 [23] and NASA STD 8739.4 [24]. As can be seen in Figure 21, the Command Cable has a 'Y' split whose construction was not sufficiently defined in NASA documentation. The following interpretation was taken for the cables construction:

- Sheaving must overlap by approximately 2 inches
- The overall sheaving must go over the smaller strands
- Teflon wire ties are to be used to secure the sheaving along with epoxy to lock wire ties in place

Figure 22 shows the nominal wire dimensions of each pigtail based on known wire diameters of MIL-W-22759 wire series. The diameter of each cable is increased slightly in the overlap area especially where the wire ties hold the small sheaving to the breakout wires. Once this had been determined, STP was contacted and instructed us to ensure the cable running did not include a clamp in the overlap regions.

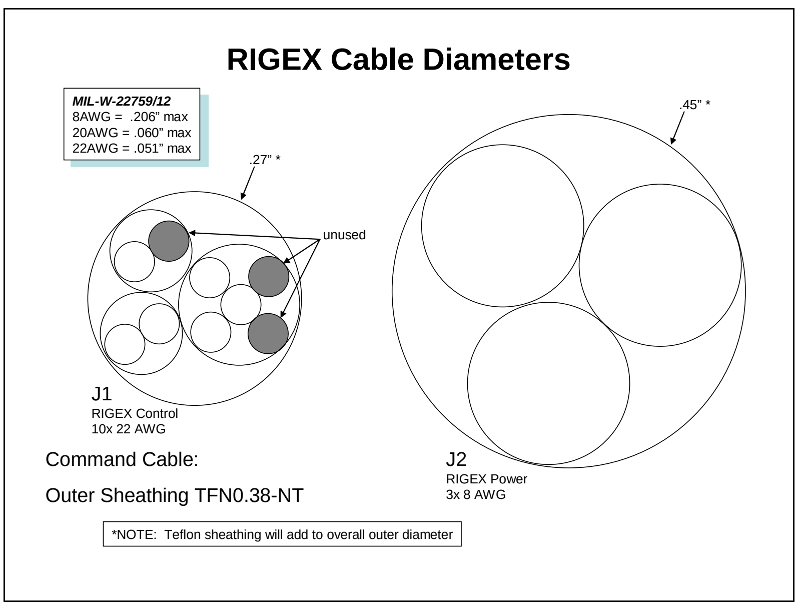


Figure 22. RIGEX Pigtail diameter determinations

The flight pigtails are the only electrical component that will be fully exposed to the space environment, so extra care was taken during the assembly to ensure each connection was tight and secure. The design calls out for each Teflon wire tie to be coated with Master Bond Epoxy (P/N EP21TCHT-1) [18] which had been identified for its low-out gassing properties and its previous approval by NASA for use for spaceflight. (Aside: this epoxy is the same used to secure the wire tiedowns to the structure, the thermocouples to the tubes and the Minco heaters to the oven. The epoxy is also used as back-off prevention on the latching relay fasteners.)

In order to properly seat the #8 American Wire Gauge (AWG) wires in the main power cable in the connector pins, a hydraulic crimper was needed. After consulting with the 445th Air Lift Wing's C-5 electrical maintenance section, a hydraulic crimper was identified. The technicians in the section assisted with the connections and inspected the work to verify the proper seating of the wire. An independent technician performed an electrical check verifying the functionality of the cabling and that the cables were built as specified in the drawings. This precaution was taken to ensure that there would be no problem after RIGEX is handed over to NASA, as there is no way for AFIT to verify this connection prior to shipment to KSC.

6. Ovens

At the CDR, the experimental ovens were configured as Maddux [17] had described minus the ceiling tile insulation (see Figure 24) and wired as Goodwin [9] (see Figure 23) describes. A more appropriate insulation was selected by thorough testing conducted as part of this research and described by the "Insulation Selection" Test described in Chapter III.

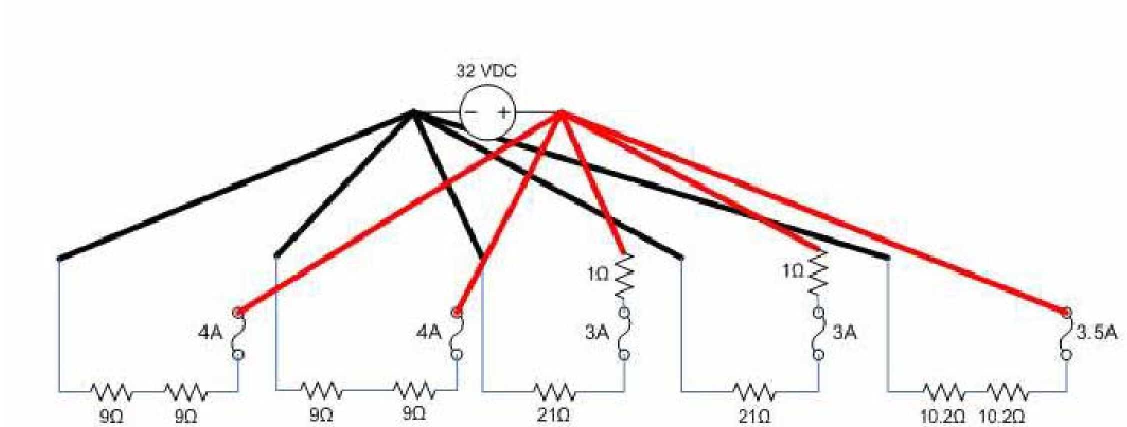


Figure 23. Goodwin's [9] Circuit schematic

Figure 24. Maddux [17] oven setup

Once an appropriate insulation was determined, one issue remained from a materials standpoint. Note in Figure 24 how the Minco heaters have been painted black as Maddux [17] indicated should be done. However, the origin of the paint used could not be determined, nor could a cost effective space rated alterative be found, the decision was made to not paint them. Unfortunately, this required an additional purchase of heaters, but since the ones in stock were all painted, there was choice but to replace the heaters. Further modifications were made to the ovens but only after a safety required test indicated that the modifications were necessary. These modifications will be discussed in detail in Chapter III.

7. Wiring Selection.

Goodwin [9] designed the RIGEX heating circuits to be two fault tolerant in that if an oven were to fail 'On' in the previous bay, the current bay's oven could be activated and not blow the fuse. (Note: A fault is a component failure of some sort, which could be caused by a number of reasons). His concern focused on the solid-state relays, which control power to the individual ovens that are located in the computer bay.

$$V = IR -> I = V / R \quad (1)$$

However, his configuration of the individual ovens wiring resulted in resistive load of ~4Ω. Using Ohms Law (Eqn 1), at 32 VDC (maximum voltage to be delivered by the shuttle to RIGEX), this would result in a current draw of ~8A. With two ovens 'On' the current draw is increased to ~16A. As expected if both the solid-state relays were to fail 'On' then when the third relay was activated the current draw would increase to ~24A and blow the 20A fuse. This was acceptable if the selection of the wire and the protective device was based solely on the expected load

According to Darilyn [4], the fuse at its 'Max Blow' must still protect the wire current carrying capability. Table 6 shows the different size wire current carrying capability under spaceflight related conditions. At 135% current load, the 20A fuse would allow the wire to carry 27A if it were not to blow, which is 1 more Amp than the 14 AWG wire is rated for so the next size wire needed to be used to ensure the integrity of the wire.

Table 6. Wire Selection for Spacecraft Darilyn [4]

	Maximum Current A (Amps) under the following conditions		
AWG #	72°F at 14.7 psi	72°F at 10E-6 Torr	200°F at 10E-6 Torr
1/0	**470**	**361.1**	**332**
2	**341**	**245.8**	**225**
4	**267**	**171.6**	**157**
6	**211**	**128.9**	**118**
8	**169**	**88.4**	**81**
10	**91**	**56.2**	**51**
12	**74**	**40.9**	**37**
14	**60**	**28.7**	**26**
16	**43**	**21.4**	**20**
18	**37**	**19.1**	**17**
20	**27**	**13.9**	**13**
22	**23**	**10.4**	**9.5**
24	**16.4**	**7.5**	**6.8**
26	**13.2**	**5.3**	**4.8**

Additionally, during RITF testing conducted by NASA, the 14 AWG wire purchased for use failed to meet the specification to which the wire was to be manufactured. (ASIDE: The Receiving Inspection Test Facility (RITF) is defined by the JSC Design and Procedural Standards Manual (JSC 8080.5) [26] as NASA's independent verification agency that independently verifies vehicle components such as fasteners and wiring. All wiring to be used and all #8 and larger fasteners must be sent through this agency prior to use on all vehicles and spacecraft.) Based on the wires inability to be protected by the current fusing scheme and it's specification compliance failure, the decision was made to completely remove the 14 AWG wire from the system and utilize the 12 AWG wire in its place. The final wiring schematic shown in Appendix D reflects this change.

Ensuring Both Mission Success and Adherence to Safety Regulations and/or Concerns

Mission Success

The following are the mission statement and mission objectives of RIGEX as defined by DiSebastian [5] and revised by Goodwin [9]:

- Mission Statement:
  - Verify and validate ground testing of inflation and rigidization methods for inflatable space structures against the zero-gravity space environment
- Primary Mission Objective:
  - Design a Get-Away-Special (Revised: Canister for All Payload Ejections) experiment to collect data on space rigidized structures for validation of ground testing methods
- Secondary Mission Objectives:
  - Return inflated/rigidized structures to laboratory for additional testing
  - Enable application of rigidized structures to operational space systems

In order to ensure the mission success of the mission, both the mission statement and mission objectives must be realized. The detailed design of RIGEX was completed by Goodwin [9] in 2006. Since then the payload has been built to his specifications with the modifications mentioned earlier. Now we need to certify that RIGEX is capable of verifying and validating the ground tests of the tubes. This certification was accomplished by performing the following self-imposed tests to validate RIGEX's ability to meet the intent of the mission statement and certify the objectives of both

DiSebastian [5] and Goodwin [9] have been met (Both tests are documented in Chapter IV):

- **Deployment Test:** Verify system operability using RIGEX heaters to heat the tube and then the inflation system to deploy the tube
- **RIGEX Ground Test:** Utilize RIGEX to collect data on the Ground using 'test' tubes. This will give an 'apples to apples' comparison of the flight data and the same system will excite and collect the modal data of each tube.

Safety

Safety of personnel is always a concern on a shuttle manned flight project. All of the requirements listed in Table 3 is a result of concern for the safety of the mission and the well-being of the astronauts. NASA Safety reviews add additional scrutiny to projects that fly aboard the shuttle, as the number one concern is the safety of the individuals and there safe return from the heavens. Their certification that the payload has met the requirements in NSTS 1700.7B [38] is required for spaceflight certification. As of Sept 2007, RIGEX has been through the following Safety Reviews:

- **Phase 0/1**: Preliminary Review of proposed project to identify possible hazards
- **Phase 2**: Complete Review of final design to identify addressed hazards through analysis and remaining hazards requiring additional testing/analysis
- Phase 3:
- **Ground**: Review of Ground processing procedures during the integration with the shuttle
- **Flight**: Complete Review of Flight Hardware and verification that all safety issues have been addressed

Through out the safety review process, the following items were asked of AFIT to verify for safety certification:

- **No Sharp Edges**: Verify 'rounded' edged of any edge that may come in contact with the astronauts during External Vehicle Activities (EVA)
- **Use of NASA approved Materials**: Verify all materials used are in compliance with NASA STD-6001

- **Touch Temperature**: Verify CMP temperature remains below 112^{o}C during operation
- **Electrical Distribution** : Verify "As-built" compliance with NASA STD 8739.3 and NASA STD 873.4
- **Pressure System Verification:**
  - Verify will not rupture due to thermal variations (proof check)
  - Verify pressurization procedures and complete

Some tasks were completed by reviewing documentation to verify compliance with NASA standards (mentioned above). Materials of each component and if treated, how it was treated, was compiled into RD-6 *RIGEX Parts and Materials Listing*, which has been reviewed and verified to comply with NASA STD-6001. Likewise, RD-4 *RIGEX Electrical Architecture* and RD-3 *RIGEX Power Scheme* were compiled and verified to comply with both NASA STD 8739.3 and NASA STD 8739.4. The "No Sharp Edge" requirement was verified by reviewing the schematic and verifying the part was made as drawn. (Note: all RIGEX parts were verified to comply with submitted drawings).

Analytical verification of safety requirements was completed by previous students; however, these items required additional testing and/or review for spaceflight qualification. As a result, the following tests and reviews at the level indicated were conducted:

- **Component level testing (Chapter III)**:
  - **Run-Away Heater:** To measure temperature of the CAPE mounting plate as a result of failed solid-state relay operation
- **Component level Reviews:**
  - **Material Selection**: This was also incorporated into the over design
  - **Sharp Edge Test:** CAPE mounting plate only RIGEX external surface and its design incorporated this requirement

- **System level testing (Chapter IV)**:
  - **Pressure system**:
    - **Leak check:** Verify Pressure system will hold pressure in a vacuum
    - **Over pressurization**: Verify will not burst when pressurized to 115% of flight pressure
- **System Level Reviews**:
    - **Structure Verification**: Review Structure components for compliance with drawings

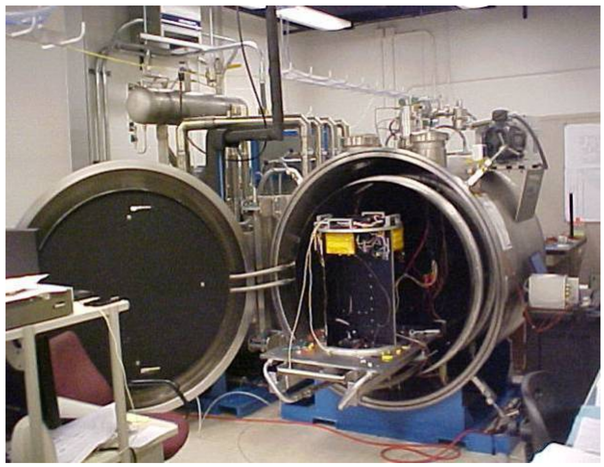


Figure 25. RIGEX Resting in the New Thermal Vacuum Chamber

To accomplish both the component level and system level testing required, AFIT recently installed a new thermal vacuum chamber to finish the spaceflight qualification of the RIGEX payload. Testing in this thesis was conducted in both the old and new thermal vacuum chamber (shown in Figure 25), the operation of which was sufficiently documented by Miller [19]. With this new chamber, AFIT is capable of performing tests that require as close to space like conditions as possible.

Chapter Summary

Chapter II focused on the RIGEX payload and efforts made in lieu of testing for spaceflight qualification, highlighting configuration changes since CDR. Additionally all testing for spaceflight qualification was introduced, defining the purpose and intent for each test that are summarized in Tables 7 and 8.

Table 7 illustrates the testing that is documented in Chapter III while Table 8 illustrates testing in Chapter IV. All testing must be complete prior to delivery of the RIGEX payload to Kennedy Space Center (KSC), which is expected to take place on 23 October 2007. As of the publication of this document, all but the Thermal Vacuum Test are complete.

Table 7. Component Level Tests

Test	Name	Quick Purpose
3.A	**Insulation Selection Test**	Determine Insulation to use
3.B	**Runaway Heater Test**	Verify Thermal Model, Determine Cape Mounting Plate
3.C	**Component Suitability Test**	Thermally verify operation of computer, camera, solid state relay, LEDs, and oven controllers

Table 8. System Level Testing

Test	Name	Quick Purpose
4.A	**System Pressurization Test**	Leak test and over pressurization test for flight safety
4.B	**System Deployment Test**	Verify payload operation and current consumption at 28 and 32 VDC
4.C	**Electro-Magnetic Inference Test**	Verify electro-magnetic inference radiative and conductive levels are within allowable tolerance
4.D	**Vibration Test**	Verify system structural Integrity
4.E	**Weight and Balance Test**	Determine Weight and Center of Gravity (C.G.)
4.F	**Thermal Vacuum Test**	Verify system survivability and operability and structures ability to handle thermal loading Collect modal characteristics of test tubes

III. Component Level Testing and Validation

The RIGEX system level test cannot be performed until the individual components have been proven and certified for flight. In most cases, components are designed into the system that meet or exceed environmental criteria. The manufacturers' certification of the components conformance to the specification to which it was designed is retained as part of the certification record. However, with the "uniqueness" of the RIGEX payload, space qualified components were not always available, some items needed to be individually tested before use in RIGEX. The three tests covered in this chapter are the Insulation Selection test, the Runaway Heater test, and the Component Suitability test.

Insulation Selection Test (3.A)

Problem and/or Solution to Test

The deployment performance of the rigidizable tubes is dependant upon a AFIT designed and developed heater box comprised of resistive heaters manufactured and sold by Minco and an exterior construction made of Ultem© (a prototype is shown in Figure 26). Through previous testing documented by Maddux [17], it was determined that although the Ultem© construction provides a substantial thermal resistance; it is optimal to insulate the exterior of the oven to further reduce power consumption and boost heat retention within the oven. Further, in order to comply with NASA-STD-6001 [23], a material must be selected that does not out gas a volatile bi-product. Compliance is done in one of two ways for materials [23]:

- Database check of known tested materials by NASA materials directorate located Marshal Spaceflight Center (MSC), in Huntsville, Alabama.
- Submitting the material to testing as outlined in NASA-STD-6001

Material Safety Data Sheets (MSDS) for the candidate materials were forwarded to MSC for database review.

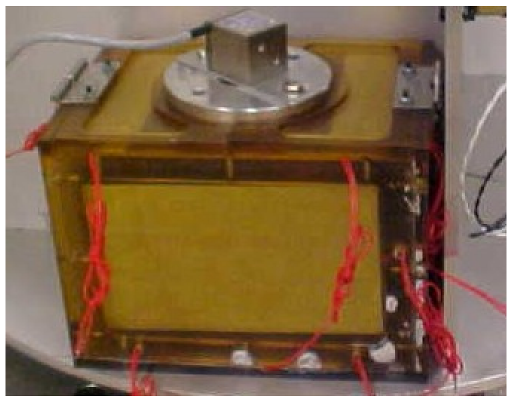


Figure 26. RIGEX Heater Prototype

Insulation Selection Test Configuration

In an effort to determine the best insulation, two companies, Zircar Zirconia INC© and Zotefoams plc (United Kingdom), provided samples of their products for testing. Each sample was cut to the same surface area size, so the same size surface area will be insulated. Table 9 shows which insulation materials were tested.

Table 9. Insulation Test Setup Identification

Letter	Specimen	Thermocouple	Donated by:
A	**ZYFB-6**	1	Zircar Zirconia, INC©
B	**Zotek® F38HD**	2	Zotefoams plc
C	**Zotek® HD30**	3	Zotefoams plc
D	**ZYW-15**	4	Zircar Zirconia, INC©
E	**Zotek® F30**	5	Zotefoams plc
F	**Zotek® NB50**	6	Zotefoams plc

For the test configuration a plastic sheet was chosen, which is assumed to have a consistent material make-up throughout. Two non-flight Minco heaters where attached to one side of the plastic sheet and configured in parallel with each other. The test samples was positioned on the opposite side of the sheet equally spaced from each other as shown in Figure 27. Sufficient spacing was used to ensure the thermocouple readings would not be biased from neighboring insulations effects. Finally, a thermocouple was placed on the insulation material itself, and two others were used to measure the temperature of the Minco heaters. Each insulation specimen was given a letter A-F as indicated in Table 9 for tracking performance.

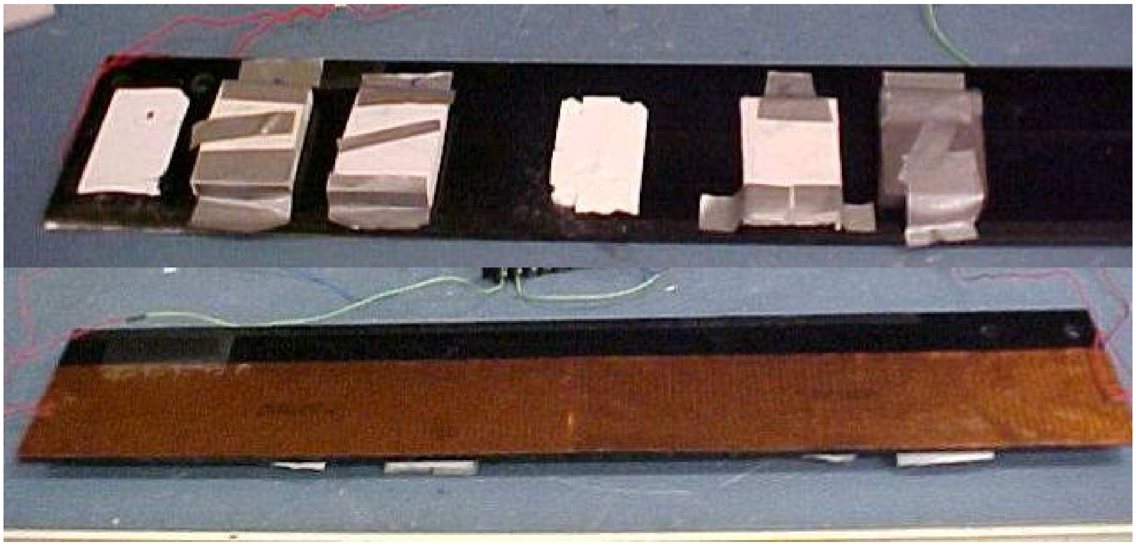


Figure 27. Insulation Selection Test Setup (Top) Minco Heater Placement (Bottom)

Insulation Selection Test and Setup Procedures

Vacuum Chamber Preparations

To view the test structure inside the vacuum chamber during the test, a modification to the chamber was completed using the same lighting mechanism that will allow the RIGEX imaging system to capture photographs. The light emitting diodes (LEDs) shown in Figure 28 were arranged in series approximately 2 inches from each other and suspended from in the top part of the chamber. A quick check showed that the configuration provided ample lighting for the test.

Figure 28. Light Emitting Diode (LED), Star Cluster

Test Specimen Physical Properties

The Zircar specimens were much lighter and thinner than the Zotefoams specimens, which proved to be a problem when attempting to place thermocouples on them. The specimens provide by Zircar tore more and more with every effort to re-attach the thermocouples to the outside of them. Further, these samples left a powdery residue on whatever it came in contact with. Based on the inability to adequately collect data, the decision was made to exclude these samples from further testing, leaving the four samples from Zotefoams to test. The completed test structure was placed in the vacuum chamber and atmospheric pressure removed.

Insulation Selection Test Results

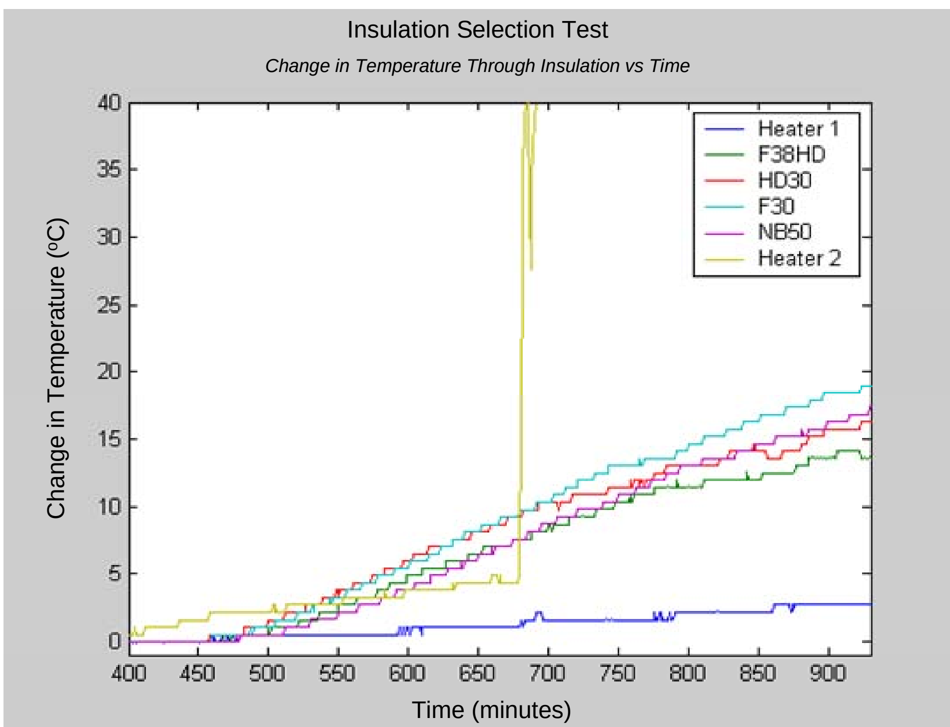


Figure 29. Insulation Test data plot

Component Implementation/design changes

All specimens insulated well, but only one needed to be selected for use on RIGEX. As seen in Figure 29, the F38HD thermocouple showed the lowest temperature at the end of the test and the slowest rate of temperature rise over time. We will call this the baseline, but as mentioned above these results are too close to one another to say for sure which was better, so other factors were needed to base a final decision.

During the setup for this test, it was observed that each specimen had a certain degree of difficulty being shaped. This shaping factor was broken into two parts, which would be given a biased rating of 1-4 where 1 was poor and 4 was excellent.

- Smoothness – Edge Jagged (poor), Smooth (excellent)
- Cut-ability –Easy (4), Difficult (1)

Table 10. Insulation Test Insulation Comparison

	Insulation Rating Wt. 3	**Smoothness Wt. 1**	**Cut-ability Wt. 2**	**Score**
F38HD	4	2	3	6.67
HD30	3	1	2	4.67
F30	1	4	4	4
NB50	2	3	1	3.67

A weight was assigned to each desired trait to keep the focus on the main goal of properly insulating the ovens as shown in Table 10. As the score indicates, the F38HD insulation received the best overall score of the insulations tested and was chosen for the flight design.

Runaway Heater Test (3.B)

Problem and/or Solution to Test

This test was intended to do the following:

Validate Thermal Model developed by Goodwin [9]
Determine the temperature the top plate reached as a result of two of RIGEX's ovens failing in the 'On' position at 32 VDC (Runaway Heater)
Determine the runaway heaters' impact to heat sensitive components

A safety concern for astronauts during an EVA, the CAPE Mounting Plate (CMP) 'touch' temperature needed to be determined if the ovens operation control mechanisms had failed and were allowed to continue to operate. This determination will verify that while in operation, our autonomous payload will not burn an astronaut if he/she were to touch the CMP while in the cargo bay of the shuttle on an external vehicular activity (EVA). The temperature threshold is 112°C as determined by the Space Test Program office (STP).

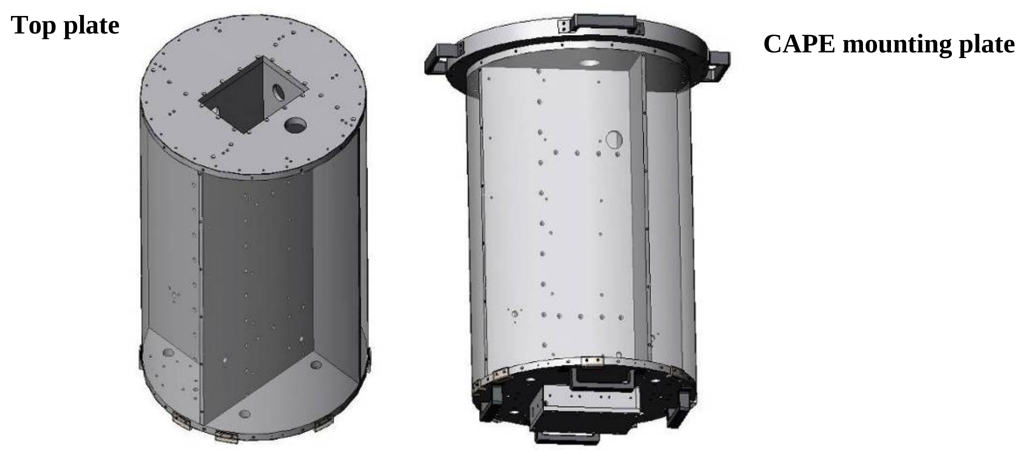


Figure 30. RIGEX Solid Works Main Structure

Further, it was determined that we needed a very conservative look at what would occur if two of the ovens failed on (three is not possible as it would blow the 10

A fuse protecting the power to the ovens (shown in Appendix D).) As can be seen by looking at the tabularized experiment events in Appendix J, in the event of an oven failing in the 'On' position power would, power would be continually supplied for a period on no longer than 4.5 hours before the third oven would come on and blow the fuse.

Runaway Heater Test Configuration

To meet the objectives of this verification, the following (highly conservative) configuration was tested:

- **No insulation around the ovens –** Allows more heat to conduct or radiate to the structure
- **Most internal components removed –**Allows free flow of heat throughout main structure
- **The oven doors remain closed –**Enables the ovens to perform at maximum
- Shroud not in place – Less thermal mass
- **Vacuum Environment –** eliminate convection, forcing heat to be conducted or radiated
- **Steady state –** Oven internal temperature change is +/- 1°C per minute, same tolerance assumed for all readings
- **Individual Power Supplies for each oven –** For protection from overloading power supplies, each oven is powered by an individual power supply (Note: Equipment to replicate shuttle power was not yet available)

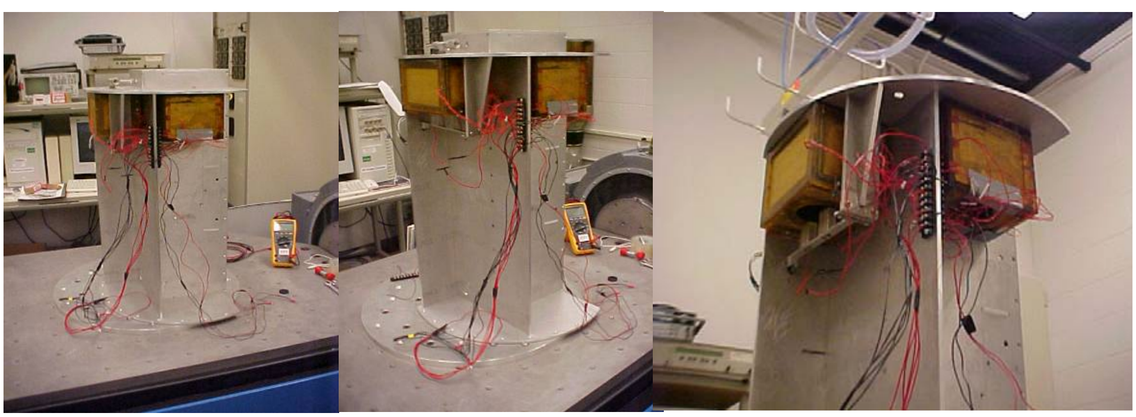


Figure 31. Run Away Oven Experiment Setup

Test and Setup Procedures

Ovens Setup

Both ovens used were prototype ovens, used for student experimentation and design implementation and verification through out the past. In an effort to conserve resources, an older oven designs prototype was lined with newer resistive heating pads (as needed) to assist in this experiment. Oven #2 had been recently used to validate the thermal model of RIGEX by Goodwin [9].

Pin Puller Setup

While compiling the Operation and Survivability table in Appendix A, it was determined that the operating temperature range of the pin puller was in question. Since it was already attached to the structure, it was allowed to remain attached for the test. Care was taken to ensure temperature readings where gathered from this area to validate its ability to withstand higher temperatures in the event the temperature was able to exceeded its operating limit of 70°C. Having the pin-puller in place allowed the #2 oven to remain closed, as it will for the heating cycle during flight. Oven #1 was secured with duct tape in order to remain closed.

Operation Setup

An old mock up (made of ¼-inch aluminum) from a previous students research was cut in a ¼ section so that it would fit into the older of the two vacuum chambers and is shown in Figure 32. This "¼-test structure" was used for the experiment further conserving our configuration by not having as much structure through which heat could flow. The structure was placed inside the vacuum chamber to prevent heat escaping the structure via convection, or at least as mush as possible. The structure was then lined with eight 'K' type thermocouples that had been used previously for the thermal model validation conducted by Goodwin [9]. The data was recorded at a sampling rate of one reading per second. Thermocouple placement is shown in Figure 32 and tabularized in Table 11.

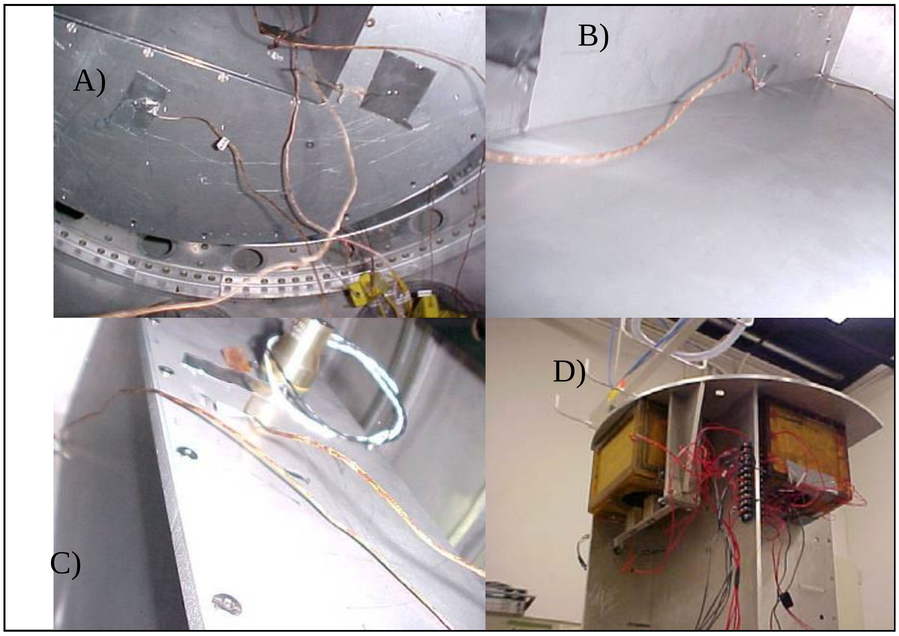


Figure 32. Runaway Heater Test – Thermocouple Placement

Table 11. Runaway Heater Test – Thermocouple Locations

Location	Channel	Figure 27
Oven #1	0	D
Oven #2	1	D
Top Plate #1	2	A
Opp. side from oven - corner	3	B
Pin puller	4	C
Opp. side from oven – ¼ structure	5	B
Opp. side from oven – near top plate	6	A
Top Plate #2	7	A

Once the chamber was sealed, the pressure was brought down to 0.4 psi (best vacuum) for the chamber. Data collection from the thermocouples ran for 60 seconds to get a bias offset for each thermocouple. Oven #2 was turned on first, and then oven #1 was turned on a short time later.

The pin puller was added to this experiment as a possible means of verifying its' functionality at higher temperatures. It was believed that with the heat produced by the two ovens, we would see temperatures near 85°C at the pin puller location if left on long enough.

Runaway Heater Test Results

- Experiment allowed to run for 100 minutes
- Steady state as defined above reached after 34 minutes of operation under ambient thermal conditions and was maintained for 38 minutes
- Maximum temperature seen at Top plate thermocouple locations was 63°C (Well under the112°C threshold)
- Maximum internal temperature of ovens with doors closed >300°C, doors open >200°C

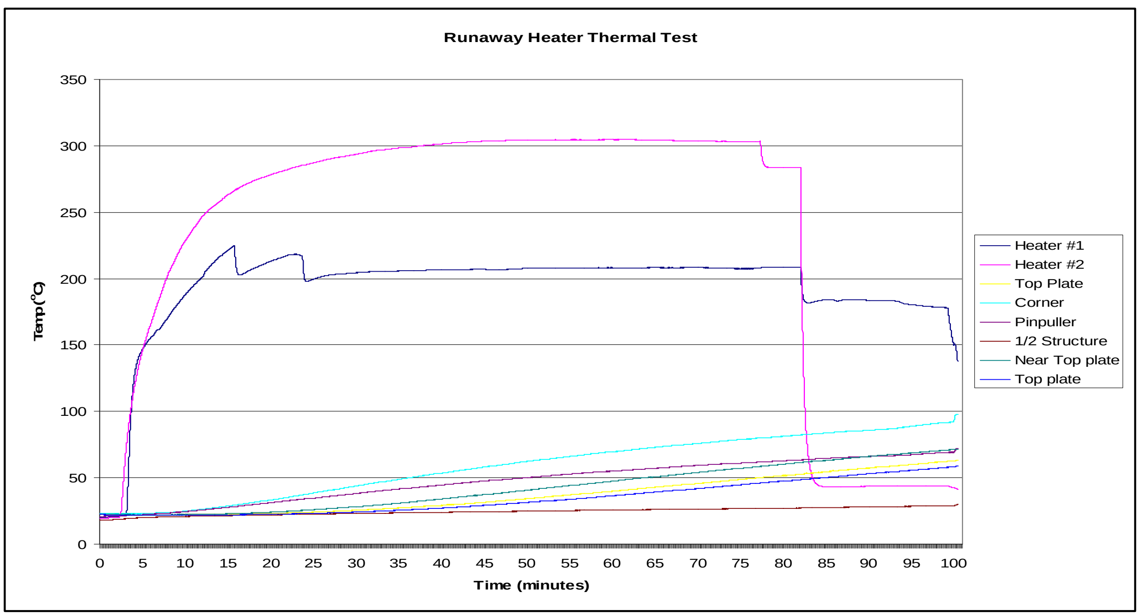


Figure 33. Data Collected During Experiment

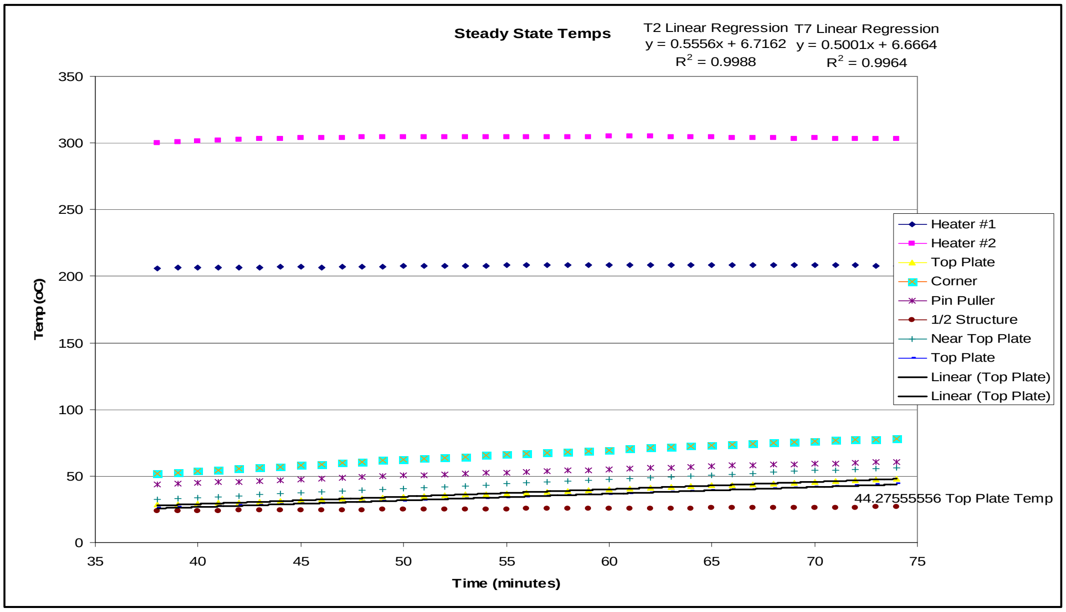


Figure 34. Enlarged Data of Steady Sate Region

The significant drops early in Figure 33 are a result of the duct tape not properly securing the doors, allowing the doors to open a little. The doors would have opened more but instead rested on the wires that where powering the heaters. Once this was realized, a note was made and the experiment was allowed to continue. Because of the ovens opening, the usable data extends until about 75 minutes from test initiation as illustrated in Figures 33 and 34.

The series of data shown in Figure 34 shows the 38 minutes of steady state data. This data shows an increase in temperature; however, the increase is under the 1°C /minute change requirement. Steady state oven #2 was terminated by the pin puller unexpectedly activating. According to the data, the pin puller thermocouple recorded a temperature at 61°C (~9°C below its upper operating limit). Once the pin puller activated, the latch over the doors of oven #2 sprang off the doors allowing the doors to fall open (due to gravity). The thermocouple had been secured by the doors and once they fully opened, the thermocouple fell out of any readable position. At this point the oven had been drawing approximately 261.5 Watts of power for >77 minutes.

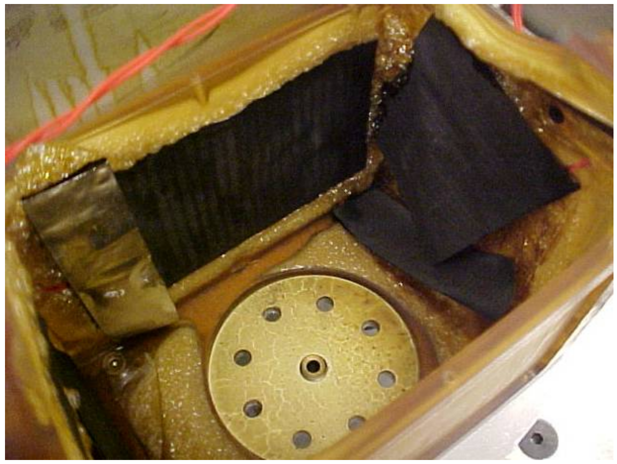


Figure 35. Damaged oven during Runaway Heater test

Upon inspection of the test configuration, once removed from the vacuum chamber, it appeared that the Ultem© material had experienced temperatures beyond its thermal limit of 200°C as shown in Figure 35

Runaway Heater Test Conclusions

Linear regression analysis on the usable data shows that if allowed to continue heating, the Top Plate thermocouples would have recorded a temperature of 112°C at approximate 190 minutes (>3hours of operation). The temperature of the Top Plate does not directly reflect the temperature on the top of the Cape Mounting Plate (CMP). The CMP adds another 3 inches of aluminum that the radiation must penetrate. Further, the ovens were not insulated. Insulation testing prior to this experiment has shown great reductions of heat dissipated by the ovens through radiation or conduction. This should further decrease the rate at which the Top Plate reaches the *touch* temperature and allow the full operation of 4.5 hours, even with two ovens failed on.

The heat from oven #2 is believed to have conducted itself along the latch onto the pin of the pin puller, causing the puller to open. Both the experimenter and the manufacturer agree that there is no way the component failed at ~9°C below its advertised upper operating limit. According to Tini Aerospace (the manufacturer of the pin puller), the shape memory material of the pin puller will react to 75oC as if it had been intentionally activated. Since the area around the puller never saw temperatures, around 85°C the component verification will need to take place in the system Thermal Vacuum Test in Chapter IV. However, the amount of heat that conducted its way through the latch to the pin puller identified the need for a small change to the RIGEX assembly. A method of separating the latch from the top tube flange to prevent heat radiation via convection must be found. Fortunately, a conducted materials formed into a tape was already in use in the RIGEX configuration. The P-213 glass tape that makes the cabling large enough to be held by the surrounding clamps and wire ties will be used around the latch to prevent a metal-to-metal heat exchange from the tube's top flange to the latch.

Upon completion of the experiment, it is observed that at full power, the melting temperature of the Ultem© was reached. Although this did not result in component failure, and is not seen as a concern for mission success, it is concluded that a temperature-monitoring device or a temperature-regulating device must be incorporated into each oven to control the amount of heat the oven will be able to put out.

Component Implementation/design changes

This test showed a need for a re-design of the oven circuitry to avoid melting the Ultem© on flight. At first, a thermal fuse was thought to be the best solution to this problem. The fuse would work like a regular fuse except, instead of being designed for an amperage load; it is designed to actuate (blow) at a specified temperature. The fuse was immediately thrown out for its serious flaw. Once blown, it is not be able to be reset, allowing power to resume to the ovens once the temperature is safe enough to resume. With the oven dead, the tube may not have reached the transition temperature ($T_g=125^{o}C$) of the tube, which would result in a failed deployment. Another alternative was discovered in Minco's passive thermal controller [20]. Utilizing a Resistive Thermal Device (RTD) to monitor the temperature, the controller would act as an 'On/Off' switch for the oven. As long as the temperature is below the set temperature, the controller will be 'On' which will then allow the oven to receive power and heat. Once the set temperature is reached, the controller prevents power from reaching the heaters.

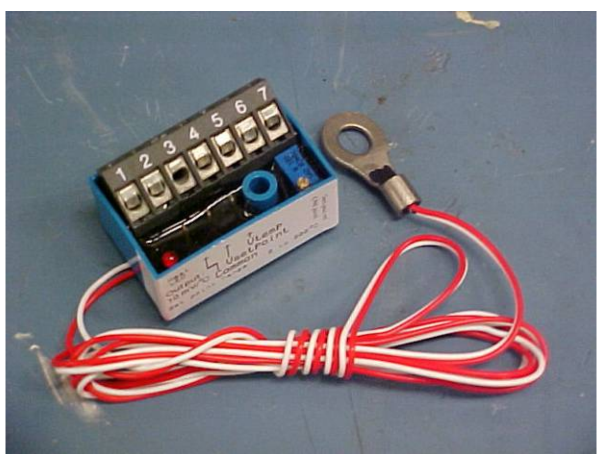


Figure 36. Oven Controller and RTD

The oven controller had limitations that needed to be addressed. The major draw back to this item was the output current limit of 4A. The circuits as designed by Goodwin [9] consumed 4.8A at 32 VDC and 4.2A at 28 VDC (see Figure 23) which meant that the controller could not sustain power to the ovens.

To get around current output limitation of the controller, the single circuit of five current paths was broken up into two circuits of two current paths shown in Figure 37. The re-utilization of the heaters identified by Goodwin [9] was done in order to make a quick turn around of this problem. This concept allowed the most amount of current consumption while utilizing the fewest number of oven controllers. The RTDs would be routed to the bolts, which hold the tubes bottom flange to the structure, which made the most use of the limited space inside of the oven (see Figure 38) As a further result of this change STP recommended making the circuits' 2-fault tolerant.

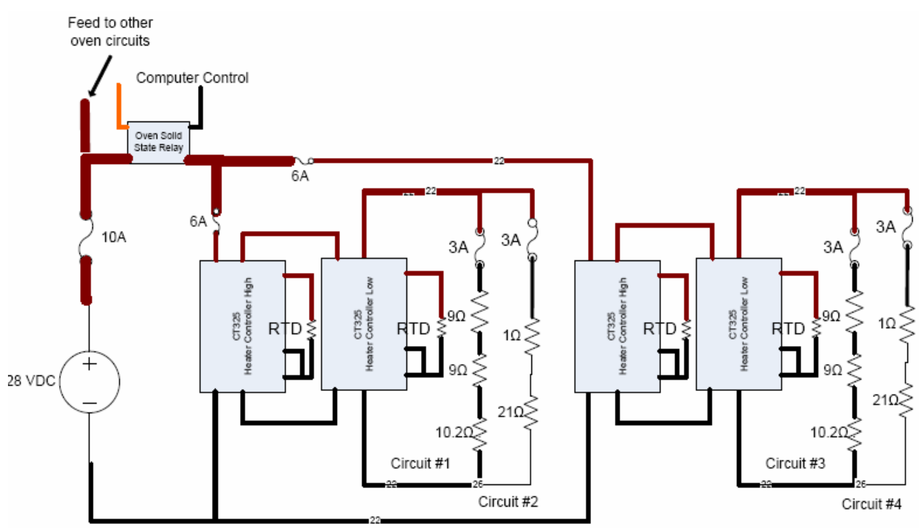


Figure 37. New oven circuit design

To make the oven circuits 2-fault tolerant, the circuit needed to be designed in a way that allowed the power to the ovens to be controlled in the event that ‘2’ components failed in the ‘On’ position. This assumption did not include the computer failing to control the solid-state relay, as this would result in mission failure. As a result of implementing a oven controller per oven circuit, the solid-state relay could fail and the oven controller could fail ‘On’ allowing the ovens to “Run Away”. The decision was then made to incorporate a second oven controller per circuit (total of 4 per oven), which then would allow the first oven controller to fail along with the solid state relay and still have the circuit being controlled by the last oven controller. Since the tubes flange is being secured to the structure with four bolts, this location was deemed appropriate to attach the 4 RTD sensors. Once the proper polarization of the controllers’ output terminals was determined, the four oven controllers were configured for the Component Suitability Test that will be described later.

