

5

Semi-Annual Technical Report

AD-A150 316

SHUTTLE FLIGHT TEST OF AN ADVANCED GAMMA-RAY
DETECTION SYSTEM

Dr. Alfred C. Rester, Jr.
Principal Investigator
Space Astronomy Laboratory
University of Florida
1810 NW 6th Street
Gainesville, FL 32609

Sponsored by

Advanced Research Projects Agency (DoD)
ARPA Order No. 4565

Monitored by AFOSR Under Contract #F48620-83-C-0131

DTIC
ELECTE
FEB 12 1985
S A D

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency or the U.S. Government.

Approved for public release;
distribution unlimited.

February 28, 1984

DTIC FILE COPY

85 01 30 050

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Distribution unlimited	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		4. PERFORMING ORGANIZATION REPORT NUMBER(S)	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 84 - 1256	
6a. NAME OF PERFORMING ORGANIZATION University of Florida	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION AFOSR/NP	
6c. ADDRESS (City, State and ZIP Code) Space Astronomy Laboratory 1810 NW 6th Street Gainesville, Florida 32609		7b. ADDRESS (City, State and ZIP Code) Building 410 Bolling AFB, DC 20332-6448	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR	8b. OFFICE SYMBOL (If applicable) NP	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F49620-83-C-0131	
8c. ADDRESS (City, State and ZIP Code) Building 410 Bolling AFB, DC 20332-6448		10. SOURCE OF FUNDING NOS.	
11. TITLE (Include Security Classification) SHUTTLE FLIGHT TEST OF AN ADVANCED GAMMA-RAY		PROGRAM ELEMENT NO. 61102F	PROJECT NO. 2.309
12. PERSONAL AUTHOR(S) Dr. Alfred C. Rester, Jr.		TASK NO. A1	WORK UNIT NO. N/A
13a. TYPE OF REPORT Semi-Annual Technical		13b. TIME COVERED FROM 01/07/83 TO 31/12/83	
14. DATE OF REPORT (Yr., Mo., Day) 1984 February 28		15. PAGE COUNT 20	
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB. GR.	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
In August of 1983 the Gamma-Ray Advanced Detector (GRAD) Project was assigned to the AFP-675 Program for flight on a future Space Shuttle mission. In order to adapt the experiment to the requirements of AFP-675 we are making a number of changes, both in hardware and software. However, the necessity for such changes is more than affected by an expansion in scope of the experiment made possible by the introduction of a Payload Specialist into the operation. The principal changes to be made are in the avionics, as GRAD was originally designed for operation through ground-based telemetry. This complete redesigning of our avionics to accomodate operation by a Payload Specialist from the aft flight deck of the Orbiter allows us to take advantage of very recent findings on radiation-induced microprocessor failure in other space shuttle experiments in order to make the GRAD avionics less vulnerable to such latch-ups. (continued on the back)			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. Henry R. Radoski		22b. TELEPHONE NUMBER (Include Area Code) (202) 767-4906	22c. OFFICE SYMBOL NP

19. ABSTRACT (continued)

Advances in bismuth germanate (BGO) scintillator technology during the year since construction of the prototype GRAD now make it possible for us to construct a BGO shield with a closed-ended geometry. This improvement will enhance the signal-to-noise ratio. In addition we are experimenting with a new type of decay-vetoed calibration probe using an alpha- rather than a beta-emitting radioactive source.

place to key words

SUMMARY

In August of 1983 the Gamma-Ray Advanced Detector (GRAD) Project was assigned to the AFP-675 Program for flight on a future Space Shuttle mission. In order to adapt the experiment to the requirements of AFP-675 we are making a number of changes, both in hardware and software. However, the necessity for such changes is more than affected by an expansion in scope of the experiment made possible by the introduction of a Payload Specialist into the operation.

The principal changes to be made are in the avionics, as GRAD was originally designed for operation through ground-based telemetry. This complete redesigning of our avionics to accommodate operation by a Payload Specialist from the aft flight deck of the Orbiter allows us to take advantage of very recent findings on radiation-induced microprocessor failure in other space shuttle experiments in order to make the GRAD avionics less vulnerable to such latch-ups.

