71

TAB 71

[redacted]CIV USA AMC

From: [redacted]
Sent: Thursday, May 24, 2001 4:01 PM
To: [redacted]
·bject: RE: M270A1 Safety Release

First off, I need to clarify the terms misused frequently.
A Safety Release is what the Govt test organization, such as ATC/DTC, prepares and issues prior to a major test series that involves the use of troops. Lockheed has very little input except for whatever info is in the Safety Assessment Report, and that is used to help develop the Safety Release. The Safety Release is not really at issue, but is often the term used by folks when they really mean Safety Approval for Materiel Release. This is what I believe Myrick is talking about.

Secondly, again, and what is really at issue, is the Material Release.
The SAR that is currently under the LRIP 3 contract was an attempt to combine the IFCS and ILMS efforts in addition to M270A1 configuration updates in the area of System Safety. All we got approval for was the 450 or so hours to complete it. The wording in the contract suggests a much larger effort than what the 450 or so hours allowed. This is what is at issue. Lockheed cut the hours down, but did not modify the wording in the contract to tailor the effort to the hours. In addition, the safety certification issue came up, and this will require additional hours to satisfy and place the data in the LRIP 3 SAR. The big documentation meeting we had seemed to meld these two issues together, when they should have been handled separately. [redacted] would like to hold Lockheed's feet to the fire and make them submit a SAR that is closer to the wording in the contract, regardless of the hours Lockheed reduced themselves down to. This beefed up SAR is supposedly going to include the new Safety Certification, or Safety Risk Reduction Effort, but Lockheed plans on charging the Govt the extra hours in a new soon to be presented proposal.

›, in a nutshell, yes Lockheed still owes us a SAR, but in order to complete it to the ·tent we need them to, they will send us a bill.
ˌrick believes the contract wording forces them to deliver it without any addtional payments. Realistically, we will pay for it, in my opinion.
The contract currently requires a full blown effort with anyalyses. We are asking Lockheed to perform more under the Risk Reduction Effort that is ongoing, or in some people's opinion, we are asking Lockheed to perform to the level they should. Yes, Lockheed should do it without extra payment, but, realistically they can make a case that the Govt concurred in the original reduced hours.

That's all I know. Kinda confusing, but all I am concerned about is completion of the safety effort, and don't really think I can add anything to a contract disagreement.

I hope this answers it. Let me know if I can assist any further.

[redacted]

-----Original Message-----
From: [redacted]
Sent: Thursday, May 24, 2001 2:11 PM
To: [redacted]
Subject: M270A1 Safety Release

ɟ a meeting today with [redacted] on various issues.

he brought up safety release. I don't believe he really understands where we are today. Based on our Monday discussion, what I understand is that LMMFC can meet the specific contract requirements in the SOW but that they do not have enough hours/money to do as good a job as we desire and do all the analyzes we need to be comfortable.

ɿ you give me a brief lay down of just what the contract requires versus what we are asking ·4FC to do for us?

[redacted]
MLRS Prof Ofc
6-1599

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TAB 72

72A

30 June 2008

MEMORANDUM FOR RECORD

SUBJECT: Discussion with [redacted]

On Monday, 5 May 2008, I had a discussion with retired [redacted] who was MLRS Project Manager at the time the independent Safety Assessment Report (SAR) was performed. He has retired from the Army and currently works for SAIC in Huntsville. [redacted] stated he did not remember the exact timeframes or details, but did remember that Lockheed Martin was required to do a SAR under their contract, but the report was delayed and lacking. As a result, he directed an independent assessment be performed. He said the reports showed the safety danger would be a rare occurrence and would require a combination of mistakes; so they decided the risk was minimal compared to the need to get the system fielded.

The attached memorandum dated 18 Mar 03, Subject: M270A1 Delivery issues, signed by [redacted] is consistent with his recollection of the events to me during our discussion.

Encl
as

[redacted]
Investigative Officer

72B

DEPARTMENT OF THE ARMY
PROGRAM EXECUTIVE OFFICE, TACTICAL MISSILES
5250 MARTIN ROAD
REDSTONE ARSENAL AL 35898-5000

REPLY TO
ATTENTION OF:

SFAE-MSL-PF

18 Mar 03

MEMORANDUM FOR U. S. Army Aviation and Missile Command, MLRS Contracting Office (AMSAM-AC-TM-C[redacted]), 5300 Martin Road, Redstone Arsenal, AL 35898-5000

SUBJECT: M270A1 Delivery Issues

1. Reference your letter to Lockheed Martin, February 12, 2003, giving the contractor a deadline of 19 Mar 03 to resolve issues relating to the outstanding Safety Assessment Report (SAR) FCA Action Item Number 573, the Precision Fires Rocket & Missile Systems (PFRMS) PMO respectfully asks you to extend that deadline to 23 Apr 03.