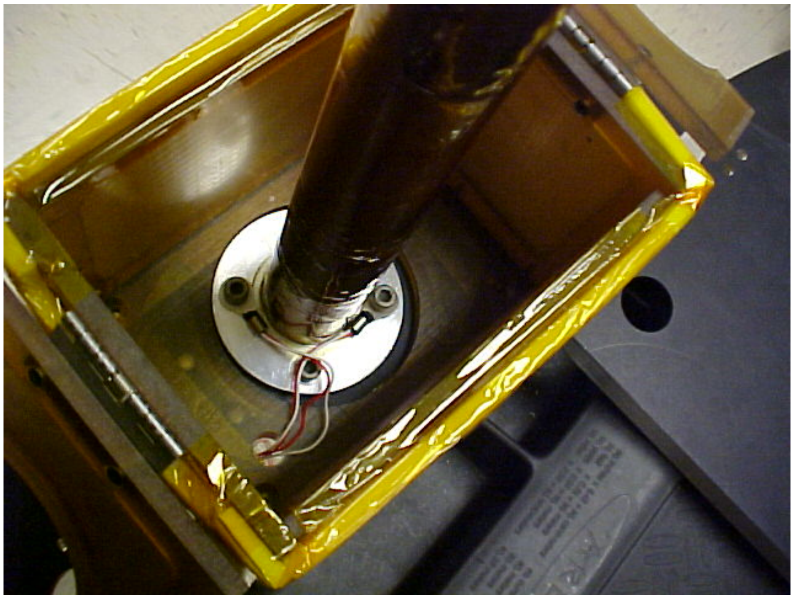


Figure 38. RTD positioning on the bottom flange of each tube

The proper set temperature needed to be determined to properly control the power to the oven. (Note: The 'set' temperature is the temperature that the oven controller will stop power to the heaters). A simple test was setup where the oven was commanded 'On' by the computer's DioTEST software. A thermocouple was placed on the Ultem© to determine the temperature of the oven material as it heated. Utilizing the controller's ability to view the RTD's temperature through a voltmeter, the temperature of the RTD was monitored as the oven heated. Once the thermocouple indicated 90% of the materials transition temperature (roughly 180^{o}C), The reading from the RTD indicated 80^{o}C. Remember, the Ultem is non-conductive, but the aluminum flange of the tube is. To make matters worse, it is directly connected to the main structure, which is also a large heat sink. As a result, this temperature difference between the oven material and the RTD's reading was expected. The low oven controllers on each oven circuit were then set to 80^{o}C via the controller's setscrew. (Note: The low oven controller is the primary controller that was incorporated to control the temperature of the oven. The high controller is the safety controller for the 2-fault tolerance, and is therefore set to a higher temperature). The high oven controllers were set to a temperature of 95^{o}C. This was done for two reasons:

- To not prematurely cut off the low controller
- To attempt to save the ovens if the low oven controller failed.

The Runaway Heater test destroyed the only test and checkout oven built as shown in Figure 35. It was assumed that if the temperature in the oven was exceeded by 120% of the set temperature of the lower controller that it had indeed failed. As a result, the High oven controllers are set to 95^{o}C.

Component Test (3.C)

Problem and/or Solution to Test

In order for RIGEX to be certified for flight, each component must either be certified by the manufacturer to be operated under the planned environment and conditions, or proven through testing. Additionally, each component must be certified to meet the extremes of space *before* they are integrated with the RIGEX system. Certifying each component before integration ensures that the component will not need to be removed for failure due to environmental failure later during system level testing. Table 12 is a quick snapshot of the environmental constraints from Table 2. As indicated by Table 13, five components fail to meet the environmental requirements in Table 12 or are in need of checkout. The setup and execution of this test is documented in Miller [19] but here is a quick outline of event during the test:

1. Vacuum to 1E-7 Torr
2. Bring temperature down to -65^{o}C, let dwell for 1 hour
3. Bring temperature up to -45^{o}C
4. Execute component test (modified FVT code)
5. Bring temperature up to 70^{o}C, let dwell for 1 hour
6. Bring temperature down to 45^{o}C
7. Execute component test (modified FVT code)
8. Bring to ambient conditions

Table 12. Thermal Requirements snap shot of Table 2

2	**Thermal Environment**	**The CAPE/Payload shall meet the following conditions without heaters for the cold case and with runaway heaters for the hot case if heaters are used for each category.**	
		Operating Temperature	–40 deg C to +55 deg. C.
		Survival Temperature	–60 deg C to +85 deg C.

Table 13. Operability and Survivability of Components snap shot

		Operating Limits		Storage Limits	
		Temp (^oC)		Temp (^oC)	
Subsystem	Component	Low	High	Low	High
Command and Control (Computer)					
	Thermocouple	-25	85	-25	85
Ovens					
	Ovens	N/A	N/A	N/A	N/A
	Oven Controller	-40	70	-40	70
Power Distribution					
	Solid State Relays: output	-20	80	-40	100
Imaging System					
	Cameras	-20	100	-20	100

Component Suitability Test Results

The thermal vacuum chamber was not able to get to the cold temperature desired by Miller [19], because of the unpredicted consumption of liquid nitrogen by the chamber. As a result, the decision was made to conserve the liquid nitrogen for the transition to upper temperature which left the components being baked at only -50^oC instead of the desired -60^oC. However, even after the decision was made to conserve the nitrogen, there was still not enough to get the chamber to the upper limit of 70^oC. Fortunately, discussions were taking place at the time for the system level Thermal Vacuum (TVAC) test and its limits. The limit for the TVAC test upper limit was being set to 65^oC so the decision was made to incorporate this upper limit as well. Unfortunately, this meant that the oven controllers' upper limit could not be verified, but it was determined that this can be watched during the system level test and could be ignored for during this test.

Recall this test is a function check, so all the data observed was only to determine whether the component was functioning. Indications of functionality at temperature real-time showed that the following did function at temperature:

- Camera
- Oven Controller
- Oven
- Solid state relay

Post processing of the computers data was the only way to verify the functionality of the thermocouple board. Once the data was extracted, it was confirmed that thermocouple board operated beyond the manufacturers operating limit.

Component Implementation/design changes

Unfortunately, when the camera data was post processed, there were no pictures and the compact flash disk needed to be formatted, which indicated a failure of the hardware. This failure was attributed to the non-flight compact flash disk that was being used for the test. Because of the failure at temperature of the compact flash disk, an alternative compact flash disk needed to be found that would function at the space environment temperature. WinSystems® makes industrial grade Compact Flash disks, which are spec'd out to withstand the space temperature environment, but there is no data on vacuum testing. As such, this component will also need to be verified during the system level TVAC test

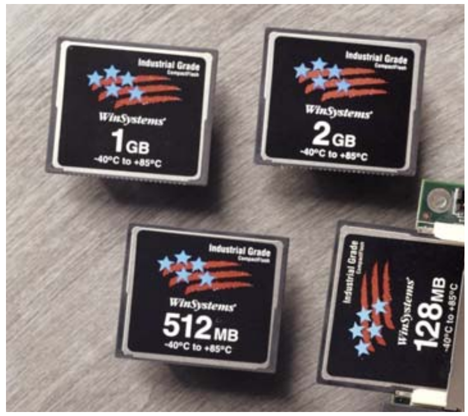


Figure 39 WinSystems® Compact Flash Cards

Chapter Summary

Throughout this chapter, the individual components of RIGEX were tested and functionally verified for use on RIGEX. During the system level testing, two component's usability is still in question, and needs to be resolved during system level testing as described on the next chapter. These tests must be done prior to delivery of the payload to NASA.

IV. System Level Testing and Validation

System level testing involves testing for both functionality of RIGEX and spaceflight certification. Table 8tabulates the testing conducted both at AFIT and at JSC. All testing done at JSC was conducted with RIGEX installed in CAPE and is referred to as the RIGEX/CAPE system. Because tests in this configuration are with CAPE, STP controlled the test set-ups and direction. The results of these tests are published here for the spaceflight qualification of RIGEX, as well as AFITs involvement in troubleshooting certain results to ensure its certification.

For the EMI test, the Vibration test, and the Weight and Balance test, RIGEX was sent to JSC to be integrated with CAPE. This was done to satisfy requirements for both pieces of flight hardware (RIGEX and CAPE) to be checked out simultaneously, and so that the spaceflight qualification associated with these tests could be properly documented by NASA officials.

Pressure System Performance Test (Test 4.A)

Objectives:

- Validate the RIGEX Pressure System:
- Verify Pressure System will hold pressure for an extended duration (Mission Success)
- Verify System is properly protected from over pressurization (Safety)

This test is broken down by sections; each section addresses one of the above objectives.

Figure 40. RIGEX Tank Pressure Transducers

Figure 41. External Power and Data Acquisition Lines for Pressure Testing

Pressure System Leak Test:

In this section, we will verify that the pressure system will retain pressure through flight, and not leak nitrogen gas into the vacuum of space before it is purposely done. In this test, the RIGEX tank pressure transducers (shown in Figure 40) were temporarily re-wired to allow external power and data acquisition (see Figure 41). This is accomplished by temporarily disconnecting the transducer via twisting off the transducer's back shell.

Pressure System Leak Test Configuration

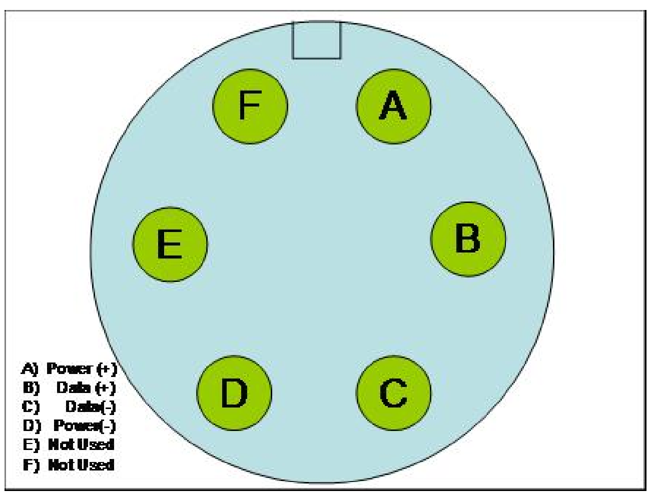


Figure 42. Pressure Transducer Pin-Out for Pressure System Testing

In order to record data, 24-32 VDC must be applied to the transducer. Each transducer outputs a voltage on a scale from 0-5 VDC. Five VDC represents 15 psi, which is the largest pressure able to be measured by the transducers. Because of this, the entire experiment is placed inside AFIT's Thermal Vacuum chamber and brought down to an internal pressure of 1E-2 Torr. (Aside: 1 Torr = pressure required to displace1 mm of Hg). The Transducers' pin-out is shown in Figure 42 and the electrical wiring is shown in Figure 43. The experiment was run for approximately 24 hours. The Data Acquisition System is shown in Figure 44.

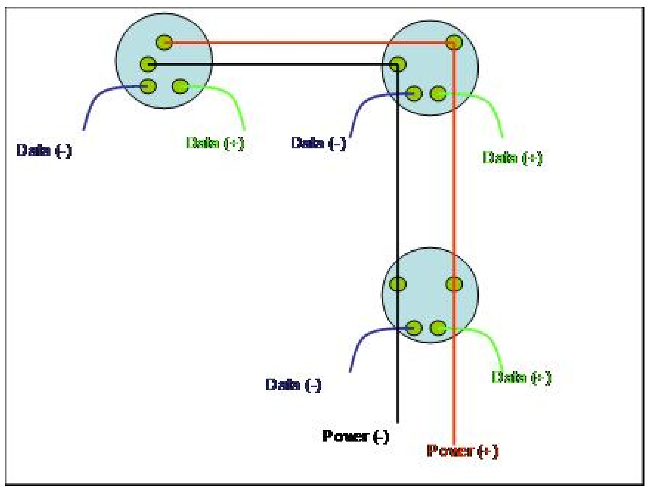


Figure 43. Pressure Transducer Wiring Diagram for Pressure System Testing

Data is recorded via the Laptop's Lab View interface using the Lab View 6.0 software. The voltage output of each transducer is recorded. The software was set to record each value at a rate of one sample per second.

Each of the fill port screws was removed and the valves opened allowing each tank to pressurize to atmospheric pressure (see Figure 45). This is ideal for two reasons. For flight, RIGEX will be pressurized to 14.7 psia or 0 psig, which means that on the ground, there will be no difference in pressure between the inside of the tank and the outside. The other reason is that tanks do not need to be filled with anything other than air to perform this test. Once the valves are open to ensure that they are at atmospheric pressure, they are closed to lock in the pressure.

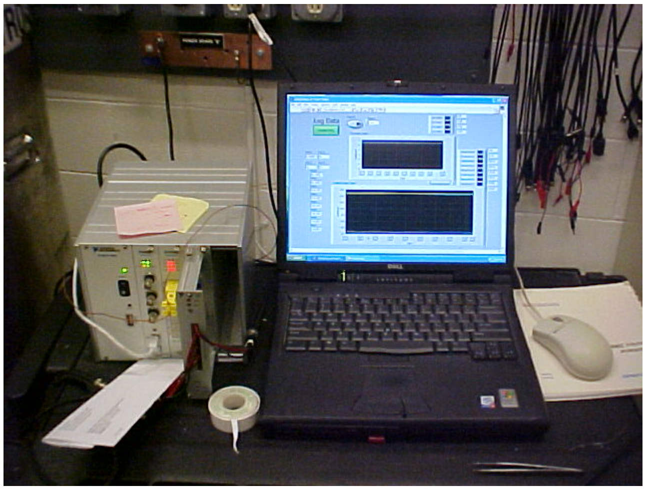


Figure 44. Data Acquisition System Running Lab view 6.0

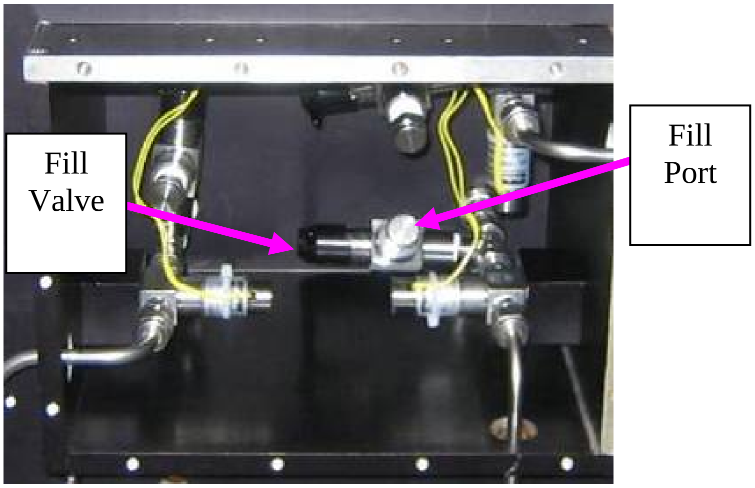


Figure 45. Fill valves and ports

Pressure System Leak Test Results

Once the chamber reached vacuum (<1E-2 Torr), the recorder was initiated. During the18 hour period, the vacuum chamber pressure remained at 1E-2 Torr. The graph from the data recorder (shown in Figure 44) showed no significant change in data, so the test was terminated.

Figure 46 shows that after 18 hours of being under vacuum, neither tank had leaked. This is graphically shown by no drop in pressure over time.

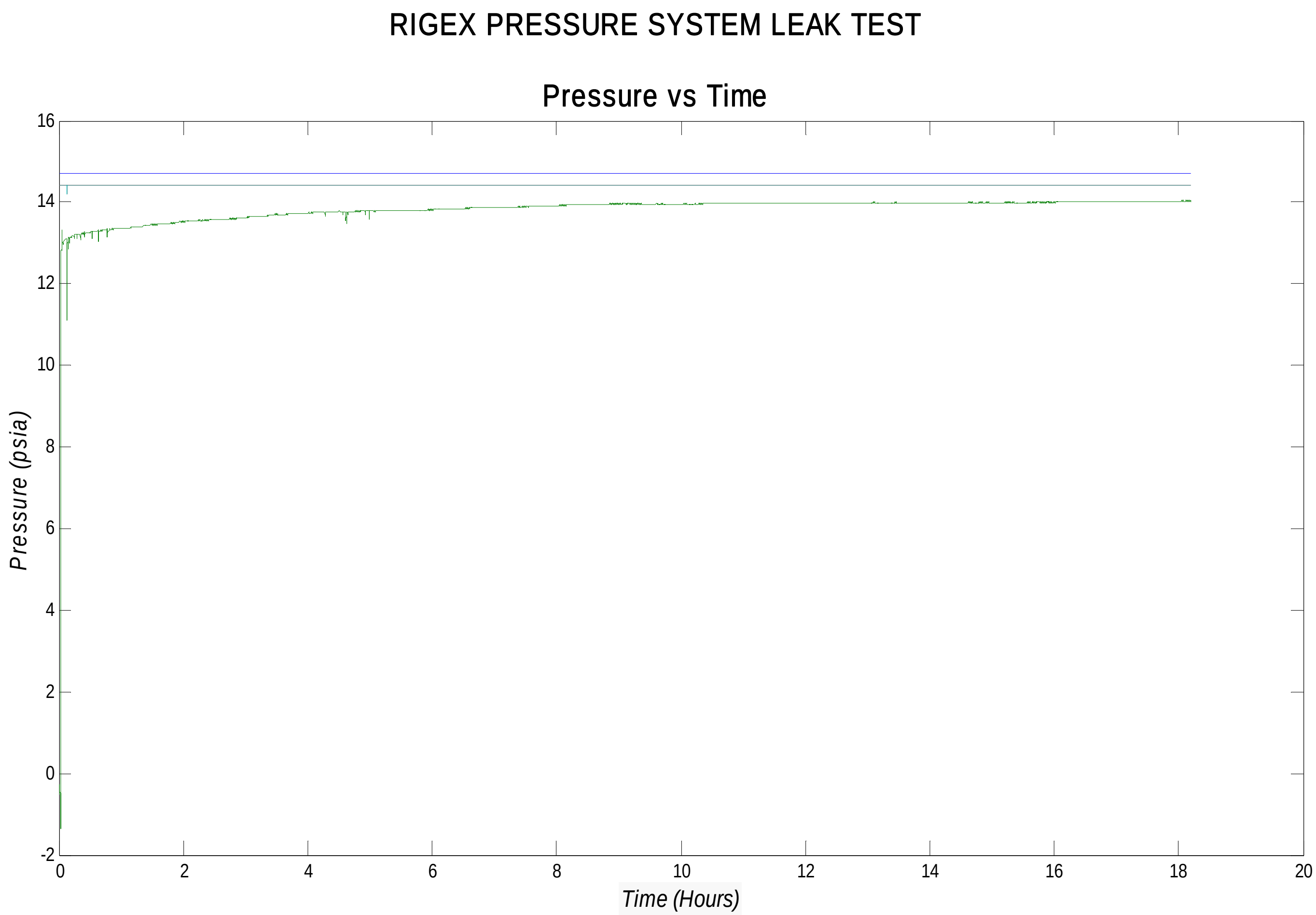


Figure 46. Pressure Data over length of Pressure System Leak Test

The rise indicated on one of the channels is an issue, which required additional investigation. Obviously, pressure could not rise in the tank without being heated or having more gas added to the tank, which indicates a problem with the transducer itself. After reviewing the inflation systems assembly procedure, it was noted this transducer was dropped during the pressure system assembly. Because of this fall, the calibration of the transducer must have been lost. During the flight of RIGEX, the tank pressure transducers will be used to verify that the pressure is greater than zero psia, which this transducer is still able to provide as indicated. Although it would be desired to have the transducer properly calibrated to have an exact pressure reading, it was determined that a calibrated reading is not required for mission success.

Pressure System Leak Test Conclusion

RIGEX has a zero leak rate for each of its internal storage tanks. After 18 hours under vacuum, no leakage was detected from the system indicating the system is air tight and ready for flight.

Pressure System Over Pressure test

In space, the shuttle will have an orbital period of 90 minutes and as such, the time that the shuttle will be exposed to the direct solar radiation is approximately ½ the orbit or ~45 minutes. The structure will be naturally heated by solar radiation when the cargo bay is exposed to direct sunlight. The natural heating by the direct solar radiation could escalate the structure's temperature to a point where pressure in the tanks would begin to increase. In this section, we look at the ability of the pressure system to withstand being pressurized to 135% of what will be seen in flight. The over-pressurization of the system is to satisfy the safety requirements established in NSTS 1700.7B, 200.3 Environmental Compatibility, 200.4a Safe without Services, 208.3 Stress Corrosion, 208.4 "Pressure Systems, and 208.4c Pressurized Lines, Fittings and Components”.

Possible causes of pressure system failure are:

- Inadequate design strength to withstand maximum design pressure (MDP) and other loading environments.
- Improper materials selection and processing
- Material incompatibility with inflation gas.
- Improper assembly
- Propagation of crack-like defects
- Overfilling of pressure vessel/system during ground operations.

In order to mitigate the potential of any of the above, this proof test will verify that the RIGEX pressure system is not a safety concern.

Pressure System Test Configuration

In this test, each pressure cylinder will be evacuated and filled with nitrogen gas utilizing RIGEX_MGSE_4 (Figure 47 and Figure 48) and RP-9 RIGEX Fill Procedure.

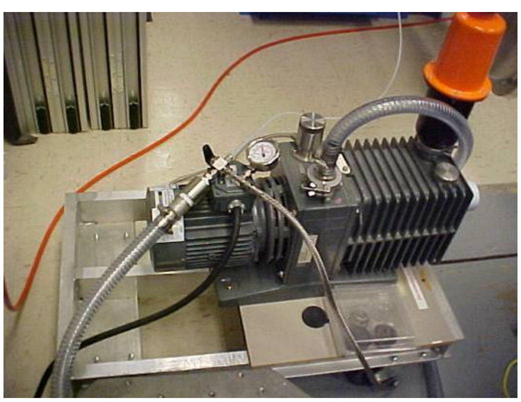


Figure 47. RIGEX Mechanical Ground Support 4 (MGSE_4)

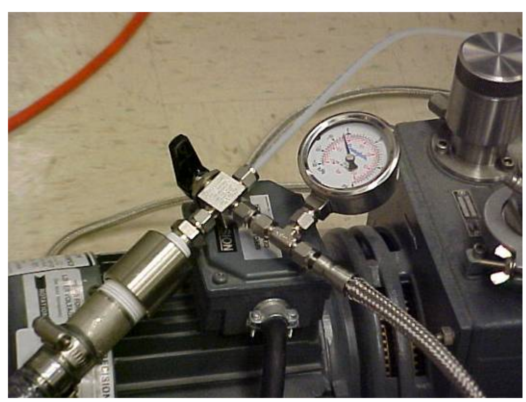


Figure 48. RIGEX MGSE_4 User control gage and valve

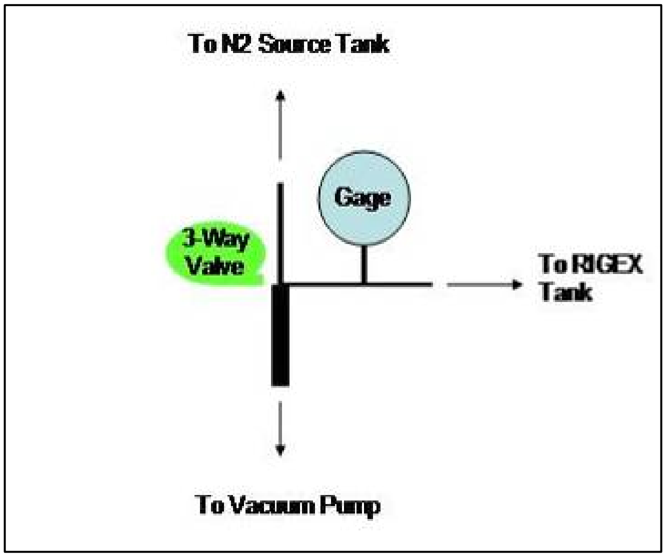


Figure 49. RIGEX_MGSE_4 Schematic

RIGEX Mechanical Ground Support Equipment #4 was designed and built specifically to deal with the operation of emptying and filling the gas storage tanks on RIGEX. Operation is dictated in RP-9, but here is a quick snapshot of how it works.

- Attach to Fill port (shown in Figure 45)
- Turn Valve to Vacuum pump line to empty the tank
- Turn Valve to NITROGEN Source line to fill the tanks
- Read desired pressure (0 psig)

For this test, however, the desired pressure will be 20 psig as explained below. The pressure inside the tanks will be increased to 34.7 psia (20 psig) and be held for 1 hour. To prove that RIGEX has a factor of safety (FOS) built into the system >110%, the requirement is to test to 17.4 psia (2.7 psig). However, this value is too difficult to accurately measure using our dial gage shown in Figure 48, so the pressure was set to 20 psig proving a FOS of 236%. (Note: All components of the pressure system are rated significantly higher than 20 psig.)

Over Pressure Test Results

The following was recorded for each tank:

Start Time 2251

End Time 2351

Figure 50. Tank#1 Over-Pressure Test Result

Start Time 0003

End Time 0106

Figure 51. Tank#2 Over-Pressure Test Result

Start Time 0113

End Time 0216

Figure 52. Tank#3 Over-Pressure Test Result

As can be seen with Figures 50 thru 52, the pressure did not decrease after one hour of being under this higher pressure.

Over Pressure System Test Conclusions

We have proven that not only will the tanks hold an increased pressure to 1.18 atm (17.4 psia) or 118% of the desired pressure, but that it will also hold 37.4 without rupture or leak

RIGEX has exceeded the FOS criteria of 118% and has proven that the pressure system can handle any additional pressure increases that may result due to structural heating caused by solar radiation.

Deployment Test (Test 4.B)

Problem and/or Solution to Test

The mechanical operation of RIGEX needed to be verified once it was built, so this test was designed to execute a full deployment of the Bay 1 test tube. While this test is conducted, the ambient current profile was also collected for RIGEX at 28 VDC and again at 32 VDC in order to establish a current draw profile at the different voltages for the Acceptance Data Package (ADP).

Note: the flight code is set to deploy the tube based on one of two criteria being met:

- Tube reaches and average temperature of 130^{o}C
- Heater has been on for two hours

Deployment Test Configuration

The RIGEX T-VAC test configuration was used which means that RIGEX was powered and commanded by the emulator through the TVAC chamber (see Figure 53). The control test software is compiled and loaded onto the flight computer and the computer is then configured to run this test software upon startup.

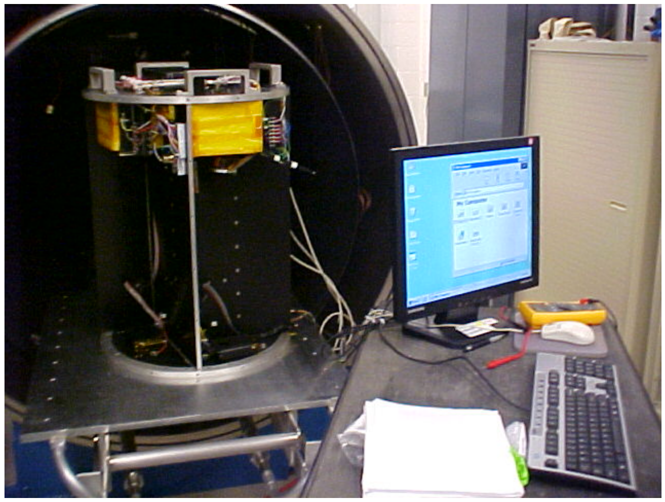


Figure 53. RIGEX TVAC Configuration

Deployment Test and Setup Procedures

This test was conducted as follows:

- **Verify setup –** Ensure system is wired correctly and that test tubes are installed
- **Fill Bay 1—**Using RP-9 fill tank to ~14.7 psig to mimic pressure difference on orbit
- **Start data acquisition program –** Initiate the data acquisition computers recording
- Turn 'On' emulator (powering at 28VDC)
- Set emulator to output 28VDC and turn S-13 switch to 'Up' position momentarily
- Record current changes and time from emulator display
- **Verify Deployment of the Tube –** Indicate the tube deployed
- Stop data acquisition program and turn emulator 'Off' –Turn emulator S-13 switch to 'Down' momentarily
- **Repeat steps 2 through 6 at 32 VDC—**Note: The test tube needs to be removed, re-folded, and re-stowed in the Bay 1 oven

In this test, the mission success of RIGEX will be verified. This is done through an overall system test conducted under ambient conditions and in plan view to verify the actual deployment of the tube.

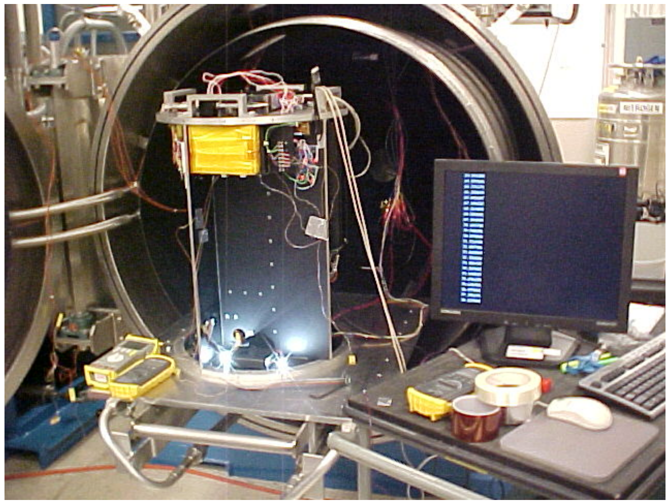


Figure 54. RIGEX Operation during Deployment Test

Figure 55. Successful Deployment of Tube

Deployment Test Results

The collected profiles are in Appendix E. After two hours, the tube was successfully deployed and the test was terminated.

Component Implementation/design changes

Although the tube deployed, it took the full two-hour time limit set in the software to do so. Upon inspection of the real-time data, it was evident that the average temperature recorded by the flight computer was not increasing as expected. The connections were inspected and no fault was found in the external wiring. The cabling in the computer was inspected, and again no fault was found in the wiring. It was therefore assumed that the thermocouple board was not reading a channel to which that one of these thermocouples is attached. The board's manufacturer was contacted and stated that this has been a growing trend with this part number. There was nothing they could do to fix the problem without shipping the board to back to them for repair.

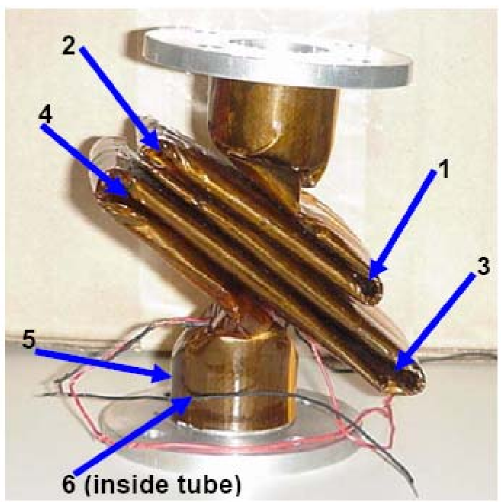


Figure 56. Lindenmuth [16] Thermocouple placement

To verify that the channel was faulty, a program was written to check each channel of the board, and it was determined that channel 3 of the thermocouple board is faulty and fortunately is the only bad channel on the board. The decision was made to proceed despite the bad channel reading due to time constraints and the fact that one thermocouple is sufficient to gather data. The channel 4 thermocouple is working fine and is located in the #3 fold as identified by Lindenmuth [16] (see Figure 56). This is the location, which took the longest to heat in his profile analysis and as such, the best place to have the thermocouple.

This test program identifies the faulty channel by the value that is read from the thermocouple board's mux data chip. The value read by the program is a twos compliant 12 byte binary number, which is then converted by the software to a temperature in Celsius based on the board manufactures conversion factor. In the case of the faulty channel, it would continually show a temperature of 256^{o}C, which most certainly was not the case.

The flight software is configured to take the lower of the two readings and place it into a 15 element of array. This data array contains the last 15 temperature readings, which the program then uses to determine an average temperature. Due to the faulty channel showing the highest temperature the board is set to read, no modifications were made to the flight code to compensate for the bad channel. The other channel will always meet the lower criteria, which will feed the data average array mentioned above resulting in the temperature criteria taking longer to be reached for Bay 1.

Despite the determination of the faulty channel in the thermocouple board, the RIGEX system performed as desired with the successful deployment of the test tube. The system functionality for mission success will be verified upon completion of the thermal vacuum testing, as these conditions are not flight like enough to certify its operation on orbit.

Electro-Magnetic Interference Testing (Test 4.C)

Problem and/or Solution to Test

In accordance with SL-E-0002 Book 3 Volume I [30], an Electromagnetic Interference (EMI) test is conducted to characterize the electromagnetic characteristics of the payload and verify the characteristics are within a given set of control limits for use on the Shuttle. EMI testing is accomplished though a series of specified tests; the actual number of tests are payload dependent and are determined by the respective NASA authority. In the case of RIGEX, the respective NASA authority for EMI testing was the EMI Test Facility at JSC. When RIGEX was presented, it was determined that the following sub tests were required for EMI certification:

- **CE102 –** A Conductive test to measure EMI generated and conducted along power and command and control lines that specifically interface with the shuttle
- **RE102 –** A Radiative test to measure EMI generated and radiated out of the payload
- **TT101 –** A Transient test to measure the payloads ability to respond from an 'Off' state while transitioning to an 'On' state.

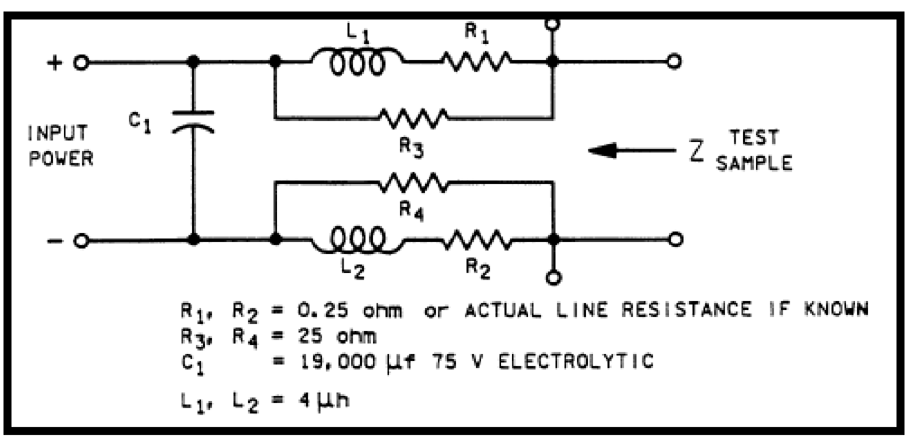


Figure 57. NASA's Line Impedance Stabilization Network (LISN) Device Schematic [30]

EMI Test Configuration

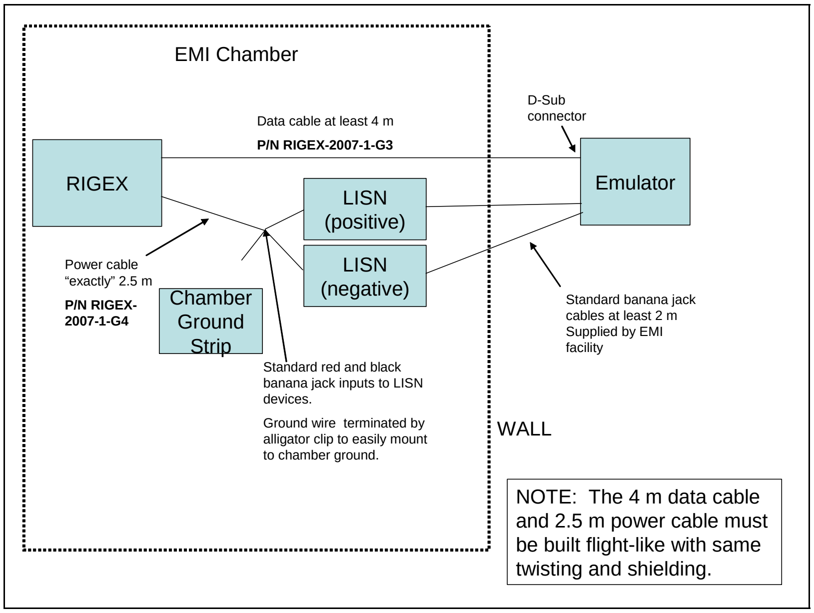


Figure 58. Electro-Magnetic Interference (EMI) Testing Setup

The EMI test facility requires that the main cable utilized for the test be as flight like as possible. Based on Figure 58, special cables needed to be built for this test due to the required length. The RIGEX-2007-1-G3 (white) and - G4 (orange) cables were built specifically for this test, but also have the ability to be used for additional ground testing. These cables are shown in use in Figure 59 connected to the NASA LISN device and again in Figure 60 protruding from the CMP. To measure conducted electromagnetic interference, NASA has built the Line Impedance Stabilization Network (LISN) device, which was connected to both the POS and NEG power lines in –G4 shown in Figure 59.

Figure 59. Actual EMI Test Setup at JSC

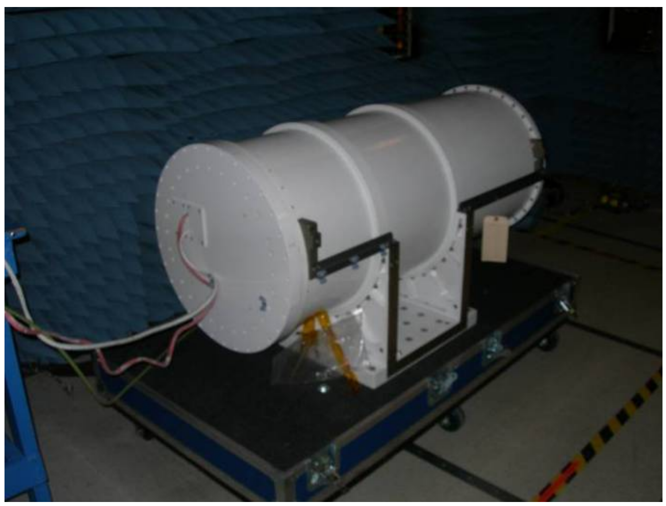


Figure 60. EMI Test Structure is the RIGEX/CAPE System Assembly

The RIGEX/CAPE system configuration was not required for this test; however, it was required for later testing at JSC. Being in this configuration provided no additional components to monitor as CAPE will not be powered for flight. Rather it provided RIGEX added attenuation that would only help if the radiative emissions were close to the defined limits.

EMI Test Procedure

The EMI test was conducted in accordance with TPS 8U0720003 [2]. The test code was configured to execute the following (the current profile as a result of this operation is shown in Figure 61):

- Nominal Functional Verification Test (FVT) as defined by Goodwin [9]
- Nominal Bay run – Heating ,solenoid activation, imaging system activation, and nominal computer operation
- Never Ending loop of cycling 'On' and 'Off' both the ovens and the solenoids as these transients were determined to be the most interesting by the EMI test facility

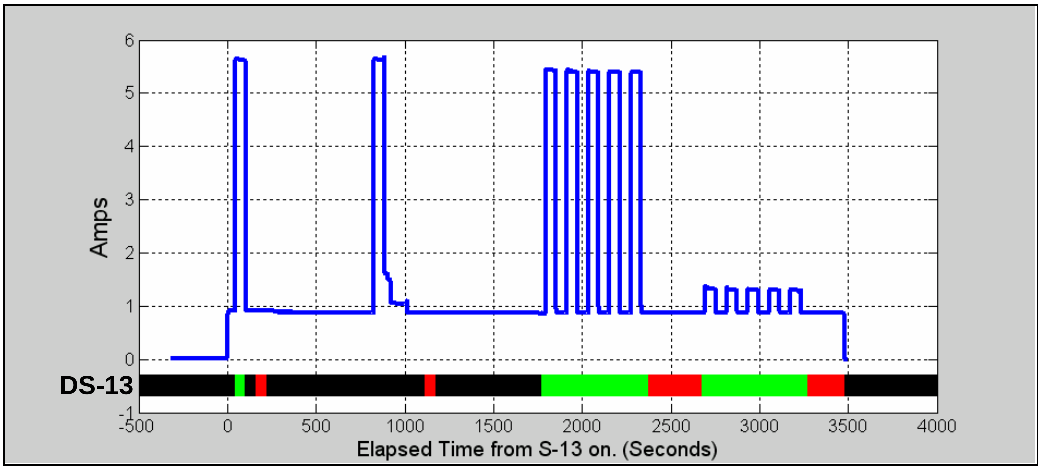


Figure 61. EMI Test Current Profile for RIGEX/CAPE System Configuration

The peaks seen in Figure 61represent the following:

- Peak 1: FVT portion of Code
- Peak 2: Bay Operation portion of Code
- Remaining Peaks: Cyclic operation portion of the oven (larger) and solenoid (smaller)(repeats until turned off by user through the emulator)
- The color strip indicates the color of the indicator LED on the emulator that is active during the respective portion of the test execution

EMI Test Results

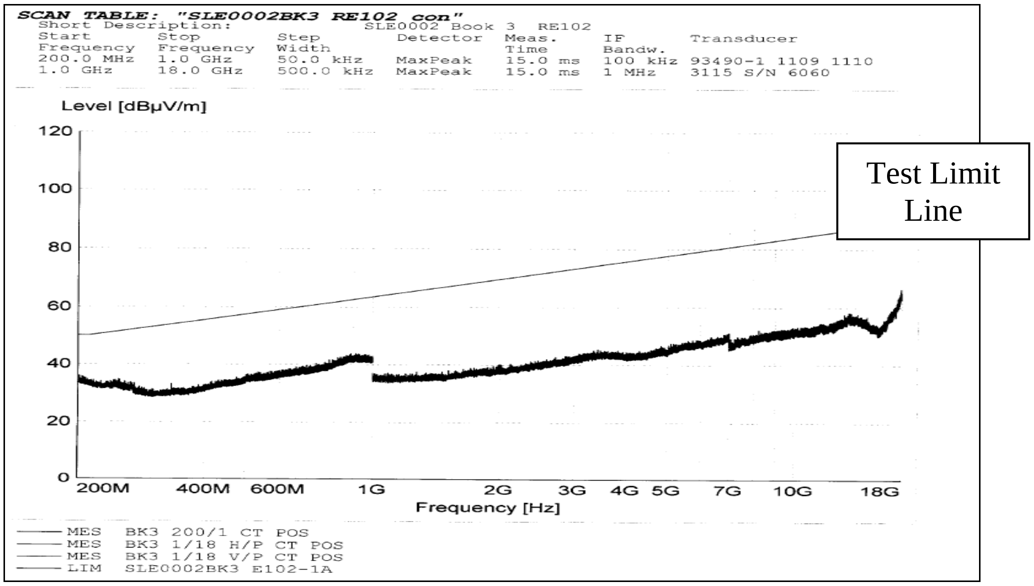


Figure 62. RE102 Test Results from TPS 8U0720003 [2]

Figure 62 shows the results of the radiative EMI testing. For the collection of data during this test, RIGEX executable program was allowed to operate through the bay operation portion of the code shown in Figure 61. The RIGEX/CAPE system configuration passed the radiative test, as the limit line in Figure 62 was not surpassed.

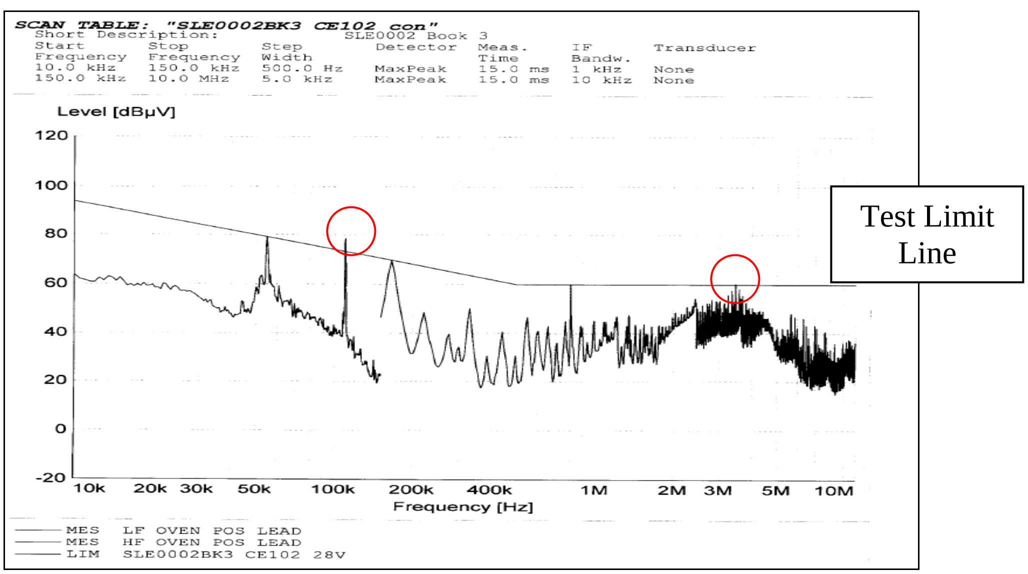


Figure 63. CE102 Test Results from TPS 8U0720003 [2]

Figure 63 shows the results of the conductive EMI testing. As can be seen, the limit was breached during this test once at approximately 109 kHz. At four other frequencies, the conductive emission levels came close enough to the limit line that a zoomed in look on the data was taken. Upon closer inspection of these points via the testbed computer's data display, it was determined that the limit had only been breached at the 3.4 MHz in addition to the 109kHz location mentioned earlier.

At this point, the certification test was halted in order to determine if it the test setup might have caused the failure. It was noted by an EMI facility technician that they usually utilize the facility's highly filtered, clean power for these types of tests to ensure that the power supply does not cause the conductive failure. The data supported another technician's theory that peaks seemed to be cyclic, which would indicate a harmonic mode in the system. A side test was requested to test this theory, which required a deviation to the test plan.

Once the deviation was written and approved by the EMI test conductor the emulator alone was setup in the chamber as shown in Figure 64 and the criteria of CE-102 as defined by SL-E-0002 Book3 Volume I [30] was applied. The results of the emulator conductive emissions test, shown in Figure 65, reveal that it fails to meet the CE102 test specification. When this data is compared to the data from Figure 63, as done in Figure 66, the emulator role in the systems failure of this test is evident.

Figure 64. Emulator Conductivity Emission Test Setup

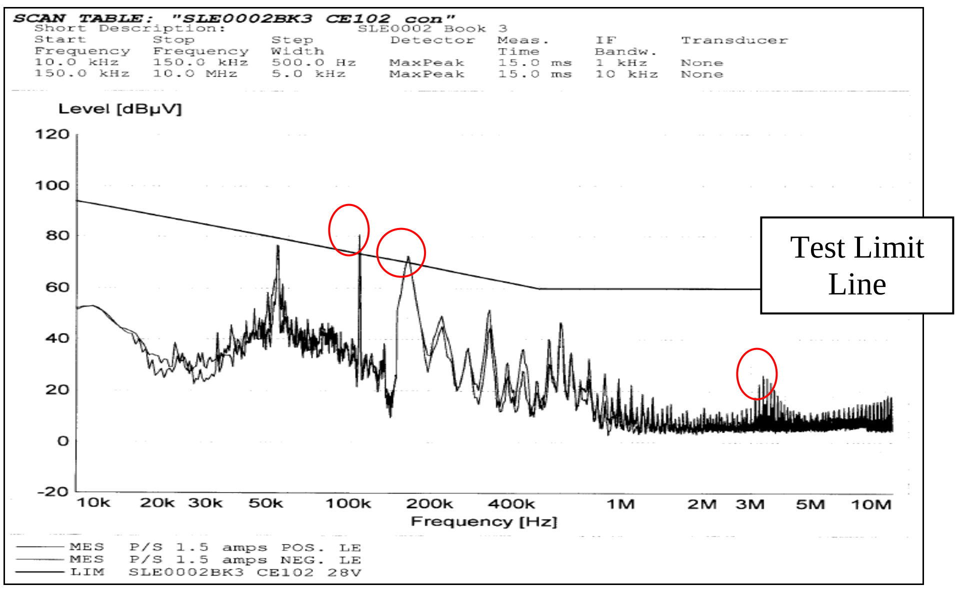


Figure 65. RIGEX emulator Electromagnetic Conductive Emission Levels [2]

NOTE: Circles indicate peaks at frequencies which the RIGEX system failed the CE102 criteria

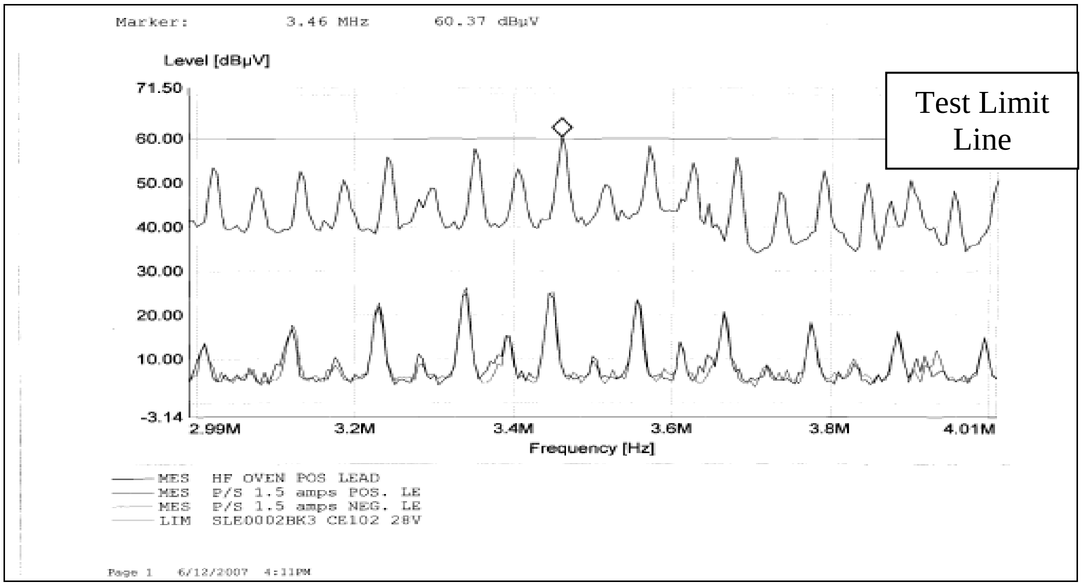


Figure 66. Emulator Conductive Emission Contribution to RIGEX system
NOTE: This data provided by the EMI test facility at JSC and is reproduced here with their permission

To ensure that the fault lay with the ground support equipment, permission was obtained to repeat the CE102 test utilizing the facility's clean power supply. To do this required a re-configuration of the test setup to run power from the facility to the LISN devices. The emulator remained hooked up for its command and feedback circuits, which were used to follow the payload through its code execution. Figure 67 shows the graphical results of this test. Because the limit line was not breached during this test, it was determined that the very noisy emulator did indeed cause the initial test failure. The data gathered from the Emulator Conductive Emission Test and the EMI Facility Powered Conductive Emission Test would be used to support the dispute, headed by STP. The dispute was filed requesting to ignore the first CE102 test. The data presented from the deviation showed beyond a doubt that the emulator was the cause of the initial failure. Upon this determination, it was agreed by AFIT and NASA to proceed with remaining light certification testing.