Advances in bismuth germanate (BGO) scintillator technology during the year since construction of the prototype GRAD now make it possible for us to construct a BGO shield with a closed-ended geometry. This improvement will enhance the signal-to-noise ratio. In addition we are experimenting with a new type of decay-vetoed calibration probe using an alpha- rather than a beta-emitting radioactive source.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFSC)
NOTICE OF TRANSMITTAL TO DTIC
This technical report has been reviewed and is
approved for public release as IAW AFR 190-12.
Distribution is unlimited.
MATTHEW J. KERPER
Chief, Technical Information Division

Table of Contents

Introduction	1
Outline of GRAD Mission Goals	1
Status of GRAD	4
Delivery and Testing of Major Components	4
Modifications Required on Flight Electronics	7
Loss of Vacuum in the nGe Detector Cryostat	7
GRAD Project Organization	10
GRAD Project Administration	11
GRAD Project Operations	12
GRAD Ground Support Equipment and Testing Facilities	12
GRAD Flight Hardware and Software	13
GRAD Calibration	14
GRAD-to-ESS and -STS Integration Support	14
GRAD Crystal Sample Package	15
GRAD Data Reduction and Analysis	15

Account for	
NAME	CHART
NAME	TAB
NAME	LOCATION
Availability Codes	
Avail and/or	Special
AT	



1. INTRODUCTION

At the annual Tri-Services Meeting in May of 1983, the GRAD experiment was rated fourth in priority out of the 37 DoD-sponsored space projects presented for review. Subsequently the experiment was assigned a place in the AFP-675 Program. A number of hardware and software changes will be required for operation of the experiment by a Manned Spaceflight Engineer (MSE) rather than by the experimenters through ground-based telemetry. This change in procedure is viewed as an advantage; however, operation of the experiment by a MSE plus the extensive requirements of the AFP-675 Program for documentation, certification, training, support of meetings, mission rehearsals and simulations have greatly increased the complexity of the GRAD Project. Although we have just come into the AFP-675 Program, we find that our already extensive developmental work on GRAD and our previous Shuttle experience have already put us in step with the other AFP-675 experiments.

Having been assigned a specific mission we are now in a position to more clearly define our objectives and the means by which we intend to achieve them. These are outlined in the following section. The present status of GRAD and the major modifications which will be made to the system are then briefly discussed. A list of tasks and the budgets complete the report.

2. OUTLINE OF GRAD MISSION GOALS

I. Technological Goals

- A. Determine the effects on bismuth germanate (BGO) and n-type germanium detector materials of exposure to the launch, space and landing environments.

How attained:

1. Determine performance characteristics of GRAD before, during and after the mission. These characteristics include energy resolution, angular resolution, response function and BGO shield efficiency.
 2. Monitor housekeeping information (temperatures, voltages, counting rates, dead times)
 3. Study crew-removed sample crystals as quickly as they can be removed from returning Orbiter.
 4. Do postmission activation measurements on GRAD instrument in OPF-type facility and in ORNL low-background counting laboratory.
- B. Test the performance of GRAD as a gamma-ray spectrometer in space and on the ground.

How attained:

1. Accumulate spectra of the ^{239}Pu calibration source plus ambient gamma-ray background.
 2. Accumulate spectra with the ^{239}Pu calibration source switched on and switched off to determine how well one can extract a desired signal from the background.
 3. Accumulate spectra with the BGO shield switched on and off to determine effectiveness of the shield.
- C. Determine radioactivation of detectors and surrounding materials and the nature of the background.

How attained:

1. Study initial activation of Orbiter by turning on GRAD prior to first passage through the South Atlantic Anomaly (SAA).
2. Expose the GRAD to hard particle flux by periodic passage through the SAA and measure the decay of the induced gamma-ray background

in 30-second intervals as the Orbiter passes out of the SAA. (Two sets of 5 upward passages through SAA).

3. Measure spectra with the BGO shield turned off as well as turned on in order to identify the prompt gamma-ray background induced in the nGe and BGO detectors.
 4. Measure the decay of postmission activity with intermediate half lives (15m - 24h) by low-background counting of sample crystals flown in the Crystal Sample Package (CSP).
 5. Measure the radioactive background with GRAD as soon as the Orbiter is returned to an OPF-type facility.
 6. Perform measurements of residual radioactivity in GRAD instrument in the ORNL low-background counting laboratory. (See p. 2).
- D. Test the sensitivity of GRAD for the detection and identification of target sources in space.