2. Reference the safety letter to your office, 13 Mar 03, the M270A1 Safety POC states that his office has no safety objections to the continued acceptance of M270A1 launchers. I recognize the Safety Office as the subject matter expert in this area, and consequently feel satisfied their opinion is well researched and sound. My office intends to place a priority on sorting out the other issue brought up by AMCOM Safety, that being non-compliance of the launcher to MIL-PRF-35500. My staff, in conjunction with your staff, is diligently working to come to an equitable solution to this issue, but I believe extra time is needed to do a thorough effort.

3. Given the real-life situation we find our country in, I believe it is essential to continue production flow in order to meet any operational requirements this office is called upon to support.

[redacted]

COL, FA
Project Manager, Precision Fires
Rocket and Missile Systems

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TAB 73

[redacted]Mr CIV USA AMC

From:	[redacted]CIV USA AMC
Sent:	Monday, June 30, 2008 6:07 PM
To:	[redacted] Mr CIV USA AMC
^^:	[redacted]CIV USA AMC
›ject:	RE: The "Other" safety Report (UNCLASSIFIED)
‹achments:	LMMFC - SAR Settlement.doc

Classification: UNCLASSIFIED
Caveats: NONE

[redacted]

There was never a contract issued like we do here in the Acq. Center and I never received a copy of any of the SETA task orders. The PMO directed by[redacted] issued the tasks directly to their SETA contractors and it was only much later when I was informed about this fact by [redacted]. [redacted] gave me a copy with the contractors names and the dollar amount they were paid for their effort. This was the basis for our request stated in the attached letter.

Hope this helps,
[redacted]

-----Original Message-----
From: [redacted] Mr CIV USA AMC
Sent: Monday, June 30, 2008 5:48 PM
To: [redacted]Ms CIV USA AMC
Subject: The "Other" safety Report

[redacted]

‹eep running across references to there being another contractor hired to do the SAR when Lockheed couldn't or wouldn't do it for that period of time. But I have yet to see any reference to a contract. All I have seen is the SRRE report.

[redacted] said that was the other safety report and the contractors were from the SETA support the PM had under contract - and that the SRRE they produced as a combined effort with government people is the only other report.

Is that (or does it sound) right to you?

Thanks

[redacted]
Classification: UNCLASSIFIED
Caveats: NONE

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TAB 74

11 July 2008

MEMORANDUM FOR RECORD

SUBJECT: Meeting with PFRMS Project Office Regarding Investigation

On 17 June 2008, I met with members of the Precision Fires Rocket and Missile Systems (PFRMS) Project Office (formerly MLRS Project Office) including [redacted] to discuss the issues surrounding the Safety Assessment Reports mentioned in the allegations. A summary of the information provided to me in that meeting is as follows:

1. There was no separate contract issued to develop a Safety Assessment Report. This effort was handled by the Safety Risk Reduction Effort (SRRE) Team, which did include support contractor personnel working for the MLRS Project Office, and whose efforts were documented in the "MLRS M270A1 Safety Risk Reduction Effort" Final Report dated January 31, 2002. (A copy of that report was furnished to me by [redacted])

2. The Conditional Materiel Release for the M270A1 was signed by MG Dodgen, Commander, U.S. Army Aviation and Missile Command, in February 2002.

3. [redacted] stated he was not aware of any safety incidents in the field associated with uncommanded cage movement.

4. [redacted] stated he would provide Reliability Data for the M270A1. (Information provided by email on 17 June 2008).

[redacted]
Investigative Officer

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TAB 75

MLRS M270A1 Safety Risk Reduction Effort

Final Report

January 31, 2002

EXECUTIVE SUMMARY

Background - A background summary of the "Safety Risk Reduction Effort" (SRRE) is provided to summarize why the SRRE team was initiated and to address the team's roles/responsibility. The team was established to define the safety criteria, identify areas of consideration, and perform tests to evaluate the launcher safety environment. The premise is that the launcher became unstable, resulting in uncontrolled launcher movement. Since the prime contractor would not certify the M270A1 weapon system to be a safe platform, then the only government option was to perform limited analysis and testing to ascertain its safety condition.

Objective - The objective of the SRRE teams was to identify any hazardous conditions resulting from the launcher's attributes.

Approach - The approach was to evaluate how the launcher responds under certain conditions. An event was specified to create the desired condition, looking at how the launcher responds and not focusing on how the condition was created.

Results - There were ground rules established, which are identified in the report, so the effort can be bound and accomplished within the specified time period. The team focused on two primary areas, which are launcher movement and munition firing.

> **Launcher Movement** - The analysis, testing, and data reduction identified a design deficiency which allowed uncontrolled cage movement when the inner and outer control loops were interrupted. When this condition occurred, the only means of stopping cage motion was with the emergency stop functions (i.e. overspeed and damage zones). Another second deficiency was hanging commands left active (i.e. Boom command remained active with 4.5 S/W when the kill switch was used to stop launcher but the engineering release of

5.0 S/W corrected this specific problem – ***How about others not found?***) It was determined that the system kill switch as implemented will not stop cage movement in all modes.