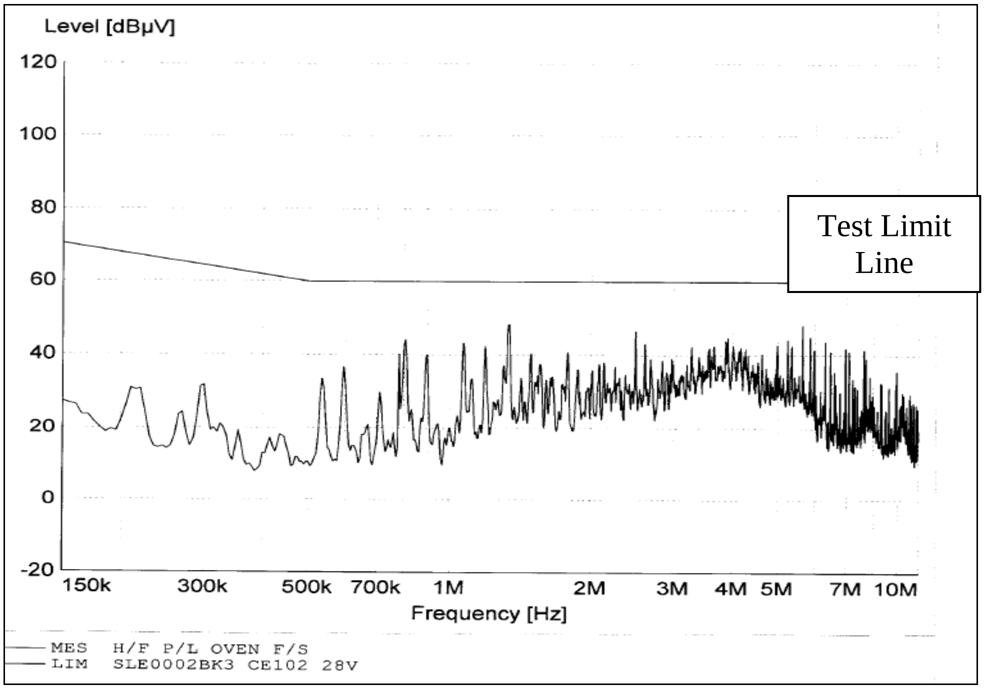


Figure 67. EMI Conductive Emission Testing with EMI Test Facility Power supply [2]

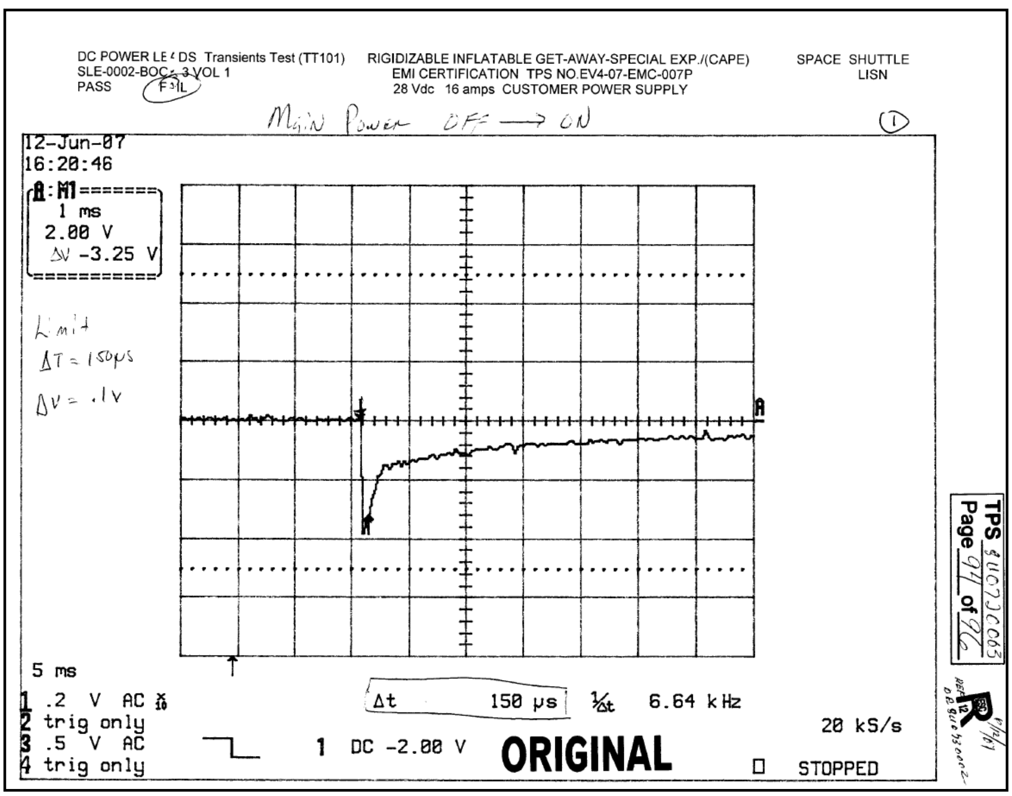


Figure 68. RIGEX/CAPE Transient Test (TT101) Results [2]

Figure 68 shows the results of the transient test. This verification required the following:

- The voltage potential to the payload returns to with-in 0.1VDC of the 28 VDC load within 150 μs.
- The voltage transient drop does not exceed 4 VDC upon initiation.

RIGEX did respond well having only a 2 VDC transient drop in voltage upon initiation. However, RIGEX did not respond within the specified time, instead 7.9 ms to get within the 0.1 VDC criteria of 28 VDC.

Although this meant RIGEX did not receive the EMI certification as a result of failing the Transient Test, a strong case can be made t for a waiver of this requirement. At the time of the publication of this document, an informal response from NASA assured that the waiver would be granted, but a formal response had not yet been received.

Component Implementation/design changes

Although not directed by NASA, it was recommended that the FVT code be adjusted to exercise components in all three bays to verify payload operability. The FVT code from Goodwin [9] was then adjusted to execute each bay. Once RIGEX returned to AFIT, STP's suggestion was implemented in the flight FVT code. The final FVT profile is shown in Appendix E.

Vibration Testing (Test 4.C.)

Problem and/or Solution to Test

Vibration Testing is the method used to verify launch/landing survivability and workmanship of the RIGEX payload. In preparation for spaceflight, both CAPE and RIGEX must under go vibration acceptance testing; it was determined by STP to be both logical and cost effective to perform this test as a combined system.

Table 14. Types of Faults expected to be revealed by Vibration Acceptance Testing [27]

Fault	Fault Mode	
	Mechanical	Electrical/ Mechanical
Loose electrical connections		X
Loose nuts, bolts, etc.	X	
Low-frequency relay contact chatter		X
Low–frequency switch contact chatter		X
Physical contaminants (loose foreign matter)	X	
Cold solder joints and solder voids		X
Incomplete weld joints		X
Close tolerance mechanisms		X
Improperly crimped connections		X
Wire defects such as strands cut away with insulation removal		X
Insufficient clearance resulting in impact of component parts	X	
Shrinkage of potting resulting in loose assembly within housing	X	
Potting too soft, allowing excessive movement of components and wiring	X	
Wire fatigue failure due to routing	X	
Loose or missing mounting hardware	X	
Excessive valve leakage or abnormal closure	X	
Defective piece parts	X	X

Table 14 illustrates common problems identified because of vibration testing. The vibration test will establish that RIGEX as both correctly a built and designed adequately to handle the violent loads on the structure during launch and landing.

Although the primary objective of the test is to verify structural integrity, data gathered from the Vibration Test and the Weight and Balance Test will be used to "tune" the analytical model. NASA requires an accurate model of the payload to be able to perform detailed analysis of the response of the payload to alternative load cases in the event of catastrophic failure of the shuttle.

Vibration Test Configuration

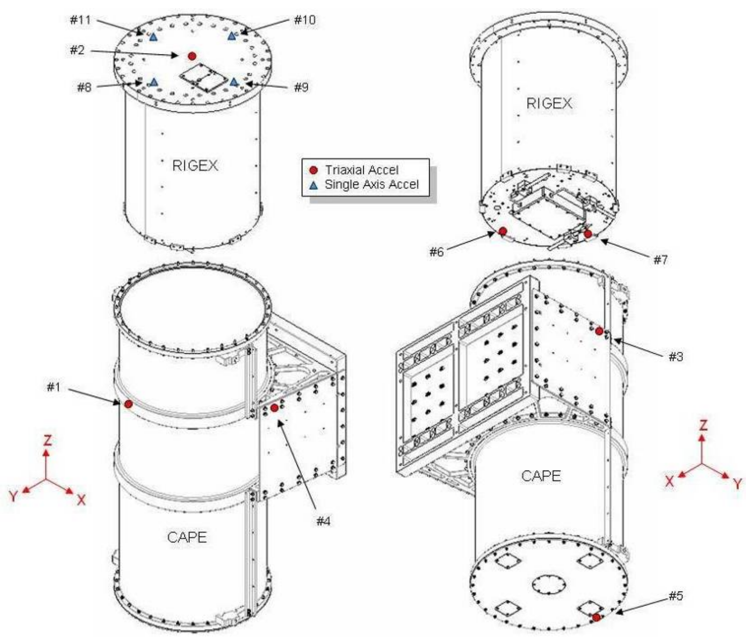


Figure 69. Vibration Test Accelerometer Placement (Taylor [39])

The Vibration Test was conducted in accordance with TPS 8U0720004 (Taylor [39]). The accelerometer placement is shown in Figure 69 and Figure 70 thru Figure 73 show the actual test set-up. Each axis test was done as follows:

- Sine Sweep from 200-10-200 Hz at a slew rate of 3 decades per minute
- Random vibration test to levels shown graphically in Figure 74
- Sine sweep as above, to verify structural health
- Function verification test

Figure 70. RIGEX/CAPE X Axis Test Configuration View I

Figure 72. RIGEX/CAPE Y Axis Test Configuration View I

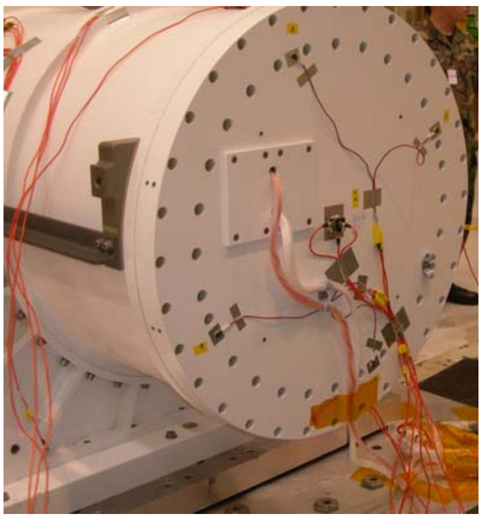


Figure 71. RIGEX/CAPE X Axis Test Configuration View II

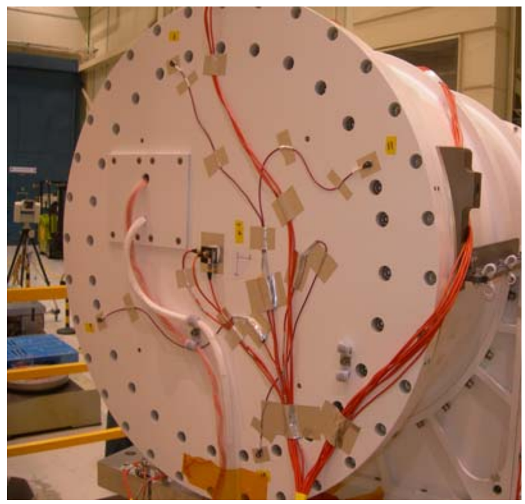
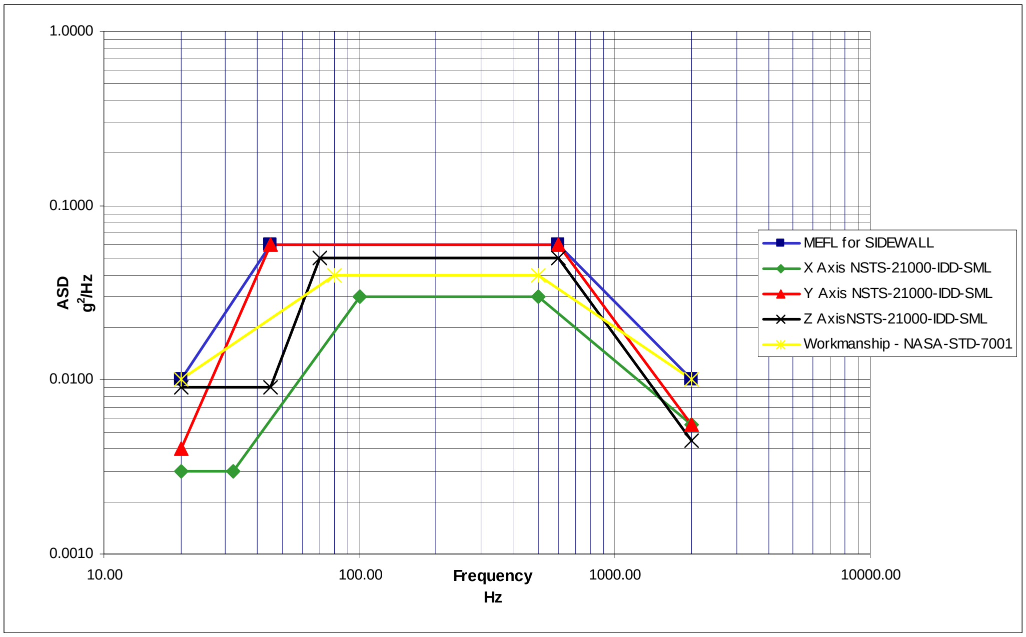


Figure 73. RIGEX/CAPE Y Axis Test Configuration View II



X-Axis		Y-Axis		Z-Axis	
FREQ (Hz)	ASD (G^2/Hz)	FREQ (Hz)	ASD (G^2/Hz)	FREQ (Hz)	ASD (G^2/Hz)
20	0.01	20	0.01	20	0.01
80	0.04	45	0.06	70	0.05
500	0.04	600	0.06	600	0.05
2000	0.01	2000	0.01	2000	0.01

Figure 74. Acceleration Spectral Density (ASD) vs. Frequency Random Vibration Spectrum (Graph and Tabular Form) [37]

The Random Vibration test for each axis was started at -12dB and increased in 3dB increments until 0 dB is reached. The FVT was run in order to verify no electrical components had been become disconnected following the post-random sine sweep. The sine sweeps were conducted in order to have pre and post-random vibration data to compare real time to verify the system experienced no faults or breaks during the random vibration testing.

Vibration Test Results

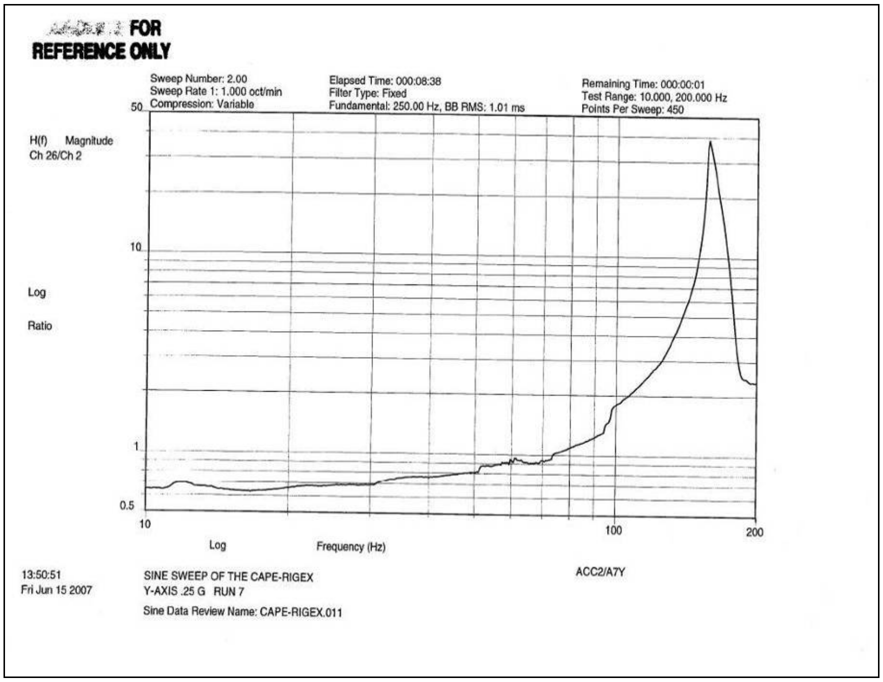


Figure 75. RIGEX/CAPE Sine Sweep Transfer Function Y-Axis Results

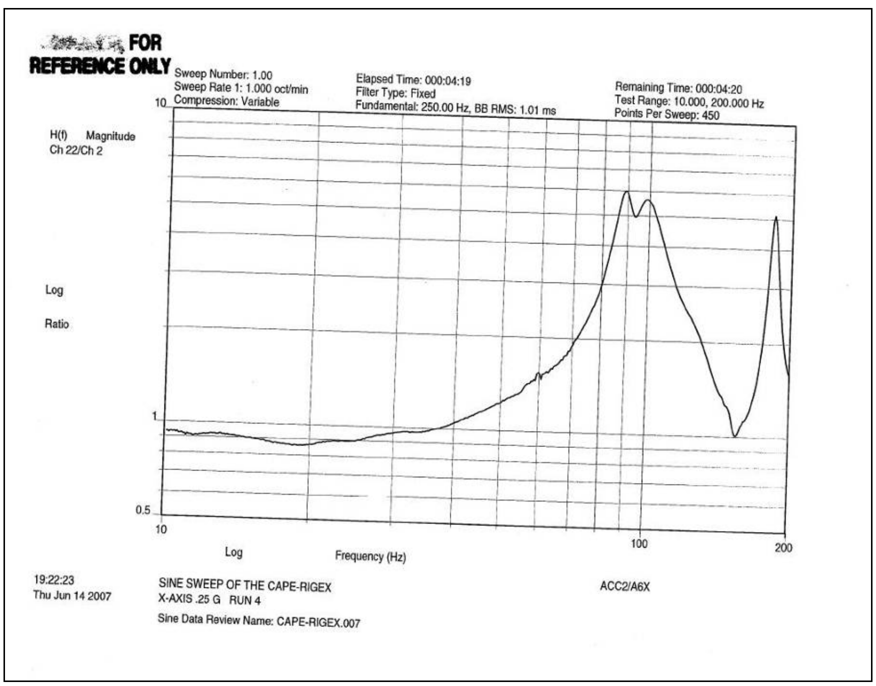


Figure 76. RIGEX/CAPE Sine Sweep Transfer Function X Axis Results

Figure 75 and Figure 76 are examples of transfer functions derived from two of the accelerometers that were attached to the RIGEX/CAPE system. Definitively, based on these results, the RIGEX/CAPE system has its first significant mode above 50 Hz, which validates the analytical models completed by both Helms [11] and Gunn-Golkin [10], on the main structure design.

Vibration Test Conclusions

This validation would have structurally qualified RIGEX and CAPE for flight, but during post processing of the vibration data, it was discovered that the bolt analysis, conducted by Gunn-Golkin [10], had set the RIGEX main structure bolt torque values to a level that may have been damaging to the bolt threads or worse the main structure threads.

Table 15. Joint ID and Margins of Safety of Over Torqued Bolts with ½ Sheer Area of Grip Assumption Excerpt from ERB notes

RIGEX Bolted Joints			APPLIED Torque (in-lbf)		Margin of safety 1/2 shear area					
					Room Temp			On-orbit		
Joint	Joint Description (defined)									
	Part 1 to	Part 2	Max	Min	Tension Yield	Thread Shear	Gapping	Tension Yield	Thread Shear	Gapping
3	**Rib**	**Rib**	68	58	-0	0.14		-0.1	0.01	
4	**Oven Mounting Plate**	**Rib**	68	60	-0	0.14		-0.1	0	
11	**Inflation Mounting Plate**	**Rib**	77	60	-0.2	0.01		-0.2	-0.1	

These negative margins as listed in Table 15 were determined because of the model tuning that was done STP from the data obtained in the RIGEX/CAPE system Vibration Test. (Aside: ‘Model Tuning’ or ‘Model Correction’ is the method of adjusting parameters such as mass and stiffness variables in the finite element model in order to match the model's simulated response to the input, to the real world data obtained through experimentation (Cobb [2]).)

Component Implementation/design changes

The Structures Working Group (SWG) was consulted in an Engineering Review Board (ERB) composed of AFIT and STP personnel. The direction of the board was as follows (for full notes from this ERB, see RIGEX Document-7 (RD-7)):

- Remove main structure bolts, **ONE AT A TIME**
- Replace with fresh "non-preloaded" bolt
- Re-torque each to an applied torque of 32 +/- 2 in-lbf above running.
- Utilize standards of ST-P-0023 for thermal testing

The SWG mandated the fasteners be removed one at a time to ensure the integrity of the joint so that the vibration test would not need to be repeated. All but 4 of the main structure bolts were removed and replaced. The 4 that remained where due to the obstruction of the oven mounting plate, which left just enough room to back out each bolt a small amount. The ERB was addressed again with the notion of un-torquing these bolts and applying the desired torque indicated. They accepted this approach for the obstructed fasteners and it was applied to the remaining 4 fasteners.

In order to change the majority of the main structure fasteners, the following components needed to be removed to get to the main structure bolts:

- Oven (x3)
- Oven Brackets (x3)
- Computer
- Power Distribution Plate

The fasteners that held these on were re-used when re-assembling the components to the structure. (Aside: Gunn-Golkin [10] had selected the same bolt size fastener for these components as what was used for the main structure in an effort to keep the part count down.) In an effort to remain consistent with the torque change for the 3/16 diameter bolt, the torque value suggested by the SWG was applied to these bolts instead of the total 66 +/- 4 in-lbf that was originally used.

In order to verify integrity of all electrical connections (after rework), the SWG mandated that during the TVAC test, the criteria of NASA's ST-P-0023 Specification Environmental Acceptance Testing [25] be used. Their reasoning was that the thermal variants seen under this criterion would be enough to ensure mission success.

Weight and Balance Test (Test 4.D.)

Problem and/or Solution to Test

The analytical weight of RIGEX was determined by Gunn-Golkin [10] to be approximately 236 lbf with a center-of-gravity located at +0.4, +0.2, +11.7 inches with respect to the coordinate system shown in Figure 77. This needed to be verified. STP advertises the weight of CAPE to be approximately 230 lbf [6]. By adding the two weights, it is expected that the RIGEX/CAPE system configuration will weigh approximately 466 lbf. This weight will be used by NASA as part of the overall shuttle weight and balance modeling.

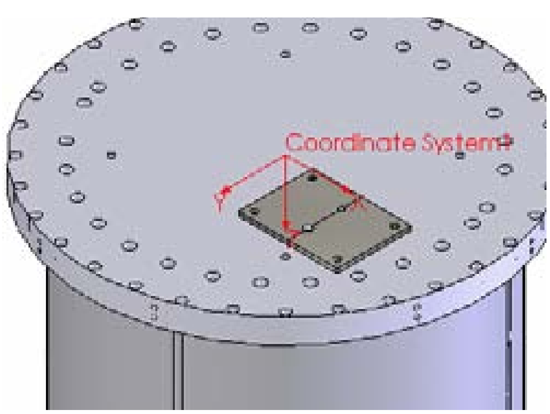


Figure 77. RIGEX Coordinate System Identification defined by Gunn-Golkin [10]

Weight and Balance Test and Setup Procedure

This test was conducted at JSC and, as described earlier, was conducted on the RIGEX/CAPE system per TPS 8U0720006 (Taylor [37]). The RIGEX/CAPE system configuration was lifted onto the balance scale and weighed. Figure 78 shows NASA personnel handling the RIGEX/CAPE system in an effort to roll the system over on its side and gently set it down on the scale in order to get the Y-axis coordinate of the C.G. The coordinates given for the Center of Gravity (C.G.) are measured from the top right corner of CAPE beam attachment plate (shown in Figure 78).

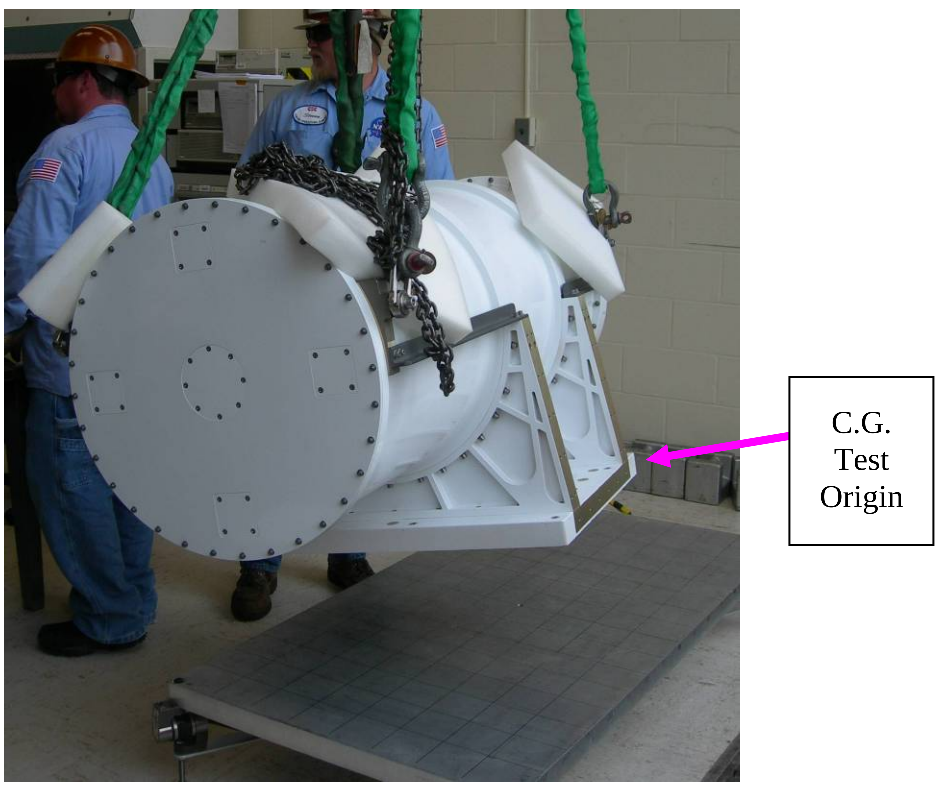


Figure 78. RIGEX/CAPE Mid-Air Rotation Handling

Weight and Balance Test Results

The test determined that the RIGEX/CAPE system configuration weighed 461.02 lbf (approximately 5 lbf lighter than the predicted weight) (see Table 16). This results in a percent difference of 1.08 % error. In order for the analytical model to be accepted for simulated testing, the model needed to be within 2% error of the actual weight, so the RIGEX/CAPE system model was validated and ready to be handed to NASA.

Table 16. Weight and Balance Results of TPS 8U0720006 (Taylor [37])

RIGEX/CAPE					
Weight			C.G. Distance from test origin (cm)		
Analytical	Actual	% Difference	X	Y	Z
466	461.02	1.08%	38.74	37.09	21.03

Thermal Vacuum (TVAC) Test (Test 4.E)

Problem and/or Solution to Test

A full system test of the payload in, as close to the space environment as possible is required for certification and mission assurance, however RIGEX is not completely exposed to the space environment, so only the extremes expected *inside* of CAPE need to be met (see Table 12). Originally, in order to satisfy this requirement, RIGEX was going to be subjected to one thermal cycle of the max-min limits defined in Table 12 strictly for showing that RIGEX would survive and operate in the space environment. The thermal excitation profile was changed due to the bolt over-torquing issue discussed in the vibration test results.

The following are the minimal requirements for the test as defined by SP-T-0023 [25]:

- A local environment to the test article of 10E-5 Torr or less
- Duration of 1 and a half thermal cycles (see Figure 79)
- Be witnessed by Government and/or contractor quality control officer
- Operation of the test article to commence after steady state + 1 hour

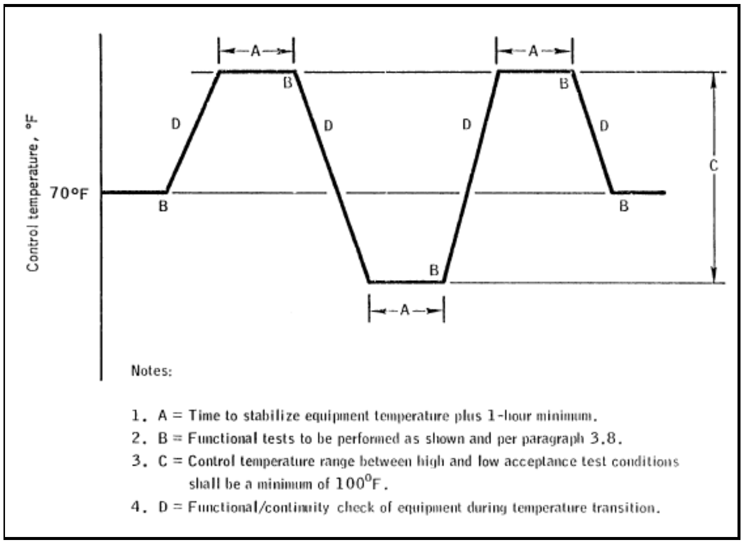


Figure 79. Minimal Thermal Test Spectrum [25]

Table 17. Types of Faults exposed by Thermal Cycling and Thermal Vacuum Testing [25]

Fault	Test Condition	
	Thermal Cycling	Thermal/Vacuum Cycling
Voids in potting	X	(X)
Short run wires	X	
Welded and soldered connections	X	
Corona leakage		X
Outgassing contaminants		X
Bimetallic effects of leaf spring	X	
Solder splash on printed circuits	X	(X)
Insulation penetration	X	X
Thermal grease application	X	(X)
Close tolerance mechanisms	X	(X)
Hermetically sealed components (environmental seals)		X
Thermal interface integrity		X
Thermal control paint		X
Improperly crimped wires	X	(X)
Poor solder and weld joints	(X)	X
Excessive periods of abnormal continuity	X	
Defective piece parts	X	X

NOTE: ( ) indicates test where fault is most sensitive [25]

As a minimum, the thermal vacuum has commonly exposed workmanship flaws as such as those listed in Table 17. Successful operation in this test will earn the remaining bit of certification it requires for spaceflight qualification.

Figure 80 shows the wiring schematic for the TVAC setup. Note: as indicated earlier, the temperature of one of the cameras will be recorded to verify its operability in the space environment, as it was not accomplished during the Component Suitability Test discussed in Chapter III.

TVAC Test Configuration

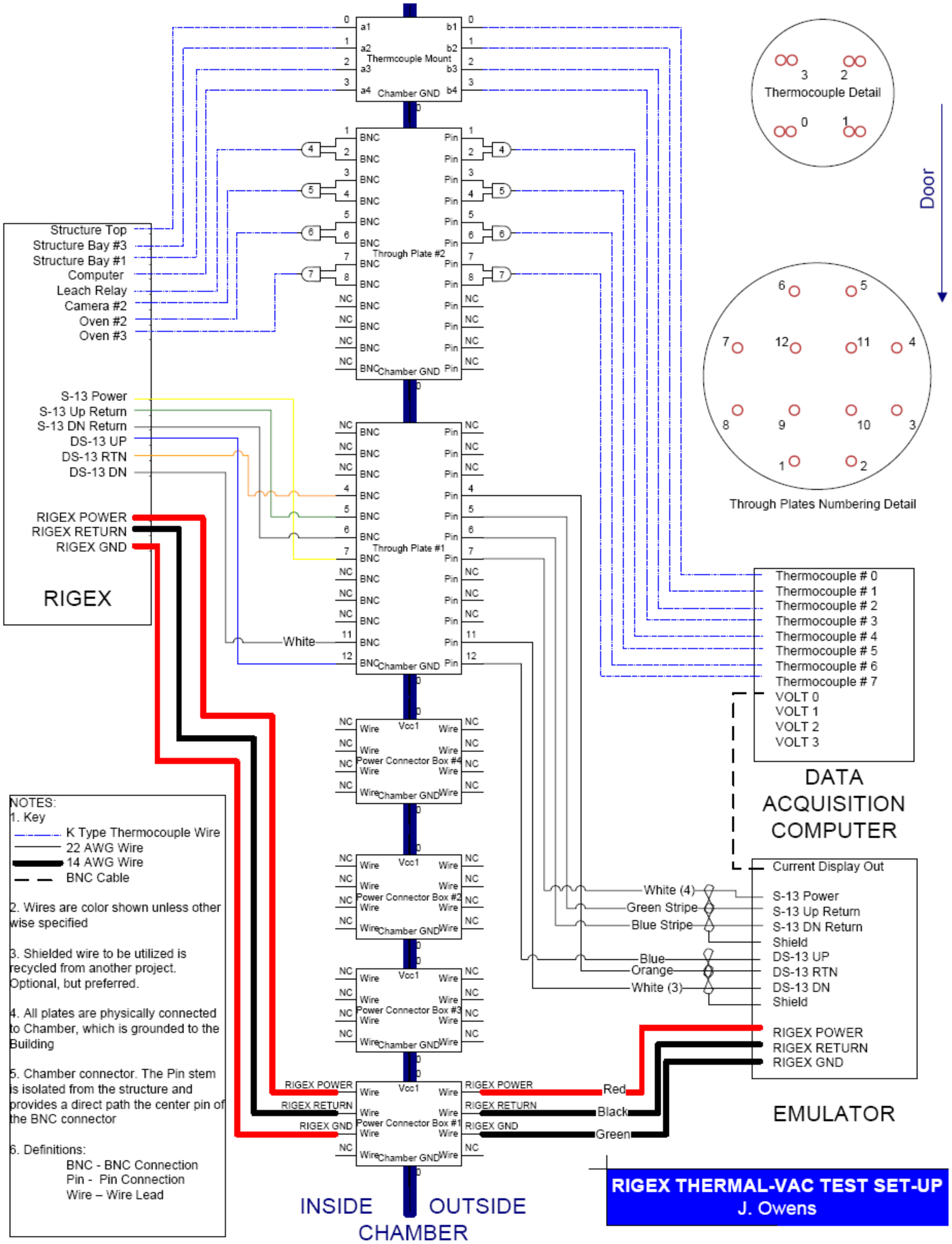


Figure 80. RIGEX TVAC Test Setup

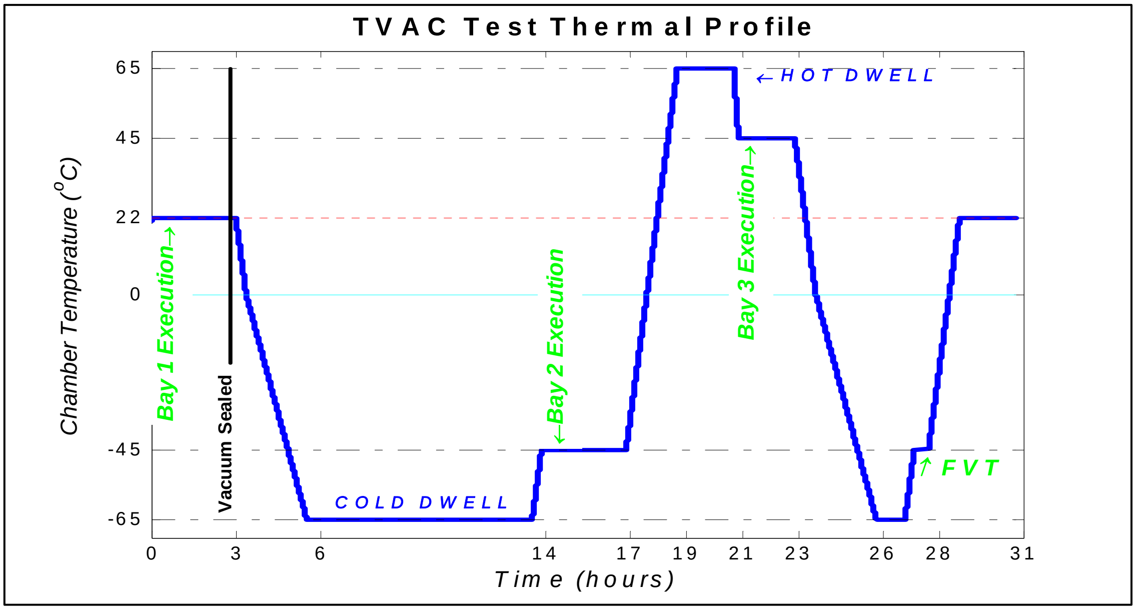


Figure 81. TVAC Thermal Profile

RIGEX will have its pressure tanks charged with nitrogen gas per RP-9 (RIGEX Fill Procedure) for this test. Bay one will be deployed under ambient conditions as part of the system checkout procedure and as such will be filled to 30 psia. This will negate the reading from both the Bay one tube and tank pressure transducers for this test as the sensor is saturated at pressures above 15 psig. However, as the remaining bays will be filled, as they will be for flight, the pressurization profile will be determined from the remaining two sets of sensors.

Figure 81 illustrates the planned profile for this test. To meet the criteria of ST-P-0023 and the SWG, the decision was made to flip the profile shown in Figure 79. As shown in Figure 81, the test will take approximately 30 hours to complete, depending on whether or not the chill and warming rates are adequate to reduce the liquid nitrogen high use rate that was seen in the Component Suitability Test.

The limits of this test were disputed upon for some time. Remember the intent is to be as close to the environment *inside of CAPE* as possible while on orbit. During discussion with STP and NASA, it was determined that the CHUG lists general guidelines and does not reflect the actual thermal environment inside CAPE while on orbit. After several discussions, the following limits were defined:

- **Operating Limit**: -45^{o}C to 45^{o}C
- **Survival Limit**: -60^{o}C to 65^{o}C

Based on the establishment of the above limits, the pin puller and the oven controller no longer require qualification through the TVAC testing as they now meet the requirements for component qualification defined in Chapter II. The limits where applied to the profile defined by Figure 81.

According to ST-P-0023, the operation of the test article is to occur at steady state plus 1 hour. This requirement has been waived for RIGEX due to the prolonged wait at the survivable temperature, known as “baking”, that is planned (graphically shown in Figure 81). (Note: Steady state is defined as the point where the temperature change is less than 1^{o}C per minute.). Operation of RIGEX will commence when the *chambers internal temperature* reaches the operating limit.

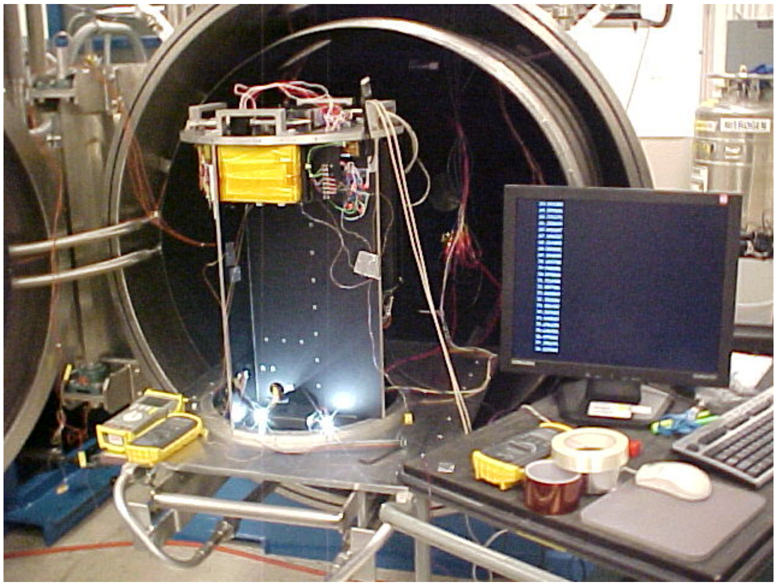


Figure 82. TVAC Test Configuration

Test Results

At the time of publication of this document, the TVAC test had not yet been completed and as such, there are no results to present. The test is anticipated to begin on 10 Sep 2007 and take three days to perform. The details of the test are included in TP-05.

Chapter Summary

In this chapter, RIGEX system received the following certifications:

- Pressure System (Safety)
- Electromagnetic Interference*
- Structural Strength and Stiffness
- Weight and Balance
- Analytical Model
- Safety**

Note:
** Certification to be received once waiver is received by STP.*
***-Safety Certification came upon review of the tests defined in this chapter at the Phase III Flight Safety Review held 6 Sep 2007*

The TVAC test is setup and is ready to be performed. Once the TVAC test is complete, RIGEX will receive all the certification for space flight that is required and that can be completed before integration into the shuttle.

V. Conclusion and Recommendations

The spaceflight qualification of the RIGEX payload is almost complete. The qualification process for the RIGEX payload started by taking the detailed design as it was defined by Goodwin [9] and turning it into a physical structure, ensuring that each step of the assembly was properly documented in a procedure. Before each component was attached, their flight worthiness was determined either through documentation or through testing, making necessary configuration changes as needed in order to take the payload to system level testing where in most cases it performed as desired. Only the items marked in red in Table 18 remain to be completed

RIGEX Current Status

Unfortunately, RIGEX has the following open items that must be addressed or completed prior to delivery to KSC:

- Waiver for the Electromagnetic Interference Transient Test criteria requirement (Verbal confirmation has been received)
- Completion of TVAC testing
- Final Launch Preparation (RP-4)
- Flight Software Load and Full Software Run (Electrical)
- Final Wire harness restraints and routing
- Load Flight Sub T_g Tubes

Table 18. RIGEX Spaceflight Qualification Issues

		Analysis		Test	
Subsystem	Qualification Issue	Required	Complete	Required	Complete
Mechanical					
	Mass Properties	x	x [10]	x	x
	Structural Strength	x	x [10]		
	Structural Stiffness	x	x [10]	x	x
	Fracture	x	x [10&33]		
	Pressurization/ Depressurization	x	x [11]	x	x
	Containment	x	x [9&10]		
	Thermal	x	x [9]	x	9/10-15
	Random Vibration			x	x
Electrical					
	Functional Verification Test			x	x
	Interface Verification Test			x	11/7
	Electromagnetic Interference Test			x	x

NOTE:
- The number in the [] in Table 18. are the references to the RIGEX past personnel who completed that analysis.
-The date shown is the anticipated date of the test as of the publication of this document

Recommendations

One of the hardest parts about qualifying this payload for spaceflight was the lack of proper configuration control that comes in programs with heavy personnel turnover. In order to avoid this, it would be wise to have a permanent party member, either faculty or staff, remain fully involved in the project from start to finish. Other difficulties encountered include a severe learning curve that had to be overcome in order to bring new members up to speed on the project to a point where they could make significant contributions. Focusing on the project, I would recommend the following for future work:

- **Use another computer system**: The PC-104 was limited by its processor and could not be upgraded any further than what was done to it.
- **Change oven material**: Find a different material than the Ultem to adhere the heaters to.

A natural follow-on to the RIGEX project would be to design and build a platform that would deploy a mini structure comprised

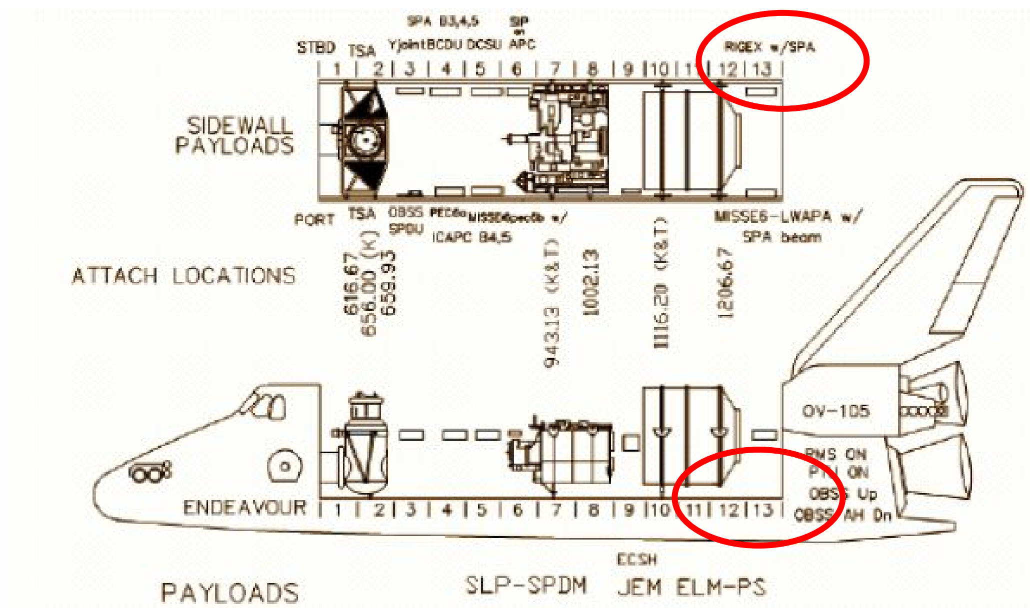


Figure 83. Orbiter Depiction -- Bay location description

Conclusions

As of the publication of this document, the RIGEX payload is a functional payload that is nearly ready to be handed over to NASA. The remaining schedule for RIGEX includes being shipped to KSC on 23 Oct 2007 where it will undergo:

- Final Assembly
- Final Integration with CAPE
- RIGEX/CAPE System Configuration integration in the shuttle
- Interface Verification Testing (IVT) with the space shuttle

Once integrated with CAPE, the RIGEX/CAPE system assembly will be located in Orbiter Bay 13 as indicated by Figure 83. The anticipated launch date is 14 February 2008, aboard STS-123 *Endeavour*, for a 14-day mission to the International Space Station.