How attained:

1. Measure the ^{239}Pu calibration source against the Shuttle background.
 2. Measure spectra from the galactic center.
 3. Measure spectra from targets of opportunity, including solar flares.
- E. Explore the usefulness of a gamma-ray spectrometer as a flight crew-controlled instrument for use in the detection and assessment of sources of gamma radiation in space.

How attained:

Provide experiment control and monitoring functions for MSE (see p. 1) through the Command and Monitoring Panel.

II. Scientific Goals

- A. Measure the strength of the 0.511-MeV gamma-ray line emitted from the galactic center. Why the strength of this line should fluctuate so dramatically over the span of a few years in such a large astronomical source is not at all understood.

How attained:

Alternate taking spectra of galactic center and preselected background region for a total measuring time of at least 10 hours on each. These spectra would best be taken on orbits which do not pass through the SAA. Pointing accuracy should be $\pm 10^\circ$.

- B. Take solar spectra if a flare should occur during the mission.

3. STATUS OF GRAD

3.1 Delivery and Testing of Major Components

The status of the major hardware and software is summarized in Table 1. Those components of the experiment requiring modification for operation on the AFP-675 pallet are marked with asterisks.

With the exception of a cryostat vacuum problem reported in more detail below, the performance of the n-type germanium (nGe) detector and the bismuth germanate (BGO) shield has been satisfactory in every way. A response function for the integrated spectrometer is shown in Figure 1. Other performance characteristics have been described in an invited paper presented at the International Workshop on BGO at Princeton University (A.C. Rester, et al., submitted to Nuclear Instr. Methods).

Table 1

GRAD Status Report

October 1, 1983

	Design	Construction	Delivery to SAL	Operational Testing	Electrical Testing	Mechanical Testing	Thermal Vacuum Testing	Environmental Testing
A. Flight Ops Hardware								
1. BGO Shield	C	C	C	U	U	C		
2. nGe Detector	C	C	C	U	U			
3. LN Dewar	C	C	C	U		U		
4. Cryogenic Interface*	U							
5. Electronics Cannister*	C	C	C	U		U		
6. Mounting Brackets	U							
7. Nuclear Electronics	C	C	C	U	U			
8. Interface Electronics*	U	U						
9. Command Avionics	U							
10. Calibration Probe*	C							
11. Sample Crystal Container	C	C						
B. Flight Ops Software								
1. Data Acquisition*	C	C	C	U				
2. Data Output*	C							
3. Command and Monitoring Panel								
4. Crew Training Procedures								
C. Ground Ops Hardware								
1. Emulator Computer*	C	C	C	U				
2. Data Handler Computer	C	C	C	U	U			
3. Cryogenics	U							
4. Calibration Hardware	U							
5. Portable Counting Equipment	C							
6. ORNL Hardware	U							
D. Ground Ops Software								
1. Emulator*	U	U	U					
2. Data Handler*	U	U	U					
3. Data Analysis	U	U	U					
4. Monte Carlo.	U	U	U					

Legend:

C = Completed

U = Underway

*These items will require extensive modifications for flight on the USAF P-675 pallet.