Munition Firing - During this SRRE effort, one test created a condition that allowed an "Ok to Fired" function to be reported incorrectly, thereby allowing the system to fire a rocket outside of the + 3 mil safety window.

Having identified these problems, the SRRE team evaluated them in accordance with the definition of a safe launcher.

Conclusion - The SRRE team has identified some design deficiencies that should be addressed prior to fielding the M270A1 weapon system, thereby assuring that known launcher safety environments are satisfied.

SRRE

Final

Report

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1.0 Background - A background summary of the "Safety Risk Reduction Effort" (SRRE) is provided to set the stage for the understanding of this report. The SRRE team's roles/responsibilities, goal/objective, ground rules and approach identifies the basic condition/constraints applicable to this report.

The initial SRRE meeting was conducted on 18 May 01 to establish a government/support contractor team for defining the safety criteria for fielding the M270A1 weapon system and to evaluate the system to these safety criteria. Two team leaders were identified to ensure full coverage throughout the SRRE process. Team members were added as specific tasks were identified and defined. The prime contractor (LM) was invited to actively participate, but only agreed to respond to questions generated by the team.

The premise was that the launcher became unstable resulting in uncontrolled movement rather than an input from some foreign source causing the cage movement. This premise led the team to focus on the system control loops ("inner" and "outer"). In the beginning it was obvious that the team must answer this question, "What is a safe launcher?" In order to answer this question the elements that contribute to a safe launcher must be identified, and they are:

- A launcher operates safely when it knows and executes valid commands for cage movement and firing operations.
- A single failure will not cause a safety critical condition.
- The FCS monitors operations in real time and knows the **truth**.
- The FCS shuts operations down when unsafe conditions are present.

The LM Uncommanded Root Cause Report was reviewed during this effort to determine what the prime contractor had done and to understand their conclusions. In summary, their conclusions were that the launcher works **as designed** in all aspects of operations.

It was imperative that the SRRE team understands how the launcher responds under specific conditions so that a safety statement could be written prior to fielding. The safety statement will be based upon the results of this SRRE team's findings. A complete safety analysis will not be performed (Reference Ground Rules 2 & 5). Be advised that the mechanical, electrical, and thermal safety factors will not be addressed since they were already considered and implemented during the design phase.

2.0 Goal/Objective of M270A1 Risk Reduction Effort - The objective of the SRRE was to identify an acceptable level of risk in support of fielding the tactical configuration of the M270A1 Launcher through a "tailored" safety analysis, assessment, and test effort.

3.0 Ground Rules – The SRRE team identified five ground rules which were used to minimize the effort but still bound the task. The ground rules were:

1. A Risk Reduction Effort (RRE) will be conducted in lieu of a full Safety Certification. The difference is that the RRE was tailored to address only those hazards as described in section 3.2 to achieve a minimum level of acceptable safety risk to support a fielding decision.

2. The RRE addresses only personnel safety and rocket firing safety issues with a Catastrophic or Critical (Cat I and Cat II) Hazard potential. Only those hazards directly

related to LLM Movement and Firing Operations during operation and maintenance would be considered under the RRE.

3. No hardware damage or loss of mission issues would be included in the RRE.

4. Applicable Single Point Failures (SPFs) would be highlighted for resolution, but applicable hazards with multiple failure modes will be identified for discussion and possible resolution after an impact assessment is made by the team. Of these hazards resulting from multiple failure modes, if the failure mode is undetected by the system, regardless of the number of failure modes assessed, it will be treated as a SPF for resolution.

5. The time frame for conducting this RRE does not allow for a quantitative assessment of probability for applicable Cat I and Cat II hazards. A determination of probability based on qualitative assessment, using MIL-STD-882 as a guide, would be utilized and be rooted in sound engineering judgment and experience individually or as a team where appropriate.

4.0 Approach - After much discussion and several ideas, the team agreed to approach the evaluation from a three-fold condition:

- To set the launcher into a condition to evaluate launcher response.
- To observe how the launcher responds to the "event".
- Not to be concerned with how the event is created.

In order to evaluate the response of the launcher, the SRRE team had to define a method of approach. The sequence of events were to:

- Obtain documentation
- Review specific subsystem designs
- Identify test scenarios
- Write detailed test procedures
- Define and fabricate test tools
- Identify instrumentation requirements

This approach allowed the team to insert an event into the launcher with the test tool and to measure the launcher's response through the instrumentation system. By understanding the test, the expected result, and reducing and analyzing the data, the SRRE team would be able to understand the launcher's response as a function of the as **designed** launcher. This information would then allow the SRRE team to accomplish a system assessment based upon how the launcher responds under controlled specified conditions. A detailed schedule was developed as tasks were defined and an appropriate level-of-person was assigned the responsibility to complete the task in accordance with the detailed schedule, Figure 4-1.