Appendix A Operation and Survivability of RIGEX Components

(According to Manufacturer Specifications)

Table A.1 RIGEX Component Operation and Survivability Part I

	Operating Limits								Storage Limits*			
	Required Voltage (VDC)		Current (mA)		Temp (°C)		Humidity %		Temp (°C)		Humidity %	
Subsystem Component	Low	High	Low	High	Low	High	Low	High	Low	High	High	Low
General												
Master Bond Epoxy	N/A	N/A	N/A	N/A	-270	205			-270	205		
Experiment												
Sub-Tg Tube	N/A	N/A	N/A	N/A	N/A	110	N/A	N/A	N/A	110	N/A	N/A
Piezoelectric Actuator - PZT												
QuickPack strain actuator	-500	1500			N/A	85	N/A	N/A		160	N/A	N/A
Accelerometer - Precision Aligned wide Input Voltage Triaxial Accel.	2.7	5	0.6	1500	-40	85	N/A	N/A	-55	150	N/A	N/A
Pin Puller	5	5	17	980	-60	70	N/A	N/A	-60	70	N/A	N/A
Command and Control (Computer)												
Quartz Timer/Counter	5	5	0	220	-40	85	N/A	N/A	-40	85	N/A	N/A
PC-104 Computer (imaging / data acq)	5	5		90	-40	85	N/A	N/A	-55	85	N/A	N/A
Filter - Proto-PC	5	5		50	-40	85	N/A	N/A	0	70	N/A	N/A
Thermocouple (data acq)	5	5	0	50	-25	85	N/A	N/A	-25	85	N/A	N/A
Parvus Relay (Data acq)	5	5	0	1500	-40	85	10	85	-40	85	10	85
Diamond DAQ	5	5	0	200	-45	85	5	95	-45	85	5	95
High Efficiency PC-104 Power Supply	3	40	0	15000	-40	85	N/A	N/A	-40	85	N/A	N/A
DiskOnChip 2000DIP (Harddrive)	5	5	0.006	40	-40	85	10	90	-40	85	10	90
Wire M22759 22AWG	N/A	N/A	0	9500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
High Efficiency PC-104 Power Supply (24VDC Suply)	6	40		50	-40	85	N/A	N/A	-40	85	N/A	N/A
D-Sub Connectors	N/A	N/A	0	7000	-55	105	N/A	N/A	-55	105	N/A	N/A
Ribbon Cable	N/A	N/A	0	6800	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heaters												
Heaters (3.5x2.75in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
Heaters (3x5in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
Heaters (1x4in)	N/A	N/A	0	13500	-200	200	N/A	N/A	-200	200	N/A	N/A
Oven Controller	4.75	60	0	4000	-40	70	N/A	N/A	-40	70	N/A	N/A
Oven Insulation (ZOTEFOAM 38 HD)	N/A	N/A	N/A	N/A		160	N/A	N/A		290	N/A	N/A

Table A.2 RIGEX Component Operation and Survivability Part II

	Operating Limits								Storage Limits*			
	Required Voltage (VDC)		Current (mA)		Temp (°C)		Humidity %		Temp (°C)		Humidity %	
Subsystem Component	Low	High	Low	High	Low	High	Low	High	Low	High	High	Low
Power Distribution												
6 AWG 4P Terminal Strip	0	300	0	15000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8 AWG 10P Terminal Strip	0	300	0	15000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22AWG 6P Terminal Strip	0	300	0	50000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
24 AWG 5P Terminal Strip	0	300	0	50000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5-Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
4-Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
2 Fuse Block	0	300	N/A	N/A	-40	110	N/A	N/A	-40	110	N/A	N/A
4 Amp Fuses	N/A	N/A	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3 Amp Fuses	N/A	N/A	0	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2 Amp Fuse	N/A	N/A	0	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5 Amp Fuse	N/A	N/A	0	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20 Amp Fuse	N/A	N/A	0	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6 Amp Fuse	N/A	N/A	0	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EMI Filter (FME28-461/ES)	0	28	0	15000	-55	125	N/A	N/A	-65	150	N/A	N/A
Solid State Relays: output	1	50										
Solid State Relays: input	3	32	N/A	N/A	-20	80	N/A	N/A	-40	100	N/A	N/A
Transformers	-6.3	6.3	0	600	-40	105	N/A	N/A	-40	105	N/A	N/A
YCL Latching Relay	0	29	0	30	-70	125	N/A	N/A	-70	125	N/A	N/A
Diodes	0	40	0	5000	-55	150	N/A	N/A	-55	150	N/A	N/A
Resistors (1ohm)	N/A	N/A	N/A	N/A	-55	250	N/A	N/A	-55	250	N/A	N/A
8 AWG Wire	N/A	N/A	0	81000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pressure System												
Pressure Transducer	20	36	200	360	-54	121	N/A	N/A	-54	121	N/A	N/A
Pressure Transducer Wire	N/A	N/A	0	95000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Solenoid	18	24		900	-40	105	N/A	N/A	-40	105	N/A	N/A
Imaging System												
Lights - LEDs	0.7	13	0	700	-40	110	N/A	N/A	-40	120	N/A	N/A
Cameras	8.5	12	0	100	-20	100	N/A	N/A	-20	100	N/A	N/A

Appendix B Pigtail Drawing Package

Prepared by: J Owens

CHANGE LOG				
Rev. Ltr. Change	Justification and Description of Change	Affected Pages	Release Date	Change Approval (*Initial & Date*)
IR	Initial Release	All	23-Mar-07	N/A
A	Lengths of cables adjusted to actual needs	2	6 Apr 07	JJO -- 6 Apr 07
B	Drawing Numbers Fixed	1 - 2	7 May 07	JJO -- 7 May 07
C	Parts list updated/ Nomenclature Standardized	All	29 May 07	JJO -- 29 May 07
D	Detail updates Add lengths page	All	26 Jun 07	JJO –26 Jun 07
E	Vendor Update	2,3	24 JUL 07	

Revision : E

Date 24 JUL 07

APPROVED BY:______________________________

REVIEWED BY:________________________________

AIR FORCE INSTITUTE OF TECHNOLOGY				
RIGEX CABLE DRAWING PACKAGE				
SIZE A	FSCM NO	DWG NO RIGEX-2007-1		REV E
SCALE 1:1	JOwens	SHEET 1 OF 6		

Figure B.1 Pigtail Cable Drawing Package cover page

C1	C2	G1	G2	G3	G4	Item #	Part or Identification #	Nomenclature or Description	Material	Notes or Remarks
X							C1	Flight Command Pigtail Assy		
	X						C2	Flight Power Pigtail Assy		
		X					G1	Ground Command Pigtail Interface to Emulator Assy		Used to interface with Pigtail Assembly
			X				G2	Ground Power Pigtail Interface to Emulator Assy		Used to interface with Pigtail Assembly
				X			G3	Ground Command Cable Assy, TVAC		Used for Ground Testing
					X		G4	Ground Power Cable Assy, TVAC		Used for Ground Testing
1						1	MS27484T20F35SA	Circular Connector		△24 MIL-C-38999 P103
1						2	MS27484T20F35SB	Circular Connector		△24 MIL-C-38999 P108
	1					3	MS3456L22-22S	Circular Connector		△24 MIL-C-38999 P501
		1				4	MS27474T20F35PA	Circular Connector		△24 MIL-C-38999 J103
		1				5	MS27474T20F35PB	Circular Connector		△24 MIL-C-38999 J108
			1			6	MS3454L22-22P	Circular Connector		△24 MIL-C-38999 J501
2		2				7	MS27506-F-20-2	Circular Backshell		△24
	1		1			8	M85049/52N20N	Circular Backshell		△24
AR		AR		AR		9	M27500-22RC3S06	Wire, 22 AWG, Shielded Twisted Triple		NEMA-WC-27500
AR		AR		AR		10	M27500-22RC4S06	Wire, 22 AWG, Shielded Twisted Quartro		NEMA-WC-27500
	AR		AR			11	M22759/11-8-X	Wire, 8 AWG, MIL-W-22759		△29
	2					12	26H3465	Terminal, 90 degree, Ring, 8 AWG, #10 Stud		△21
6				6		13	66H7086-90	Terminal, 90 degree, Ring, 22 AWG, #6 Stud		△21
AR	AR	AR	AR	AR	AR	14	TFN0.25-NT	Sheathing, Teflon, 0.25 Φ		△23
AR	AR	AR	AR	AR	AR	15	TFN0.38-NT	Sheathing, Teflon, 0.38 Φ		△23
AR	AR	AR	AR	AR	AR	16	TFN0.50-NT	Sheathing, Teflon, 0.50 Φ		△23
AR	AR	AR	AR	AR	AR	17	HTCM-SCE-1/4-4H-9	Cable, Marker		△24
AR	AR	AR	AR	AR	AR	18	37161	Marking Pen, Ultra Fine Point		△21
AR	AR	AR	AR	AR	AR	19	404-4	Tape Lacing		MIL-T-43435
AR	AR	AR	AR	AR	AR	20	EP21TCHT-1	EPOXY, Masterbond		△22
AR	AR	AR	AR	AR	AR	21	248	Loctite		△21
AR	AR	AR	AR	AR	AR	22	P-213	Tape, Glass		△21
AR		AR		AR		23	M23053/5-103-0	Tubing, Heat Shrink 3/32" Φ		AMS-DTL-23053/5
AR		AR		AR		24	24-6337-9713	Solder		△26
133						25	MS-27488-22-1	Sealing Plug #22		△20
	1					26	MS-27488-8-1	Sealing Plug #8		△20
AR	AR	AR	AR	AR	AR	27	78F580	Wire TIES, 4"		△21
			3			28	PP25G	8 AWG Banana Plug		△26
		1		1		29	43F236	15-Pin D-Subminiture, Solder Cup		△21
2						30	MS27510F20A	Circular Dust Cover		△24
	1					31	MS25042-22DA	Circular Dust Cover		△24
		2				32	MS27511F20A	Circular Dust Cover		△31
			1			33	MS25043-22DA	Circular Dust Cover		△24
2		2				34	M22759/11-22-X	Wire, 22 AWG, MIL-W-22759		△29
					AR	35	M22759/11-14-X	Wire,14 AWG, MIL-W-22759		△29
					1	36	SPC15170	Standard Banana Plug, Green		△21
					2	37	66H6921	Terminal, Ring, 12AWG, #6 Stud		△21
					1	38	SPC15329	Standard Banana Plug, Red		△21
					1	39	SPC15327	Standard Banana Plug, Black		△21
					1	40	28F514	Test clip, 10Amp		△21
1		1				41	66H7086	Terminal, Ring, 22 AWG, #6 Stud		△21

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	RIGEX CABLE PARTS LIST			
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Figure B.2 RIGEX Pigtail Bill of Materials (BOM)

NOTES: UNLESS OTHERWISE SPECIFIED

1. WIRE/CABLE TO BE TERMINATED, CONNECTORS ASSEMBLED AND HARNESSES FABRICATED, MARKED AND TESTED PER NASA STD-8739.4.

2. GENERALLY CLEAN PER NASA/JSC DOCUMENT SN-C-0005.

3. BAG AND TAG TO IDENTIFY PART NUMBER PER NASA/JSC PRC-9002.

4. ITEM(S) 30, 31, 32, AND 33 (DUSTCOVERS) ARE TO BE INSTALLED DURING SHIPPING AND GENERAL HANDLING OF THE HARNESS ASSEMBLY. REMOVE ONLY PRIOR TO USE.

5. APPLY A SPOT OF ITEM 20 (EPOXY) TO ALL ITEM 19 (TAPE LACING) SPOT TIES TO ACT AS A LOCKING FEATURE. CURE EPOXY AT ROOM TEMPERATURE FOR 1 HOUR.

6. MARK ITEM(S) 9, 10, OR 11 (WIRE) WITH ITEM 18 (MARKING PEN) AS DIRECTED 1 +/- 0.5 INCHES FROM THE CONNECTOR END OF THE HARNESS ASSEMBLIES WITH INDICATE SYMBOL FOR INDENTIFICATION AFTER SHEATHING WIRE.

7. COVER THE WIRE BUNDLE USING ITEM(S) 14, 15, OR 16 (SHEATHING) AS DIRECTED USING ITEM 27 (WIRE TIE). SECURE THE SHEATHING TO THE WIRE BUNDLES AS REQUIRED. TERMINATE THE SHEATHING AT THE FOLLOWING LENGTHS FOR EACH ASSEMBLY

   A. –C1: 89 +/- 0.5 INCHES
   B. –C1 (P103 split): 25 +/- 0.5 INCHES
   C. –C1 (P108 split): 24 +/- 0.5 INCHES
   D. –C2: 107.9 +/- 0.5 INCHES
   E. –G1: 170 +/- 1 INCHES
   F. –G1 (J103 split): 11 +/- 0.5 INCHES
   G. –G1 (J108 split): 11 +/- 0.5 INCHES
   H. –G2: 180 +/- 1 INCHES
   I. –G3: 177.2 +/- 3 INCHES
   J. –G4: 98.4 +/- 1 INCHES

8. APPLY ITEM 22 (GLASS TAPE), AS REQUIRED, TO WIRE BUNDLE NEAR ITEM 7 AND 8 (BACKSHELL) AND OTHER LOCATIONS IN ORDER TO PROVIDE SUFFICIENT MATERIAL FOR STRAIN RELIEF.

9. APPLY ITEM 21 (LOCTITE) TO INTERNAL THREADED PORTION OF ITEMS 7 AND 8 (BACKSHELL)

10. PIN NOT SHOWN OR SHOWN AS N.C. ARE NOT WIRED. ON –C1 AND –C2 ONLY, INSTALL ITEMS 25 AND 26 (SEALING PLUG) AS APPROPIATE INTO UNUSED CONTACT LOCATIONS.

11. USING ITEM 24 (SOLDER), SOLDER PER NASA-STD-8739.3.

12. USING A LEFT-HAND LAY. CONDUCTOR PAIRS A/C ARE TO BE TWISTED 1 TURN EVERY 5 +/- 1.5 INCHES TO WITHIN 6 +/- 2 INCHES OF THE OPEN END OF THE HARNESS ASSEMBLY.

13. MARK ITEM 17 (CABLE MARKER) WITH ITEM 18 (MARKING PEN) AS INDICATED. INSTALL IDENTIFICATION MARKER USING ITEM 19 (LACING TAPE) 2 +2/-0 INCHES FROM THE BACKSHELL OF THE CONNECTOR END OF THE CABLE HARNESS ASSEMBLY. ITEM 27 (WIRE TIE) MAY BE SUBSTITUTED FOR ITEM 19 (LACING TAPE)

14. USING A 2 +/-1 INCH PIECE OF ITEM 24 (WIRE) ITEM 24 (SOLDER), EXTEND THE BRAIDED SHIELD TO ALLOW FOR CRIMP CONTACT INSTALLATION. COVER THE SOLDER JOINT USING ITEM 23 (HEAT SHRINK)

15. –C1 AND –C2 ARE FLIGHT CABLES. ALL OTHERS ARE GROUND ONLY

16. MARK ITEM 17 (CABLE MARKER) WITH ITEM 18 (MARKING PEN) AS INDICATED. INSTALL IDENTIFICATION MARKER USING ITEM 19 (LACING TAPE) APPROXIMATELY IN THE MIDDLE OF THE CABLE ASSEMBLIES. ITEM 27 (WIRE TIE) MAY BE SUBSTITUTED FOR ITEM 19 (LACING TAPE)

17 ITEM(S) 14, 15 AND 16 (SHEATHING) MAY BE SUBSTITUTED FOR ONE ANOTHER AS NEEDED TO ACHIEVE BEST FIT.

18 ALL TERMINALS ARE TO BE CONNECTED IAW RIGEX RD-3 (RIGEX POWER SCHEME)

19. USE ONLY THE FOLLOWING LOT NUMBERS OF ITEMS 9, 10, AND 11 (WIRE) FOR –C1 AND –C2 RESPECTIVELY.

   A. ITEM 9 – M27500-22RC3S06 LOT# 052604-01
   B. ITEM 10 – M27500-22RC4S06 LOT# 7636254
   C. ITEM 11 – M22759/11-8-0 LOT# 36546
   D. ITEM 11 – M22758/11-8-9 LOT# 213043

20. AICONICS
POWAY,CA 92064
CAGEC: 0EUH6

21. NEWARKONE CORP
CHICAGO, IL 60640-4496
CAGEC: 02929

22. MASTER BOND INC
HACKENSACK, NJ 07601
CAGEC: 59504

23. TECHFLEX
SPARTA, NJ 07871
CAGEC: 3BTW3

24. OCEANEERING SPACE SYSTEMS
HOUSTON, TX 77058 - 2253
CAGEC: 2F262

25. MARK ITEM 13 (TERMINAL) WITH ITEM 18 (MARKING PEN) AS DIRECTED WITH INDICATED SYMBOL FOR INDENTIFICATION

26. ALLIED ELECTRONIC INC
FT. WORTH, TX 76118
CAGEC: 1NNN2

27. ITEM 36, 37, AND 38 (BANANA CLIPS) MAY BE SUBSTITUTED FOR ONE ANOTHER.

28. TERMINATE SHEATHING EXACTLY 1 FOOT FROM ITEM 36 (BANANA PLUG). DO NOT TWIST UNSHEATHED WIRE.

29. 'X' IN PART NUMBER SPECIFIES INSULATION COLOR PER MIL-W-22759.

30. CABLE LENGTHS ARE DETERMINED BETWEEN BACKSHELL, BACKSIDE OF TERMINALS, D-SUB, BANANA PLUG OR LUG OF EACH CABLE

31. GLENAIR INC
GLENDALE,CA 91201-2497
CAGEC: 06324

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	RIGEX CABLE NOTES					
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Figure B.3 RIGEX Pigtail Notes page

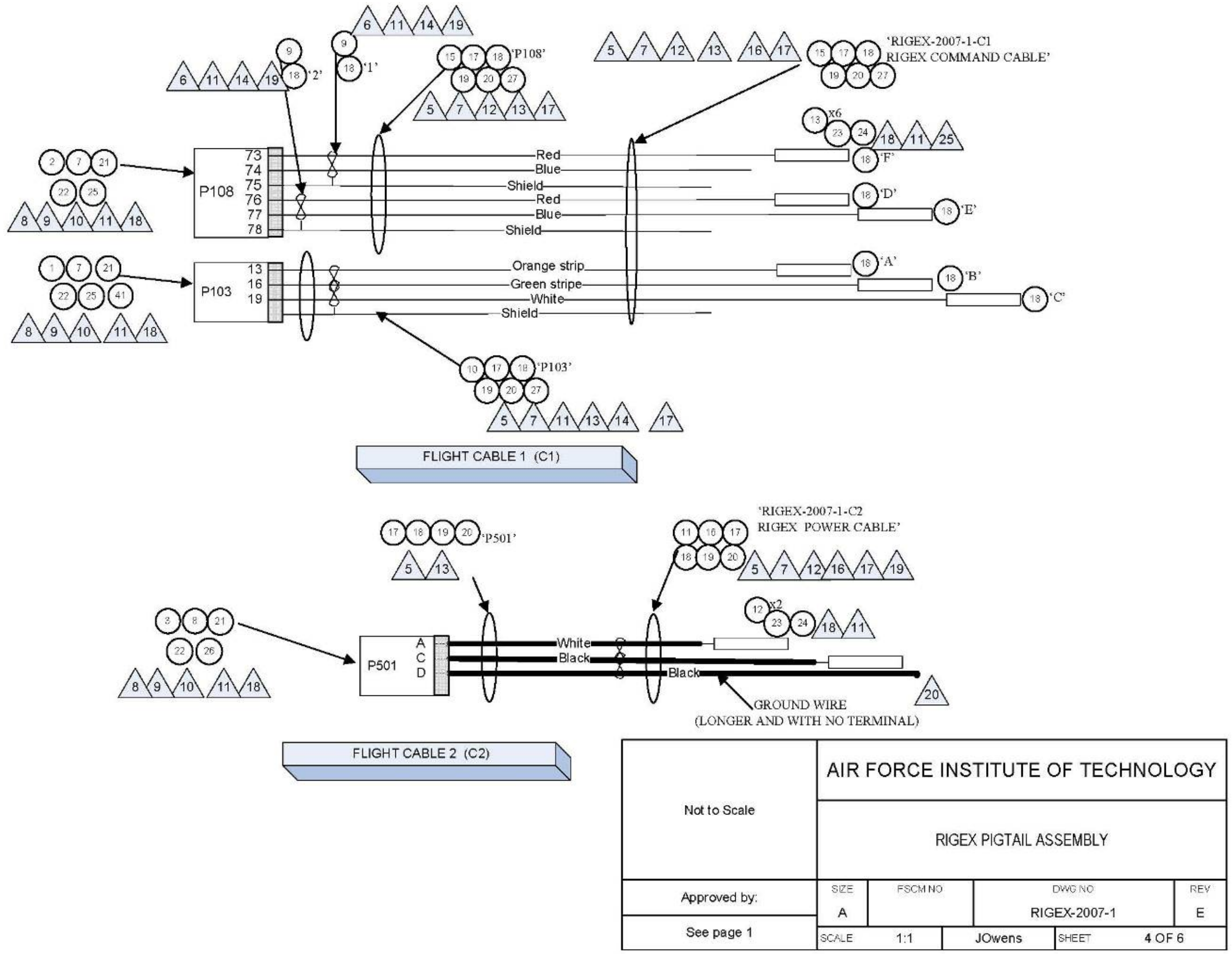


Figure B.4 RIGEX Flight Pigtail Cable Drawings

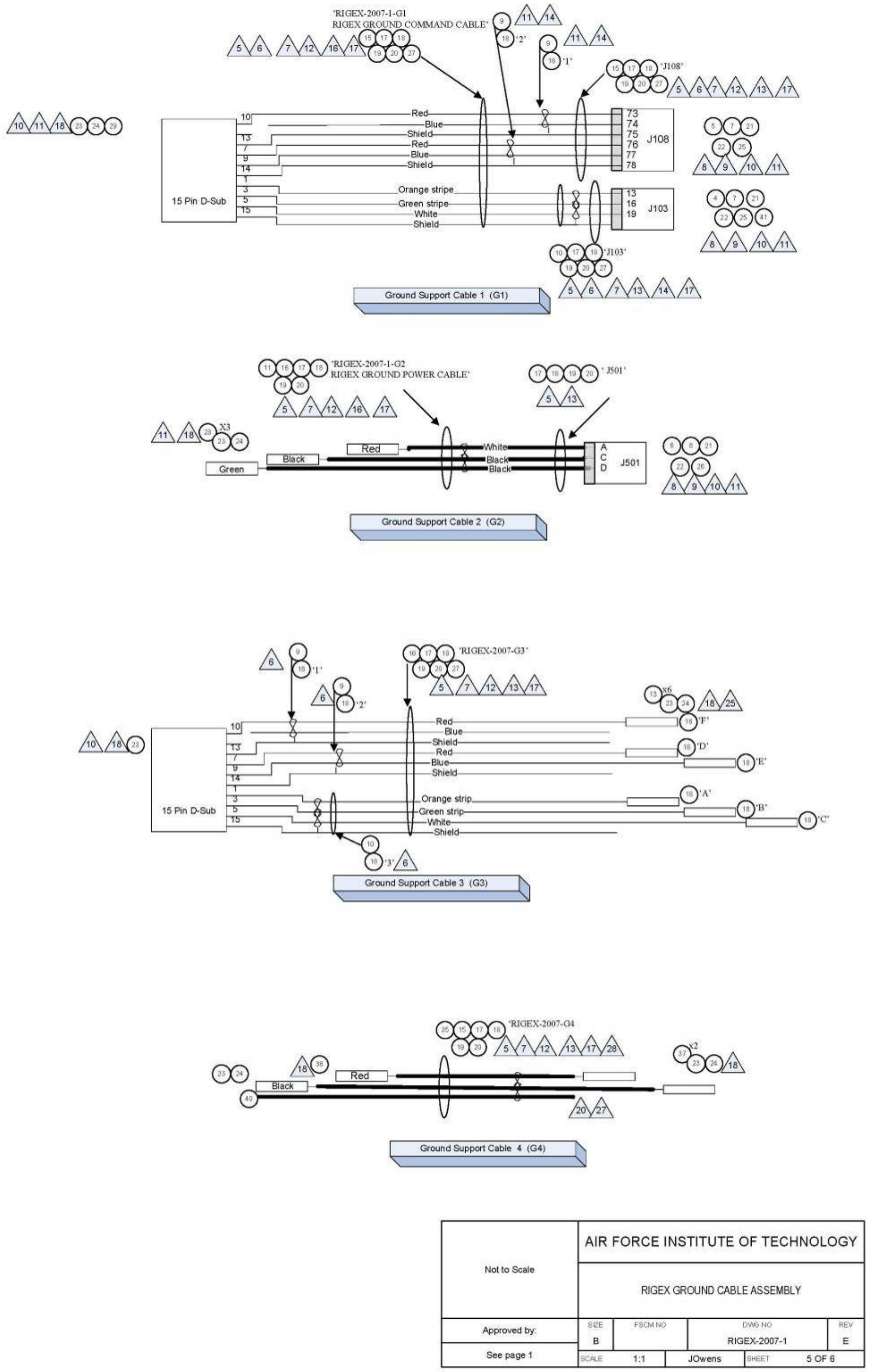


Figure B.5 RIGEX Ground Pigtail Drawings

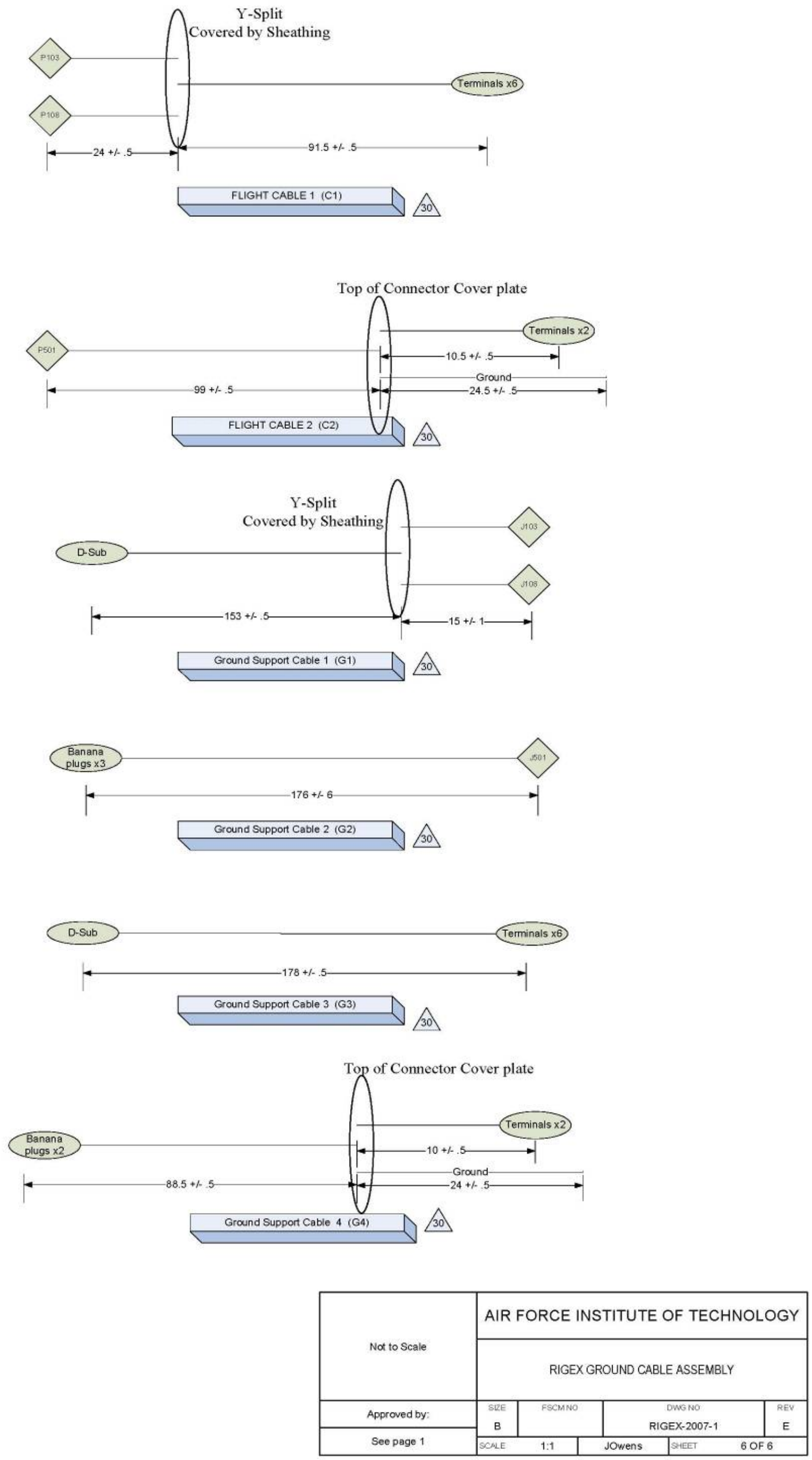


Figure B.6 Pigtail Cable Lengths

Appendix C RIGEX Code

```
/* RIGEX:  Program Routine
Routine executes the RIGEX experiment while collecting temperature,
pressure, and vibration data.   The program will produce 12 data files,
4 data files for each tube tested.   The program will update a 3 required
file called rigex_failsafe.dat, FVTrun_file.dat, and run_file.dat.
rigex_failsafe.dat is used to monitor how far in the experiment the computer
has progressed in the case of power failure.  FVTrun_file monitors the number
of times the Fucvtion verification test has been ran and assists with file naming
run_file performs the same function as FVTrun_file however it applies to the
actual experiment.

External to this program are the individual bays camera which contain there own
removeable media.

This file was originated by: David Moody GA [22]
Modifications to it have been completed by: Jeremy Goodwin GAEM06 [9]
Jeremy Owens GAEJ07
Last modified on: 10 Aug 07   by: Jeremy Owens
Assistance provided by Sean Miller
*/

#include <stdio.h>
#include <conio.h>

// Global variables containing the addresses for the different boards
const short int AD_addr = 0x380;
const short int temp_addr = 0x300;
const short int relay_addr = 0x240;
const short int timer_addr = 0x2C0;

// Function declarations for the data collection subroutines
int FVT_gas(short int,short int);
int temp(short int,short int); //JJO change to one 'int' for flight code
int gas(short int,short int); //JJO change to one 'int' for flight code
int excite(short int,short int,short int Xdigi[],short int Ydigi[],short int Zdigi[],short int MMSB[],short int
LLSB[],short int Dac[]);
int inflate(short int,short int,short int Xdigi[],short int Ydigi[],short int Zdigi[],short int press[] );
int HOLD(short int);

int main(void){
short int *X_array= new short int[125000];
short int *Y_array= new short int[125000];
short int *Z_array= new short int[125000];
short int *press_array= new short int[25000];
short int *LLSB_array= new short int[5000];
short int *MMSB_array= new short  int[5000];
short int *Dac_array=new short int[125000];

// Needed variables
FILE *failsafe_file;
FILE *run_file;
FILE *FVTrun_file;
FILE *fidl;
FILE *fidm;
short int failsafe;
```

```
short int run = 0;
short int FVTrun;
const int pin_puller_pause = 1;
short int mdummy,ldummy;
short int i = 0;
short int k = 0;
short int r = 0;
const short int cool_down_pause = 60;
const short int LED_display_pause = 60;
const short int camera12 = 5;
const short int FVT_completion_pause =300;
const short int FVThold=10;
const short int flight = 0; // Change to '1' to convert to flight code
const short int EMI = 0;    // Change to '1' to convert to EMI test code
const short int FVT = 1;    // Change to '0' to trouble shoot code

// RESET all boards
//Ensure all relays are de-activated
printf("Reseting Relay board...\n");
outp(relay_addr+4,0x20); //Reset board and select bank 1
outp(relay_addr+0,0);

// Initialize A/D Board
printf("Reseting the A/D board...\n");
outp(AD_addr+8,32);

// Enable AD (internal timer controlled) and Timer 0
// interrupt interrupts occur on base+9 read
printf("Initializing Timer 0\n");
outp(AD_addr+9,0x21);

// Configure timer 0 to use internal clock source
printf("Configure timer 0 to use internal clock source\n");
outp(AD_addr+10,0xC2);

// set counter 0 to mode 2 operation (clk source)
printf("%d\n",inp(AD_addr+10));
outp(AD_addr+15,0x14);
outp(AD_addr+12,0x02);

printf("Initializing Timer Board...\n");
outp(timer_addr+1,0x17);      // Access Master Mode Register
outp(timer_addr+0,0xF0);      // Write LSB to MM Register
outp(timer_addr+0,0x51);      // Write MSB to MM Register
//TEST FOR
ARRAYS_____________________________________________________________________________

if(X_array==NULL){       // Memory Allocation Check
printf("Error allocating memory for X-Axis!\n");
return 0;
}

if(Y_array==NULL){       // Memory Allocation Check
printf("Error allocating memory for Y-Axis!\n");
return 0;
```

```
}
if(Z_array==NULL){        // Memory Allocation Check
printf("Error allocating memory for Z-Axis!\n");
return 0;
}
if(press_array==NULL){        // Memory Allocation Check
printf("Error allocating memory for Tube Pressure Measurement!\n");
return 0;
}
if(MMSB_array==NULL){        // Memory Allocation Check
printf("Error allocating memory for MMSB!\n");
return 0;
}
if(LLSB_array==NULL){        // Memory Allocation Check
printf("Error allocating memory for LLSB!\n");
return 0;
}
if(Dac_array==NULL){        // Memory Allocation Check
printf("Error allocating memory for Dac!\n");
return 0;
}

fidl = fopen("ex_LSB.dat","r");
fidm = fopen("ex_MSB.dat","r");

i = 0;
while(i<5000){
fscanf(fidl,"%d",&ldummy);
LLSB_array[i] = ldummy;
fscanf(fidm,"%d",&mdummy);
MMSB_array[i] = mdummy;
i++;
}
printf("Register Loaded...\n");
fclose(fidl);
fclose(fidm);

//END TEST FOR
ARRAYS__________________________________________________________________________

// Beginning of FVT
if(FVT){
// Mark FVTrun file to continuously count # of times run
// NEED to install "FVTrun_file.dat" file in same folder as program
printf("\nMarking run # for FVT files...\n");
FVTrun_file = fopen("FVTrun_file.dat","r");
fscanf(FVTrun_file,"%d",&FVTrun);
fclose(FVTrun_file);
FVTrun_file = fopen("FVTrun_file.dat","w");
fprintf(FVTrun_file,"%d",FVTrun+1);
fclose(FVTrun_file);
printf("Current run of FVT is %d...\n",FVTrun);

printf("Intializing Functional...\n");
```

```
// Turn DS13-Up On
printf("Turning DS13-Up On...\n");
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x04);

// Hold
HOLD(4);  // Adjust this number to get DS-13 off in 125s // JJO

//____________________________________________________________________________
printf("\n\nStarting Functional for tube experiment 1...\n");

// Activate Tube 1 Heaters and lights
printf("\n Activating Heaters and Lights......BAY 1\n");
outp(relay_addr+4,0);          //Select Bank 0
outp(relay_addr+0,0x02);
outp(relay_addr+4,0x03);       //Select Bank 3
outp(relay_addr+0,0x01);

// Hold
HOLD(FVThold);

// Shut off heater
printf("\n Shutting off heaters\n");
outp(relay_addr+0,0);

// Hold
HOLD(FVThold);

//Turn Camera on
printf("\n Starting Camera for experiment bay #1...\n");
outp(relay_addr+4,0);          //Select Bank 0
outp(relay_addr+0,0x03);       //Leave LED on and turn on Camera

// Hold
HOLD(FVThold);

// Stop Camera
printf("\n Bay #1 Functional Complete!...\n");
outp(relay_addr+0,0);

// Hold
HOLD(FVThold);

//__________________________________________________________________________________
printf("\n\nStarting Functional for tube experiment 2...\n");

// Activate Tube 2 Heaters and lights
printf("\n Activating Heaters and Lights of experiment bay #2...\n");
outp(relay_addr+4,0);          //Select Bank 0
outp(relay_addr+0,0x08);       // Turn on LED 2
outp(relay_addr+4,0x03);       //Select Bank 3
outp(relay_addr+0,0x04);       //Turn on Oven 2

// Hold
HOLD(FVThold);
```

```
// Shut off heater
printf("\n Shutting off heaters\n");
outp(relay_addr+0,0);

// Hold
HOLD(FVThold);

//Turn Camera on
printf("\n\tStarting Camera for experiment bay #2...\n");
outp(relay_addr+4,0);         //Select Bank 0
outp(relay_addr+0,0x0C);      //Activate Camera

// Hold
HOLD(FVThold);

// Stop Camera
printf("\n Bay #2 Functional Complete!...\n");
outp(relay_addr+0,0);

// Hold
HOLD(FVThold);

//___________________________________________________________________________________
printf("\n\nStarting Functional for tube experiment 3...\n");

// Activate Tube 3 Heaters and lights
printf("\n Activating Heaters and Lights of experiment bay #3...\n");
outp(relay_addr+4,0);         //Select Bank 0
outp(relay_addr+0,0x20);      // Turn on LEDs
outp(relay_addr+4,0x03);      //Select Bank 3
outp(relay_addr+0,0x10);      //Turn on Oven 3

/// Hold
HOLD(FVThold);

// Shut off heater
printf("\n Shutting off heaters...\n");
outp(relay_addr+0,0);

// Hold
HOLD(FVThold);

//Turn Camera on bay 3
printf("\n Starting Camera for experiment bay #3...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x30);   //Activate Camera
// Hold
HOLD(FVThold);

// Stop Camera
printf("\n Bay #3 Functional Complete!...\n");
outp(relay_addr+0,0);  //
// Hold
HOLD(FVThold);
```

```
//______________________________________________________________________________
// Check Storage Tank Pressures
for (k=1;k<4;k++){
printf("\tChecking Tank #%d pressure\n",k);
FVT_gas(k,FVTrun);
}

// Turn DS13-Up Off
printf("\n Turning DS13-Up Off...\n");
outp(relay_addr+4,0x01);
outp(relay_addr+0,0);

// HOLD
HOLD(LED_display_pause);

// Turn DS13-Down On
printf("\n Turning DS13-Down On...\n");
outp(relay_addr+0,0x08);

// HOLD
HOLD(LED_display_pause);

// Turn DS13-Down Off
printf("\n Turning DS13-Down Off...\n");
outp(relay_addr+0,0);

// HOLD
HOLD(FVT_completion_pause);

// End of FVT
}
//______________________________________________________________
//Intialize Actual Experiment


// Mark run file to continuously count # of times run
//NEED to add "run_file.dat" file to same directory as main program
if (!flight){
printf("\nMarking run # for run files...\n");
run_file = fopen("run_file.dat","r");
fscanf(run_file,"%d",&run);
fclose(run_file);
run_file = fopen("run_file.dat","w");
fprintf(run_file,"%d",run+1);
fclose(run_file);
printf("Current run of experiment is %d...\n",run);
}

printf("\n Starting Actual Experiment.\n");

// Turn DS13-Up On
printf("Turning DS13-Up On...\n");
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x04);
```

```
// Check Failsafe File
//NEED to add "rigex_failsafe.dat" file to same directory
// FOR EMI actuate only the full bay of #2, comment out from here to Bay #2 Process
if (!flight){  //JJO add 'not' before TVACdeployment testing
printf("Checking failsafe file to determine if interrupt..");
failsafe_file = fopen("rigex_failsafe.dat","r");
fscanf(failsafe_file,"%d",&failsafe);
fclose(failsafe_file);
printf("Checking Failsafe value:  %d\n",failsafe);


if (failsafe !=0){ //failsafe file needs to be reset to 0
if (failsafe == 10) // Heating and inflating of Tube #1
goto Tube10;
if (failsafe == 15) // Excitation and data collection of Tube #1
goto Tube15;
if (failsafe == 20) // Heating and inflating of Tube #2
goto Tube20;
if (failsafe == 25) // Excitation and data collection of Tube #2
goto Tube25;
if (failsafe == 30) // Heating and inflating of Tube #3
goto Tube30;
if (failsafe == 35) // Excitation and data collection of Tube #3
goto Tube35;
else
goto Data_collect;
}
}

if(EMI){
goto Tube20;
}

//___________________________________________________________________
// Tube 1 Process
// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",10);
fclose(failsafe_file);

Tube10:     // Activate Tube 1 Heaters and lights
printf("Activating Heaters and Lights for experiment bay #1...\n");
outp(relay_addr+4,0);     //Select Bank 0
outp(relay_addr+0,0x02);   //Turn on Bay LED
outp(relay_addr+4,0x03);   //Select Bank 3
outp(relay_addr+0,0x01);   //Turn on Oven 1

// Collect temperature data and check versus threshold
printf("Collecting Temperature Data...\n");
temp(1,run);
printf("Threshold Temperature Achieved for experiment bay #1...\n");

// Sample Gas Storage Container
printf("Checking Gas Storage Pressure for experiment bay #1...\n");
```

```
gas(1,run);

//Turn Camera on
printf("Starting Camera for experiment bay #1...");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x03);    //Leave LED on and turn on Camera

// Hold for Camera Buildup
HOLD(3);

// Open Heater Box and Inflation Valve
printf("\n Opening Heater Box for experiment bay #1...\n");
outp(relay_addr+4,0x03);    //Select Bank 3
outp(relay_addr+0,0x03);    //Turn on Pin puller and leave ovens on

//Hold
HOLD(pin_puller_pause);

printf("\n Opening Gas Valve for experiment bay #1...\n");
outp(relay_addr+0,0x40);   //Turn off pinpuller and oven, but activate solenoid

// Sample Pressure and Vibration Upon Inflation
printf("Inflation Data being collected for experiment bay #1...\n");
inflate(1,run,X_array,Y_array,Z_array,press_array);  //inflate(1,run);

// Stop Camera
printf("Stopping Camera for experiment bay #1...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x02);   //Leave LEDS on

// Hold to cool the tube
printf(" Cooling tube ...\n");
HOLD(cool_down_pause);

// Vent the gas from the tube
printf("\n Venting Gas for experiment bay #1...\n");
outp(relay_addr+4,0x03);   //Select Bank 0
outp(relay_addr+0,0);      //Turn off solenoid

// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",15);
fclose(failsafe_file);


Tube15:       // Take one picture
printf("Turn camera on to get 1-2 pictures of current state of tube for experiment bay #1...\n");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x03);    //Activate Camera while leaving the LEDs on.

//Hold
HOLD(camera12);

printf("\n Stopping pictures for experiment bay #1...\n");
outp(relay_addr+0,0x02);    //Keep LEDs on for now
```

```
// Excite Tube and measure vibrations
printf("Exciting the tube and collecting data for experiment bay #1...\n");
excite(1,run,X_array,Y_array,Z_array,MMSB_array,LLSB_array,Dac_array);      //excite(1,run);

// Take one picture
printf("Turn camera on to get 1-2 pictures of final state of tube for experiment bay #1...\n");
outp(relay_addr+4,0);         //Select Bank 0
outp(relay_addr+0,0x03);      //Activate Cameras

//Hold
HOLD(camera12);

printf("\n END EXPERIMENT IN BAY #1...\n");
outp(relay_addr+0,0);          //Turn off Cameras and LEDs
// Mark failsafe point

failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",20);
fclose(failsafe_file);

if (!flight){
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x08);
HOLD(LED_display_pause);
outp(relay_addr+0,0x04);
}
//____________________________________________________________________
// Tube 2 Process


Tube20: // Activate Tube 2 Heaters and lights
printf("Activating Heaters and Lights for experiment bay #2...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x08);   //Turn on Bay LED
outp(relay_addr+4,0x03);   //Select Bank 3
outp(relay_addr+0,0x04);   //Turn on Oven 2

// Collect temperature data and check versus threshold
printf("Collecting Temperature Data...\n");
temp(2,run);
printf("\n Threshold Temperature Achieved for experiment bay #2...\n");

// Sample Gas Storage Container
printf("Checking Gas Storage Pressure for experiment bay #2...\n");
gas(2,run);

//Turn Camera on
printf("Starting Camera for experiment bay #2...");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x0C);    //Leave LED on and turn on Camera

//Hold for Camera buildup
HOLD(3);
```

```
// Open Heater Box and Inflation Valve
printf("\n Opening Heater Box for experiment bay #2...\n");
outp(relay_addr+4,0x03);    //Select Bank 3
outp(relay_addr+0,0x0C);    //Turn on Pin puller and solenoid and leave ovens on

//Hold
HOLD(pin_puller_pause);

printf("\n Opening Gas Valve for experiment bay #2...\n");
outp(relay_addr+0,0x80);   //Turn off pinpuller and oven, but activate solenoid

// Sample Pressure and Vibration Upon Inflation
printf("Inflation Data being collected for experiment bay #2...\n");
inflate(2,run,X_array,Y_array,Z_array,press_array); //inflate(2,run);

// Stop Camera
printf("\n Stopping Camera for experiment bay #2...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x08);   //Leave LEDS on

// Hold to cool the tube
printf(" Cooling tube ...\n");
HOLD(cool_down_pause);

// Vent the gas from the tube
printf("\n Venting Gas for experiment bay #2...\n");
outp(relay_addr+4,0x03);   //Select Bank 0
outp(relay_addr+0,0);      //Turn off solenoid

// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",25);
fclose(failsafe_file);

Tube25:  // Take one picture
printf("Turn camera on to get 1-2 pictures of current state of tube for experiment bay #2...\n");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x0C);    //Activate Camera while leaving the LEDs on.

//Hold
HOLD(camera12);

printf("\n Stopping pictures for experiment bay #2...\n");
outp(relay_addr+0,0x08);    //Keep LEDs on for now

// Excite Tube and measure vibrations
printf("Exciting the tube and collecting data for experiment bay #2...\n");
excite(2,run,X_array,Y_array,Z_array,MMSB_array,LLSB_array,Dac_array);   //excite(2,run);

// Take one picture
printf("Turn camera on to get 1-2 pictures of final state of tube for experiment bay #2...\n");
outp(relay_addr+4,0);        //Select Bank 0
outp(relay_addr+0,0x03);      //Activate Cameras
```

```
//Hold
HOLD(camera12);

printf("\n END EXPERIMENT IN BAY #2...\n");
outp(relay_addr+0,0);          //Turn off Cameras and LEDs

if (!flight){
if (EMI)
goto EMI;
// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",30);
fclose(failsafe_file);

outp(relay_addr+4,0x01);
outp(relay_addr+0,0x08);
HOLD(LED_display_pause);
outp(relay_addr+0,0x04);
}

//____________________________________________________________
// Tube 3 Process

Tube30:        // Activate Tube 3 Heaters and lights
printf("Activating Heaters and Lights for experiment bay #3...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x20);   //Turn on Bay LED
outp(relay_addr+4,0x03);   //Select Bank 3
outp(relay_addr+0,0x10);   //Turn on Oven 3

// Collect temperature data and check versus threshold
printf("Collecting Temperature Data...\n");
temp(3,run);
printf("Threshold Temperature Achieved for experiment bay #3...\n");

// Sample Gas Storage Container
printf("Checking Gas Storage Pressure for experiment bay #3...\n");
gas(3,run);

//Turn Camera on
printf("Starting Camera for experiment bay #3...");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x30);    //Leave LED on and turn on Camera

//Hold for Camera buildup
HOLD(3);

// Open Heater Box and Inflation Valve
printf("\n Opening Heater Box for experiment bay #3...\n");
outp(relay_addr+4,0x03);    //Select Bank 3
outp(relay_addr+0,0x30);    //Turn on Pin puller and leave ovens on


//Hold
HOLD(pin_puller_pause);
```

```
outp(relay_addr+4,0x03);
outp(relay_addr+0,0);   //Turn off pinpuller and oven, but leave solenoid active
outp(relay_addr+4,0x04);
outp(relay_addr+0,0x01);    // Activate Solenoid

// Sample Pressure and Vibration Upon Inflation
printf("Inflation Data being collected for experiment bay #3...\n");
inflate(3,run,X_array,Y_array,Z_array,press_array); //inflate(3,run);

// Stop Camera
printf("Stopping Camera for experiment bay #3...\n");
outp(relay_addr+4,0);      //Select Bank 0
outp(relay_addr+0,0x20);   //Leave LEDS on

// Hold to cool the tube
printf(" Cooling tube ...\n");
HOLD(cool_down_pause);

// Vent the gas from the tube
printf("\n Venting Gas for experiment bay #3...\n");
outp(relay_addr+4,0x04);   //Select Bank 0
outp(relay_addr+0,0);      //Turn off solenoid

// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",35);
fclose(failsafe_file);

Tube35:         // Take one picture
printf("Turn camera on to get 1-2 pictures of current state of tube for experiment bay #3...\n");
outp(relay_addr+4,0);       //Select Bank 0
outp(relay_addr+0,0x30);    //Activate Camera while leaving the LEDs on.

//Hold
HOLD(camera12);

printf("\n Stopping pictures for experiment bay #3...\n");
outp(relay_addr+0,0x20);    //Keep LEDs on for now

// Excite Tube and measure vibrations
printf("Exciting the tube and collecting data for experiment bay #3...\n");
excite(3,run,X_array,Y_array,Z_array,MMSB_array,LLSB_array,Dac_array);   //excite(3,run);

// Take one picture
printf("Turn camera on to get 1-2 pictures of final state of tube for experiment bay #3...\n");
outp(relay_addr+4,0);         //Select Bank 0
outp(relay_addr+0,0x30);      //Activate Cameras

//Hold
HOLD(camera12);

printf("\n END EXPERIMENT IN BAY #3...\n");
outp(relay_addr+0,0);         //Turn off Cameras and LEDs
```

```
// Mark failsafe point
failsafe_file = fopen("rigex_failsafe.dat","w");
fprintf(failsafe_file,"%d",40);
fclose(failsafe_file);
if(!EMI)
goto Data_collect;


// FOR EMI TEST ONLY

// DO nothing for 60 seconds
EMI:
printf("Doing nothing and waiting...\n");

// HOLD
HOLD(LED_display_pause);

// Turn DS13-Up Off
printf("Turning DS13-Up Off...\n");
outp(relay_addr+4,0x01);
outp(relay_addr+0,0);

// HOLD
HOLD(LED_display_pause);

// Turn DS13-Down On
printf("Turning DS13-Down On...\n");
outp(relay_addr+0,0x08);

// Keep DS13-Down On for 60 seconds
// HOLD
HOLD(LED_display_pause);

// Turn DS13-Down Off
printf("\nTurning DS13-Down Off...\n");
outp(relay_addr+0,0);

// Keep DS13 Off for 600 seconds (10 Minutes)
// HOLD
HOLD(600);

// Start Endless loop seqence

while(i !=0){


// Turn on DS-13 UP
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x4);

printf("\n\t\tStarting Oven on/off Cycle...\n");
for(r = 0; r < 5; r++){

// Turn on oven
outp(relay_addr+4,0x03);    //Select Bank 3
```

```
outp(relay_addr+0,0x10);

// HOLD
HOLD(LED_display_pause);

//Turn off Oven
outp(relay_addr+0,0x0);

// HOLD
HOLD(LED_display_pause);
}
// Down time DS-13 DN on
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x08);

// HOLD
HOLD(LED_display_pause*5);

//Turn DS-13 Up Back on
outp(relay_addr+0,0x04);
printf("\n\t\tStarting Solenoid on/off Cycle...\n");
for(r = 0; r < 5; r++){
// Turn on Solenoid
outp(relay_addr+4,0x04);   //Select Bank 4
outp(relay_addr+0,0x01);

// HOLD
HOLD(LED_display_pause);

//Turn off Solenoid
outp(relay_addr+0,0x0);

// HOLD
HOLD(LED_display_pause);

// Down time DS-13 DN on
outp(relay_addr+4,0x01);
outp(relay_addr+0,0x08);

// HOLD
HOLD(LED_display_pause*5);
}
}

// Turn on DS13-Down
Data_collect:
outp(relay_addr+4,0x01);  //Reset Relay Board and Select Bank 1
outp(relay_addr+0,0x08);      //Turn DS-13 DN on.

printf("The Ridizable Inflatable Get-A-Way-Special EXperiment is complete!...\n");
printf("The failsafe file will need to be manually opened and reset to 0...\n");
delete[] X_array; //deleted memory allocation after data was recorded to vibdat
delete[] Y_array; //deleted memory allocation after data was recorded to vibdat
delete[] Z_array; //deleted memory allocation after data was recorded to vibdat
delete[] press_array; //deleted memory allocation after data was recorded to vibdat
```

```
delete[] Dac_array;     //deleted memory allocation after data was recorded to vibdat
delete[] MMSB_array;    //deleted memory allocation after data was recorded to vibdat
delete[] LLSB_array;    //deleted memory allocation after data was recorded to vibdat
return 0;

}

// BEGINNING OF GENERAL ROUTINES

int HOLD(short int time){
// Time should be recieved in seconds
int i,k;
int status;

printf("\tWaiting...%d seconds\n", time);
for(k = 0; k < time; k++){
i = 0;
while(i<5000){                    // Loop to count 5000 cycles of clk
do {                              // Loop to wait for timing interrupt
status = inp(AD_addr+9) & 0x20;  // load status register
} while(status != 32);            // check for timing interrupt
outp(AD_addr+8,0x08);             // Activate interrupts
i++;
}
printf(".");
}
printf("\n");
return 0;
}

// BEGINNING OF FVT SUBROUTINES
int FVT_gas(short int tube_num,short int FVTrun){
FILE *gas_str;
short int status;
short int MSBad,LSBad;
short int ad_result;
short int ch;
char filename[];

if (tube_num == 1)
ch = 3;
if (tube_num == 2)
ch = 4;
if (tube_num == 3)
ch = 5;

sprintf(filename,"%dgas%d.dat",FVTrun,tube_num);
gas_str = fopen(filename,"w");

// Configure to use only selected channel
outp(AD_addr+2,ch);
outp(AD_addr+3,ch);

// Configure channels to 0-5V range  (for new pressure transducers)
outp(AD_addr+11,13);
```

```
// Disable FIFO and scanning
outp(AD_addr+7,0);

// Wait for A/D to settle
do{
status = inp(AD_addr+11) & 0x80;
}while(status != 0);

// Activate A/D conversion
outp(AD_addr+0,0);

// loop to wait till A/D conversion complete
do{
status = inp(AD_addr+8) & 0x80;
}while(status != 0);
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
ad_result = MSBad*256+LSBad;
fprintf(gas_str,"%d",ad_result);
fclose(gas_str);
return 0;
}

// END OF FVT SUBROUTINES;

//____________________________________________________________________

// BEGINNING OF FULL EXPERIMENT SUBROUTINES

int temp(short int tube_num,short int run){

short int temp_threshold = 130;
float temp_high;
float temp_low;
short int status;
short int volt1;
short int volt2;
short int k,j;
long int i=1;
short int ch_high,ch_low;
float temp_struc;
float br_temp;
float temps[] = {0.0};
float small_temp;
float temp_sum = 0.0,temp_ave = 0.0;
FILE *temp_data;
char filename[];
long int time = 18000000; //JJO

if (tube_num == 1)
{
ch_high = 7;
ch_low = 6;
}
```

```
if (tube_num == 2)
{
ch_high = 5;
ch_low = 4;
}
if (tube_num == 3)
{
ch_high = 3;
ch_low = 2;
}

sprintf(filename,"%dtemp%d.dat",run,tube_num);
temp_data = fopen(filename,"w");

printf("\tMonitoring temp_ave\n");

j=0;
while(i != time){                     // Loop to count 5000 cycles of clk per second
do {                              // allowing to work for 1 hour
status = inp(AD_addr+9) & 0x20; // Loop to wait for timing interrupt
} while(status != 32);            // check for timing interrupt
outp(AD_addr+8,0x08);             // Activate interrupts
i++;j++;

if (temp_ave > temp_threshold)
break; //If heaters are hot enough break out

//Take Board Temperature
outp(temp_addr,0x48+0);
do{
status = inp(temp_addr+8) & 1;
}while(status != 0);

volt1=(inp(temp_addr+1) & 0x0F)*256;
volt2=inp(temp_addr+0);

if (volt1>2048.0)
br_temp = 1000.0*((volt1+volt2)/4095.0-1.0)-10.0;
else
br_temp= 1000.0*(volt1+volt2)/4095.0 - 10.0;

//Take Thermocouple Temperature

// High Temp
outp(temp_addr+0,0x48+ch_high);
do{
status = inp(temp_addr+8) & 1;
}while(status != 0);
volt1=(inp(temp_addr+1) & 0x0F)*256;
volt2=inp(temp_addr+0);

if (volt1>2048.0)
temp_high = 1000.0*((volt1+volt2)/4095.0-1)-20;
else
temp_high= 1000.0*(volt1+volt2)/4095.0-20;
```

```
// Low Temp
outp(temp_addr+0,0x48+ch_low);
do{
status = inp(temp_addr+8) & 1;
}while(status != 0);
volt1=(inp(temp_addr+1) & 0x0F)*256;
volt2=inp(temp_addr+0);

if (volt1 >= 2048.0)
temp_low = 1000.0*((volt1+volt2)/4095.0-1)-20;
else
temp_low= 1000.0*(volt1+volt2)/4095.0-20;

// Temp struc
outp(temp_addr+0,0x48+1);
do{
status = inp(temp_addr+8) & 1;
}while(status != 0);
volt1=(inp(temp_addr+1) & 0x0F)*256;
volt2=inp(temp_addr+0);

if (volt1 >= 2048.0)
temp_struc = 1000.0*((volt1+volt2)/4095.0-1)-20;
else
temp_struc= 1000.0*(volt1+volt2)/4095.0-20;

if(j==5000){
j=0;
printf("\t%f\n",temp_ave);
}

fprintf(temp_data,"%f  %f  %f  %f\n",br_temp,temp_high,temp_low,temp_struc);

for(k = 13;k>=0;k--){
temps[k+1] = temps[k];
}

if(temp_high <= temp_low)
small_temp = temp_high;
else
small_temp = temp_low;

temps[0] = small_temp;

for(k = 0;k<15;k++){
temp_sum = temp_sum + temps[k];
}
temp_ave = temp_sum/15;
temp_sum = 0;

}

fclose(temp_data);
return 0;
```

```
}

int inflate (short int tube_num, short int run, short int Xdigi[],short int Ydigi[], short int Zdigi[], short int
press[]){     //int inflate (int tube_num, int run){
const int inflation_time = 5;
short int i,k;
int status;
short int ch_high,ch_low,ch_press;
FILE *vibdat;
short int MSBad,LSBad,MSBpr,LSBpr;
char filename[];
const short int num_samp = 25000;

if (tube_num ==1)
{
ch_high = 12;
ch_low = 10;
ch_press = 0;
}
if (tube_num == 2)
{
ch_high = 15;
ch_low = 13;
ch_press = 1;
}
if (tube_num == 3)
{
ch_high = 26;
ch_low = 24;
ch_press = 2;
}

k = 0;
while(k<inflation_time){
i = 0;
printf("\tInflation Time %d\n",k);
while(i<5000){
do {                              // Loop to wait for timing interrupt
status = inp(AD_addr+9) & 0x20; // load status register
} while(status != 32);          // check for timing interrupt
outp(AD_addr+8,0x08);

// Configure to use only selected channels
outp(AD_addr+2,ch_low);
outp(AD_addr+3,ch_high);

// Configure channels to 0-5V
outp(AD_addr+11,13);

// Enable FIFO and scanning
outp(AD_addr+7,0x0C);

// Wait for A/D to settle
do{
status = inp(AD_addr+11) & 0x80;
```

```
}while(status != 0);

// Activate A/D conversion
outp(AD_addr+0,0);

// loop to wait till A/D conversion complete
do{
status = inp(AD_addr+8) & 0x80;
}while(status != 0);

// Collect data from FIFO
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Xdigi+k*5000+i) = LSBad+MSBad*256;
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Ydigi+k*5000+i) = LSBad+MSBad*256;
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Zdigi+k*5000+i) = LSBad+MSBad*256;

// Reset FIFO
outp(AD_addr+7,0x0F);

// Configure to use only selected pressure channel
outp(AD_addr+2,ch_press);
outp(AD_addr+3,ch_press);

// Configure channels to 0-5V
outp(AD_addr+11,13);

// Disable FIFO and scanning
outp(AD_addr+7,15);

// Wait for A/D to settle
do{
status = inp(AD_addr+11) & 0x80;
}while(status != 0);

// Activate A/D conversion
outp(AD_addr+0,0);

// loop to wait till A/D conversion complete
do{
status = inp(AD_addr+8) & 0x80;
}while(status != 0);
LSBpr = inp(AD_addr+0);
MSBpr = inp(AD_addr+1);
*(press+k*5000+i) = LSBpr+MSBpr*256;
i++;
}
k++;
}

sprintf(filename,"%dinfla%d.dat",run,tube_num);
```

```
printf("\t Filename is %s\n",filename);

vibdat = fopen(filename,"w");

printf("writing to file...\n");
k = 0;
while(k<num_samp){
fprintf(vibdat,"%d  %d  %d  %d\n",Xdigi[k],Ydigi[k],Zdigi[k],press[k]);
k++;
}
printf("Done writing to file...\n");

fclose(vibdat);

return 0;
}

int gas(short int tube_num, short int run){
FILE *gas_str;
short int status;
short int MSBad,LSBad;
short int ad_result;
short int ch;
char filename[];

if (tube_num == 1)
ch = 3;
if (tube_num == 2)
ch = 4;
if (tube_num == 3)
ch = 5;

sprintf(filename,"%dgas%d.dat",run,tube_num);
gas_str = fopen(filename,"w");

// Configure to use only selected channel
outp(AD_addr+2,ch);
outp(AD_addr+3,ch);

// Configure channels to 0-5V range
outp(AD_addr+11,13);

// Disable FIFO and scanning
outp(AD_addr+7,0);

// Wait for A/D to settle
do{
status = inp(AD_addr+11) & 0x80;
}while(status != 0);

// Activate A/D conversion
outp(AD_addr+0,0);

// loop to wait till A/D conversion complete
```

```
do{
status = inp(AD_addr+8) & 0x80;
}while(status != 0);
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
ad_result = MSBad*256+LSBad;
fprintf(gas_str,"%d",ad_result);
fclose(gas_str);
return 0;
}

int excite(short int tube_num, short int run,short int Xdigi[],short int Ydigi[],short int Zdigi[],short int
MMSB[],short int LLSB[], short int Dac[]){//int excite(int tube_num, int run){

char filename[];
const double num_samples = 125000;
short int ch_high = 0;
short int ch_low = 0;
short int status = 0;
short int LSBad = 0;
short int MSBad = 0;
short int i = 0;
short int k = 0,j=0;
short int p = 0;
const short int num_iterations = 25;
const short int channelnum = 0;
short int updateDAC = 0;
FILE *results;


outp(relay_addr+4,0x04);

if (tube_num == 1)
{
ch_high = 12;
ch_low = 10;
outp(relay_addr+0,0x02); //Turn on Transformer #1
}
if (tube_num == 2)
{
ch_high = 15;
ch_low = 13;
outp(relay_addr+0,0x04); //Turn on Transformer #2
}
if (tube_num == 3)
{
ch_high = 26;
ch_low = 24;
outp(relay_addr+0,0x08); //Turn on Transformer #3
}

// Loop to perform iterations
k = 0;
while(k<num_iterations){
// Loop to go through the data array
```

```
i = 0;
printf("\tIteration #%d\n",k);
while(i<5000){
// Loop to wait for timing interrupt
do {                                    // load status register
status = inp(AD_addr+9) & 0x20;    // check for timing interrupt
} while(status != 32);

// wait if DAC not ready
while((inp(AD_addr+4) & 0x80) == 0x80){}

// load LSB to register
outp(AD_addr+4,LLSB[i]);

// load MSB to register
outp(AD_addr+5,MMSB[i] + 64*channelnum);

// Activate DAC
updateDAC = inp(AD_addr+5);
// reset interrupts
outp(AD_addr+8,0x08);

// Configure channels to sample
outp(AD_addr+2,ch_low);
outp(AD_addr+3,ch_high);

// Configure channels to 0-5V
outp(AD_addr+11,13);

// Enable FIFO and scanning
outp(AD_addr+7,0x0C);

// Wait for A/D to settle
do{
status = inp(AD_addr+11) & 0x80;
}while(status != 0);

// Activate A/D conversion
outp(AD_addr+0,0);

// loop to wait till A/D conversion complete
do{
status = inp(AD_addr+8) & 0x80;
}while(status != 0);

// Collect sampled data from A/D FIFO
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Xdigi+k*5000+i) = LSBad+MSBad*256;
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Ydigi+k*5000+i) = LSBad+MSBad*256;
LSBad = inp(AD_addr+0);
MSBad = inp(AD_addr+1);
*(Zdigi+k*5000+i) = LSBad+MSBad*256;
```

```
// Create a excitation data vector
*(Dac+k*5000+i) = LLSB[i] + MMSB[i]*256;

i++;
}
k++;
}
printf("Done collecting data...\n");
outp(relay_addr+0,0); //Turn off Transformers
sprintf(filename,"%dexcit%d.dat",run,tube_num);
printf("\t Filename is %s\n",filename);
results = fopen(filename,"w");
printf("writing to file...\n");
p=0;
while(p<5){
j=0;
while(j<25000){
fprintf(results,"%d %d  %d  %d
%d\n",Dac[p*25000+j],Xdigi[p*25000+j],Ydigi[p*25000+j],Zdigi[p*25000+j]);
j++;
}
p++;
}
fclose(results);
printf("I'm done writing to the file...\n");

return 0;
}
```