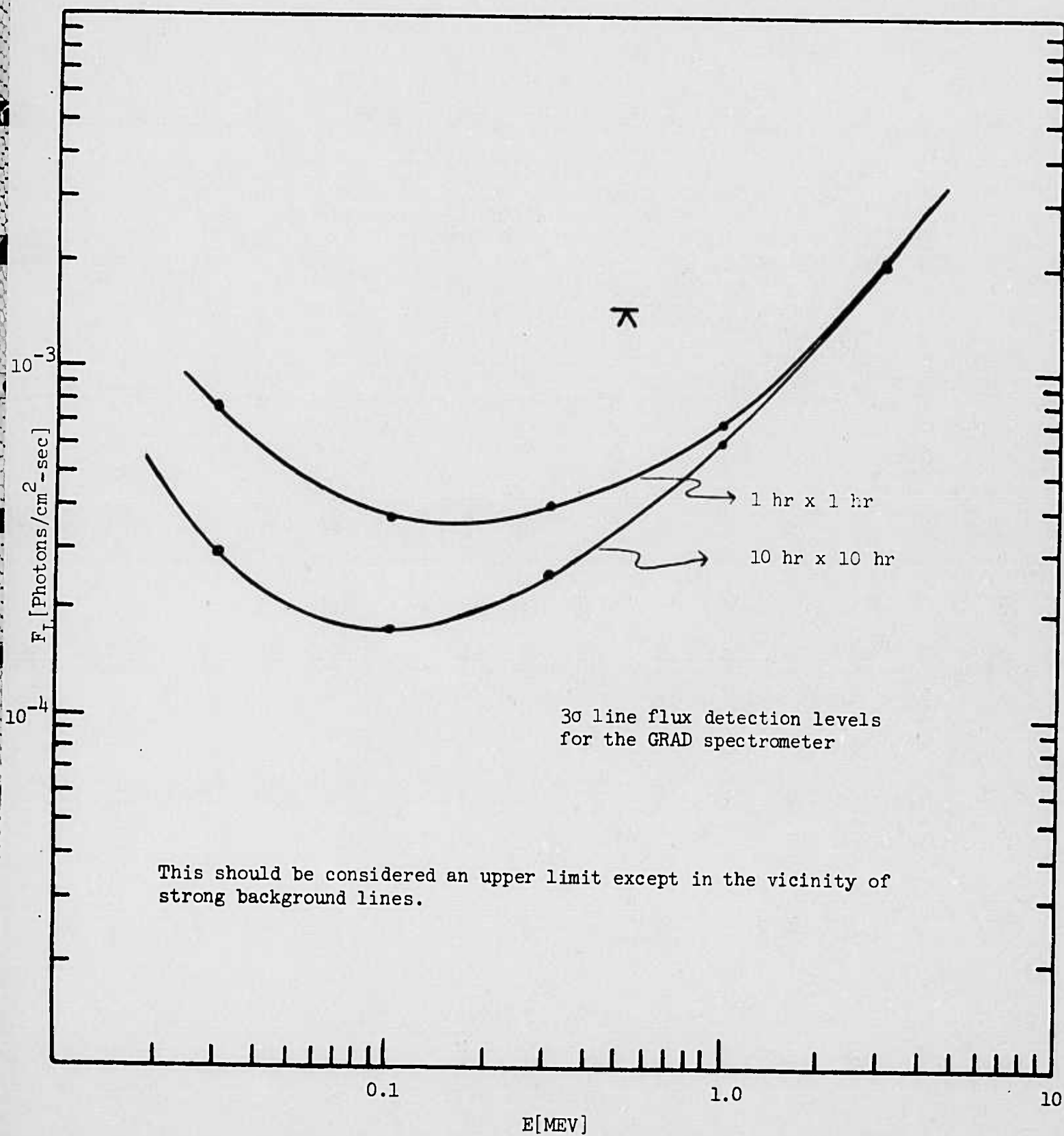


Figure 1

3.2 Modifications Required on Flight Electronics

The present GRAD Flight Electronics Package was designed for interfacing with the OSS-1 ground-linked telemetry system or with a self-contained recorder system for possible operation with reduced mission objectives. These electronics were delivered to SAL in August 1983 for bench testing and subsequently returned to Cedar Rapids for second-pass modifications. Interfacing GRAD with AFP-675 has required extensive changes in the controller microcomputer but not the nuclear electronics. In the new configuration the experiment will be controlled from a Command and Monitoring Panel on the aft flight deck of the Orbiter by an MSE. The GRAD microcomputer has been replaced by a more versatile computer having the capability to handle the more complex operations required for control by a flight crew member. As a result of an engineering study comparing the Rockwell 6502, INTEL 8086 and Motorola 68000 microprocessors, we have selected the 68000 microprocessor and will build at the modular, rather than the chip level.

The greater versatility of the redesigned controller will also permit us to program a "fast" data acquisition mode for better observation of targets of opportunity.

3.3 Loss of Vacuum in the nGe Detector Cryostat

On September 7, 1983 a failure of the vacuum in the germanium detector cryostat occurred. Prior to this failure the detector had been kept at room temperature for about a month while a new check valve was being installed in the nitrogen vent tube. The loss of vacuum appears to have been due to outgassing