SRRE Schedule

#	Task Name	Start	End
1	SRRE Schedule	07/18/2001	07/31/2001
2	VME Bus Monitor	07/03/2001	08/15/2001
3	VME Insertion Tool	07/30/2001	10/22/2001
4	WLULU Cover Redesign	07/17/2001	08/15/2001
5	Mfg WLULU Covers/Cables	08/15/2001	09/14/2001
6	Develop Method for Event Insertion (OB)	07/24/2001	10/22/2001
7	Develop Instrumentation Plan	07/03/2001	08/01/2001
8	Generate Simplified CCA Drawings	07/24/2001	08/08/2001
9	Generate Scenarios	07/03/2001	08/16/2001
10	Generate Simplified Munition Circuits	08/05/2001	08/24/2001
11	PNU Assessment Plan	07/11/2001	08/31/2001
12	Write Test Procedures	08/15/2001	09/28/2001
13	Define Test Support Hardware	08/15/2001	08/16/2001
14	GPS Support	07/18/2001	10/01/2001
15	All Defined Hardware at Test Site	10/01/2001	10/02/2001
16	Assemble and Conduct Baseline Tests	10/02/2001	10/08/2001
17	Interface Test Tools	10/08/2001	10/22/2001
18	SRRE Testing	10/08/2001	12/31/2001
19	Evaluate Test Data	10/22/2001	01/15/2002
20	Write Report	12/03/2001	01/15/2002

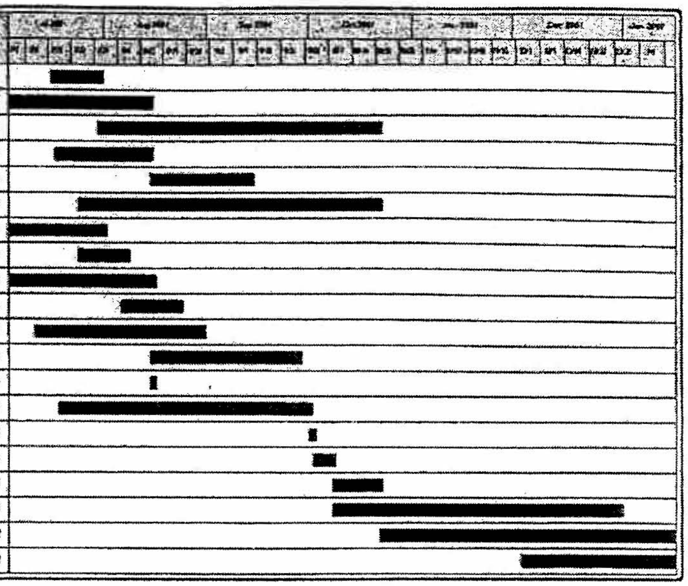

Figure 4-1

The SRRE approach to testing was to write sufficient detailed test procedures for each test condition using the scenarios, which are included as Appendix 2. A detailed procedure provides the structure for controlling the sequence of execution and a means for duplicating the test if a rerun is required. From a data analysis position, the SRRE team performed sufficient testing to verify the premise and reduced/analyzed sufficient data to validate that the premise is **truth**.

4.1 General - Operating within the tailored constraints of the established Ground Rules and Goal/Objective of the RRE, it was agreed by the SRRE team that a simplified and logical top level functional division of the M270A1 system, driven but not defined by undesirable safety events, be established for this effort to further the analysis and assessment. Major functional areas were used as a basic road map to operate under, and would be used as a guideline to continue the detailed RRE analysis and assessment while keeping the safety ground rules in perspective. This differs from a Fault Tree Analysis, which considers a specific failure as an undesirable event. Instead, the team used an overall major function of the launcher where all anticipated and applicable identified safety hazards to be assessed could be categorized, evaluated and addressed, as specifically related to that function. The report divides the task into two major subsystems: LLM cage movement and firing operations.

4.1.1 LLM Cage Movement – The cage movement was the major concern for creating a personnel hazard condition, therefore the major SRRE team effort will focus on this area. Scenarios 1 - 4, 7 and 8 address functions that affect control and monitoring of the cage. The intent was to insert an event into the launcher design and determine the effects on launcher movement. This allowed the SRRE team to assess the **as designed** launcher to determine the safety condition of the M270A1 weapon system. The scenario provided a summary of the affected element, the method of insertion, the duration of the event, any special instructions, and the desired response of the launcher.

4.1.2 Munition Functions – The approach to evaluating the munition firing circuit was to insert events into the system and evaluate how the system responded. Scenario 5 and 6 were written to exercise these circuits, thereby providing data to evaluate these circuits at the system level. One scenario addresses the SNVT operation and the other scenario addresses the firing operation function.

4.2 Tools - There were six tools, which were identified as being needed to support the Safety Risk Reduction Effort. The tools used in the testing included the Gunter Box, SNVT Box, PNU Box, pulse generator, oscilloscope, and a GPS signal repeater. The specially designed boxes (Gunter Box, SNVT Box, and PNU Box) have unique functions and their characteristics will be described in the following sections.