Appendix D Electrical Architecture

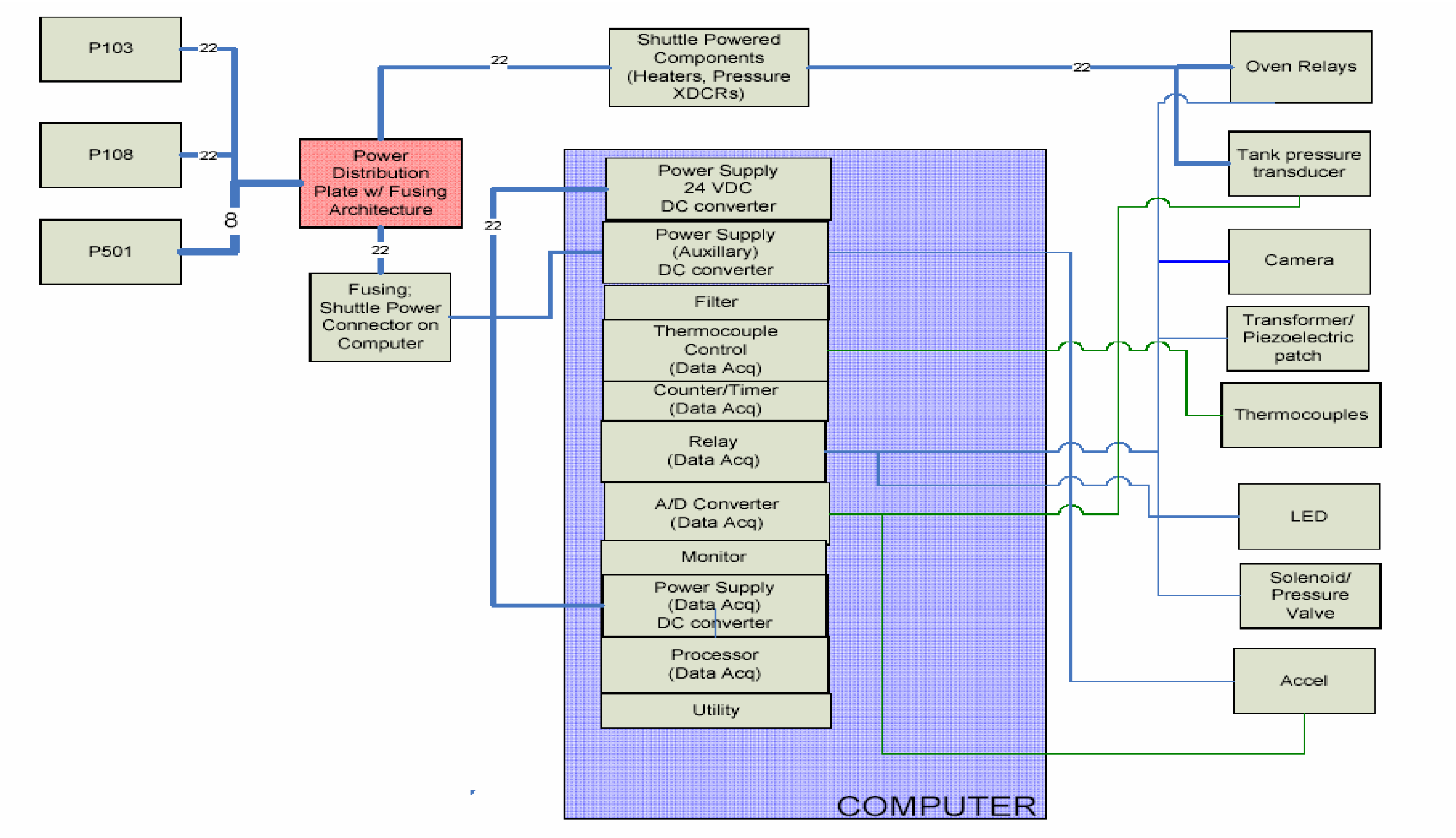


Figure D.1 RIGEX Top Level Electrical Architecture

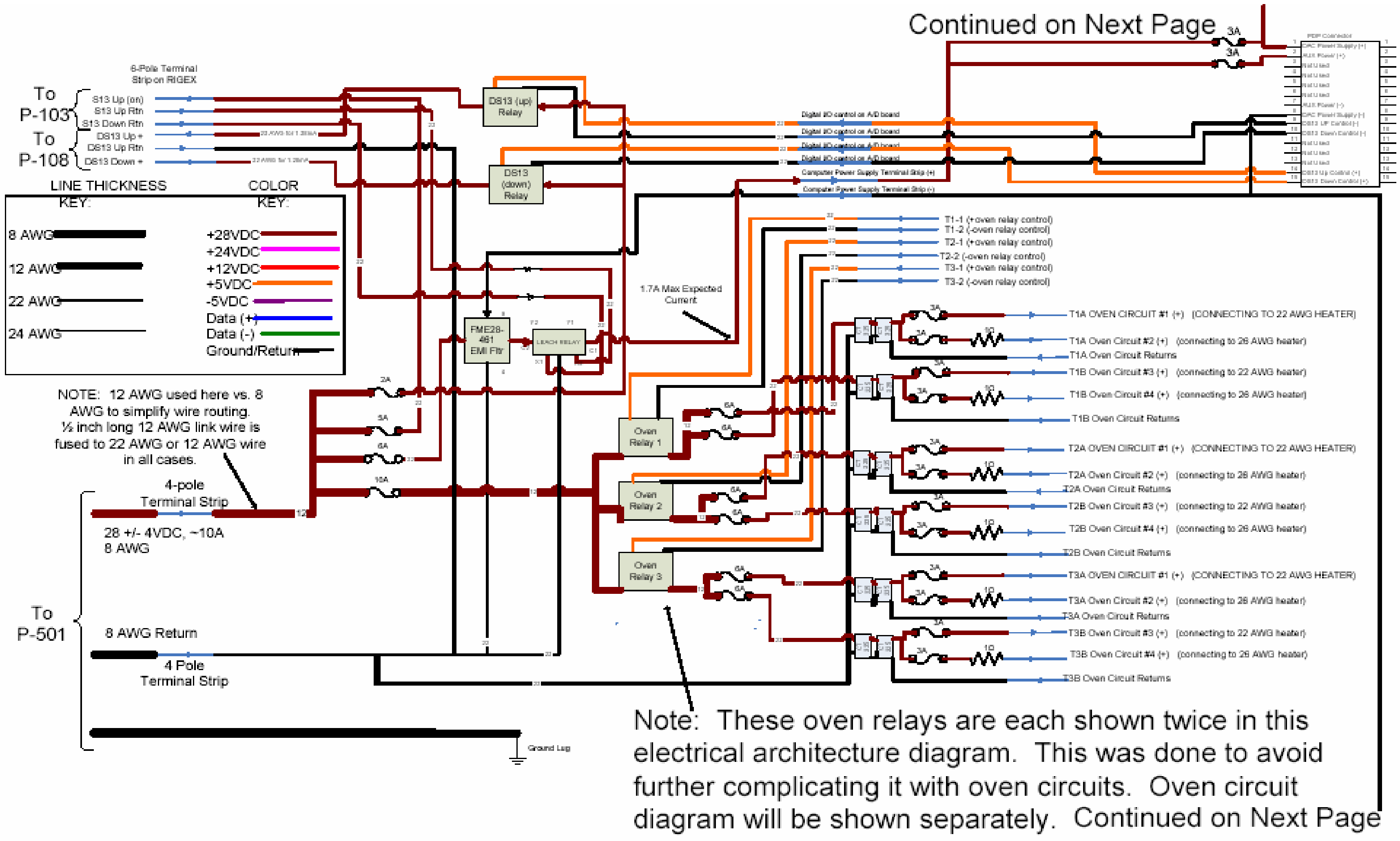


Figure D.2 RIGEX Computer Bay Power Distribution Architecture

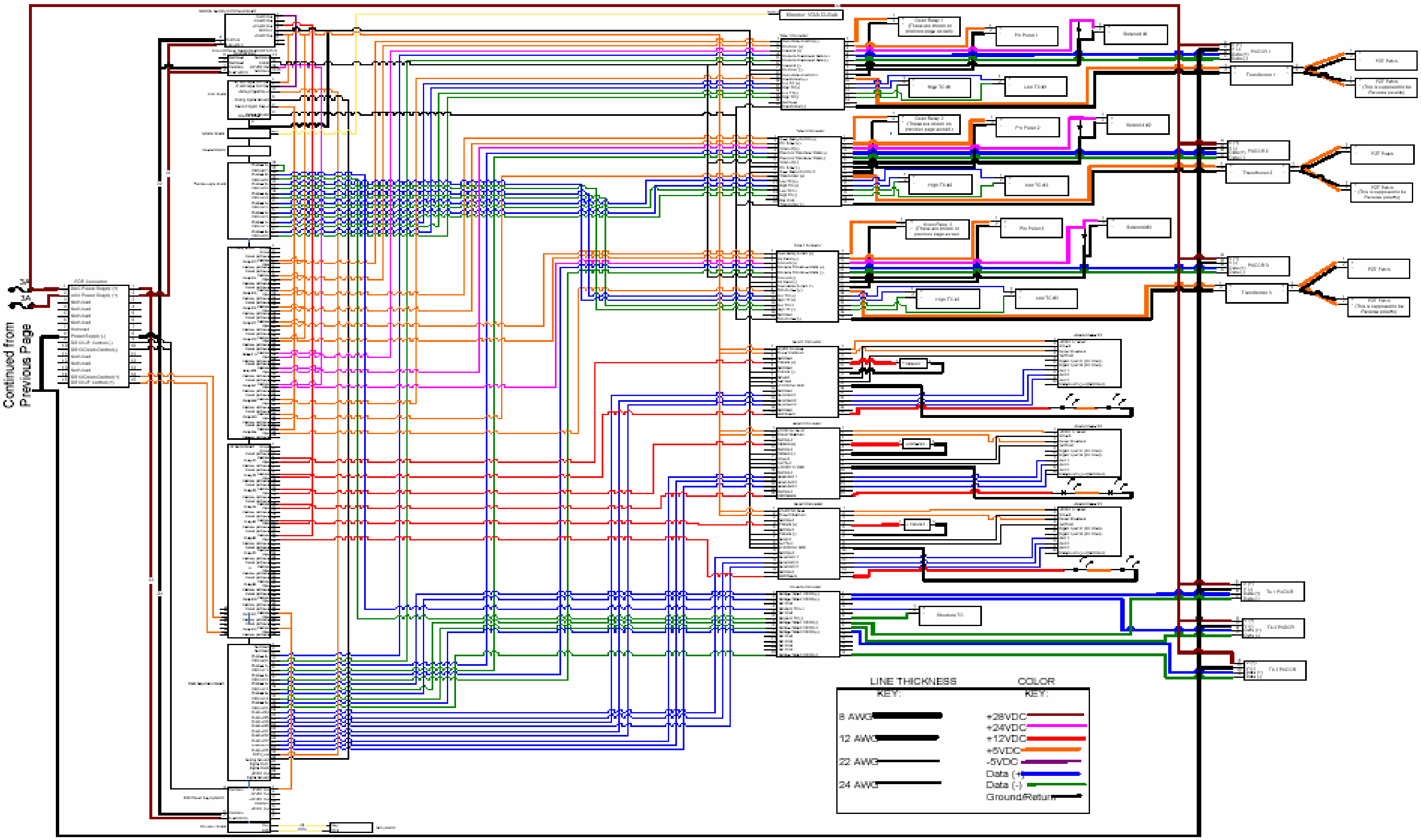


Figure D.3 RIGEX Computer Architecture and Component Power Distribution

Appendix E Current Profiles

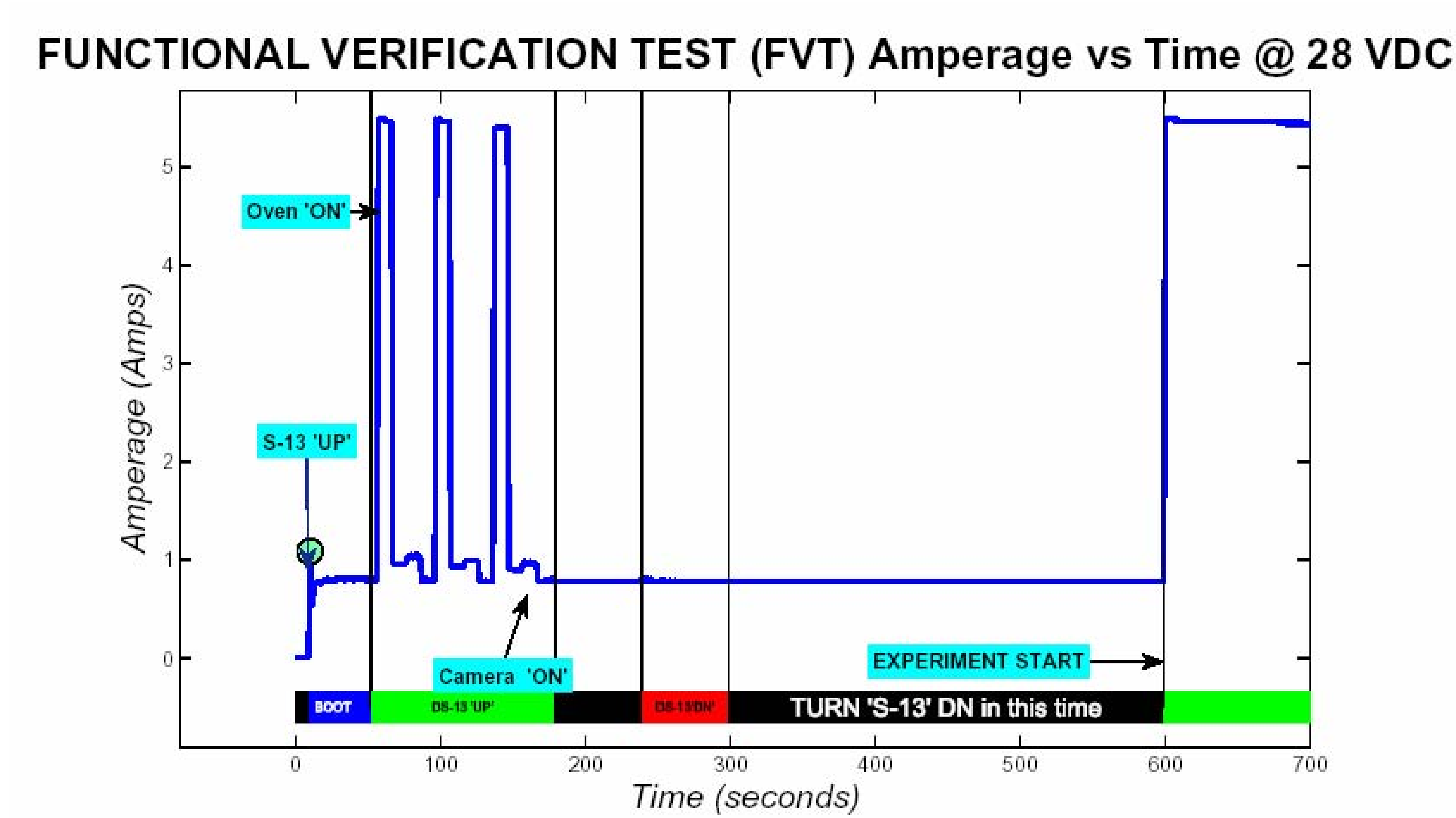


Figure E.1 RIGEX Functional Verification Test Current Profile Detail

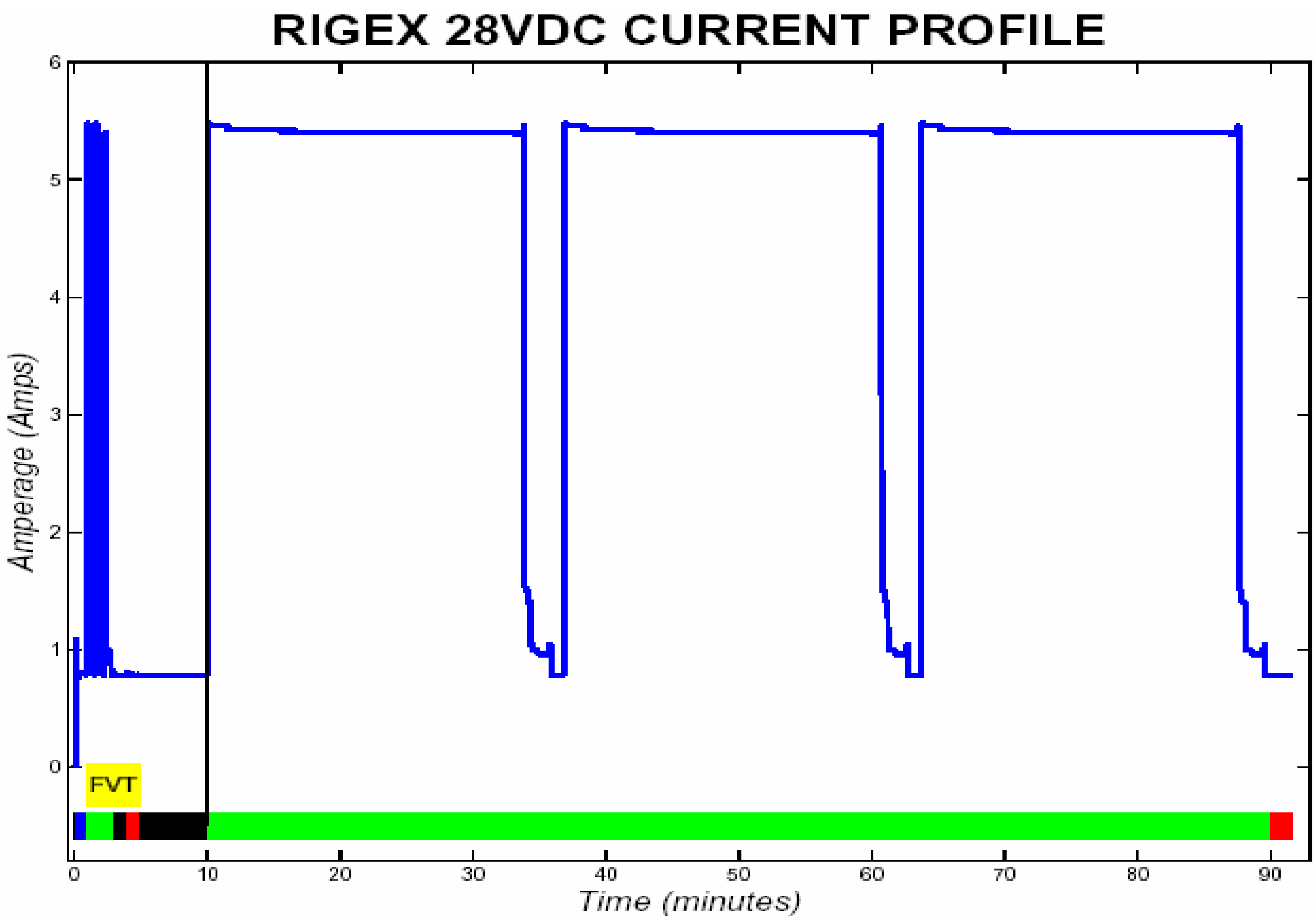


Figure E.2 RIGEX Mission Current Profile @ 28 VDC

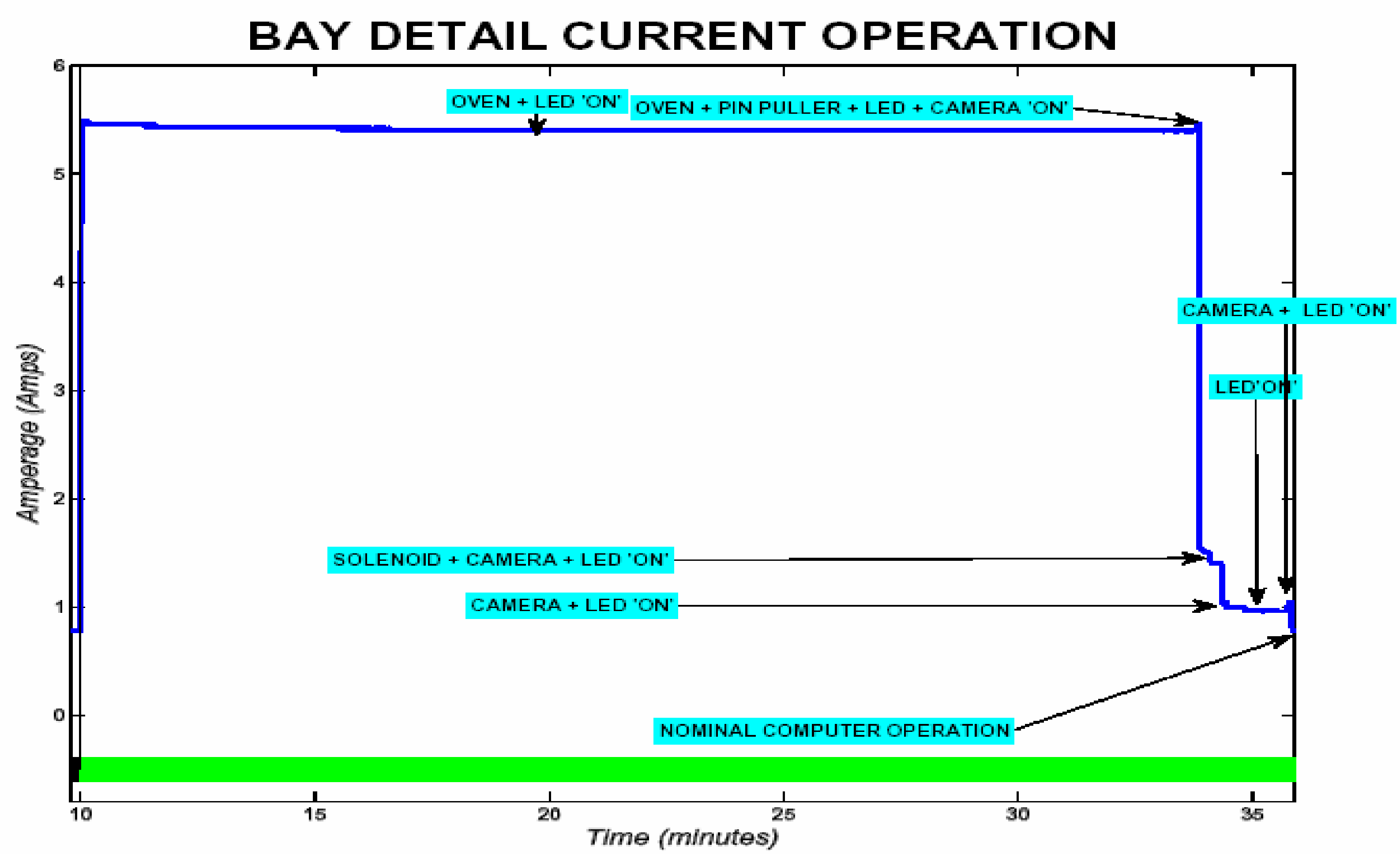


Figure E.3 RIGEX Experiment Bay Detailed Current Profile

Appendix F Acceptance Data Package

Doc No. RD-8
Rev. IR

DRAFT

ACCEPTANCE DATA PACKAGE

RIGEX		2007RIGEX	SN 001
PART NAME	CI No.	Part Number	Serial Number

☒ Flight Hardware ☐ Ground Support Equipment

Included	None	Section	Title
☒	☐	I	RIGEX CERTIFICATE OF CONFORMANCE (SHIPPING)
☒	☐	II	IDENTIFICATION-AS-BUILT CONFIGURATION LIST
☒	☐	III	WAIVERS/DEVIATIONS
☒	☐	IV	LIST OF NON CONFORMANCES/PROBLEMS
☐	☒	V	TEMPORARY INSTALLATIONS REMOVALS
☐	☒	VI	LIMITED LIFE/AGE SENSITIVE ITEMS/OPERATING OR TIME CYCLE
☒	☐	VII	HISTORICAL LOG / COMMENTS / NOTES
☐	☒	VIII	WEIGHT AND BALANCE DATA
☒	☐	IX	RECORD OF OPEN/DEFERRED WORK
☒	☐	X	MATERIAL DATA/CERTIFICATIONS
☒	☐	XI	PROCEDURES/INSTRUCTIONS
☒	☐	XII	ACCEPTANCE TEST DATA

ACCEPTANCE DATA PACKAGE APPROVAL:

______________________________ __________
RIGEX INTEGRETION ENGINEER DATE

______________________________ __________
RIGEX PAYLOAD PRINCIPAL INVESTIGATOR DATE

Section I -- Shipping Certificate of Conformance

8-Oct-07

Air Force Institute of Technology
Wright-Patterson Air Force Base

RIGEX Delivery Item List

Certificate of Compliance

Primary Investigator: Richard Cobb, PhD Air Force Institute of Technology

Engineer: Jeremy Owens, Capt, USAF AFIT RIGEX Project Engineer

The Air Force Institute of Technology confirms that the following items listed below are the hardware and support items necessary for test and integration of the project satellite. They are the as specified parts delivered for final assembly, integration with the Canister for All Payload Ejections (CAPE) and launch aboard STS-123

Container #1 -RIGEX 30"x30"x44.5" DxWxH **Blue box**					
Part Number	***Description***	***Lot# / Serial#***	***Class***	***Qty***	***Notes:***
RIGEX-SHP-P	RIGEX payload-Shipping	SN 001	I	1	
RIGEX-2007-1-G2	RIGEX Ground Power Cable	SN 001	I	1	
RIGEX-2007-1-G1	RIGEX Ground Command Cable	SN 001	I	1	
RIGEX-2007-1-C2	RIGEX Power Cable	SN 001	I	1	
RIGEX-2007-1-C1	RIGEX Command Cable	SN 001	I	1	
RIGEX-2006-16-P	Snubber "Bumpers"	Lot 001	I	12	
RIGEX-2006-13-P	Handles	Lot 001	I	1	
RIGEX-2006-26-P	Shroud Tri-Angular Washers	Lot 001	I	42	
NAS8402-8	8-32 .5 WSHR HD PHIL RIB A-286	Lot 75554-01	I	104	Shroud fasteners + spares
NAS1189E04P8	4-40 1/4 A-286	Lot 27328	I	30	
78f580	4" wire ties	COTS	I	10	Spares
94f6327	1.25" Teflon Wire Tie	COTS	I	10	Spares
66H7086	Ring tongue terminal #6 Stud 22 AWG	COTS	I	10	Spares
NAS1351N6-28	Socket head cap screw: 3/8-24, 1.75" long, A286	Lot	I	28	CMP to EXP bolts
344-0.060-SS-12A	Washers for NAS1351N6-28	Lot	I	30	2 spares

Container #2 -CMP 27"x27"x3.5" DxWxH Wooden Box					
Part Number	***Description***	***Lot#/Serial#***	***Class***	***Qty***	***Notes:***
RIGEX-2006-1-P	Cape Mounting Plate (CMP)	SN 001	I	1	w/ handles & covers attached
RIGEX-2006-14-P	CMP Handles	Lot 001	GSE	4	Attached to CMP
RIGEX-2006-24-P	Connector Hole Cover plates	SN 001-002		2	Attached to CMP
1/4-28x1/2" Screws, 1	Handle fasteners	COTS	GSE	16	Attached to CMP
NAS1189E3P12B	Connector Cover fasteners	Lot 27199	I	8	Attached to CMP

Container #3 -Emulator 11"x11"x8" DxWxH Wooden Box					
Part Number	***Description***	***Lot# /Serial#***	***Class***	***Qty***	***Notes:***
RIGEX_EGSE_1	Shuttle Emulator	SN 001	GSE	1	

Estimated cost of all payload, parts and support equipment listed above is $200,000.

Questions, comments or concerns regarding this shipment should be directed to either Dr. Cobb at 937-255-3636 x4559 or to Capt Owens at 937-207-0999. Air Force Institute of Technology RIGEX Program, 2950 Hobson Way, WPAFB, OH 45433.

Signature: ______________________ Name: Richard Cobb__________

Section II -- "As Built" Configuration

Note: The Attached file is other wise known as RIGEX Document 6 (RD-6) "RIGEX Parts and Materials" and RD-5 "RIGEX Drawing Package"

Section IV-- List of Non-Conformance Items

Note: The Attached file is other wise known as RIGEX Document 7 (RD-7) "RIGEX Discrepancy Reports"

Section V -- Temporary Installations

Note: The following parts are temporarily installed and are considered "remove before flight". This list is accurate at the time of handover to NASA Kennedy

Part Number	Nomenclature	Qty	LN/SN
RIGEX-2006-13-P	Foot Handle	4	LN 001
RIGEX-2006-14-P	CMP Handle	4	LN 001

Section VI -- Limited Life AGE Sensitive Installations

Note: The following parts are items that limit the shelf life of the payload. Included are the effects the part will have on the payload and what needs to be done in the event that the life expectancy is exceeded.

Part Number	Nomenclature	Qty	LN/SN	Effect	To be done
TERN EyeC	Camera (Specifically Soldered on Battery)	3	SN F0400700000 SN F0400700001 SN F0400700002	Loss of Temporary Memory, internal camera clock and calendar	Nothing. Cameras have been hard programmed with correct addressing for how to operate and where to store data. Clock and Calendar are extras.

Section VII -- HISTORICAL LOG / COMMENTS / NOTES

Note: This log first captures the known usage of flight components for check out and then captures the historical timeline of the overall assembled system from 4 June 2007

	DATE	Comment	Under Vacuum	Extreme Thermal
Component History	May-05 --> May-07	LED C-2 (as identified by RP-6) was used in a test configuration of the Imaging Lighting set-up on a test board. This test board was utilized inside the Vacuum chamber at AFIT as a lighting source for the following Tests: --Insulation Selection Test --Run Away Heater Test This board was utilized in the Thermal Vacuum Chamber at AFIT as part of the imaging system component test for the following tests: --Component Test After Completion of the Component test the LED was integrated onto the RIGEX structure for flight	♦	
Component History	May-07	Bay 3 Oven (as identified by RP-1A), Bay 3 Oven Bracket Sub-Assembly (as identified by RP-1A), Oven Controllers (C1A, C1B, C2A, and C2B) (as identified by RP-6), DiskOnChip 2000DIP (Hard drive) (as identified in RIGEX-2007-COMP-D), Aux Power Supply (as identified in RIGEX-2007-COMP-D),Solid State Relay C (as identified by RP-6), and Camera Sub-Assembly C (as identified by RP-6) were utilized in the Component Test. After the Component Test, These items were integrated onto the RIGEX structure.	♦	♦
	28-May-07	Assembly Complete - Functional Test Performed		
	4-Jun-07	RIGEX-BASE-SHP sent to Oceaneering Space Systems, Houston, TX. Shipping Container #1 Sustained damage in transit. All Shock indicators tripped		
	7-Jun-07 thru 8-Jun-07	Integrated into Canister for All Payload Ejections (CAPE), became "RIGEX/CAPE" assembly. Post Ship functional Test performed		
	11-Jun-07	RIGEX/CAPE shipped to Johnson Space Center (JSC), EMI Test facility, in CAPE Shipping Container, Post Ship Functional Performed		
	11-Jun-07 thru 12- Jun-07	RIGEX/CAPE Electromagnetic Interference Testing TP-4 Performed 4 times.		
	12-Jun-07	RIGEX/CAPE shipped to Johnson Space Center (JSC), Vibration Test facility, in CAPE Shipping Container. Post Ship Functional Performed		

	DATE	Comment	Under Vacuum	Extreme Thermal
	14-Jun-07	RIGEX/CAPE 'X' Axis 200-10-200 Hz Sine Sweep Test RIGEX/CAPE 'X' Axis Random Vibration Test RIGEX/CAPE 'X' Axis 200-10-200 Hz Sine Sweep Test Post Vibe Functional Performed RIGEX/CAPE 'Z' Axis 200-10-200 Hz Sine Sweep Test RIGEX/CAPE 'Z' Axis Random Vibration Test RIGEX/CAPE 'Z' Axis 200-10-200 Hz Sine Sweep Test Post Vibe Functional Performed		
	15-Jun-07	RIGEX/CAPE 'Y' Axis 200-10-200 Hz Sine Sweep Test RIGEX/CAPE 'Y' Axis Random Vibration Test RIGEX/CAPE 'Y' Axis 200-10-200 Hz Sine Sweep Test Post Vibe Functional Performed TP-4 performed to exercise all components after vibration testing. *NOTE: Functional Test to be re-written to exercise more components*		
	18-Jun-07	RIGEX/CAPE shipped to Johnson Space Center, Weight and Balance Facility, in CAPE shipping container		
	18-Jun-07	RIGEX/CAPE Weight and Balance Performed Post Test Functional Performed		
	19-Jun-07	RIGEX/CAPE shipped to Oceaneering Space Systems, Houston, TX.		
	20-Jun-07	RIGEX De-integrated from CAPE. Functional Check performed Wire nicked during de-installation of RIGEX-2007-1-G4		
	21-Jun-07	RIGEX shipped to Air Force Institute of Technology, Wright-Patterson AFB, OH. Z-Axis 5g shock indicator tripped		
	22-Jun-07 thru 27-Jun-07	Post Ship Functional Performed Computer Removed for installation of ground comm cables, removal of EMI test data, and loading of adapted software for TVAC test Pressure System Leak Test	♦	
	28-Jun-07	5 Amp fuse blown during set-up due to short in Thermal vacuum chamber bulk head short		
	9-Jul-07	Over Pressurization Test		
	10-Jul-07 thru 20-Jul-07	Deployment Testing, Sub-System Operation Verification, and Over-all System Operation Verification under Ambient Conditions		
	13-Aug-07 thru 16-Aug-07	Over Torqued Bolt Replacement All structural bolts torque broke. All but 4 of the structural bolts have been replaced		

Section VIII -- Weight and Balance

Note: The following parts have been weighed as "flight hardware" that were not included in the combined RIGEX/CAPE Weight and Balance Test performed at Johnson Space Center (JSC)

Part Number	Nomenclature	Qty	LN/SN	Weight (kg)
RIGEX-2007-1-C1	RIGEX COMMAND CABLE	1	SN 001	0.545
RIGEX-2007-1-C2	RIGEX POWER CABLE	1	SN 001	1.17
RIGEX-2007-1-G1	RIGEX GROUND COMMAND CABLE	1	SN 001	0.72
RIGEX-2007-1-G2	RIGEX GROUND POWER CABLE	1	SN 001	1.76

Section X-- Material/Data Certification

Note: The Attached file is other wise known as RIGEX Component Certificates of Compliance

Section XI-- Procedures/Instructions

Note: The Attached file is other wise known as RIGEX Component Certificates of Compliance

The following procedures are included in theis section

Doc#	Title	Rev
RP-10	RIGEX Functional Verification Test	A
RP-8	RIGEX unpacking and Preparation Procedure	A
RP-8A	RIGEX Packing Handling Procedure	IR
RP-1B	RIGEX Wave 3 Assembly	B

Section XII-- Acceptance Test Data

Note: The attached file will be the TVAC procedure and report

Appendix G Activating RIGEX Components instructions

The DIOtest software package was provided by Parvus® with the acquisition of the 24 Form C PC-104 Relay Board.