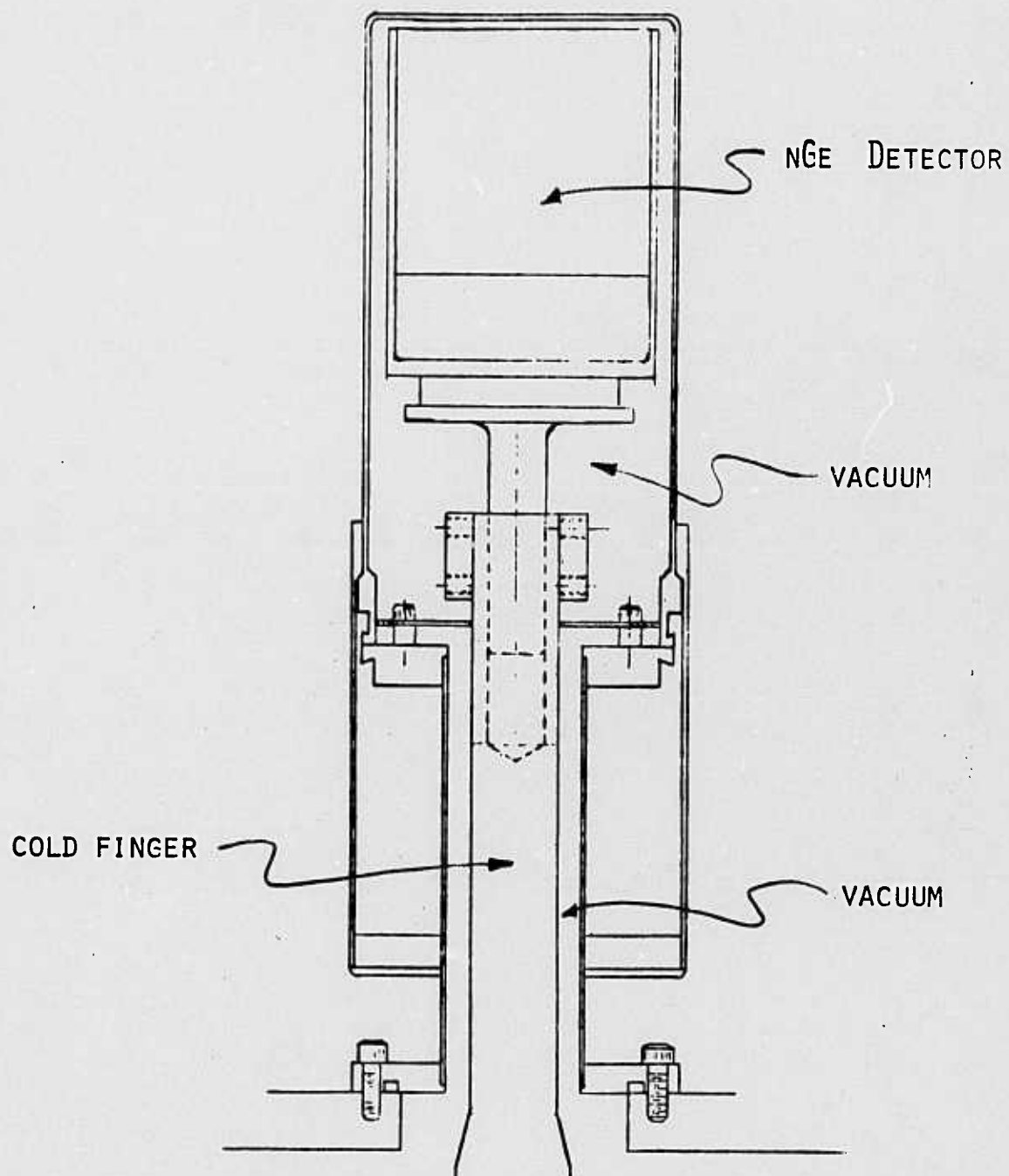
of some material within the cryostat over the month during which it was kept at room temperature.

A vacuum failure in the cryostat is a performance but not a safety problem. (As one can see in Figure 2, the cryostat is that part of the nGe detector housing that fits into the top of the liquid nitrogen dewar.) It causes a substantial, but not catastrophic increase in the liquid nitrogen boiloff rate and the detector becomes inoperable due to contamination of its surfaces. Neither effect would occur in orbit, as the entire system would be under vacuum.