4.2.1 Gunter Box (GB) - Engineers designed the Gunter Box (GB) circuitry to perform two basic functions: 1) interrupt signals, 2) insert commands into the control loop. The Research Development and Engineering Organization at Redstone Arsenal manufactured the Box. Upon completion of manufacturing, all circuitry was tested for consistency to the original design. The Box was powered up to allow current to pass through all circuitry. Finally, the GB was interfaced into to the launcher. Various baseline missions (reload and fire missions) were run on the launcher to verify that the Gunter Box didn't interfere with normal launcher performance. The GB was used to either interrupt or insert a fault into the mechanical or hydraulic controls on the M270A1 launcher. Events were inserted into the drive signals from the LIU to the azimuth and elevation motors, yoke resolvers, shaft resolvers, and azimuth and elevation LLM resolvers. Figure 4-2 provides a block diagram of the interface between GB, Fire Control System, and the Data Acquisition System.

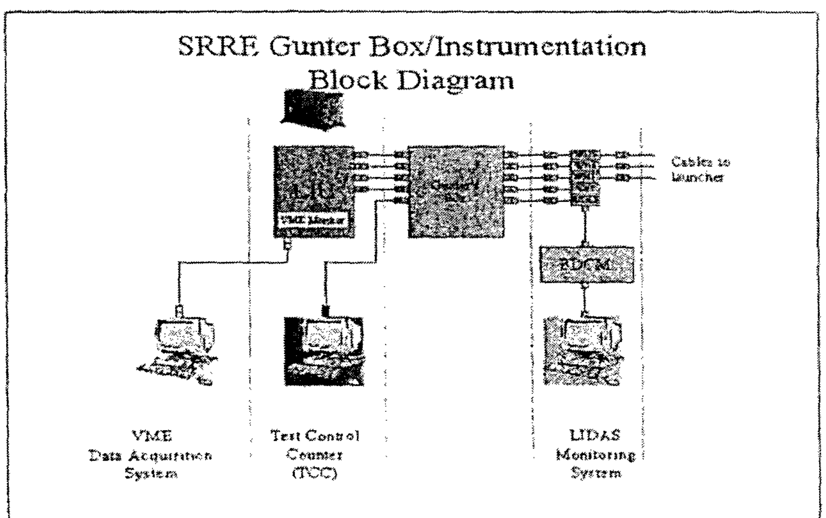

Figure 4-2

4.2.2 SNVT Box - Engineers designed the SNVT Box circuitry to perform two basic functions: 1) to interrupt the squib signal lines to the weapon system and 2) to monitor signals for HANGFIRE, MISFIRE, and SNVT conditions. The Research Development and Engineering Center at Redstone Arsenal manufactured the Box. Upon completion of manufacturing, all circuitry was tested for consistency to the original design. The Box was powered up to allow current to pass through all circuitry. When the SNVT Box was connected to the launcher, baseline missions (reload and fire missions) were run on the launcher to ensure that the SNVT Box didn't interfere with the launcher's normal performance. The SNVT Box was used to interrupt and/or monitor squib pulses going from the WIU to the weapon. The amplitude of the squib current pulses were measured, along with the number of pulses that are required in order to cause a hang fire or misfire. The SNVT box also checked out the test capabilities of the SNVT drive circuitry in the WIU; the three tests that the SNVT functions perform were verified.

4.2.3 PNU Box - Safety Risk Reduction Effort Engineers designed the PNU Box circuitry. The Research Development and Engineering Center at Redstone Arsenal manufactured the Box. Upon completion of manufacturing, all circuitry was tested for consistency to the original design. The Box was powered up to allow current to pass through all circuitry. When the PNU Box was connected to the launcher, various baseline missions (reload and fire missions) were run on the launcher to ensure that the PNU Box didn't interfere with normal launcher performance. The PNU Box was used to input false odometer readings into the Position Navigation Unit in order that launcher response to such false or incorrect operating conditions might be analyzed. The box also allowed for direct measurement of the odometer pulses independently of the PNU.

4.2.4 Pulse Generator - The Pulse Generator was a commercial off the shelf system that was used to insert various pulses of current into the launcher's control loop in order to create abnormal conditions. This device was used to vary the pulse width and magnitude of the input pulse.

4.2.5 Oscilloscope - The Oscilloscope was a commercial off the shelf system that was used to measure current to the servo coils and other parts of the launcher. This device allowed team members the ability to measure the voltage and current required to generate launcher action. Team members also gained a more precise understanding of how the M270A1 design functioned.

4.2.6 GPS Signal Repeater – The GPS Signal Repeater was primarily used to support the PNU testing. It was a commercial off-the-shelf system that was used to capture a GPS satellite signal from outside the building and repeat the signal inside the building to support launcher operation tests. The purpose of the GPS signal repeater was to provide accurate position information to the Launcher FCS when the tests were performed.