The utility accesses 8 banks of 8 bits. With this utility, the user can set outputs, read inputs, run self tests and much more. Individual banks of 8 bits can be controlled without affecting any of the other seven banks. Individual I/O points of the controller chips can be configured as either inputs or outputs. As an extension, a global command allows all I/O point of the controller chips to be configured as either inputs or outputs in one operation."

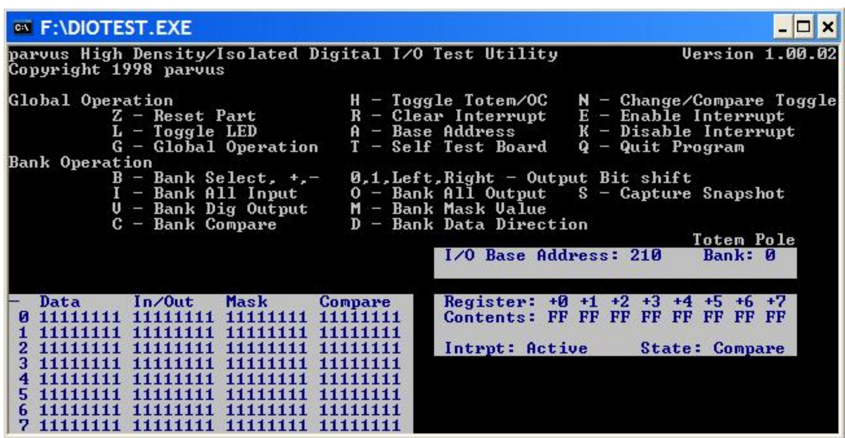


Figure G.1 DioTEST utility screen shot

The following steps should be taken to use this utility and control the components of RIGEX:

1. Start the DIOTest program
2. Type 'A 240' %This sets the program to talk to the relay board 3. Type 'B' and then the bank # (0,1,3, or 4) % Sets the bank #

4. Hit enter, the box should read something like "Enter hexadecimal number to display"

The next part is dynamic depending on what you want to turn on The number you

Bank	Address (Hexadecimal)	Bay	Item
0	1		
0	2		
0	4		
0	8		
0	10		
0	20		
1	4		
1	8		
3	1		
3	2		
3	4		
3	8		
3	10		
3	20		
3	40		
3	80		
4	1		
4	2		
4	4		
4	8		

* Activating Relay for this item doesn't do anything if the DAQ board is not outputting a signal

5. Enter the above number for the item you want to turn on To turn on more than one item in the bank add the two numbers and put there hexadecimal equivalent value on the line example Camera 2 (4) and LED 2 (8) add to 12 -> C in hexadecimal

To change the configuration of the bank repeat steps 4 and 5.
To change to an item in a different bank repeat 3 thru 5.

6. Enter Q to exit the program and then close it out.

Appendix H Emulator Description and Operation

The RIGEX emulator uses a Acopian power supply, model W1391, to power the RIGEX payload at 24, 28 and 32 Volts –Direct Current (VDC). The power supply output is altered by adjusting the AB Type J 10kΩ potentiometer (shown in Figure H.1). Nominally, the emulator is set to output 28 VDC, which is verified via a voltmeter connected to the power output verification ports.

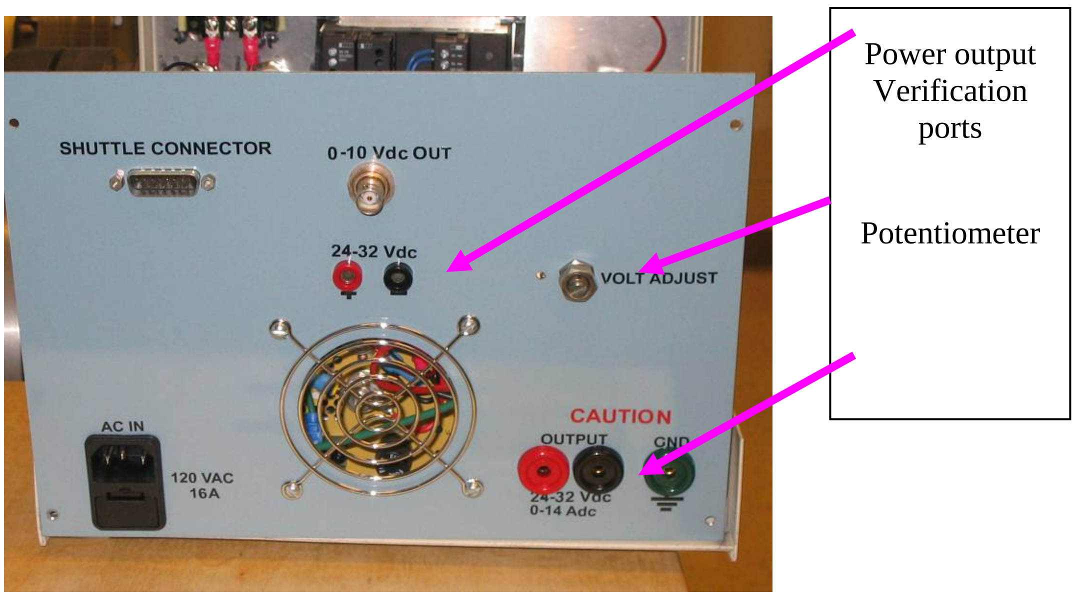


Figure H.1 RIGEX Emulator (Back) – Cable Interface

The emulator is also equipped with a Simpson ammeter, model H335111200, which displays the amount of current being drawn by RIGEX at various stages of operation. Utilizing a Simpson current shunt, model 06705, a small amount of power is diverted to the ammeter which using its internal software displays the current to the indicator shown in Figure H.2. This device also sends a 0-10 VDC signal to the BNC female to female connector (p/n M55339/I3-0) which is recorded by the external data acquisition system (Note: this feature will not be used for final preparation at KSC).

Figure H.2 RIGEX Emulator (Front)- User Interface

After the current is read, power is sent to the main power ports shown in Figure H.1, which accept either a standard banana plug or the plugs attached to RIGEX-2007-1-G2 shown in Figure H.3. RIGEX-2007-1-G4 RIGEX EMI Cable (not shown) utilizes a standard banana plug and is a direct connects cable from the emulator to RIGEX. RIGEX-2007-1-G2 is used to interface the emulator with RIGEX-2007-1-C2 RIGEX Power Cable (not shown) when it is connected to the payload.

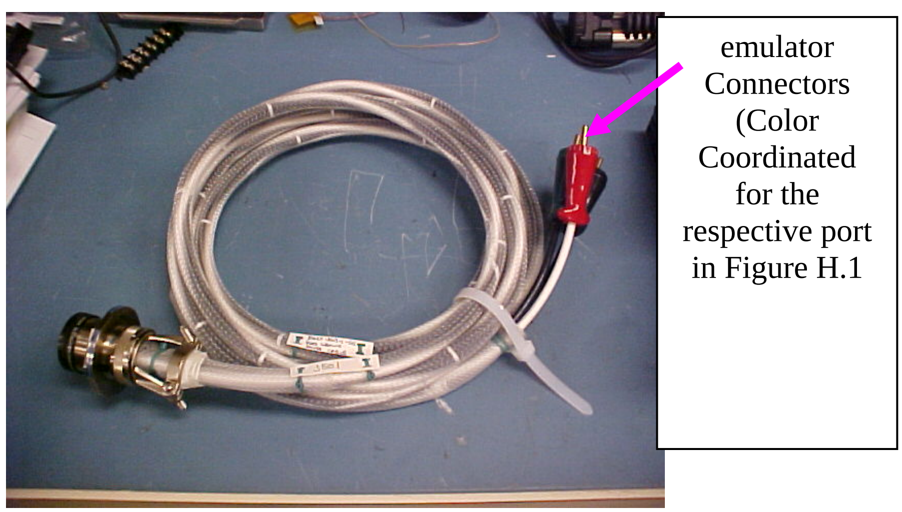


Figure H.3 RIGEX-2007-1-G2 RIGEX GROUND Power Cable

The emulator not only powers RIGEX but is also the users interface to the payload. By turning the impulse switch, EAO p/n 704.910.3, to the ‘UP’ position, a ground user takes the place of the astronaut performing the same task on the shuttle and the payload is initiated. Like wise turning, this switch to the 'DN' position will de-energize the payload. The shuttles S-13 switch is the switch that was designated to operate RIGEX and the name has been carried to this Ground Support Equipment (GSE) as well. The DS-13 LEDs , p/n 557-1X05-203, similarly simulate the astronauts display panel. The shuttle DS-13 indicator has been designated for use by RIGEX and the name has carried to the GSE. The 'green' LED simulates the 'UP' indication on DS-13 mechanical switch, while the 'red' LED simulates the 'DN'. Neither light simulates the switches 'Stripes' position.

(Note: In order to use the items described in this paragraph, RIGEX-2007-1-G1 must be connected to the emulator and RIGEX-2007-1-C1 or RIGEX-2007-1-G3 must be connected to both RIGEX and the emulator. RIGEX-2007-1-G1 is shown in Figure H.4)

Figure H.4 RIGEX-2007-1-G1 RIGEX Ground Command Cable

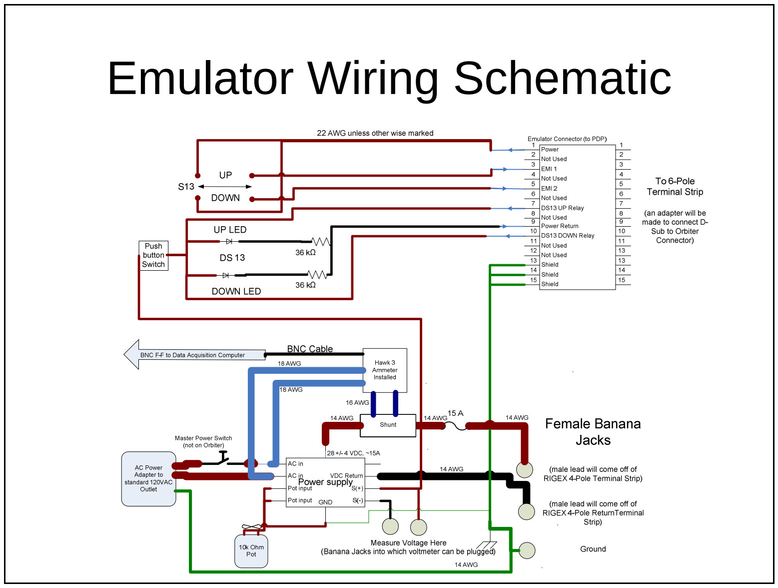


Figure H.5 Final Emulator Wiring Schematic

Table H.1 Emulator Parts List

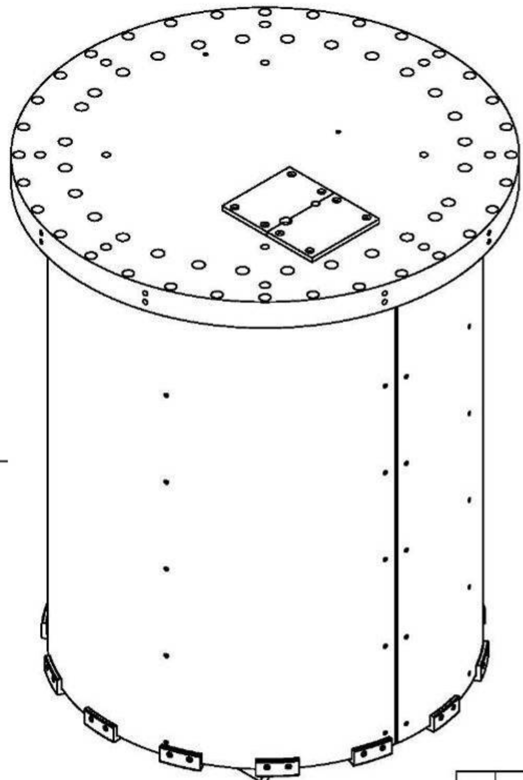
Qty	Part #	Description
1	AB Type J	10k Ohm Potentiometer
2	COTS	Standard Banana Ports (similar to SPC15179)
1	M55339/I3-0	BNC Female to Female Connector
1	COTS	15 pin D-Sub Solder-cup Male Connector (similar to Cinch DA15P)
1	COTS	AC Power Adaptor (Contains 1 16 Amp fuse, and 1 10 Amp fuse (Both COTS) see item O)
3	RS25GXX	8 AWG Power Ports
1	COTS	3 Position Terminal Block
2	557-1X05-203	LEDs (24V Dialight) (X=5 Red X=6 Green)
2	RS-10-10W	36K Ohm Resistor (Vishay Dale)
1	704.910.3	EAO Impulse Switch
1	H335111200	Current Display (Simpson)
1	MB 2061SS1W01-CA	Bushing Mount Miniature Pushbutton Switch MB 2000 series (NKK Switches)
1	CRE22F2BBRLE	Master Switch (Cherry)
1	W13691	AC/DC Power Converter (Acopian) (Contains 10 Amp Fuse
1	COTS	15 Amp Ceramic Fuse (similar to Busemann ceramic fuse)
1	COTS	Fuse Holder
1	COTS	2 Position Terminal Strip
1	06705	Current Shunt (Simpson)
1	COTS	Ground Lug
1	COTS	BNC Cable ~ 1 ft in length
AR	COTS	Spade terminals
AR	COTS	14 AWG Wire (Red, Black and Green)
AR	COTS	22 AWG Wire (Red, Black)
AR	COTS	Shrink Wrap
1	COTS	22 AWG 2 Connector Shielded wire ~7” in length
1	COTS	16 AWG Standard appliance cable ~3’ in length
AR	COTS	18 AWG wire
AR	COTS	Wire Ties
AR	COTS	Wire Tie downs
1	COTS	Case
AR	COTS	Solder

Appendix I RIGEX Final Assembly Drawings

NOTE: Drawings supplied here are an excerpt of:

RIGEX Document 5 (RD-5) "RIGEX Drawing Package"

A document published and presented to NASA as part of the Acceptance Data Package (ADP). These drawings have either never been released in the thesis format to date by the students or are significant updates to those presented by Miller[19]



Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-STOR-P	RIGEX Storage Configuration	1	

NOTE:
1. This is PART RIGEX-STOR-P with Ground Support Handles Removed
2. Cables are not shown
3. P-Clamps are not shown

	NAME	SIGNATURE	DATE
DRAWN	JJO		25 JUL 07
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

DO NOT SCALE DRAWING

REVISION A

AIR FORCE INSTITUTE OF TECHNOLOGY

TITLE:

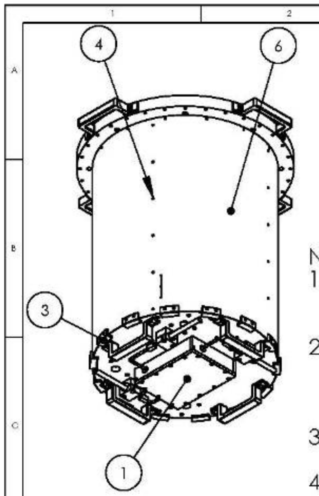
RIGEX Configuration

DWG NO. RIGEX-D

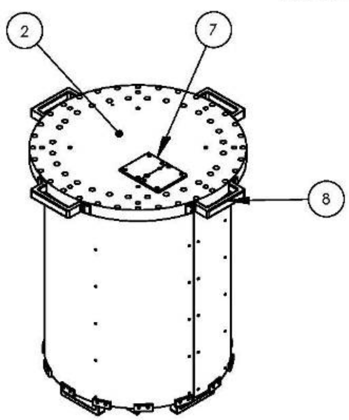
A4

SCALE:1:6

SHEET 1 OF 1



NOTE:
1. Item 20-25 (Cables) are not shown. Based on desired configuration (flight or test) use appropiate cables
2. P-Clamps retained by STP are not shown and have been omited from this drawing, including the fasteners and helicoils which attach them to RIGEX-2006-1-P
3. Not all parts are required to be attached Use proper parts for desired configuration
4. Use '-Tst' suffix on part number if test tubes installed



Revisions

Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-BASE-P	RIGEX Base	1	
2	RIGEX-2006-1-P	CAPE Mounting Plate	1	
3	RIGEX-2006-16-P	Bumpers	14	
4	RIGEX-2007-4-P	Triangular washers	25	
5	RIGEX-2007-3-P	Seam Joints	6	During Shipping attached to RIGEX-2006-15-P with NAS8402-8 (x7 bolts)
6	RIGEX-2006-15-P	Shroud	1	During Shipping attached to RIGEX-Base with NAS8402-8 (x3 bolts)
7	RIGEX-2006-24-P	Connector Hole Cover Plate	2	During Shipping attached to RIGEX-2006-1-P with NAS1189E3P16B (x8 each)
8	RIGEX-2006-14-P	Lifting handles	4	During Shipping attached to RIGEX-2006-1-P with 91772A557 (x4 each)
9	MS21209C0820L	Locking Helicoil Inserts, stainless steel Helicoil #8-32, 2x diameter --Inserts for all shroud attachment screws (52)	52	
10	MS21209F1-20L	Helicoil (locking) #10-32, 2x diameter --Connector Cover assembly to CAPE mounting plate (8)	8	
11	MS21209F6-15L	Helicoil 3/8-23 1.5x dia --Experiment Top Plate to CAPE Mounting Plate (28)	28	
12	NAS1189E04P8	Flat Screws w/ Patchlock: #4-40, 1/2" long -- 2 screws per bumper (24)	24	
13	NAS1189E3P16B	Flat Screws w/ Patchlock: #10-32, 1" long --Connector cover assembly to CAPE mounting plate (8)	8	
14	NAS1351N6-20	Socket head cap screw: 3/8-24, 1.25" long, A286 --Top Plate to CAPE Mounting Plate bolt pattern	26	
15	NAS8402-8	Flange Button Screws: #8-32, 1/2" long	52	
16	MCMasterCar: 91772A557	Standard Screw: 1/4"-28, 1/2" long -- 4 per lifting handle (remove before flight)	40	
17	McMasterCar: NF8HC	Standard Screw: 1/4"-28, 2 1/4" long	8	For Shipping Only. Attached MGSE_1 (shipping container) floor to top plate
18	Newark All In One 78F580	Wire TIES, 4"	A/R	
19	Master Bond Inc. EP21TCHT-1	Epoxy	A/R	
20	RIGEX-2007-1-C1	RIGEX Command Cable	1	For Flight
21	RIGEX-2007-1-C2	RIGEX Power Cable	1	For Flight
22	RIGEX-2007-1-G1	RIGEX Ground Command Cable	1	For health check with flight cables
23	RIGEX-2007-1-G2	RIGEX Ground Power Cable	1	For health check with flight cables
24	RIGEX-2007-1-G3	Ground Cable	1	For Ground Testing
25	RIGEX-2007-1-G4	RIGEX EMI Power Cable	1	For Ground testing (Built specificly for EMI test)

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

AIR FORCE INSTITUTE OF TECHNOLOGY

	NAME	SIGNATURE	DATE
DRAWN	JJO		25 Jul 2007
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

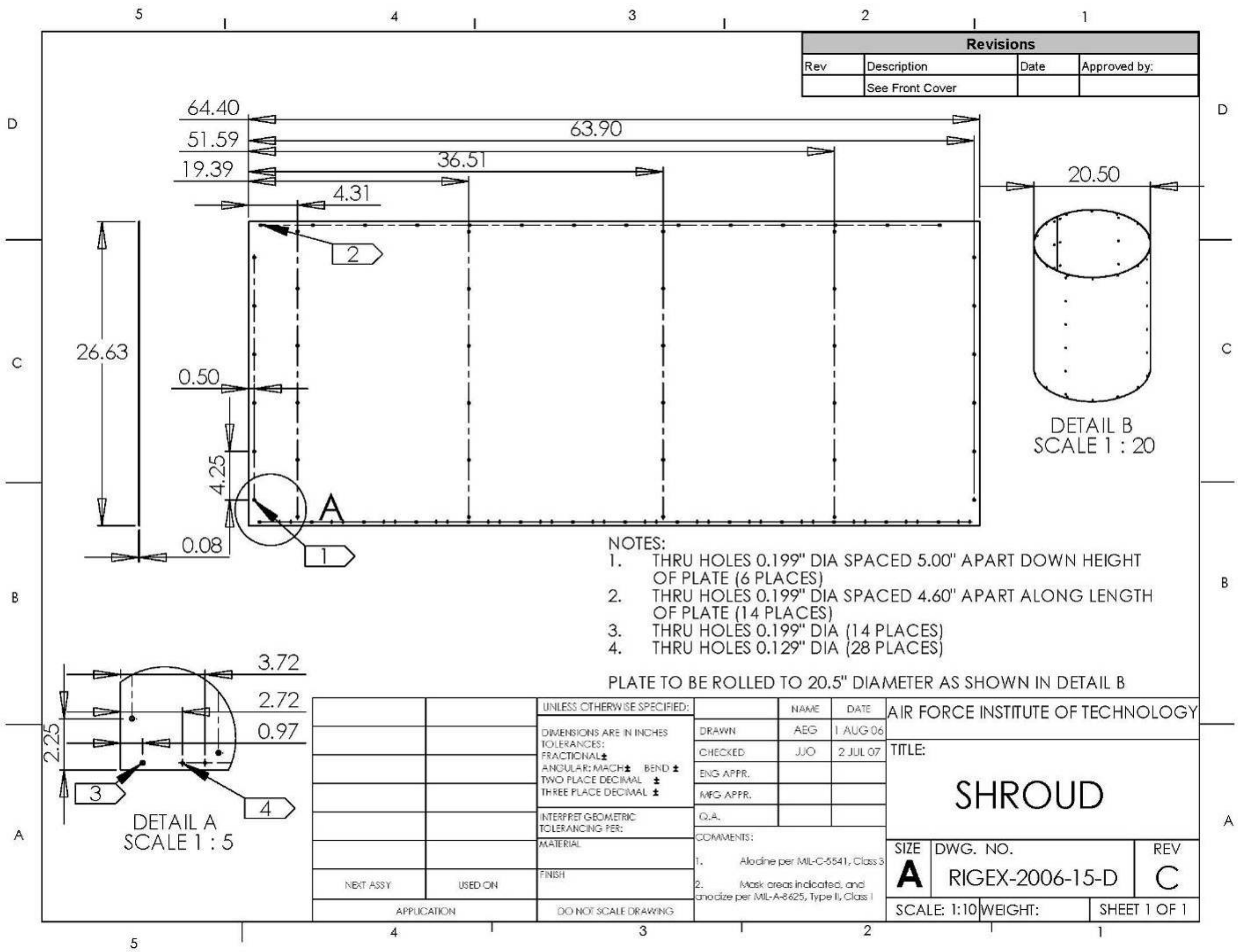
WEIGHT:

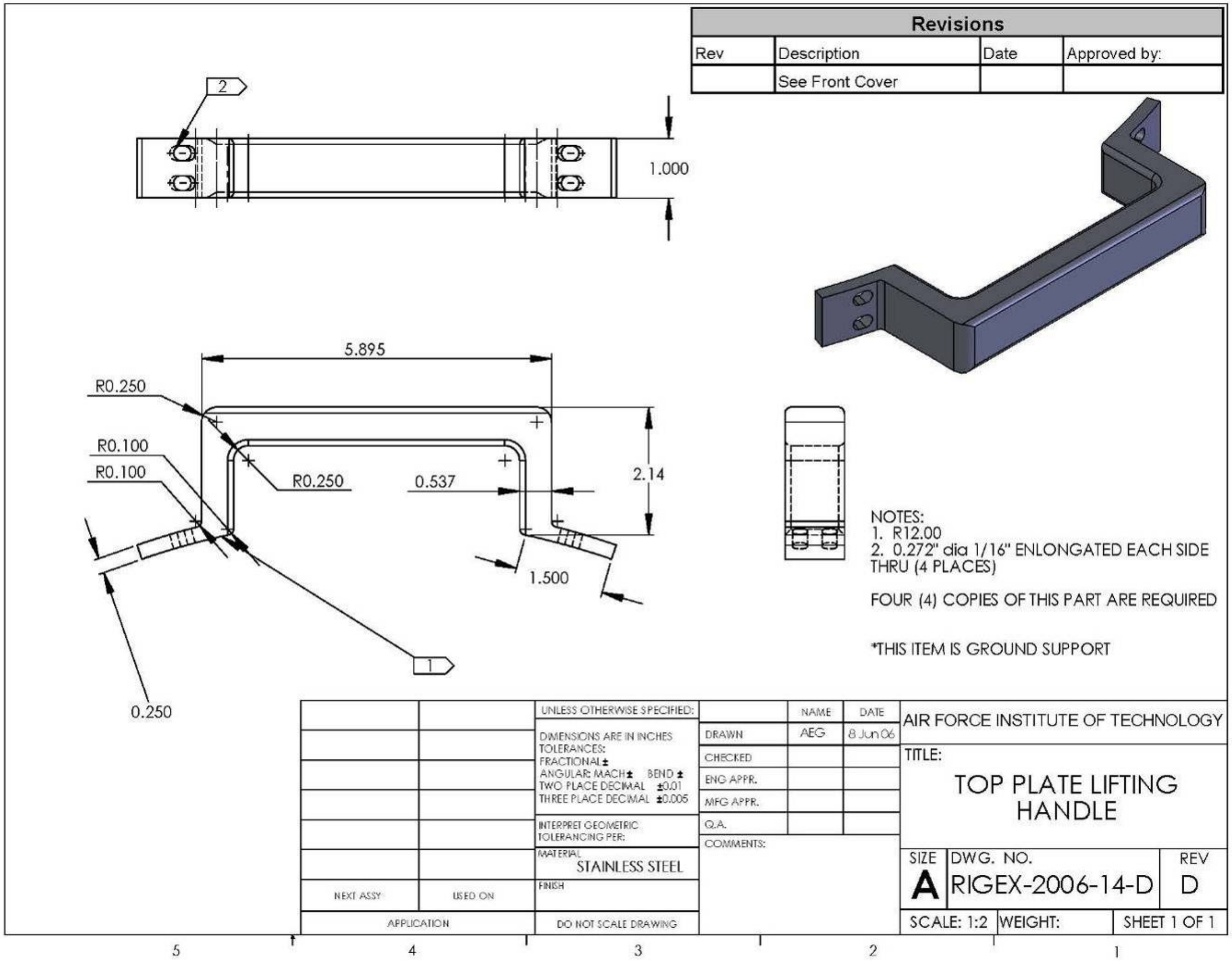
TITLE:

RIGEX STORAGE CONFIGURATION

DWG NO. RIGEX-STOR-D A3

SCALE:1:1 SHEET 1 OF 1


Revisions
Rev | Description | Date | Approved by:
See Front Cover
64.40
51.59
19.39
63.90
36.51
4.31
20.50
26.63
0.50
4.25
0.08
A
DETAIL B
SCALE 1 : 20
NOTES:
1. THRU HOLES 0.199" DIA SPACED 5.00" APART DOWN HEIGHT OF PLATE (6 PLACES)
2. THRU HOLES 0.199" DIA SPACED 4.60" APART ALONG LENGTH OF PLATE (14 PLACES)
3. THRU HOLES 0.199" DIA (14 PLACES)
4. THRU HOLES 0.129" DIA (28 PLACES)
PLATE TO BE ROLLED TO 20.5" DIAMETER AS SHOWN IN DETAIL B
3.72
2.72
0.97
2.25
DETAIL A
SCALE 1 : 5
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN AEG 1 AUG 06
CHECKED JJO 2 JUL 07
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3
2. Mask areas indicated, and anodize per MIL-A-8625, Type II, Class I
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
SHROUD
SIZE A
DWG. NO. RIGEX-2006-15-D
REV C
SCALE: 1:10
WEIGHT:
SHEET 1 OF 1


Revisions
Rev | Description | Date | Approved by:
See Front Cover
2
1.000
5.895
R0.250
R0.100
R0.100
R0.250
0.537
2.14
1.500
1
0.250
NOTES:
1. R12.00
2. 0.272" dia 1/16" ENLONGATED EACH SIDE THRU (4 PLACES)
FOUR (4) COPIES OF THIS PART ARE REQUIRED
*THIS ITEM IS GROUND SUPPORT
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
STAINLESS STEEL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AEG
8 Jun 06
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
TOP PLATE LIFTING HANDLE
SIZE
A
DWG. NO.
RIGEX-2006-14-D
REV
D
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-WAVE2-P	WAVE2 Completed configuration		
2	Luxeon:LXHL-LW5C	Lights - LEDs	6	
3	Tern INC EyeC	Cameras	3	
4	Exrtrusions INC RS3010-4000	Camera Case	3	
5	WinSystems: CFLASH-G-4096-I	Camera Memory	3	
6	Crouzet 84-134-870	Power Relays	3	
7	Stancor P-8705	Transformers	3	
8	Allied Elec: RH0051R000FC02	Resistors (1ohm)	6	
9	Newark: 66H7086	Terminal, Ring, 22 AWG, #6 Stud	A/R	
10	Newark: 78F580	1.25 " Diameter Wire Ties	A/R	
11	Newark: 89F2506	Wire Tie Fastener	A/R	
12	Newark: 66H6916	#8 22 AWG Ring Terminal	A/R	
13	Newark: 66H6921	Terminal Ring #8 12 AWG	A/R	
14	Newark: CRSZO0810	Terminal Ring #10 Bare 8 AWG	A/R	
15	Newark: 72K1978	Terminal Jumper 6 AWG	A/R	
16	ILSCO: TA-2	Ground Lug	1	
17	Bussman BK/S-8302-02	2 Fuse Block	3	
18	FM09A250V6A	6 Amp Fuse	6	
19	Minco: s1001732	Resistive Thermal Detector (RTD)	12	
20	Minco: ct325	Thermal Controller	12	
21	NAS1351N4-12	Hex head screws, 1/4-28, 3/4" long –MODIFIED: Ground Lug Fastener (1)	1	
22	NAS1352N04LB4	Standard Screws, #4-40, 1/4" long, patch lock --LED attachment (12)	12	
23	NAS1352N06LB8	Standard Screws: #6-32, 1/2" long, patch lock --Terminal Block screws: 4 per terminal block (4) --Camera to the top plate, 4 per camera (12) –MODIFIED. Fuse Holders to structure (2 each) (6)	22	
24	NAS1352N08LB4	Standard Screws: #8-32, 1/4" Long, patch lock --Transformer screws:2 screws each (6) –Power Relay screws: 2 screws each (6)	12	
25	NAS1352N02LB4	Standard Screw #2-56, 1/4" long, patch lock –Resistors to structure	12	
26	NAS1352N06LB16	Socket Head Cap Screw #6-32, 1" long, w/patchlock –Oven Controllers (12)	12	
27	Advanced Wire: M22759/11-12-0	12 AWG wire -black	A/R	
28	Advanced Wire: M22759/11-12-2	12 AWG wire -red	A/R	
29	Advanced Wire: M22759/11-22-0	22 AWG wire -black	A/R	
30	Advanced Wire: M22759/11-22-3	22 AWG wire -orange	A/R	
31	Advanced Wire: M22759/11-22-4	22 AWG wire -yellow	A/R	
32	Advanced Wire: M22759/11-22-5	22 AWG wire -green	A/R	
33	Advanced Wire: M22759/11-22-6	22 AWG wire -blue	A/R	
34	Advanced Wire: M22759/11-22-9	22 AWG wire -white	A/R	
35	Advanced Wire: M49055/11-43	50C 24 AWG Ribbon cable -multicolored	A/R	
36	Advanced Wire: M23053/5-105-0	Heatshrink (3/16") -black	A/R	
37	Advanced Wire: M23053/5-103-0	Heatshrink (3/32") -black	A/R	

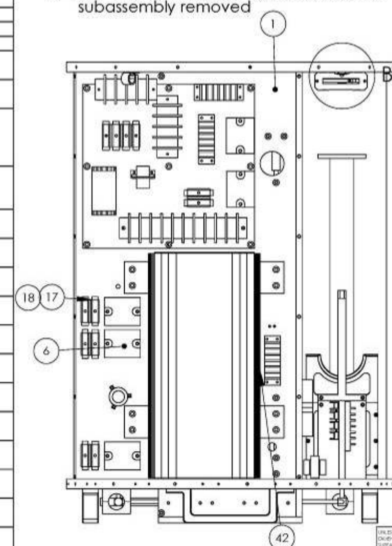
Revisions

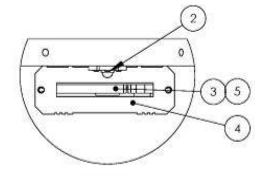
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

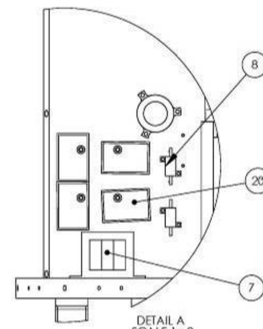
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
38	Huntsman Advanced Materials Arathane 5753	Staking compound	A/R	
39	Kester: 24-6337-8802	Solder Type-R	A/R	
40	Nevark All In One 78F580	Wire TIES, 4"	A/R	
41	Master Bond Inc. EP21TCHT-1	Epoxy	A/R	
42	Digikey CBB106-ND	22AWG 6P Terminal Strip	1	

NOTE:
1. Add '-Tst' designator to part number to indicate test tubes are loaded
2. Items 27-28 used interchangably
3. Items 29 - 34 used interchangably
4. Apply items 36-41 as necessary
5. Apply items 9-14 as necessary
6. Utilize items 21-26 as inicated in parts list
7. Bay View intentionally has oven bracket subassembly removed

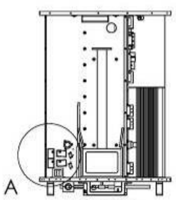




DETAIL B
SCALE 1 : 1.5



DETAIL A
SCALE 1 : 2



Bay View
SCALE 1 : 10

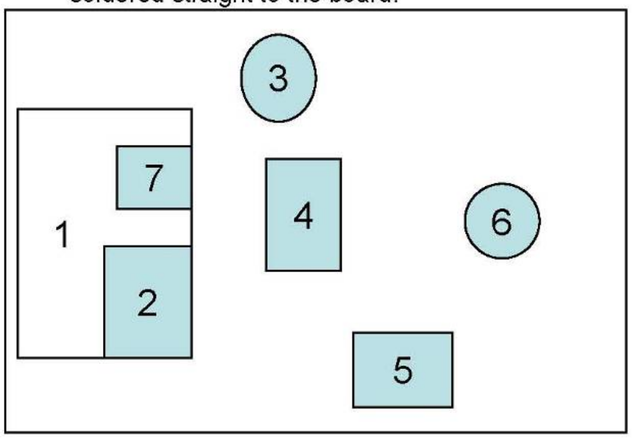
RIGEX BASE CONFIGURATION

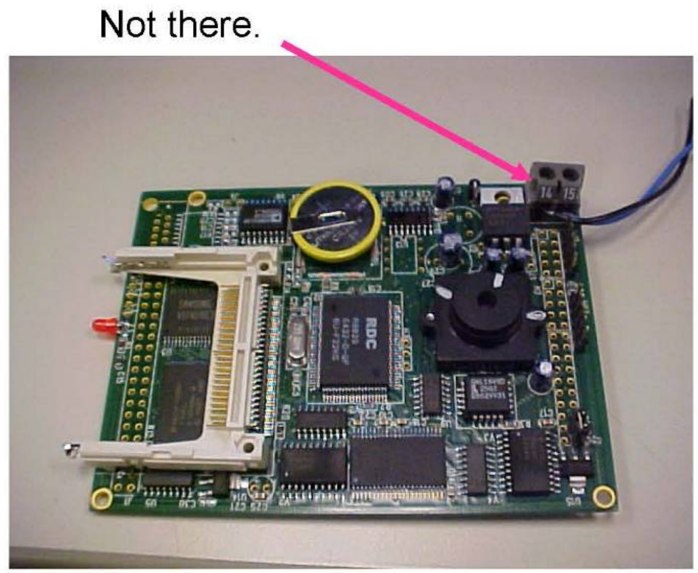
RIGEX-BASE-D A2

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

NOTES:

- Manufacturer: Tern INC
- CAGEC: 1J2W6
- Manufacturer Part # EyeC
- This part is 'COTS' . This drawing is compiled to identify larger components and chips only
- There are three of these parts on RIGEX
- Pictured is lab version with a terminal attached. Flight models have the wires soldered straight to the board.

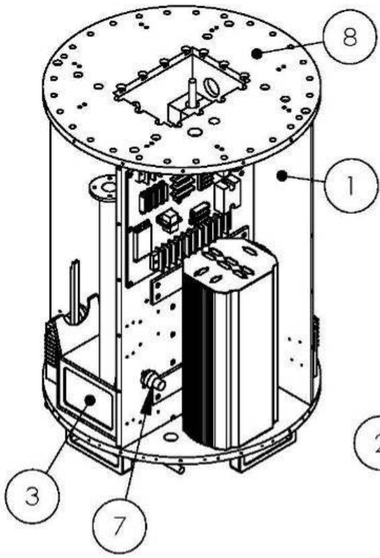




ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1		COMPACT Disk Hoder		
2	1	AM29F400BT-70EC			
3	1		3V Lithium Battery (Soldered to board)		
4	1	R8820	RDC		
5	1	K6X8008C2B	Samsung		
6	1		CMOS Sensor		
7	1	K6T4016C3B	Samsung		

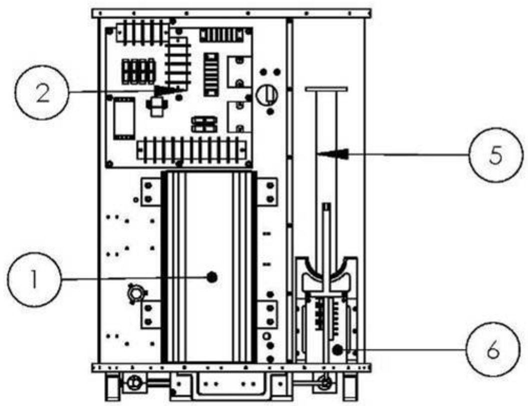
AIR FORCE INSTITUTE OF TECHNOLOGY			
EyeC Camera			
Size A	FSCM NO.	DWG No. RIGEX-CEye-P	Rev A
Scale 1:1	JOwens	SHEET 1 OF 1	

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



NOTES:

1. Part number get '-Tst' designator if test tubes are installed
2. Ground Support Equipment shown and are a part of this configuration
3. Place Fasteners as indicated on parts list



UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	JJO	25 JUL 07	TITLE:	
	CHECKED			RIGEX WAVE 2 ASSEMBLY	
	ENG APPR.				
	MFG APPR.				
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.				
MATERIAL	COMMENTS:			SIZE A	DWG. NO. RIGEX-WAVE2-D — REV A
FINISH					
DO NOT SCALE DRAWING				SCALE: 1:100	WEIGHT: — SHEET 1 OF 2

NEXT ASSY	USED ON
APPLICATION	

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX_Wave1	WAVE1 Completed configuration	1	
2	RIGEX-PDP-P	Power Distribution Plate Subassembly	1	
3	RIGEX-COMP-P	RIGEX Computer Subassembly	1	
4	RIGEX-OVEN-D	Oven Subassembly	3	
5	RIGEX-TUBE-D	Tube Assemblly	3	
6	RIGEC-OVENLATCH-P	Oven Latch SubAssembly	3	
7	TiNi Aerospace, Inc. Model #P10-405-5RS	Pin Puller	3	
8	RIGEX-2006-2-P	Top Plate	1	
9	RIGEX-2006-13-P	Feet	4	
10	MS21209F1-20L	Helicoil (locking) #10-32, 2x diameter --Holds computer mounting plate onto rib (8) --For PDP screws in Computer Rib (9)	17	
11	NAS1189E3P12B	Flat Screws w/ Patchlock: #10-32, 3/4" long --4 screws per oven to the oven mounting plate (12)	12	
12	NAS1189E3P16B	Flat Screws w/ Patchlock: #10-32, 1" long --Oven bracket to attach it to the oven mounting plate (12)	12	
13	NAS1189E3P8B	#10-32, 1/2" long Flat head w/ patchlock --PDP screws (9) --Computer mounting plate to rib (8)	17	
14	NAS1291C04M	Locknuts: #4-40 --3 locknuts per pin puller (9)	9	
15	NAS1291C4M	Locknuts: 1/4-28 -- 4 per Sub-Tg Tube (12)	12	
16	NAS1351N4-12	Hex head screws, 1/4-28, 3/4" long --Computer to computer mounting plate (4)	4	
17	NAS1351N4-24	Standard Screws: 1/4-28, 1 1/2" long --4 per Sub-Tg Tube (24)	24	
18	NAS1352N04-10	Standard Screws: #4-40, 5/8" long --3 screws per pin puller (9)	9	
19	NAS620C10	#10 washers w/ NAS1189E3P8B on Computer Mounting Plate to Rib	8	
20	NAS620C4	#4 washer --6 washers per pin puller (after bolt head and before locknut) w/ NAS1352N04-10 (18)	18	
21	NAS620C416	Washers: 1/4 --4 btwn bolt head and tube flange and 4 btwn OvenMountPlate and locknut per Sub-Tg Tube (24) --Computer to computer mounting plate w/ NAS1351N4-12 (4)	28	
22	NAS1351N3LB16	Hex head screws, #10-32, 1" long w/patchlock -- Top Plate to Ribs	24	
23	NAS1587-A3C	NAS CSK Washer A286 -- w/ NAS1351N3LB16	24	
24	MCMasterCar. 91772A557	Standard Screw: 1/4"-28, 1/2" long -- 4 per lifting handle (remove before flight)	16	

NEXT ASSY | USED ON
APPLICATION

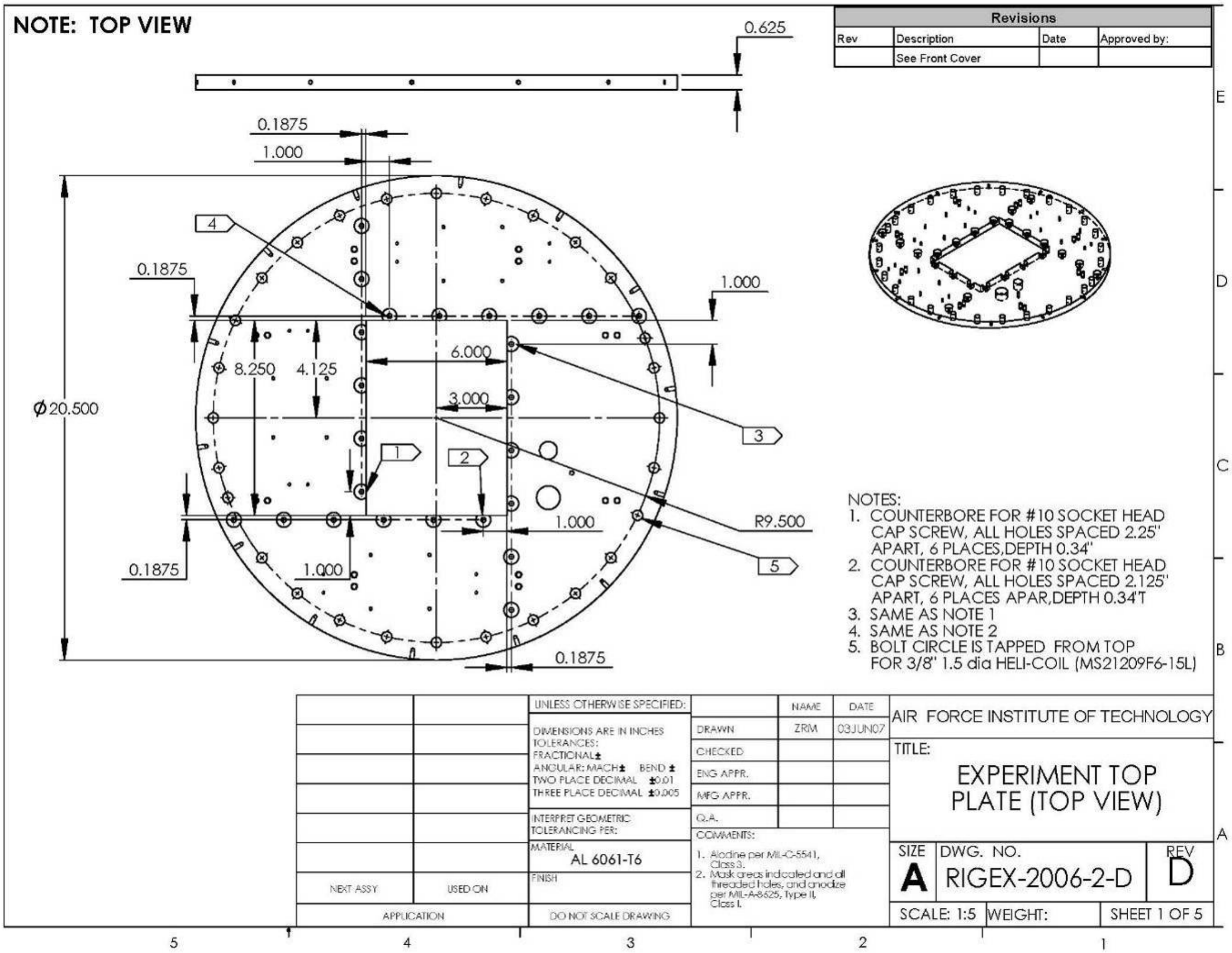
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
MATERIAL
FINISH
DO NOT SCALE DRAWING