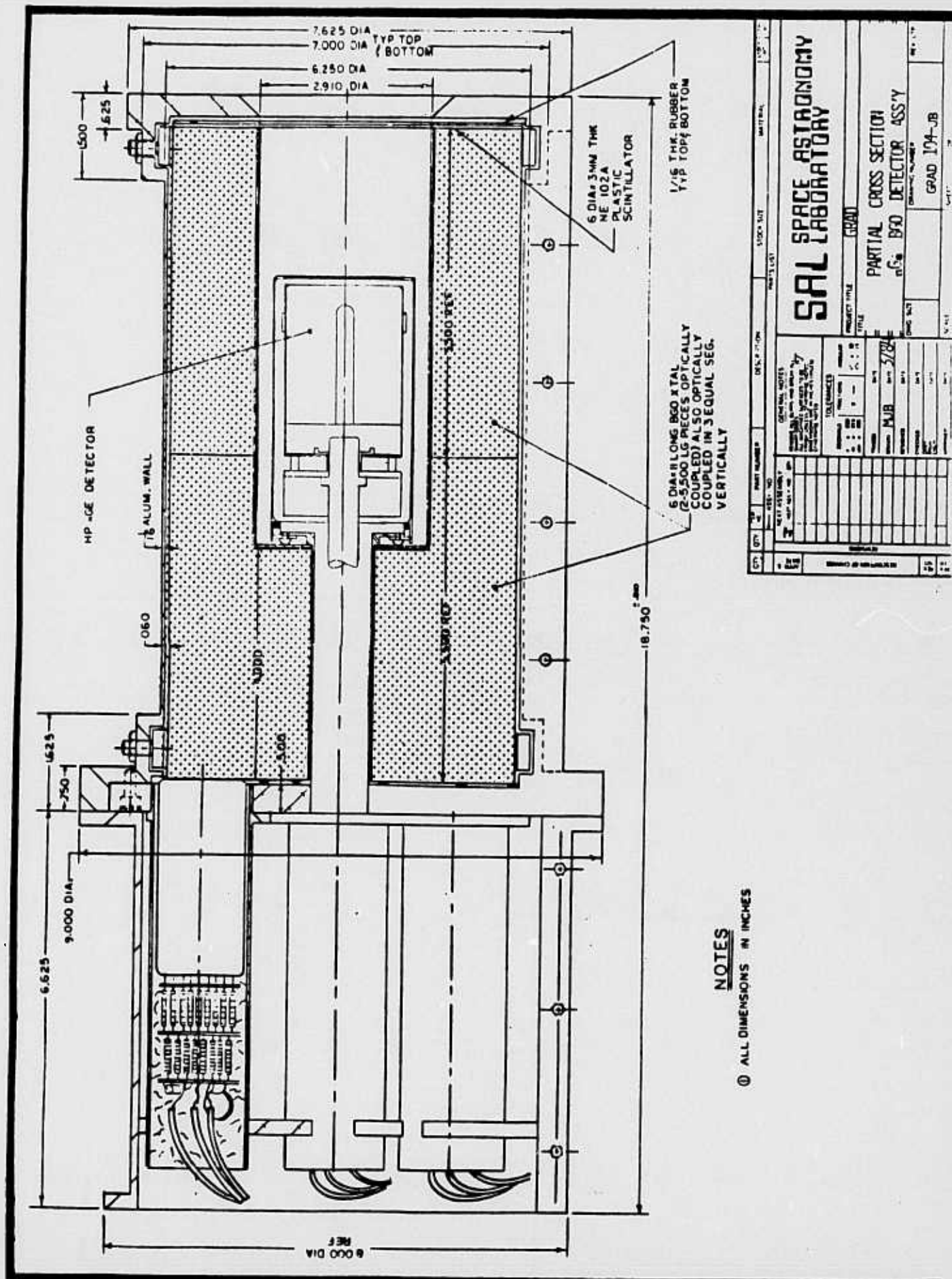
The effect of this vacuum failure on the GRAD project is not expected to be significant; however, such a failure requiring servicing inside the cryostat within 20 days of launch would be a very serious matter. To cover this single-point failure mode, we are therefore budgeting for a backup nGe detector. Other components of the GRAD hardware are already covered. Modular construction of the electronics will permit board-by-board replacement without removal of the electronics unit from the pallet.

Under the assumption that it is not required for substitution of the Flight unit, the backup nGe detector will be used for the accumulation of high-resolution spectra in the postflight measurements at the landing site.

Figure 2. Detail of GRAD nGe Detector Cryostat



* See Figure 2A for updated detail.