4.3 Instrumentation – The instrumentation data acquisition system for the SRRE team's purpose is defined as a method of monitoring and simultaneous recording of a diverse set of data buses located on an M270A1 launcher. The Instrumentation system used for data acquisition during testing consisted of three components: LIDAS, the Test Control

Counter (TCC), and a VME bus analyzer. Baseline tests were performed in order to assure that normal launcher performance was not affected by the installation of instrumentation equipment. Tests were performed after the launcher was fully equipped with LIDAS, the Test Control Counter, and a VME bus analyzer. These systems collected the data from each test in order that it could be reduced and analyzed. Refer back to Figure 4-2 to see the block diagram of the data acquisition system.

4.3.1 LIDAS – The LIDAS is the standard M270A1 data acquisition system that has been used and validated as an official MLRS instrument. It was used during SRRE to monitor and record launcher response to the various tests that were performed. This instrumentation system collects data through specialized interface devices. This data is then recorded to an MSD (mass storage device) in the launcher cab. To use the data, it can be removed from the launcher and translated with the use of Inter-Coastal Electronics Software. Once data is translated it can be reduced, analyzed, or plotted for graphical representation. LIDAS data was monitored in real time in order to provide real time information to test conductor pertaining to the launcher's state of control. LIDAS installation, use, and data manuals are available upon request.

4.3.2 Test Control Counter (TCC) - The Test Control Counter was used as an aid for LIDAS. The TCC was a software program written by SRRE engineers to identify the beginning and end of each test and was interfaced to the LIDAS system. A standard laptop was used that interfaced with the WEP LIDAS Box. This data identified the test number, scenario, and visible cage response to the insertion of abnormal events. Data was collected and stored with other LIDAS data in the MSD. The TCC decreased the time for data analysis and reduction.

4.3.3 VME Bus Analyzer - The VME bus analyzer is a monitoring system that enabled data to be collected from the LIU and stored on a computer for reduction and analysis. The analyzer was mounted in the LIU VME card cage. It collected all data that went across the VME bus. This gave the test engineers the ability to verify LIDAS data and record any data that LIDAS may not have collected. A 1/3 height VME extender card was required, with the P2 connector disconnected electrically, to separate the COTS VME analyzer from the 24Vdc on the LIU VME P2 connecter that would damage the VME monitor. The VME Bus Analyzer was connected to a standard laptop computer, which was running bus analyzer software. The software allowed for collection of data for analysis and reduction.

4.4 Type of Data Collected - VME and LIDAS data were collected. The reduced data files were stored in comma-delimited text format (commonly called Comma Separated Values (CSV) format in database terminology), which may be viewed or printed using any Windows word processing, spreadsheet, or database management program preferred by the user. The data was organized and categorized by scenario, test number and the date the test was performed. The data was then stored on electronic media for ease of use and retrieval.

4.5 Scenarios - Since the SRRE team's approach was to look at the behavior of the launcher's response, when an event is applied, eight scenarios were generated identifying many tests. Appendix 1 provides the details for each scenario.

4.5.1 Scenario 1 - This scenario establishes a reload-right condition with many test events to be inserted. The objective was to observe/evaluate launcher response to these given conditions at the reload condition while in a static condition.

4.5.2 Scenario 2 - This scenario establishes a fire mission condition with many test events to be inserted. The objective was to observe/evaluate launcher response to these given conditions at the aimpoint in a static condition.

4.5.3 Scenario 3 - This scenario objective was to observe/evaluate the launcher's response (when an event is inserted during the movement from stow to reload right/left).

4.5.4 Scenario 4 - This scenario objective was to observe/evaluate the launcher's response when an event is inserted during the movement from stow to aimpoint.

4.5.5 Scenario 5 - This scenario objective was to observe/evaluate the SNVT response to an event being inserted during a SNVT test.

4.5.6 Scenario 6 - This scenario objective was to observe/evaluate the launcher's response to a Hangfire or Misfire event being inserted into the firing circuits during a 12 round ripple firing.

4.5.7 Scenario 7 - This scenario objective was to observe/evaluate the launcher's response when an event was inserted into the PNU.

4.5.8 Scenario 8 - This scenario's objective was to exercise the launcher by selecting uncommon options available to the operator to determine if the launcher allows itself to get into an undesirable condition that would be considered a safety hazard to personnel. As these tests were performed, the path taken was documented to insure that the conditions could be repeated if an abnormal event occurred.