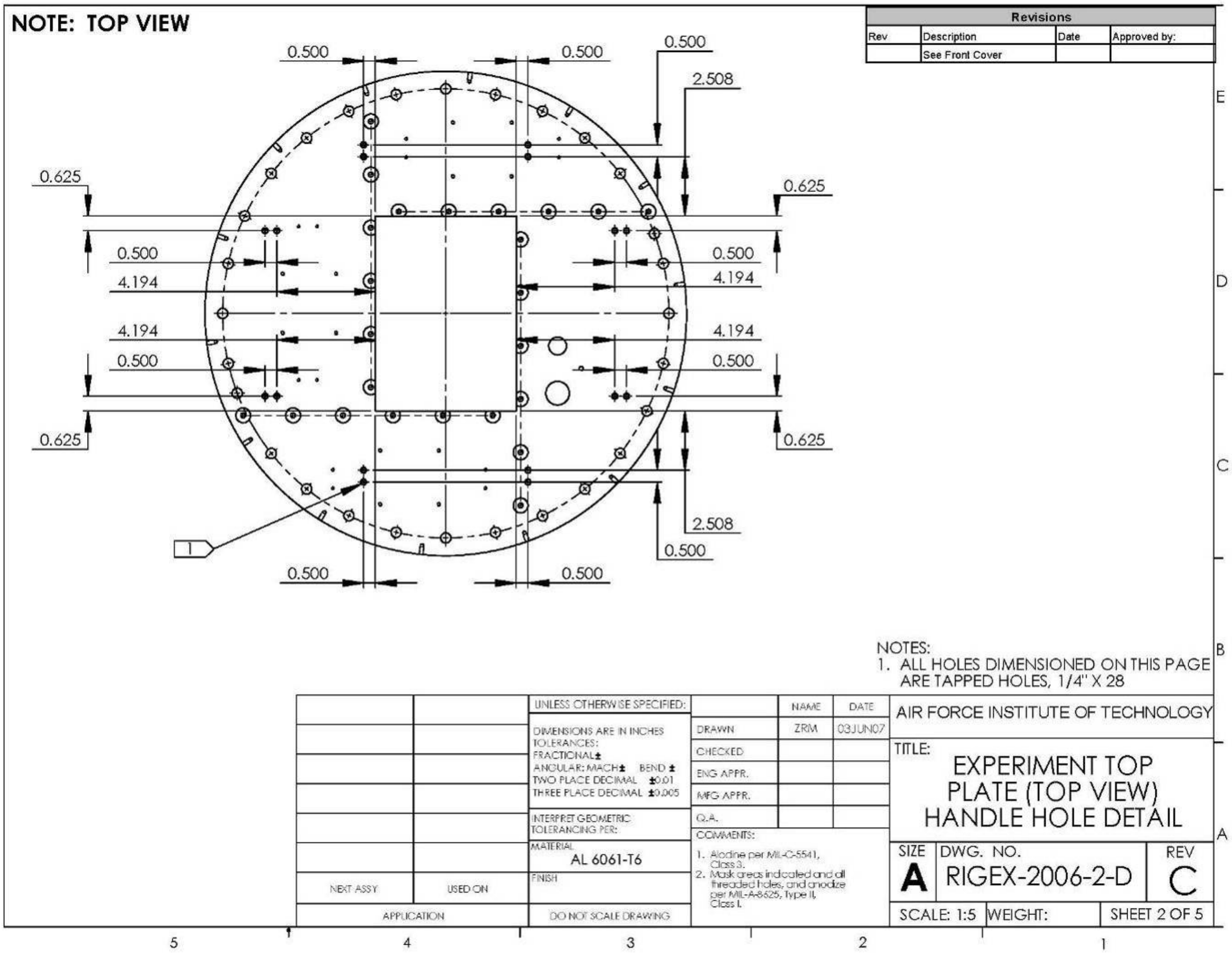
	NAME	DATE
DRAWN	JJO	25 JUL 07
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

AIR FORCE INSTITUTE OF TECHNOLOGY

WAVE 2 ASSEMBLY

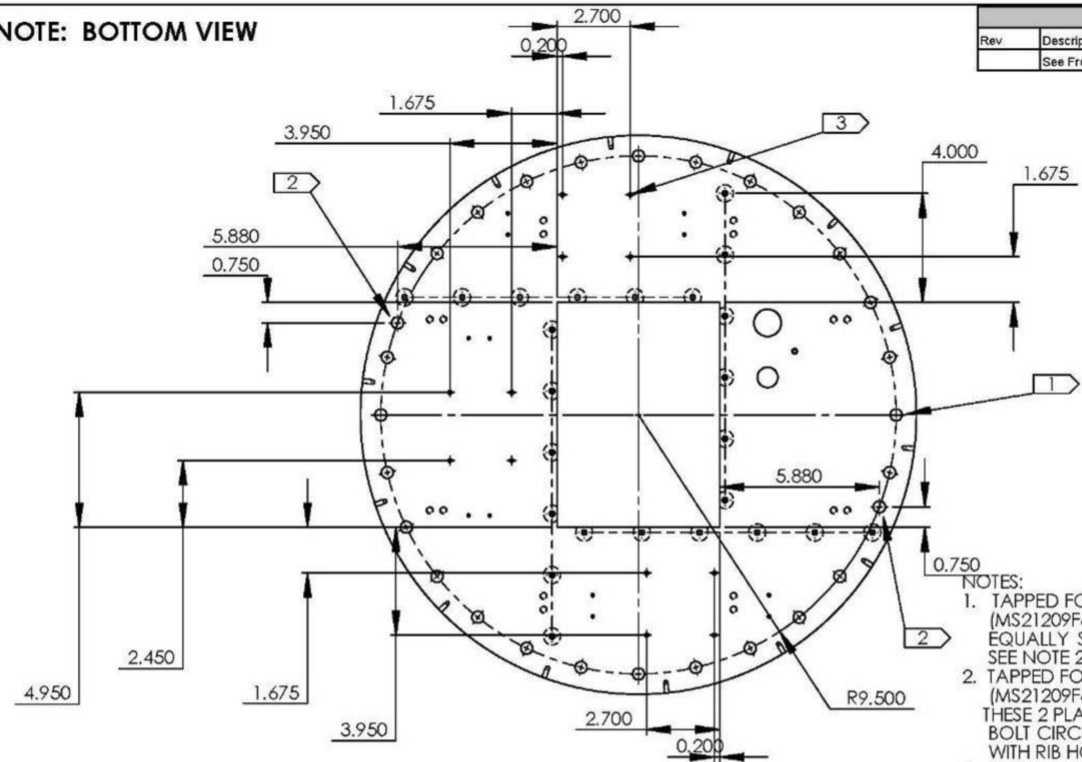
SIZE A | DWG. NO. RIGEX-WAVE2-D | REV. A
SCALE:1:1 | WEIGHT: | SHEET 2 OF 2


NOTE: TOP VIEW
Revisions
Rev
Description
Date
Approved by:
See Front Cover
0.625
0.1875
1.000
0.1875
1.000
8.250
4.125
6.000
3.000
Ø20.500
1.000
R9.500
0.1875
1.000
0.1875
1
2
3
4
5
NOTES:
1. COUNTERBORE FOR #10 SOCKET HEAD CAP SCREW, ALL HOLES SPACED 2.25" APART, 6 PLACES,DEPTH 0.34"
2. COUNTERBORE FOR #10 SOCKET HEAD CAP SCREW, ALL HOLES SPACED 2.125" APART, 6 PLACES APAR,DEPTH 0.34'T
3. SAME AS NOTE 1
4. SAME AS NOTE 2
5. BOLT CIRCLE IS TAPPED FROM TOP FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ZRM
03JUN07
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
EXPERIMENT TOP PLATE (TOP VIEW)
SIZE
A
DWG. NO.
RIGEX-2006-2-D
REV
D
SCALE: 1:5
WEIGHT:
SHEET 1 OF 5
E
D
C
B
A
5
4
3
2
1


NOTE: TOP VIEW
Revisions
Rev
Description
Date
Approved by:
See Front Cover
0.500
0.500
0.500
2.508
0.625
0.625
0.500
4.194
4.194
0.500
0.500
4.194
4.194
0.500
0.625
0.625
2.508
0.500
0.500
0.500
1
NOTES:
1. ALL HOLES DIMENSIONED ON THIS PAGE ARE TAPPED HOLES, 1/4" X 28
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ZRM
03JUN07
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
EXPERIMENT TOP PLATE (TOP VIEW) HANDLE HOLE DETAIL
SIZE
A
DWG. NO.
RIGEX-2006-2-D
REV
C
SCALE: 1:5
WEIGHT:
SHEET 2 OF 5
E
D
C
B
A
5
4
3
2
1

NOTE: BOTTOM VIEW

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



NOTES:
1. TAPPED FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L): EQUALLY SPACED FOR 28 PLACES; SEE NOTE 2 FOR EXCEPTIONS
2. TAPPED FOR 3/8" 1.5 dia HELI-COIL (MS21209F6-15L): THESE 2 PLACES ARE SEPARATED FROM R9.50" BOLT CIRCLE TO AVOID INTERFERENCE WITH RIB HOLES
3. #6-32 UNJ TAPPED HOLES, DEPTH: 0.25", 12 PLACES

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	ZRM	03JUN07
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL AL 6061-T6	COMMENTS: 1. Alodine per MIL-C-5541, Class 3. 2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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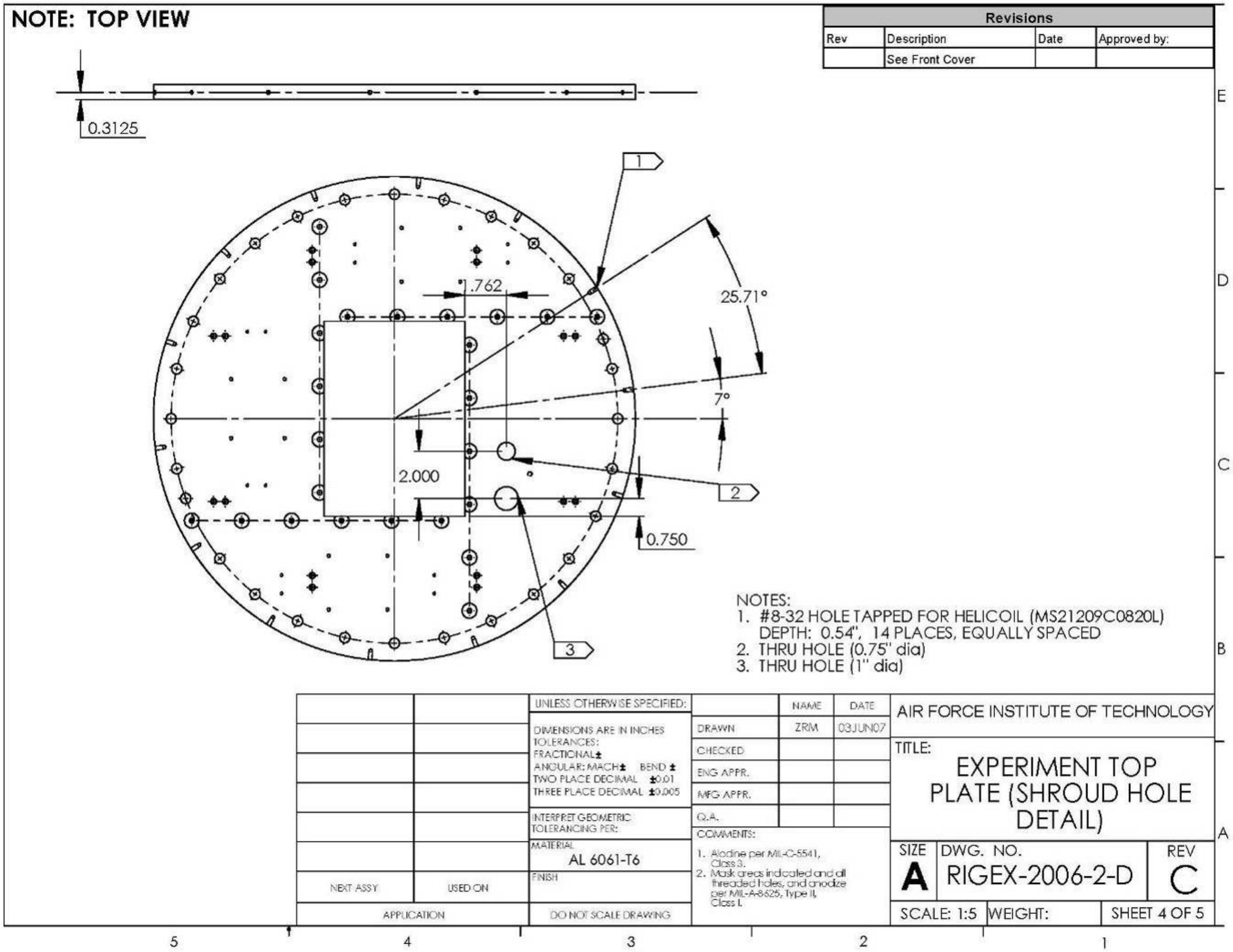
TITLE:

EXPERIMENT TOP PLATE (BOTTOM VIEW) CAMERA HOLE DETAIL

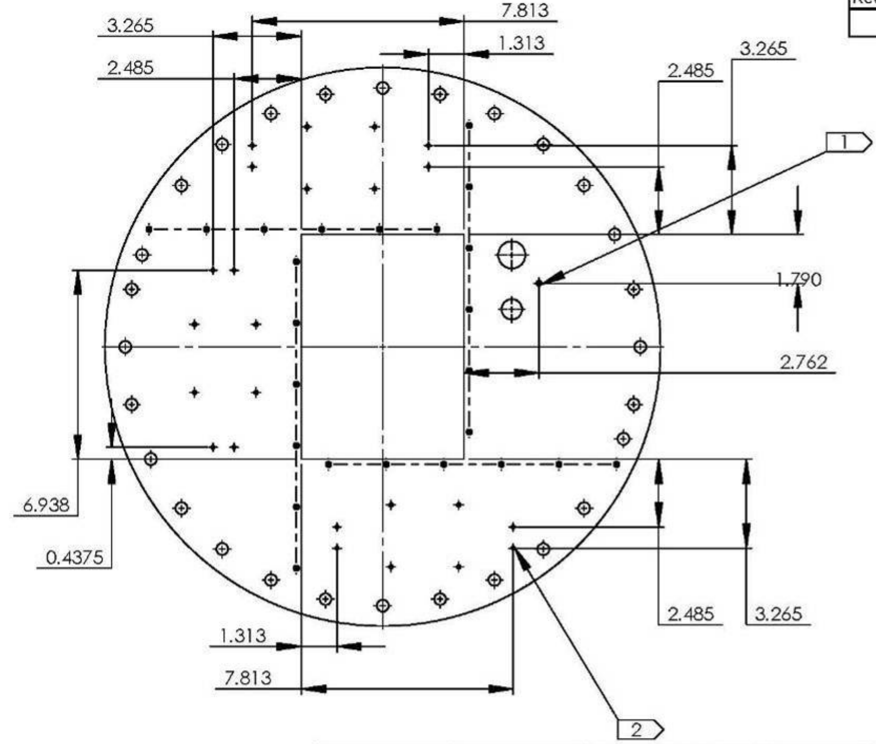
SIZE	DWG. NO.	REV
A	RIGEX-2006-2-D	D

SCALE: 1:5 WEIGHT: SHEET 3 OF 5


NOTE: TOP VIEW
Revisions
Rev
Description
Date
Approved by:
See Front Cover
0.3125
1
2
3
.762
25.71°
7°
2.000
0.750
NOTES:
1. #8-32 HOLE TAPPED FOR HELICOIL (MS21209C0820L)
DEPTH: 0.54", 14 PLACES, EQUALLY SPACED
2. THRU HOLE (0.75" dia)
3. THRU HOLE (1" dia)
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AL 6061-T6
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
ZRM
03JUN07
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
1. Alodine per MIL-C-5541, Class 3.
2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.
AIR FORCE INSTITUTE OF TECHNOLOGY
TITLE:
EXPERIMENT TOP PLATE (SHROUD HOLE DETAIL)
SIZE
A
DWG. NO.
RIGEX-2006-2-D
REV
C
SCALE: 1:5
WEIGHT:
SHEET 4 OF 5
E
D
C
B
A
5
4
3
2
1

NOTE: BOTTOM VIEW

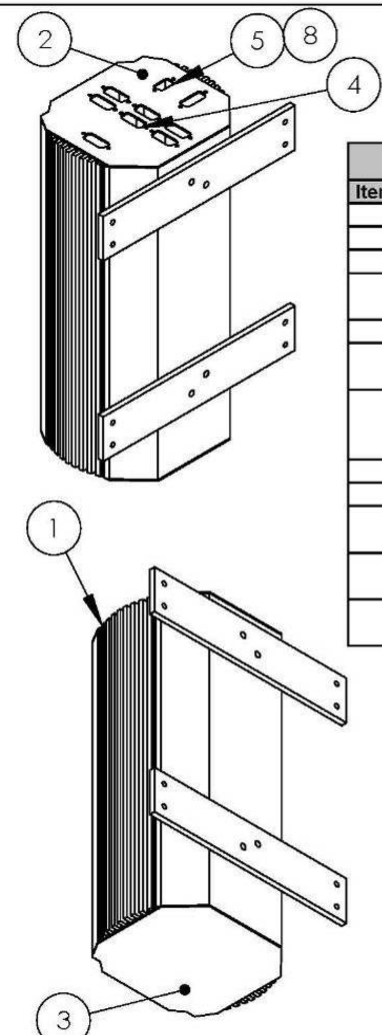
Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



NOTE:
1. #10-32 TAPPED HOLE, DEPTH 0.5"
2. #4-40 TAPPED HOLE, DEPTH: 0.2", 12 PLACES

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN	ZRM	03JUN07	TITLE: EXPERIMENTAL TOP PLATE (BOTTOM VIEW) LED & P-CLAMP DETAIL	
	CHECKED				
	ENG APPR.				
	MFG APPR.				
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.				
MATERIAL AL 6061-T6	COMMENTS: 1. Alodine per MIL-C-5541, Class 3. 2. Mask areas indicated and all threaded holes, and anodize per MIL-A-8625, Type II, Class I.			SIZE A	DWG. NO. RIGEX-2006-2-D / REV A
FINISH					
DO NOT SCALE DRAWING				SCALE: 1:5 WEIGHT:	SHEET 5 OF 5

NEXT ASSY	USED ON
APPLICATION	



Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-COMPSUB-P	RIGEX COMPSUB Assembly	1	
2	RIGEX-2007-5-P	RIGEX D-Sub Connector plate	1	
3	Came with versatainer	Computer Bottom Plate	1	COTS
4	SND15MI0M0G	15-pin Dsub Connectors (Male) / with pins	8	
5	AFIT HD-15 15 pin VGA D-Sub	VGA D-Sub	1	COTS
6	Huntsman Advanced Materials Arathane 5753	Staking compound	A/R	
7	Provided with computer box	#6-1/2" sheet metal, hex head unslotted, Self tapping screws --Computer Box top and bottom screws	16	COTS
8	AFIT: Dust Cap	VGA D-Sub Cap	1	COTS
9	Kester: 24-6337-8802	Solder Type-R	A/R	
10	Newark All In One 78F580	Wire TIES, 4"	A/R	COTS
11	Advanced Wire: M23053/5-105-0	Heatshrink (3/16") -black	A/R	
12	Advanced Wire: M23053/5-103-0	Heatshrink (3/32") -black	A/R	

NOTE:

1. Apply item 6 to all fasteners as a backout preventative
2. Apply item 6 to all wires going into item 4 before closing computer
3. Apply items 7 as directed in the parts list
4. Apply item 8 to item 5 and seal with item 6 prior to flight
5. Connect item 4 per RD-4 utilizing items 9- 12 as necessary

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	JJO	25 JUL 07
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

AIR FORCE INSTITUTE OF TEHCNOLOGY

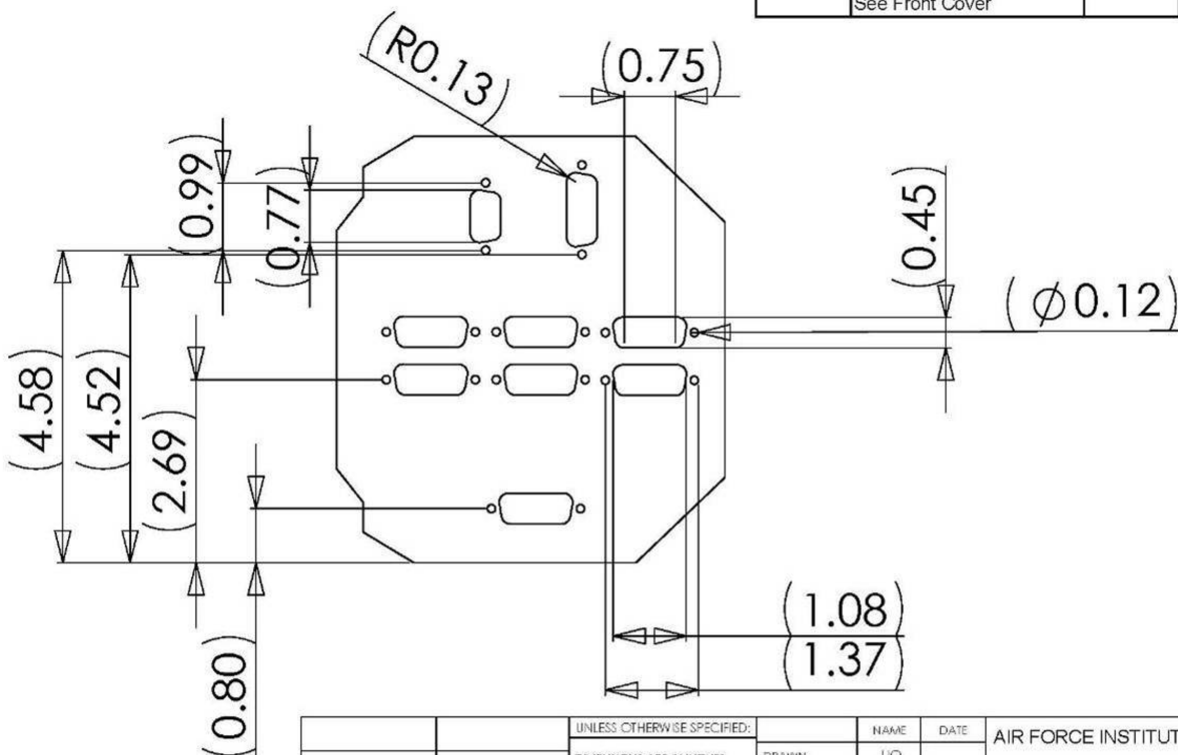
TITLE: COMPUTER SUBASSEMBLY

SIZE	DWG. NO.	REV
A	RIGEX-COMP-D	A

SCALE: 1:1 WEIGHT:

5 4 3 2 1

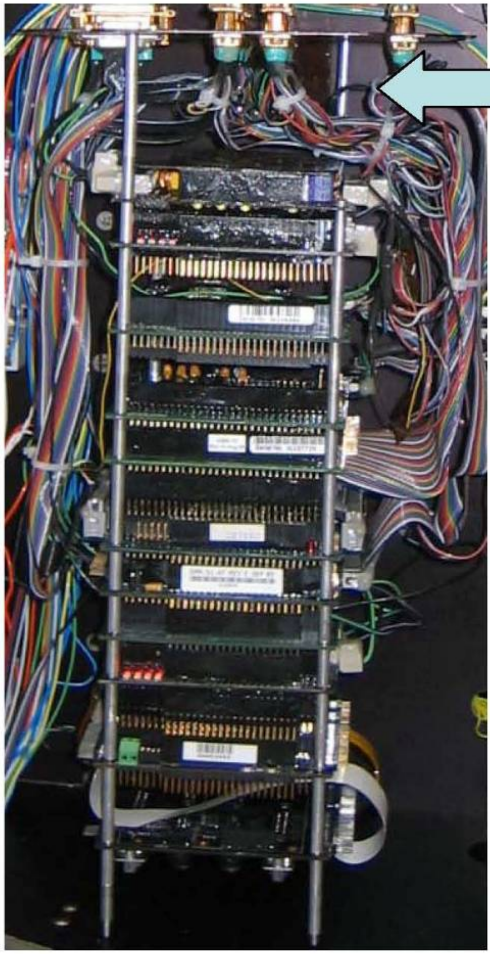
Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN	JJO		TITLE:
			CHECKED			RIGEX D-Sub Connector Plate
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL Aluminum 6061-T6	COMMENTS: This item is made out of material that came with the Tri-M part# VT-14 100008. It is customized to fit our purposes			SIZE A · DWG. NO. RIGEX-2007-5-D · REV A
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2 · WEIGHT: · SHEET 1 OF 1

5 4 3 2 1

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



COMPCAN Sub Assembly

(RIGEX-COMPUTER-P)

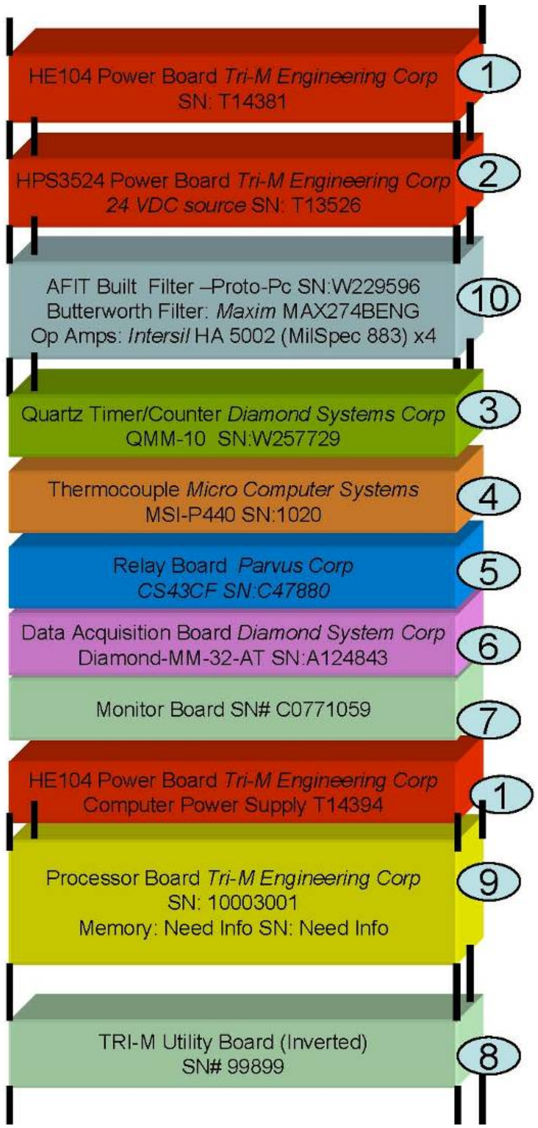
THIS .....

... IN THIS

COMPCAN Sub Assembly

(RIGEX-COMPCAN-P)

AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPSUB-D	Rev A
Scale 1:1	JOwens	SHEET 1 OF 1	



Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	Tri-M Engineering: HE-104	High Efficiency PC-104 Power Supply	2	
2	Tri-M Engineering: HPS-3524	High Efficiency PC-104 Power Supply (24VDC Suply)	1	
3	Tri-M Engineering: Quartz-MM 10 Rev D	Quartz Timer/Counter	1	
4	Tri-M Engineering: MSI-P440	Thermocouple (data acq)	1	
5	Parvus INC : PRV-0728	Parvus Relay (Data acq)	1	
6	Tri-M Engineering: Diamond-MM-32	Diamond DAQ	1	
7	Tri-M Engineering: PCM 352 Rev B	Video Graphic Adapter (VGA) Board	1	
8	Tri-M Engineering: MZ104+	Processor Board	1	
9	Tri-M Engineering: UTIL104+	Utility Board	1	
10	RIGEX-FILTER-1-P	Filter - Proto-PC	1	
11	came with PC-104 computer boards	Spacing Pins	76	COTS
12	came with PC-104 computer boards	Spacing pin screws	2	COTS
13	3M #3425 with backs	50 pin connectors for boards	3	COTS
14	3M #3452 with backs	16 pin connector	2	COTS
15	3M #3485	14 pin Connector	1	COTS
16	3M #3473	10 pin connector	2	COTS
17	Came with 24 VDC power supply	6 pin terminal	1	COTS
18	Came with 24 VDC power supply	4 pin terminal	1	COTS
19	Came with HE104 power supply	2 pin terminal	2	COTS
20	Tri-M: CABLESET2-MZ104	Processor Board to Utility Board connector	1	COTS
21	Tri-M: CABLESET2-MZ104	64 pin expansion header	2	COTS
22	Tri-M: CABLESET2-MZ104	40 pin expansion header	1	COTS
23	Advanced Wire: M49055/11-43	50C 24 AWG Ribbon cable -multicolored	A/R	
24	Advanced Wire: M22759/11-22-9	22 AWG wire -white	A/R	
25	Advanced Wire: M22759/11-22-5	22 AWG wire -green	A/R	
26	Tri-M Engineering: MD2203-D1024	DiskOnChip 2000DIP (Harddrive)	1	
27	Tr-M: SO-DIMM-64MB-RAM	64 KB Expansion Memory Card	1	
28	Huntsman Advanced Materials Arathane 5750	Conformal Coating	A/R	
29	Kester: 24-6337-8802	Solder Type-R	A/R	
30	Newark All In One 78F580	Wire TIES, 4"	A/R	COTS
31	Huntsman Advanced Materials Arathane 5753	Staking compound		

Notes: Next Sheet

▌=stack of 2 (item 11)

AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-D	Rev A
Scale 1:1	JOwens	SHEET	1 OF 13

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

Notes:

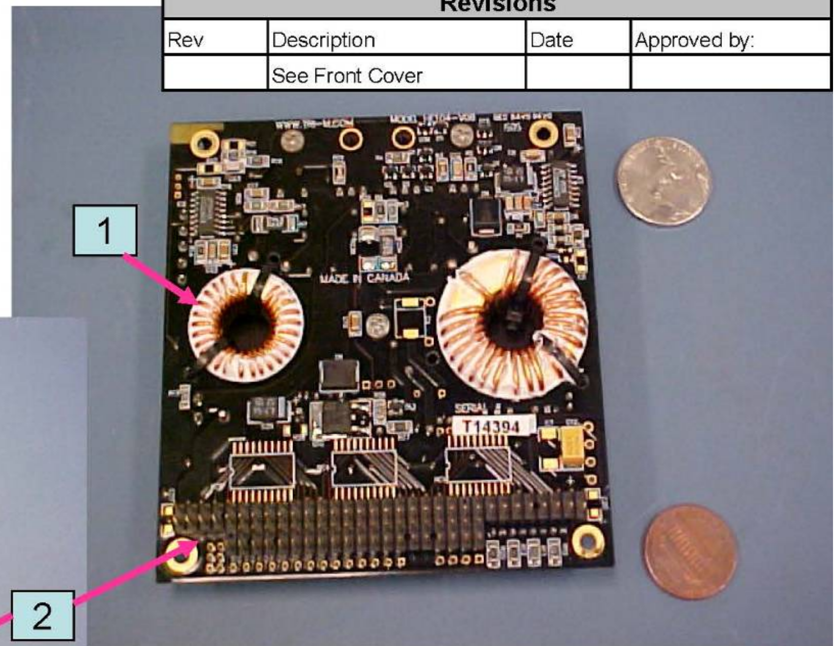
1. CONFORMAL COAT ITEMS 1 THRU 10 , AND 26 WITH ITEM 28
2. ASSEMBLE ITEMS 26 AND 27 AS SHOWN SHEET 11. STACK IN PLACE WITH ITEM 31. THEN ASSEMBLE ITEMS 1-10 AS SHOWN ON SHEET 1 USING ITEM 11
3. INTERCONNECT PER RD-4 USING ITEMS 13 THRU 27 AND 29 THRU 30 AS NECESSARY
4. SECURE ITEM 1 TO TOP OF STACK WITH ITEM 12. STACK IN PLACE WITH ITEM 31
5. THE FOLLOWING ARE ITEMS THAT HAVE BEEN PURCHASED FOR USE. THE **SOLE** PURPOSE IN THIS DRAWING IS TO IDENTIFY THE LARGER CHIPS AND ELECTRONICS THAT ARE ON EACH ITEM. IF THE ITEM IS LARGER THAN THE NICKEL, IT IS LABELED AND IDENTIFIED ON THE SHEET.

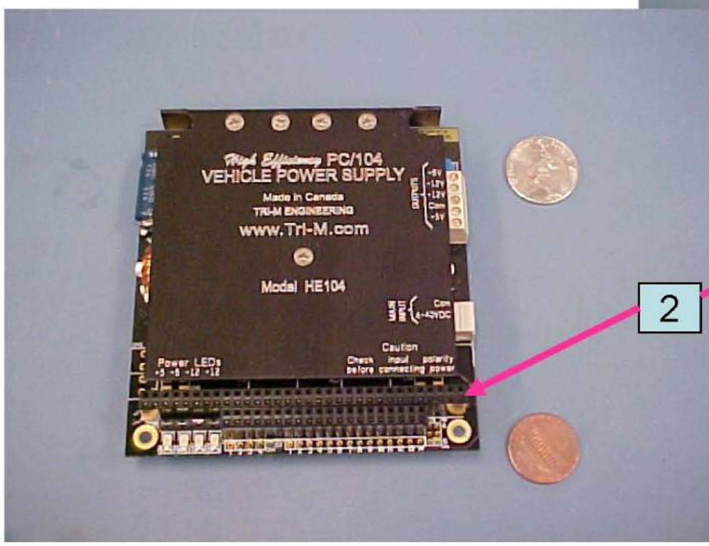
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	2 OF 13

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

NOTES:

- Manufacturer: Tri-M Systems INC
- CAGEC: L4306
- Manufacturer Part # HE104
- Serial #
  - T14394 –PRIMARY COMPUTER Power Supply
  - T14381- Auxiliary Power supply
- This part is 'COTS' . This drawing is compiled to identify larger components and chips





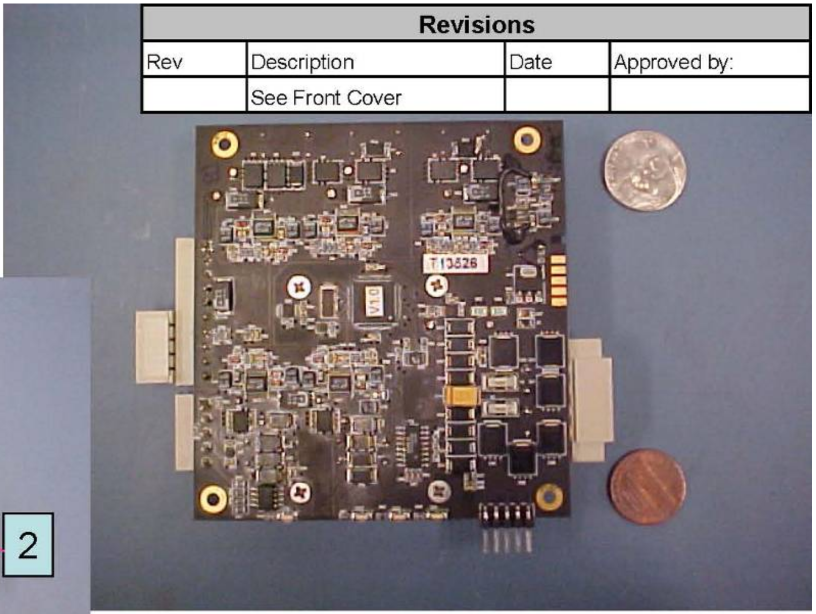
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	2	DC-DC inductor coil			
2	1		PC104 BUS		

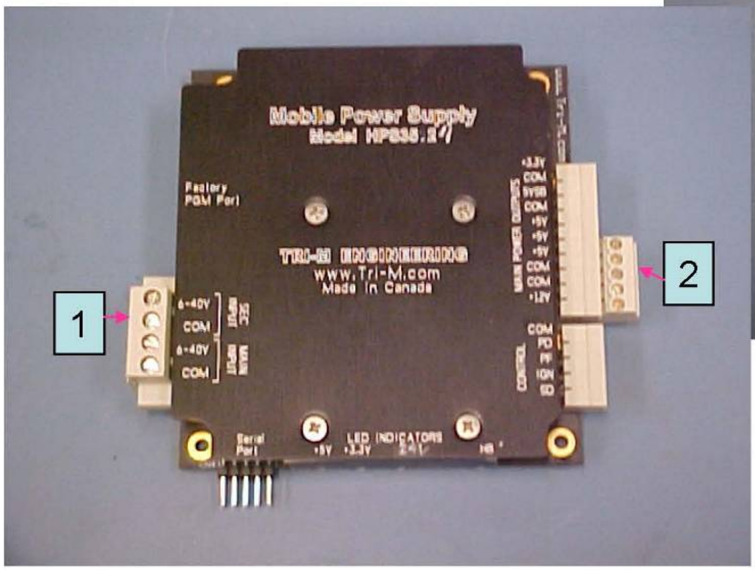
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	3 OF 13

NOTES:

- Manufacturer: Tri-M Systems INC
- CAGEC: L4306
- Manufacturer Part # HPS3524
- Serial # T13526
- This part is 'COTS' . This drawing is compiled to identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		





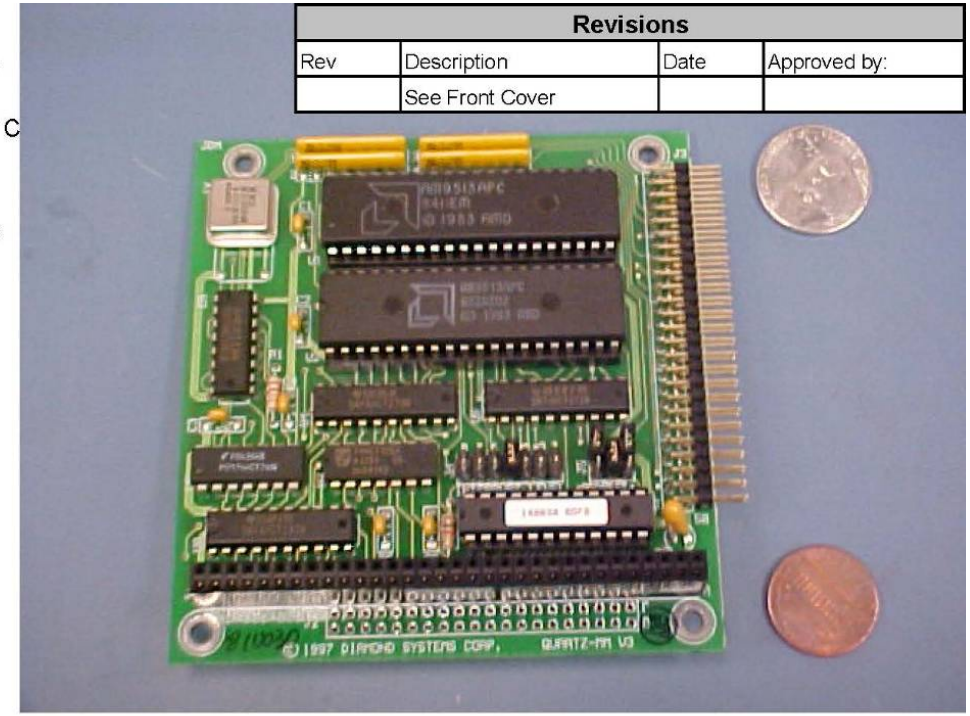
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1		4 pin wire holder Power in		
2	1		4 pin wire holder Power out		

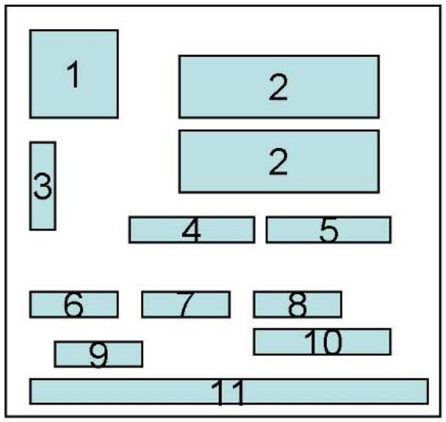
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	4 OF 13

NOTES:

- Manufacturer: Diamond Systems Corp
  CAGEC: 03AM3
- Manufacturer Part # QMM-10-XT REV C
- Serial #W257729
- This part is ‘COTS’ . This drawing is compiled to identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		





ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1	S0524 F5NFH			
2	2	A9901	CTSC		
3	1	CD74HCT368E	TEXAS INTRUMENTS		
4	1	SN74HCT273N	TEXAS INTRUMENTS		
5	1	SN74HCT373N	TEXAS INTRUMENTS		
6	1	PO436AB	FAIRCHILD		
7	1	74HCT125N			
8	1		JUMPER BUS		
9	1	55AF43K			
10	1	140030 6DF2			
11	1		PC104 BUS		

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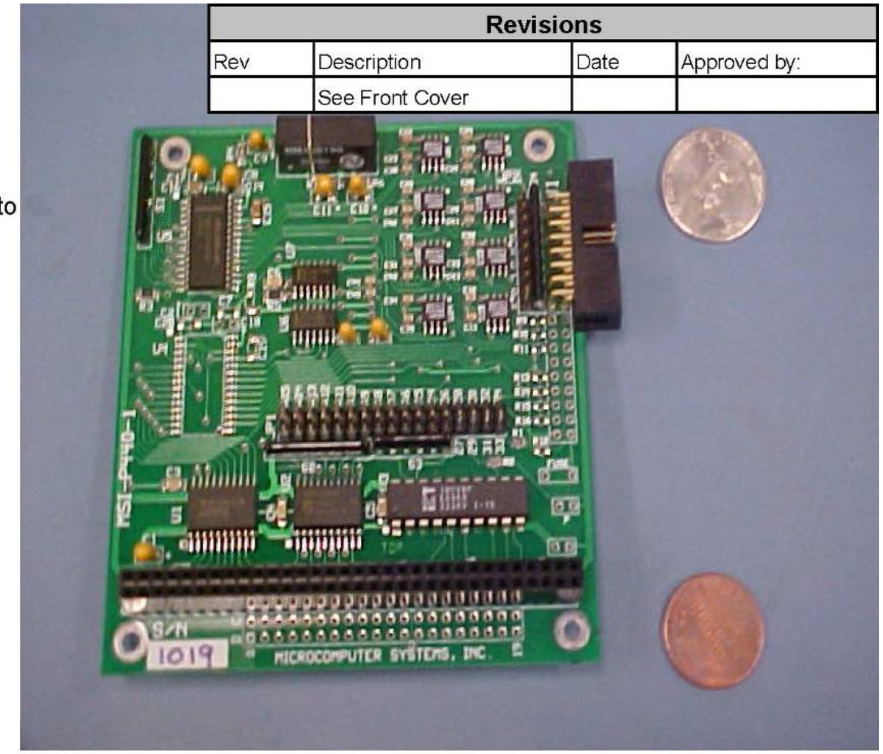
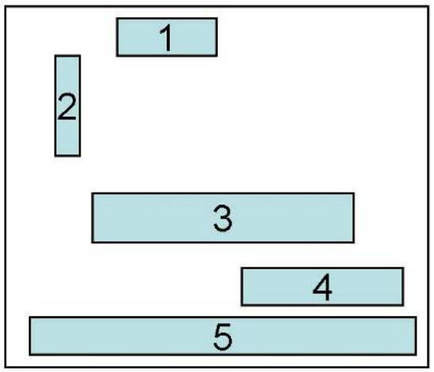
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	5 OF 13

NOTES:

- Manufacturer: Tri-M SYSTEMS INC
- CAGEC: L4306
- Manufacturer Part #MSI-P440-1
- Serial #1020
- This part is 'COTS' . This drawing is compiled to identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



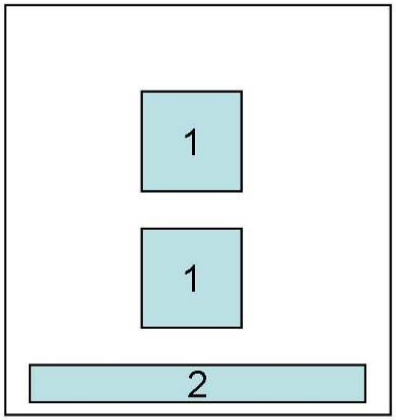


ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1	NMA0515S			
2	1	MAX197BEWI	MAXIM		
3	1		JUMPER BUS		
4	1	18CV8P E6969	ICT		
5	1		PC104 BUS		

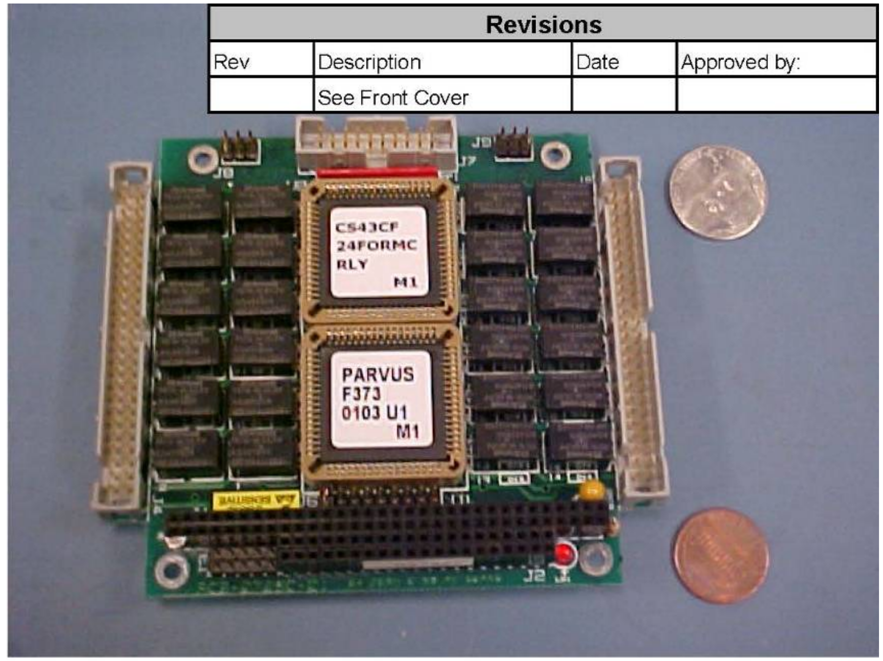
AIR FORCE INSTITUTE OF TECHNOLOGY				
Computer Sub Assembly				
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P		Rev A
Scale 1:1	JOwens	SHEET	6 OF 13	

NOTES:

- Manufacturer: Parvus INC CAGEC:
- Manufacturer Part #PRV-0728
- Serial # C47880
- This part is 'COTS' . This drawing is compiled to identify larger components and chips



Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



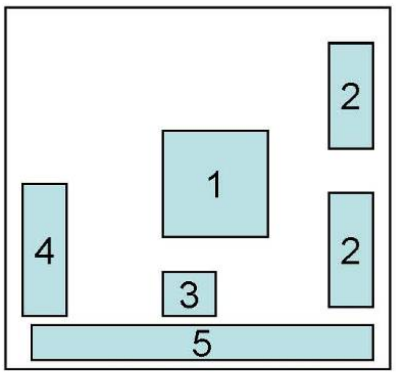
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	2	A1020B	ACTEL		
2	1		PC104 BUS		

AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	7 OF 13

NOTES:

- Manufacturer: Tri-M Systems INC
- CAGEC: L4306
- Manufacturer Part # PCM-3521
- Serial # CO771059
- This part is 'COTS' . This drawing is compiled to identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



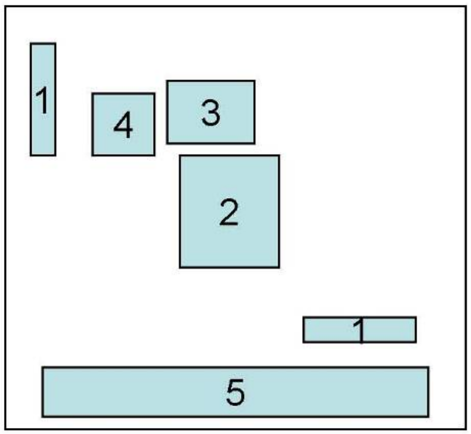
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1	F65545	CHIPS VGA Processor		
2	2	M11B416256A	Elite Mt		
3	1	FXO 221	FUJI A6X		
4	1	29EE010	SST BIOS		
5	1		PC104 Bus		