4.0 GRAD PROJECT ORGANIZATION

GRAD PROJECT ORGANIZATION

For purposes of planning and management the GRAD project is organized into eight project elements:

- 1.0 GRAD Project Administration
- 2.0 GRAD Project Operations
- 3.0 GRAD Ground Support Equipment and Testing Facilities
- 4.0 GRAD Flight Hardware and Software
- 5.0 GRAD Calibrations
- 6.0 GRAD-to-ESS and -STS Integration Support
- 7.0 GRAD Crystal Sample Package
- 8.0 GRAD Data Reduction and Analysis

GRAD TASKS PLAN

TASK ITEM	COMPLETION DATE DEADLINE
1.0 GRAD Project Administration	
1.1 support technical interchange meetings	as needed
1.2 support experimenter working group meetings	as needed
1.3 support critical design review	4Q2
1.4 support scientific interchanges	as needed
1.5 support professional meetings	as needed
1.6 support DARPA meetings	as needed
1.7 prepare semi-annual reports	as required by AFOSR
1.8 support SAL planning meetings	as needed
1.9 coordinate activities of GRAD personnel	as needed

- 2.0 GRAD Project Operations
 - 2.1 provide input to Lockheed for ICD preparation as needed
 - 2.2 provide input to Lockheed for FORD preparation as needed
 - 2.3 provide input to Lockheed for GORD preparation as needed
 - 2.4 crew training
 - 2.4.1 write GRAD training manuals TBD
 - 2.4.2 provide scientific and technical training at SAL for flight crew candidates TBD
 - 2.5 support operations meetings
 - 2.5.1 ground operation reviews 4Q2
 - 2.5.2 flight operation reviews
 - 2.5.3 technical interchange meetings at launch and landing sites ***dates classified
 - 2.6 support POCC training for experimenters ***dates classified
 - 2.7 support CMP simulator training for PI and Project Manager
 - 2.8 support flight rehearsals and simulations TBD
 - 2.9 support mission operations ***dates classified
- 3.0 GRAD Ground Support Equipment and Testing Facilities
 - 3.1 develop electronic test stand
 - 3.1.1 design and construct test stand completed
 - 3.1.2 formulate design modifications 4Q1
 - 3.1.3 complete test chamber modifications 4Q2
 - 3.2 develop component level vacuum test chamber
 - 3.2.1 design and construct test chamber completed
 - 3.2.2 formulate design modifications 4Q1
 - 3.2.3 complete test chamber modifications 4Q2
 - 3.3 develop ground support equipment for the GRAD
 - 3.3.1 design ground support equipment completed
 - 3.3.2 formulate design modifications for GSE 4Q1
 - 3.3.3 construct and assemble GSE 4Q4
 - 3.3.4 test GSE hardware 4Q4
 - 3.3.5 design GSE and ground test software 4Q2
 - 3.3.6 complete and test GSE software 4Q4

4.0 GRAD Flight Hardware and Software

- 4.1 design and construct dewar detector assembly
 - 4.1.1 design and construct germanium detector assembly completed
 - 4.1.2 design and construct liquid nitrogen dewar completed
 - 4.1.3 design and construct bismuth germanate annulus completed
 - 4.1.4 design decay vetoed calibration probe (DVCP) 4Q1
 - 4.1.5 construct and test DVCP 4Q2
 - 4.1.6 design cryo service panel 4Q1
 - 4.1.7 construct and test cryo service panel 4Q2
 - 4.1.8 design electrical I/F service panel 4Q2
 - 4.1.9 construct and test electrical I/F panel 4Q3
 - 4.1.10 final assembly of the dewar-detector assembly 4Q4
 - 4.1.11 construct (with ORTEC) backup germanium detector 5Q1
- 4.2 design and construct electronic support package
 - 4.2.1 design and construct data acquisition electronics completed
 - 4.2.2 modify design of micro processor controller 4Q1
 - 4.2.3 construct micro processor controller 4Q3
 - 4.2.4 design electronic support package housing 4Q2
 - 4.2.5 construct electronic support package housing 4Q3
 - 4.2.6 assemble electronic support package 4Q4
 - 4.2.7 design and construct wiring harness 4Q4
 - 4.2.8 design controller software 4Q2
 - 4.2.9 complete and test controller software 4Q3
- 4.3 design and construct (with Lockheed) the GRAD-SV interface
 - 4.3.1 determine interface requirements 4Q1
 - 4.3.2 input to Lockheed preliminary specifications 4Q1
 - 4.3.3 input to Lockheed final specifications 4Q2
- 4.4 design, construct and deliver to Lockheed a mass model
 - 4.4.1 input to Lockheed initial GRAD characteristics completed
 - 4.4.2 design and construct mass model 4Q1
 - 4.4.3 deliver mass model to Lockheed 4Q2
- 4.5 design and construct (with Lockheed) mechanical and thermal models
 - 4.5.1 initial mechanical model input to Lockheed completed
 - 4.5.2 initial thermal model input to Lockheed completed
 - 4.5.3 input intermediate mechanical parameters as required
 - 4.5.4 input intermediate thermal parameters as required