5.0 Testing - The Safety Risk Reduction Effort started by gaining access to an M270A1 launcher in order that testing could be performed to evaluate how the M270A1 launcher responds to the insertion of abnormal events. The launcher was delivered to Redstone Arsenal in September of 2001 and testing began October 1, 2001. As a result of testing, data collection, data reduction, and analysis, the launcher could be evaluated from a personnel safety perspective. The Test Conductor controlled all testing, assured that test procedures were followed, and that data was collected in a consistent systematic method. The Test Conductor also assured that all tools and instrumentation data acquisition system including the VME instrumentation system were operating properly before beginning any test. SRRE team members began testing using version 4.5 OT software; however testing was completed using an engineering release of version 5.0 software. The prime contractor was encouraged to participate in defining and performing the tests that would be conducted, but declined. Their (prime contractor) only input to this analysis was to answer questions that were generated by the Safety Risk Reduction Effort team members.

5.1 General Testing Approach - The SRRE approach identified various scenarios that set conditions in which test events could be inserted in order to examine launcher response and develop a "measure" of safety for the M270A1 launcher. Test procedures were written with a large amount of detail so that each test could be repeated exactly the same way every time it was executed. Several tool sets were designed, constructed, tested, and used to allow a method of event insertion into the launcher. The test tools' designs and interfaces to the launcher were a key factor for the success of this SRRE effort. The launcher was instrumented with a VME Bus Analyzer and LIDAS to record the launcher response as malfunction occurs. The data acquisition system was used to collect and record all the data required for evaluating launcher response to the event inserted into the weapon system. After testing began it became obvious that all tests identified did not need to be executed. Those tests not run will be noted in each scenario (See Appendix 1). As the data was reduced it was presented to and discussed with the government and prime contractor.

5.2 Baseline Tests - Tests were performed in order to establish a "baseline" before any "abnormal" testing began. These tests consisted of normal routine operations in which SRRE team members could measure launcher performance under normal conditions (no faults inserted). Data was captured and reduced in order to establish a basis for comparison in the upcoming tests. Baseline Tests were performed for each specific scenario for which a test was performed. The baseline testing confirmed that launcher 1002 was in working order and acceptable for SRRE testing. Baseline testing also gave SRRE team members a basis for comparing the launcher under normal operating conditions versus abnormal condition.

5.3 Scenario/Test - Testing scenarios consisted of two types of tests: 1) interruption of launcher signals and 2) inserting a signal into the launcher that could have an effect on its control system. Test scenarios were established in order to set operating conditions and constraints under which the test procedure would be written and performed. Some scenarios involved static launcher conditions while others were dynamic. Various scenarios were written and executed to verify the launchers state of control during abnormal conditions. As testing began safety team members started to understand more about the M270A1. The result of this increased knowledge was the realization that not all scenarios that had been written would impact the launcher control system; therefore, some scenarios were not performed during launcher testing.

5.3.1 Testing Scenario 1 -Test Scenario 1 established the criteria in which procedures could be written in order to perform the corresponding tests. This scenario establishes a reload-right condition with many test events to be inserted. The objective was to observe/evaluate launcher response to these given conditions at the reload condition while in a static condition. Test scenario 1 - LLM Motor functions with malfunctions or events inserted into the launcher while the launcher is in or at a hold mode at 1600 mils in azimuth and 300 mils in elevation to determine system response. The LLM was positioned to an aim point using fire mission data.

Test Scenario 1 was not performed. After developing the test scenario the safety team found that the launcher's brakes were applied while the launcher was at a hold mode; that is the LLM cage could never move with the brakes on. Therefore, the **as design** prevented the testing of this scenario.

5.3.2 Testing Scenario 2 - Test Scenario 2 established the criteria in which procedures could be written in order to perform the corresponding tests. Scenario 2 differed from 1 in that the boom control menu was going to be used to achieve test position. The objective was to observe/evaluate launcher response to these given conditions at the reload point in a static condition. Test Scenario 2 - LLM Motor Functions with malfunctions or events inserted into the launcher while the launcher is in or at a hold mode at 1600 mils in azimuth and 300 mils in Elevation to determine system response. Command LLM to test position with boom controller menu (reload right).

Test Scenario 2 was not performed. After developing the test scenario the safety team found that the launcher's brakes were applied while the launcher was at a hold mode; that is the LLM cage could never move with the brakes on. Therefore, the **as design** prevented the testing of this scenario.

5.3.3 Testing Scenario 3 - Test Scenario 3 established the criteria in which procedures could be written in order to perform the corresponding tests. This scenario objective was to observe/evaluate the launcher's response when an event is inserted during the movement from stow to reload right/left. Test scenario 3 – performed LLM Motor Function Dynamic Tests; while positioning the LLM to test position (reload right) via Reload Menu and insert event into system during motion to reload position or as directed by procedure.

After writing the test procedures for scenario 3, tests were performed on the M270A1 launcher, while interrupting or inserting various events into the launcher.

5.3.3.1 Scenario 3 Test 3 - The purpose of this test was to see how the launcher responds to opening the AZ servo coil. Commands were issued across the VME bus through the LDS card to energize servo coils to control servo valves, which provide force for cage motion. The servo coil is an integral part of the control system on the launcher, therefore the expected response is that the launcher design would recognize a lack of control and terminate launcher movement without using the emergency shut down function.