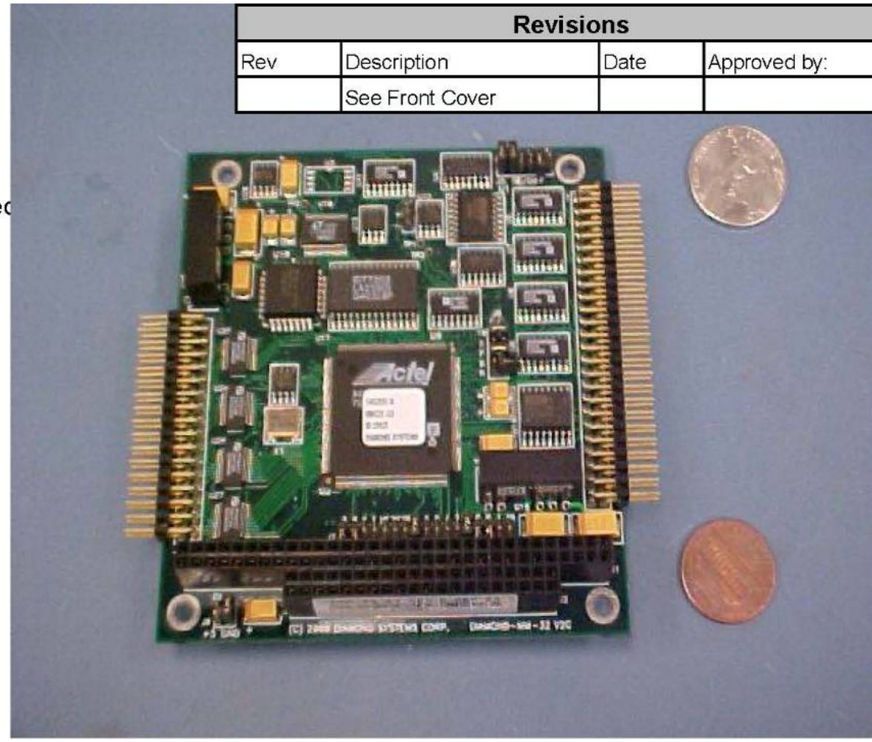
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	8 OF 13

NOTES:

- Manufacturer: Tri-M SYSTEMS INC
- CAGEC: L4306
- Manufacturer Part # DMM-32-AT Rev E
- Serial # A124843
- This part is 'COTS' . This drawing is compiled identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		





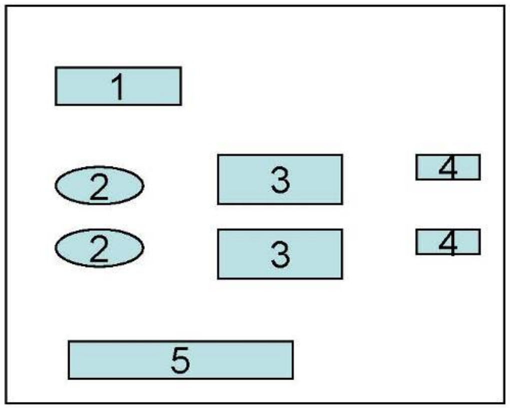
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	2	115D5HFS	MARTEK POWER		
2	1	A42MX16	ACTEL		
3	1	IDT7202			
4	1	OKI M82C54			
5	1		PC104 BUS		

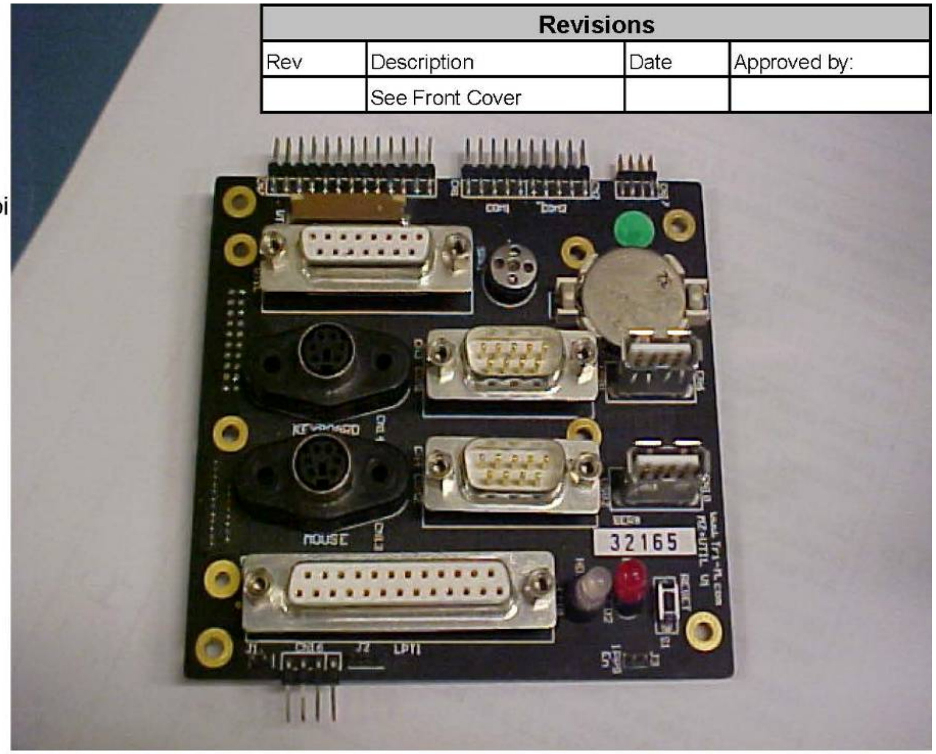
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-F	Rev A
Scale 1:1	JOwens	SHEET	9 OF 13

NOTES:

- Manufacturer: Tri-M SYSTEMS INC
- CAGEC: L4306
- Manufacturer Part # MZ104-UTIL
- Serial # 99899
- This part is 'COTS' . This drawing is compi
identify larger components and chips
- Battery is removed for flight

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		





ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1		VGA Port		
2	2		Keyboard Mousse Connections		
3	2		Serial Ports		
4	2		USB posrts		
5	1		Printer Port		

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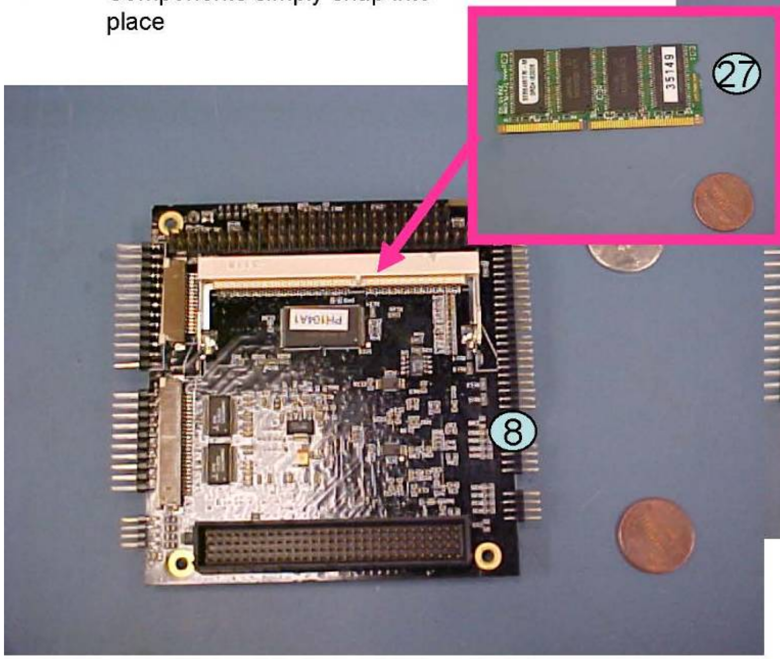
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-F	Rev A
Scale 1:1	JOwens	SHEET	10 OF 13

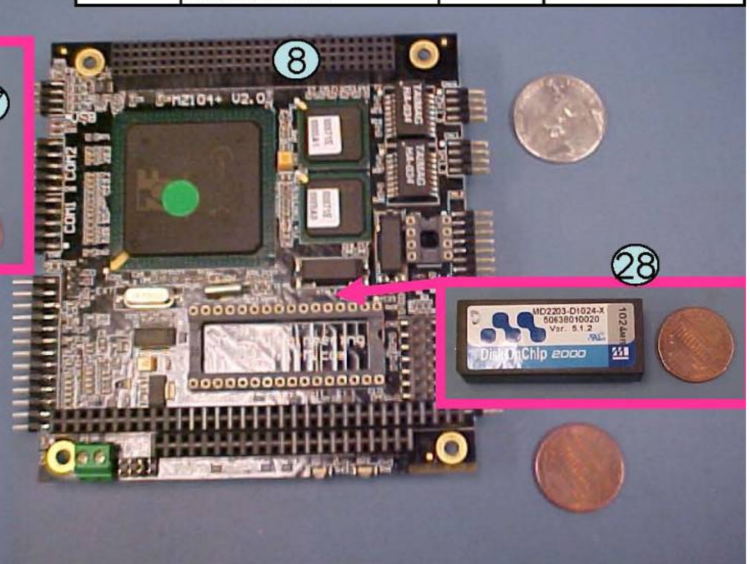
NOTES:

- Assembly to be completed to being conformal coated
- Components simply snap into place

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



Bottom View



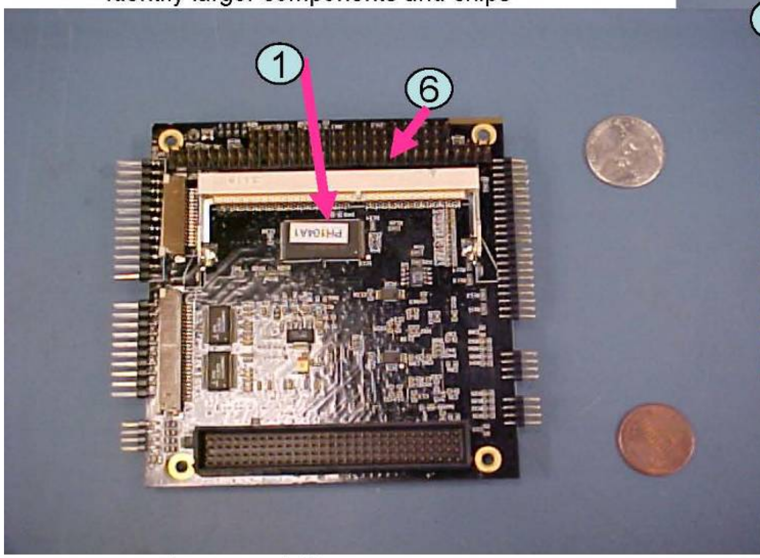
Top View

AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	11 OF 13

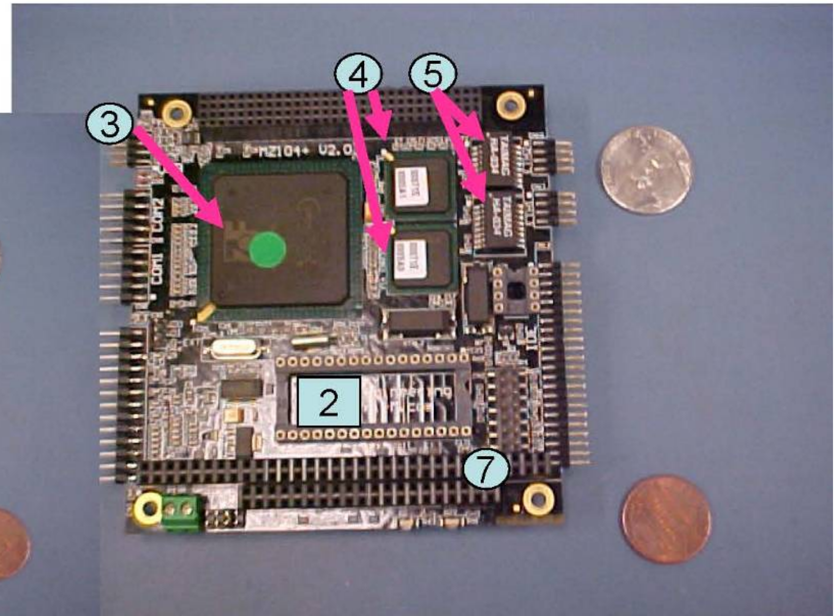
Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

NOTES:

- Manufacturer: Tri-M SYSTEMS INC
- CAGEC: L4306
- Manufacturer Part # MZ-104+ Processor
- Serial # 10003001
- This part is 'COTS' . This drawing is compiled to identify larger components and chips



Bottom View



Top View

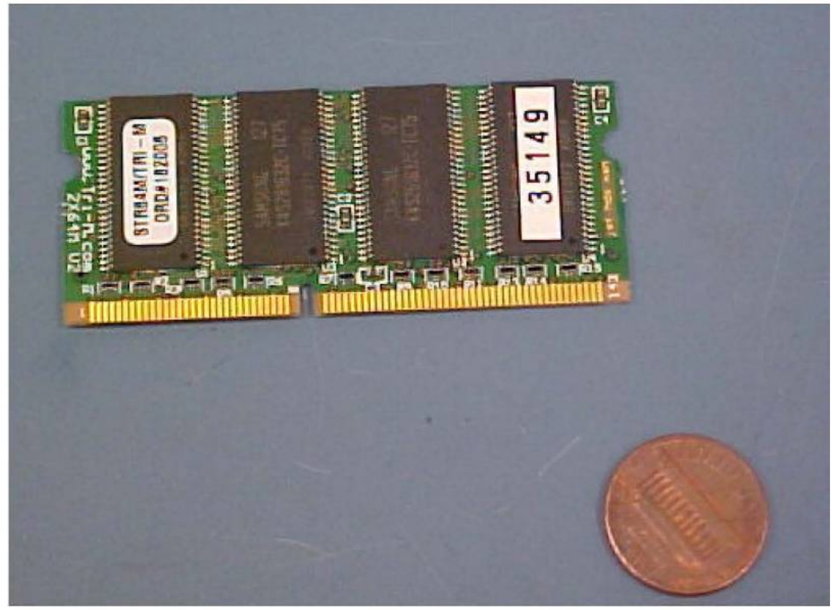
ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Material	NOTES OR REMARKS
1	2	PH104A			
2	1		Disk on chip Socket		
3	1	ZFX86	Processor		
4	2	00071E			
5	2	HA034	TAIMAG		
6	1		Extended Memory Board Holder		
7	1		PC104 BUS		

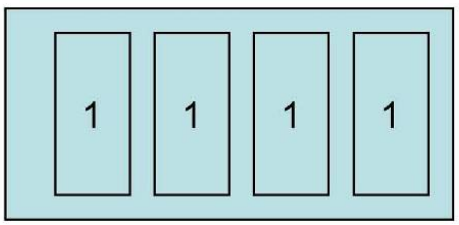
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	12 OF 13

NOTES:

- Manufacturer: Tri-M SYSTEMS INC
- CAGEC: L4306
- Manufacturer Part # SO-DIMM-64MB-RAM
- Serial # 60169
- This part is 'COTS' . This drawing is compiled to identify larger components and chips

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		





ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	4	209DG	WINBOND		

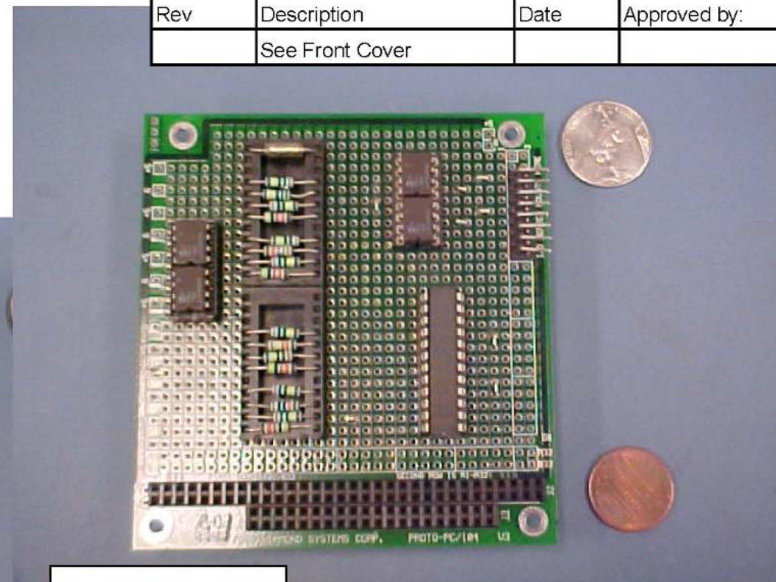
Rev IR

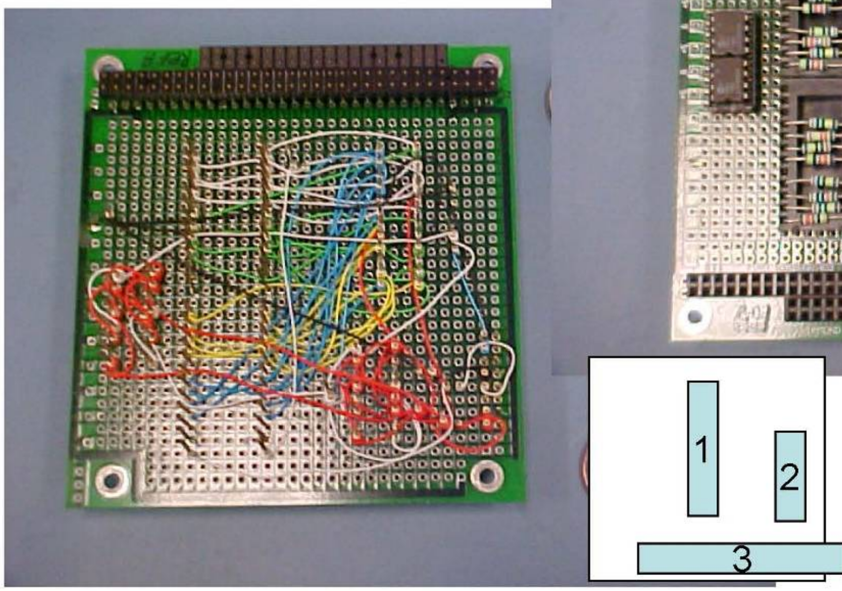
AIR FORCE INSTITUTE OF TECHNOLOGY			
Computer Sub Assembly			
Size A	FSCM NO.	DWG No. RIGEX--COMPUTER-P	Rev A
Scale 1:1	JOwens	SHEET	13 OF 13

NOTES:

- Manufacturer: AFIT
- This part was developed from the ground up at AFIT for RIGEX
- Schematic is provided on sheet 2
- A component lead wire wrap method was applied for component equation

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

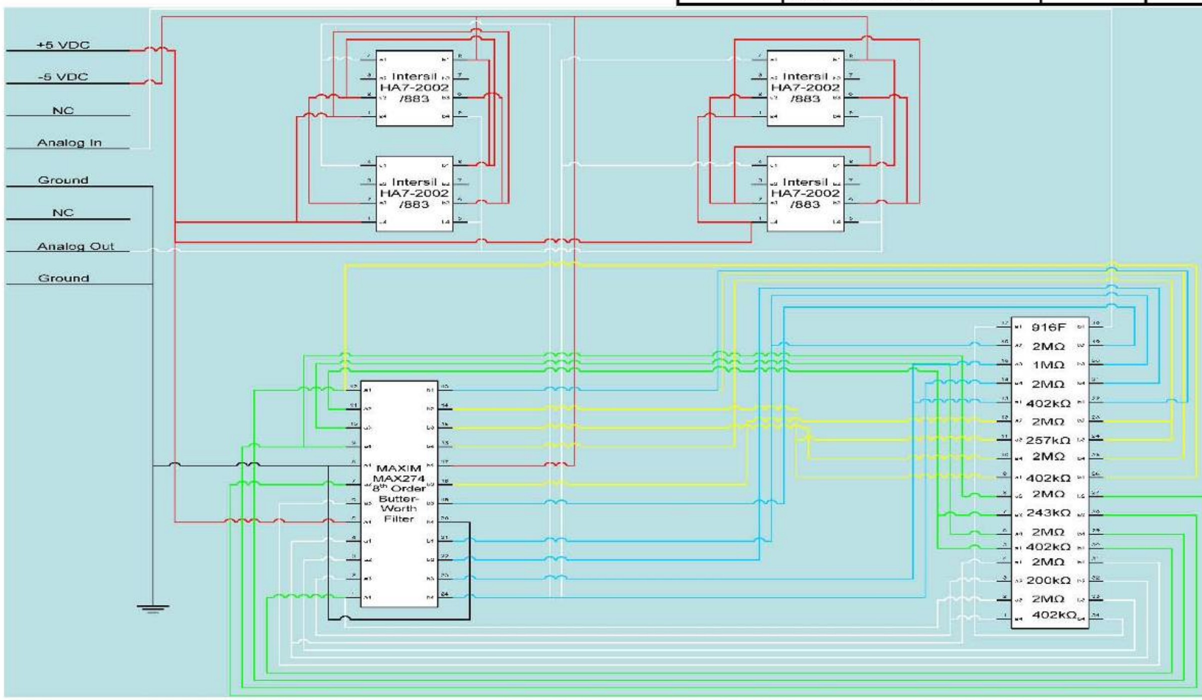




ITEM#	QTY	PART OR IDENTIFICATION #	NOMENCLATURE OR DECRIPTION	Detail Drawing	NOTES OR REMARKS
1	1		Resistor BUS		
2	1	MAX274BENG	MAXIMUM BUTTERWORTH FILTER		
3	1		PC104 BUS		

AIR FORCE INSTITUTE OF TECHNOLOGY			
Filter Board			
Size A	FSCM NO.	DWG No. RIGEX-Filter-1-D	Rev A
Scale 1:1	JOwens	SHEET	1 OF 2

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

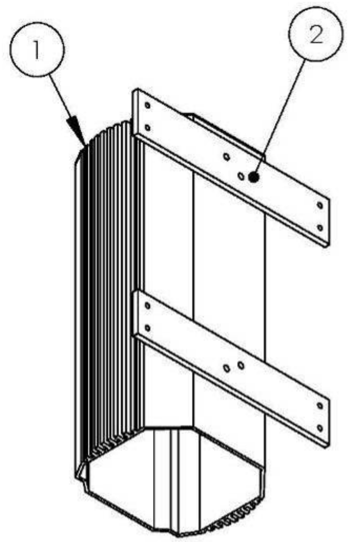


NOTE: THIS IS THE WIRING SCHEMATIC FOR THE IN HOUSE BUILT FILTER BOARD

THE INTENT OF THIS BOARD IS TO FILTER OUT DIGITAL TO ANALOG NOISE IN THE CHIRP SIGNAL TO THE TRANSFORMERS FOR THE EXCITATION PHASE OF THE EXPERIMENT

AIR FORCE INSTITUTE OF TECHNOLOGY			
Filter Board			
Size A	FSCM NO.	DWG No. RIGEX-Filter-1-D	Rev A
Scale 1:1	JOwens	SHEET	2 OF 2

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



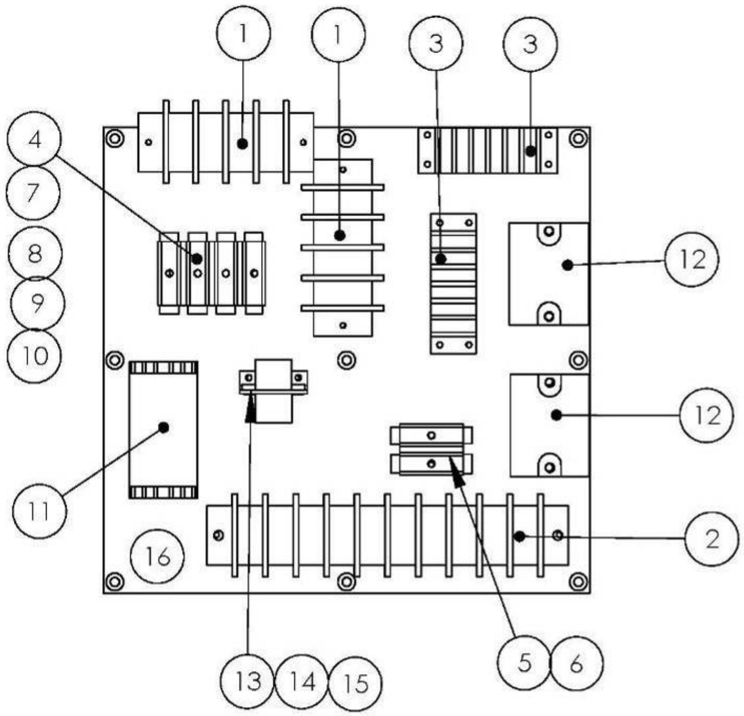
PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	Tri-M Engineering: VT-14 100008	Versatainer	1	
2	RIGEX-2007-2-P	Computer Mounting Plate	2	
3	NAS1291C4M	Locknuts: 1/4-28 -- Computer to Computer mounting plate (4)	4	
4	NAS1351N4-12	Hex head screws, 1/4-28, 3/4" long --Computer to computer mounting plate (4)	4	
5	NAS620C416	Washers: 1/4 --Computer to computer mounting plate w/ NAS1351N4-12 (4)	4	

NOTE:
1. ASSEMBLE ITEMS 3-5 AS INDICATED IN PARTS LIST

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TEHCNOLOGY
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	JJO	25 JUL 07	TITLE: COMPUTER CAN SUBASSEMBLY
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE A	DWG. NO. RIGEX-COMPCAN-D	REV A
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1	WEIGHT:

5 4 3 2 1

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



NOTE:
1. Items 23 - 27 used interchangably
2. Items 2 - 22 used interchangably
3. Apply items 28 -32 as necessary
4. Utilize items 17-20 as inicatedin parts list

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	ZRM	03JUN07	
	CHECKED	JJO	25JUL07	TITLE:
	ENG APPR.			POWER DISTRIBUTION PLATE SUBASSEMBLY
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE **A** DWG. NO. RIGEX-PDP-D REV A
FINISH				SCALE: 1:3 WEIGHT: SHEET 1 OF 2

E D C B A

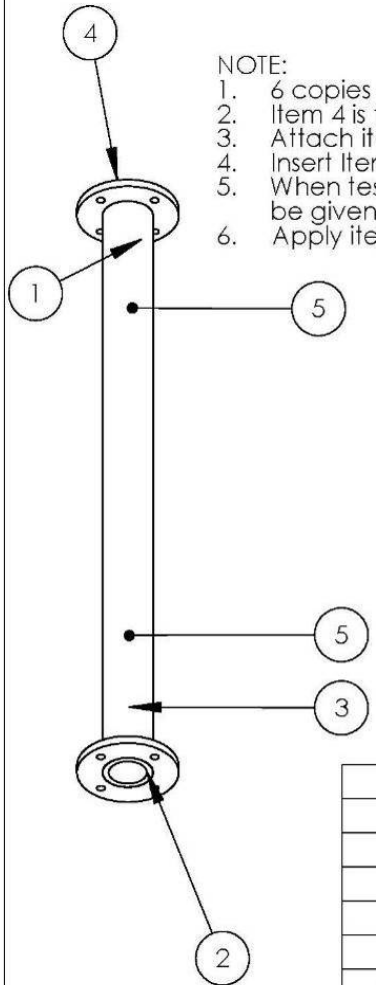
Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	Digikey WM5816ND	6 AWG 4P Terminal Strip	2	COTS
2	Digikey WM5821ND	8 AWG 10P Terminal Strip	1	COTS
3	Digikey CBB106-ND	22AWG 6P Terminal Strip	2	COTS
4	Bussman BK/S-8302-04	4-Fuse Block	1	COTS
5	Bussman BK/S-8302-02	2 Fuse Block	1	COTS
6	Newark FM09A250V3A	3 Amp Fuses	2	COTS
7	Newark FM09A250V2A	2 Amp Fuse	1	COTS
8	Newark FM09A250V5A	5 Amp Fuse	1	COTS
9	Newark FM09A250V10A	10 Amp Fuse	1	COTS
10	Newark FM09A250V6A	6 Amp Fuse	1	COTS
11	Crane Corp. 26021-001-02	EMI Filter (FME28-461/ES)	1	
12	Crouzet 84-134-870	Power Relays	2	COTS
13	Esterline Leach International: SO-1065-003	YCL Latching Relay Socket	1	COTS
14	Esterline Leach International: YCL-D4A	YCL Latching Relay	1	Sampled
15	RIGEX-2007-1-P	Leach Socket Holder	1	
16	RIGEX-2006-17-P	Power Distribution Plate	1	
17	NAS1352N04-10	Standard Screws: #4-40, 5/8" long --2 per 6 AWG terminal strip (6)	6	
18	NAS1352N04LB4	Standard Screws, #4-40, 1/4" long, patch lock --EMI Filter Screws (4) --Leach Relay plate attachment (2)	6	
19	NAS1352N06LB8	Standard Screws: #6-32, 1/2" long, patch lock --Terminal Block screws: 4 per terminal block (8) --MODIFIED. Fuse Holders to structure (2 each) (4)	12	
20	NAS1352N08LB4	Standard Screws: #8-32, 1/4" Long, patch lock --Power Relay screws: 2 screws each (4)	4	
21	Advanced Wire: M22759/11-12-2	12 AWG wire -red	A/R	
22	Advanced Wire: M22759/11-22-0	22 AWG wire -black	A/R	
23	Advanced Wire: M22759/11-22-3	22 AWG wire -orange	A/R	
24	Advanced Wire: M22759/11-22-4	22 AWG wire -yellow	A/R	
25	Advanced Wire: M22759/11-22-5	22 AWG wire -green	A/R	
26	Advanced Wire: M22759/11-22-6	22 AWG wire -blue	A/R	
27	Advanced Wire: M22759/11-22-9	22 AWG wire -white	A/R	
28	Advanced Wire: M23053/5-103-0	Heatshrink (3/32") -black	A/R	
29	Huntsman Advanced Materials Arathane 5753	Staking compound	A/R	
30	Kester: 24-6337-8802	Solder Type-R	A/R	
31	Newark All In One 78F580	Wire TIES, 4"	A/R	COTS
32	Master Bond Inc. EP21TCHT-1	Epoxy	A/R	
33	AFIT: 512-9017	EMI Filter Sockets	4	COTS

DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
	DRAWN			
	CHECKED			POWER DISTRIBUTION PLATE SUBASSEMBLY
	ENG APPR.			
	MFG APPR.			
MATERIAL	Q.A.			
FINISH	COMMENTS:			SIZE A DWG. NO. RIGEX-PDP-D REV. A
				SCALE:1:3 WEIGHT: SHEET 2 OF 2

1 2 3 4 5

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



NOTE:

1. 6 copies of this assembly are to be made (3 test and 3 flight)
2. Item 4 is to be shaped to fit into tube cap cavity
3. Attach item 6 (when wired) to item 4
4. Insert Item 4 into tube cap cavity and fill with item 7
5. When test tubes are installed on RIGEX a '-Tst' designator will be given to the configuration part number
6. Apply item 8 to item 2

PARTS LIST

Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	L'Guarde "L5"	Sub-Tg Tube	1	
2	Marco Inc. P/N V1000-129	Sub-Tg Tube O-Ring	1	
3	Smart Material Corporation M 2814 P1	Piezoelectric Actuator - PZT QuickPack strain actuator	2	
4	Kionix KXPA-4 w/ circuit board	Accelerometer - Precision Aligned wide Input Voltage Triaxial Accel.	1	
5	Omega Engineering Inc. SA1-K	Thermocouple	2	
6	3M #3473	10 pin connector	1	
7	Huntsman Advanced Materials Arathane 5753	Staking compound	A/R	
8	Braycote 601EF	O-Ring Grease - Braycote 601EF vacuum grease	A/R	

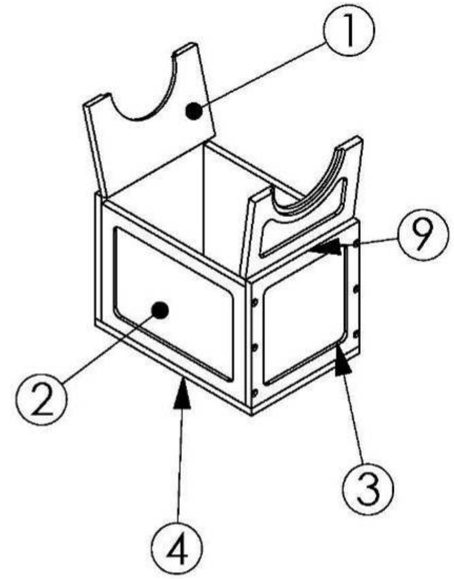
UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN	JJO	25 Jul 07	TITLE:
	CHECKED			RIGEX Tube Sub-Assembly
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE A — DWG. NO. RIGEX-TUBE-D — REV A
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:4 — WEIGHT: — SHEET 1 OF 1

NEXT ASSY — USED ON — APPLICATION

5 4 3 2 1

PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-OVEN-1	Oven doors	2	
2	RIGEX-OVEN-2	Oven front/back	2	
3	RIGEX-OVEN-3	Oven sides	2	
4	RIGEX-OVEN-4	Oven bottom	1	
5	Minco: HTK05457 R21.9L12A	Heaters (3.5x2.75in)	2	
6	Minco: HTK05467 R10.3L12F	Heaters (3x5in)	2	
7	Minco: HTK05326-104	Heaters (1x4in)	4	
8	Zotefoams: F38 HD	Oven Insulation	A/R	
9	McMaster Carr: 1624A73	Non-Springed Hinges	2	
10	NAS1291C04M	Locknuts: #4-40 --Oven hinges (24)	24	
11	NAS1352N04-8	Flat head screws, screws #4-40, 1/2" --Oven hinge (24)	24	
12	Camcar/Textron: D5637987	Hex Flat head Screw #4-10, 1/2" long	34	
13	Allied Elec: 81273	Kapton Tape	A/R	

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		

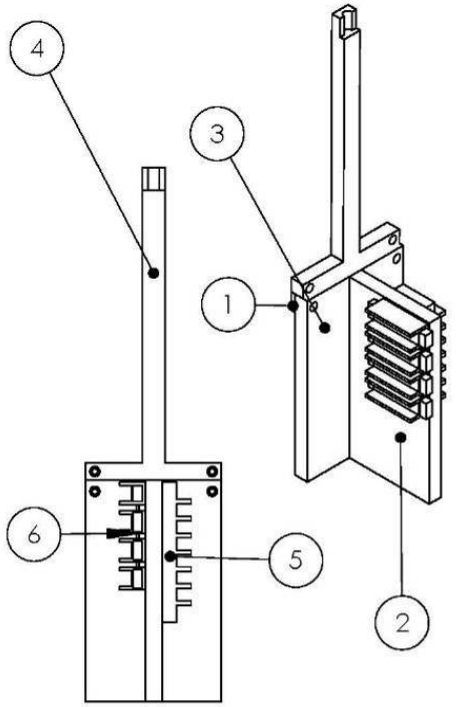


NOTE:
1. 1 item 7 is applied to each item 1 prior to assembly
2. 1 item 6 is applied to each item 2 prior to assembly
3. 1 item 5 is applied to each item 3 prior to assembly
4. 2 item 7 is applied to item 4 prior to assembly
5. Each resistive heating circuit consists of:
   A. 2 item 7 and item 6 in a series circuit
   B. 1 item 5
6. One lead from A and B above are joined for the circuit return
7. The lead from A is sent straight to the bay fuse holder while the B lead is sent to the bay resistor
8. The assembly is finished by cutting item 8 to size and wrapping the entire box with kapton tape

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN	ZRM	03JUN07	TITLE: OVEN BOX SUBASSEMBLY
	CHECKED			
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL Ultem 1000 PEI Polyetherimide	COMMENTS:			SIZE A · DWG. NO. RIGEX-OVEN-D · REV A
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:4 · WEIGHT: · SHEET 1 OF 1

5 4 3 2 1

Revisions			
Rev	Description	Date	Approved by:
	See Front Cover		



PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	Springed Hinges	Mc Master-Carr: 15205A79	1	
2	Oven Bracket 1	RIGEX-2006-10-P	1	
3	Oven Bracket 2	RIGEX-2006-11-P	1	
4	Oven Door Latch	RIGEX-2006-12-P	1	
5	Digikey CBB106-ND	22AWG 6P Terminal Strip	1	
6	Bussman BK/S-8302-04	4-Fuse Block	1	
7	NAS1352N06LB8	Standard Screws: #6-32, 1/2" long, patch lock --Terminal Block screws: (4) --MODIFIED. Fuse Holders to structure (2 each) (2)	6	
8	NAS1189E3P12B	Flat Screws w/ Patchlock: #10-32, 3/4" long --3 screws per oven bracket (3)	3	
9	NAS1291C04M	Locknuts: #4-40 --Oven bracket to oven latch hinge (4)	4	
10	NAS1352N04-8	Flat head screws, screws #4-40, 1/2" --Hinge attaching oven bracket to oven latch (4)	4	
11	NAS620C4	#4 washer --oven bracket to oven latch hinge w/ NAS1352N04-8 (4)	4	

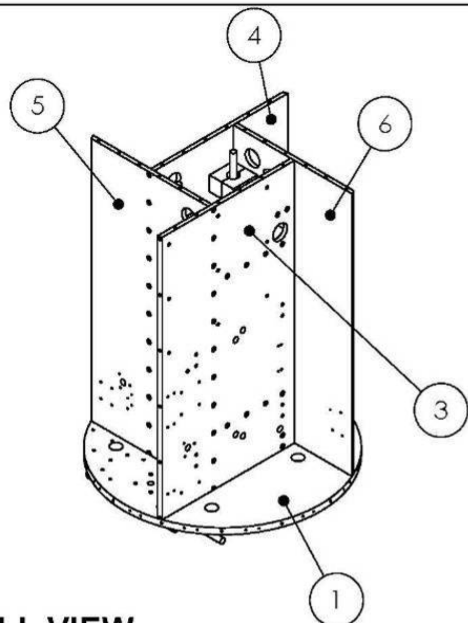
NOTE:
1. 3 copies of this assembly is to be made
2. Items are attached with indicated fasteners and componets in 'Parts List'

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ±0.01 THREE PLACE DECIMAL ±0.005	DRAWN	JJO	25 JUL 07	TITLE:	
	CHECKED			OVEN LATCH SUBASSEMBLY	
	ENG APPR.				
	MFG APPR.				
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.				
MATERIAL	COMMENTS:			SIZE A	DWG. NO. RIGEX-OVENLATCH-D
FINISH					REV A
DO NOT SCALE DRAWING				SCALE: 1:3 WEIGHT:	SHEET 1 OF 1

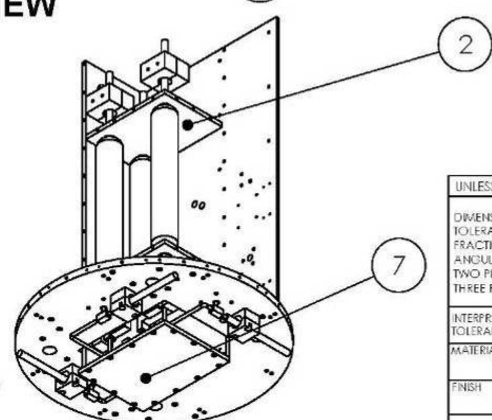
NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1

Revisions			
Rev	Description	Date	Approved By:
	See Front Cover		



FULL VIEW



PARTIAL VIEW

PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	RIGEX-2006-7-P	Oven Mounting Plate	1	
2	RIGEX-2006-9-P	Pressure System Mounting Plate	2	
3	RIGEX-2006-3-P	Computer Rib	1	
4	RIGEX-2006-4-P	Long Rib w/o Computer	1	
5	RIGEX-2006-5-P	Short Rib w/ Pin Puller	1	
6	RIGEX-2006-6-P	Short Rib w/o Pin Puller	1	
7	RIGEX-2006-8-P	Bottom Rectangular Plate	1	
8	NAS1189E3P12B	Interconnecting Rib Screws Transducer Mounts to Ribs Solenoid Mounting Bloacks to Ribs Bottom plate to Ribs Pressure System Mounting Plate to Ribs	106	
9	NAS1189E3P16B	Oven mounting Plate to Ribs	16	

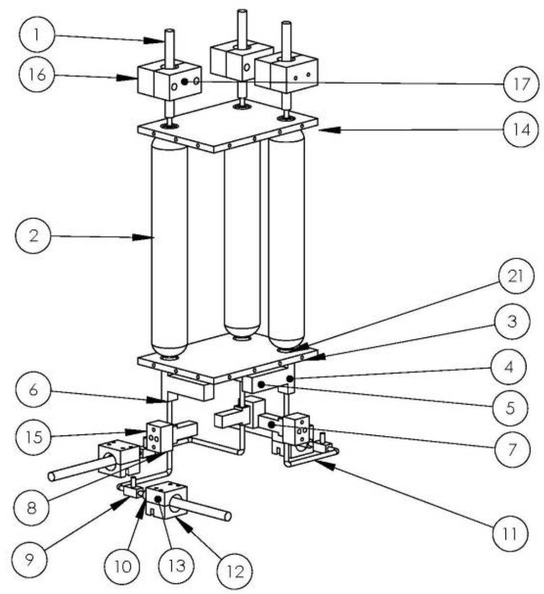
Notes:

1. Assembly of the Wave #1 Subassembly is outlined in RP-1
2. Pressure system components shown in the pictures to the left are part of the RIGEX Inflation System. A detailed sketch of the RIGEX Inflation System is shown on page 2 of this document.
3. Partial viewhas two ribs missing only to show item #2

UNLESS OTHERWISE SPECIFIED:		NAME	DATE	AIR FORCE INSTITUTE OF TECHNOLOGY
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	ZRM	03JUN07	
	CHECKED			TITLE:
	ENG APPR.			RIGEX WAVE 1 ASSEMBLY
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL	COMMENTS:			SIZE A | DWG. NO. RIGEX-WAVE1-D | REV A
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 | WEIGHT: | SHEET 1 OF 2

PARTS LIST				
Item #	Part #	NOMENCLATURE OR DECRIPTION	QTY	Note
1	Taber Industries: M2911C150AEGAAA1	Pressure Transducer	6	
2	Swagelok: 316L-HDF4-500	N2 Pressure Cylinder Tank	3	
3	Swagelok: SS-4-TA-1-4	1/4" MNPT to 1/4" tube fitting	3	
4	Swagelok: SS-400-3-4TTM	Pipe Tee - 1/4" tube OD and 1/4 male NPT	3	
5	Swagelok SS-GF4-A	Fill Valve	3	
6	Swagelok: SS-4-TA-7-4	1/8" MNPT to 1/4" tube adaptor	3	
7	Parker Instrumentation: 009-0143-900	Solenoid	3	
8	Swagelok: (male adapter) SS-4-TA-1-2	1/8" NPT to 1/4" tube fitting	3	
9	Swagelok: SS-400-3TTS	Male Branch Tee with O ring	3	
10	Swagelok: SS-43GF4-A-SC11	1/4" FNPT to 1/4" tube adaptor	3	
11	Salem Tube Inc: HT#OPY937	1/4" OD Tubing	A/R	
12	RIGEX-2006-18-P	Pressure Transducer Mount to Bottom of Oven Plate (inside)	3	
13	RIGEX-2006-19-P	Pressure Transducer Mount to Bottom of Oven Plate (outside)	3	
14	RIGEX-2006-9-P	Inflation System Mounting Plate	2	
15	RIGEX-2006-20-P	Solenoid Mount	3	
16	RIGEX-2006-21-P	Pressure Transducer Mount to Ribs (inside)	3	
17	RIGEX-2006-22-P	Pressure Transducer Mount to Ribs (outside)	3	
18	NAS1352N04-10	Solenoid Mount screw	6	Mounts Solenoid to Solenoid Mounting Block
19	Swagelok: MIL-T-27730A	PTFE Tape (thread sealant)	A/R	
20	Huntsman Advanced Materials Arathane 5753	Staking compound	A/R	
21	McMaster-Carr: 8625k24	Viton	A/R	
22	Glenair Inc.: M85049/38S11N	Pressure Transducer Backshell	6	
23	Taber Industries: 129614 (TV06RF-11-98SN)	Pressure Transducer mating plug	6	
24	Swagelok: SS-400-SET	Ferrule Set (cone and ring)	A/R	
25	NAS1189E3P12B	Transducer Mount Screw	12	Mounts outsidepiece to inside piece

Revisions			
Rev	Description	Date	Approved By:
	See Front Cover		



NOTES:
1. Inflation System is assembled in conjunction with the Wave #1 Subassembly.
2. Manufacture specifies the following installation techniques: All NPT fittings should be wrench-tight and all Compression fittings should be tightened 1 and 1/4 turn past finger-tight
3. Swagelok Teflon tape used on all NPT fittings
4. Staking compound used on all fittings to prevent back-out
5. Use of Viton between Nitrogen Pressure Tank and Inflation System Mounting Plate

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JJO	25 JUL 07
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

AIR FORCE INSTITUTE OF TECHNOLOGY

TITLE:

RIGEX WAVE 1 ASSEMBLY

SIZE	DWG. NO.	REV
B	RIGEX-WAVE1-D	A
SCALE: 1:1	WEIGHT:	SHEET 2 OF 2

Appendix J RIGEX Operation Time Line

Table J.1 RIGEX Event Timeline

Crew Action	RIGEX Action	Event Time (sec)	Display (DS13)	Time	Current Draw Amps +/- 0.1 A
Place "S13" UP Momentarily	Computer turns on (CTO) and begins boot up ~43 seconds	0	STRIPES	CTO	0
	DS13 (UP) gets at least +18V (DS 13 Indicates UP) & self-test begins	43	UP	CTO + 43 seconds	0.81
	Self-test ends; DS13 off (Stripes)	125	STRIPES	CTO + 168 seconds	0.81
	DS-13 "Down"	60	DOWN	CTO+ 228 seconds	0.81
	DS13 off (Stripes); 5-minute wait period starts	60	STRIPES	CTO + 288 seconds	0.81
	Experiment Initiation; Initiate Bay #1 DS13(up) gets at least +18V	300	UP	CTO + ~ 10 minutes	0.81
	Tube #1 Heating; inflation intialized*	7200	UP	CTO + ~ 2 hours 10 minutes	5.5
	Tube #1 is fully deployed, cooled and ventilated	600	UP	CTO + ~ 2 hours 20 minutes	1.05
	Tube #1 Actuation and Data collection	60	UP	CTO + ~ 2 hours 21 minutes	0.87
	Tube #2 Heating; inflation intialized*	7200	UP	CTO + ~ 4 hours 21 minutes	5.5
	Tube #2 is fully deployed, cooled and ventilated	600	UP	CTO + ~ 4 hours 31 minutes	1.05
	Tube #2 Actuation and Data collection	60	UP	CTO + ~ 4 hours 32 minutes	0.87
	Tube #3 Heating; inflation intialized*	7200	UP	CTO + ~ 6 hours 32 minutes	5.5
	Tube #3 is fully deployed, cooled and ventilated	600	UP	CTO + ~ 6 hours 42 minutes	1.05
	Tube #3 Actuation and Data collection	60	UP	CTO + ~ 6 hours 43 minutes	0.87
Toggle S-13 to the 'OFF' position after DS13 reads DOWN or CTO + 8 Hours	Experiment complete! ; DS13 DOWN gets at least +18V		DOWN		0.87
	RIGEX POWER OFF		STRIPES		0
	Worst Total Time:	~8 Hours			

*Deployment is dependent on the tube getting to the transition temperature. Maximum time allowed is shown.

Vita

Captain Jeremy J. Owens graduated from Covington Independent Holmes High School in Covington, Kentucky. He entered undergraduate studies at Embry-Riddle Aeronautical University in Daytona Beach, Florida where he graduated with a Bachelor of Science degree in Aerospace Engineering in December 2001. He was commissioned through the Detachment 157 AFROTC program at Embry-Riddle Aeronautical University being nominated for a Regular Commission.

His first assignment was at Vandenberg AFB as a mission planner for the now deactivated 2nd Space Launch Squadron from January 2001 through June 2005 where he earned the Meritorious Service Commendation Medal for his efforts with the "fly out" of the Atlas IIAS, Titan II, and Titan IV Space Launch Vehicle systems. In December 2004, he entered graduate studies through the University of Management and Technology where he earned a Master of Science degree in Acquisition Management in January 2007. In June 2005, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Space Material Commands Delta Launch Vehicle Wing as the Avionics systems branch chief.

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14. ABSTRACT

The purpose of this research is to complete the building, testing, verification, and qualification of the Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) for spaceflight. The process of qualifying a payload for spaceflight is discussed, specifically addressing the issues of operability and survivability verification of a general payload. The spaceflight qualification process is then applied to the RIGEX payload at the Air Force Institute of Technology (AFIT) and at the Johnson Spaceflight Center (JSC) in Houston, TX, capstoning the work of 12 masters' students and 3 summer interns that has already gone into the RIGEX project over the last 7 years.
The culmination of this effort is the necessary documentation required to turn the RIGEX payload over to the National Air and Space Association (NASA) in preparation for its launch in February 2008.

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