4.5.5	input test results and final technical input to Lockheed	5Q1
4.5.6	input final thermal characteristics to Lockheed	5Q1
4.6	GRAD hardware-software testing and burn-in	
4.6.1	subassembly functional tests	4Q3
4.6.2	subassembly thermal vacuum test	4Q3
4.6.3	subassembly vibration tests	4Q3
4.6.4	subassembly load tests	4Q3
4.6.5	subassembly burn-ins	4Q4
4.6.6	GRAD dewar certification	4Q3
4.6.7	GRAD electronics package housing certification	4Q3
4.6.8	GRAD hardware-software functional tests	4Q4
4.6.9	GRAD thermal vacuum tests	4Q4
4.6.10	GRAD vibration tests	4Q4
4.6.11	GRAD load tests	4Q4
4.6.12	final GRAD burn-in	4Q4
5.0	GRAD Calibration	
5.1	preliminary calibrations	
5.1.1	calibration of detector subassemblies	completed
5.1.2	calibration of PAD-ADC-detector subassembly	4Q3
5.2	GRAD calibrations at SAL with radioactive sources	
5.2.1	GRAD energy and efficiency calibrations	5Q1
5.2.2	GRAD compton suppression efficiency calibrations	5Q1
5.2.3	GRAD directionality calibrations	5Q1
5.2.4	GRAD thermal correction coefficients	5Q1
5.3	GRAD calibrations at UF accelerator	
5.3.1	design and construction of GRAD mounting	4Q4
5.3.2	GRAD energy and efficiency calibrations	4Q4
5.3.3	GRAD directionality calibrations	4Q4
6.0	GRAD-to-ESS and -STS Integration Support	
6.1	GRAD integration at Lockheed	***dates classified
6.2	perform post-integration GRAD tests	***dates classified
6.3	attend and support Lockheed tests	***dates classified
6.4	S/V integration at launch site	***dates classified

7.0	GRAD Crystal Sample Packages	
7.1	design and construct crystal sample packages	
7.1.1	flight deck package	4Q2
7.1.2	cargo bay package	completed
7.2	input to Lockheed interface design constraints	4Q1
7.3	design and construct sample package mounting bracket	4Q1
7.4	preparation of counting chambers	
7.4.1	primary facility at ORNL	4Q2
7.4.2	portable facility for landing site	4Q2
7.5	background and calibration measurement	
7.5.1	ORNL measurements	5Q1
7.5.2	landing site measurements	***dates classified
7.6	post-flight activity measurements	
7.6.1	measure sample crystal activation at landing site	***dates classified
7.6.2	measure GRAD/Orbiter activation before de-integration	***dates classified
7.6.3	measure long term activities at ORNL	***dates classified
7.7	dosimetry measurements	
7.7.1	measurements at radiation dosimetry lab, NASA-Johnson Space Center	***dates classified
8.0	GRAD Data Reduction and Analysis	
8.1	GRAD calibration data	
8.1.1	GRAD energy and efficiency data	5Q1
8.1.2	GRAD compton-suppression efficiency data	5Q1
8.1.3	GRAD directionality data	5Q1
8.1.4	GRAD thermal correction coefficients data	5Q1
8.2	crystal background and calibration measurements	5Q1
8.3	preflight crystal activity measurements	5Q2,
8.4	postflight crystal activity measurements	***dates classified
8.5	dosimetry measurements	***dates classified
8.6	flight data	***dates classified

- 8.6.1 experimental gamma-ray spectra
- 8.6.2 calibration spectra
- 8.6.3 housekeeping data

8.7 reporting

- | | |
|-----------------------------|-------------|
| 8.7.1 professional meetings | as required |
| 8.7.2 scientific journals | as required |
| 8.7.3 agency reviews | as required |