The first event consisted of opening the AZ servo coils, preventing current from flowing to the coils. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.2 Scenario 3 Test 6 - The purpose of this test was to see how the launcher responds to opening the EL servo coil. Commands are issued across the VME bus through the LDS card to energize servo coils to control servo valves, which provide force for cage motion. The servo coil is an integral part of the control system on the launcher, therefore the expected response is that the launcher design would recognize a lack of control and terminate launcher movement without using the emergency shut down function.

Test 6 was the same as test 3 only the EL servo coils were opened as opposed to the AZ servo coils. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.3 Scenario 3 Test 9 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Shaft Resolver. The shaft resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 9 opened the AZ resolver excitation. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.4 Scenario 3 Test 12 - The purpose of this test was to see how the launcher responds to opening the AZ sine resolver function. The AZ sine resolver function is an input to the LDS card from the AZ shaft resolver. The sine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 12 opened the AZ sine resolver function. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.5 Scenario 3 Test 15 - The purpose of this test was to see how the launcher responds to opening the AZ cosine resolver function. The AZ cosine resolver function is an input to the LDS card from the AZ shaft resolver. The cosine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 15 was similar to test 12. The test opened the AZ cosine resolver function. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.6 Scenario 3 Test 18 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Shaft Resolver. The EL shaft resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 18 opened the launchers EL resolver excitation, a test similar to test 9. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.7 Scenario 3 Test 21 - The purpose of this test was to see how the launcher responds to opening the EL sine resolver function. The EL sine resolver function is an input to the LDS card from the EL shaft resolver. The sine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 21 opened the launchers EL sine resolver function. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.8 Scenario 3 Test 24 - The purpose of this test was to see how the launcher responds to opening the EL cosine resolver function. The EL cosine resolver function is an input to the LDS card from the EL shaft resolver. The cosine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 24 opened the launchers EL cosine resolver function. This resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.9 Scenario 3 Tests 25 – 27 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ yoke coil while the launcher was moving in the clockwise direction to the reload right position.

Test 25 through 27 used the Gunter Box and signal generator to input 1, 2, and 3-milliamp pulses into the AZ yoke coil in a clockwise direction. Test 25 inserted a 1 milliamp pulse through the Gunter Box into the AZ yoke. No disruption was noticed in cage movement and the system maintained control until the design margin is exceeded. Test 26 inserted 2 milliamps through the Gunter Box into the AZ yoke. The cage speed increased in the clockwise direction, then recovered. The launcher appeared to regain control. Test 27 inserted a 3-milliamp pulse through the Gunter Box into the AZ yoke coil and the launcher came to an abrupt stop, probably caused by an over speed condition. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.10 Scenario 3 Tests 28 – 30 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ yoke coil while the launcher was moving in the counter clockwise direction to the reload left position.

Test 28 through 30 used the Gunter Box and signal generator to input 1, 2, and 3-milliamp pulses into the AZ yoke coil in a counter clockwise direction. Test 28 inserted a 1 milliamp pulse through the Gunter Box into the AZ yoke. There was a small reduction in cage speed, launcher recovered, and the system maintained control until the design margin was exceeded. Test 27 inserted 2 milliamps through the Gunter Box into the AZ yoke. The cage speed decreased in the counter clockwise direction, then recovered. The launcher appeared to regain control. Test 28 inserted a 3-milliamp pulse through the Gunter Box into the AZ yoke coil and the launcher experienced a drastic decrease in speed and then recovered.

5.3.3.11 Scenario 3 Tests 31 – 33 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the EL yoke coil while the launcher was ascending out of the stow position.

Test 31 through 33 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp pulses into the EL yoke coil while cage was ascending out of stowed position. Test 31 inserted 3 milliamps through the Gunter Box into the EL yoke. There was a small reduction in cage speed, launcher recovered, and the system maintained control until the design margin was exceeded. Test 32 inserted 6 milliamps through the Gunter Box into the EL yoke. The cage stopped moving in the upward direction and then recovered. The launcher appeared to regain control. Test 33 inserted a 9-milliamp pulse through the Gunter Box into the EL yoke coil and the launcher stopped, reversed direction (went down), and then recovered.

5.3.3.12 Scenario 3 Tests 34 – 36 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the EL yoke coil while the launcher was descending into the stow position.

Test 34 through 36 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp pulses into the EL yoke coil while cage was descending into the stow position. Test 34 inserted 3 milliamps through the Gunter Box into the EL yoke coil and no noticeable affect on the launcher occurred. Test 35 inserted 6 milliamps through the Gunter Box into the EL yoke coil and the cage experienced one jerk/bump down and then recovered. Test 36 inserted a 9-milliamp pulse through the Gunter Box into the EL yoke coil and the launcher jerked/bumped downward 4 times and then recovered.

5.3.3.13 Scenario 3 Tests 37 – 39 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ & EL yoke coils while the launcher was proceeding from reload left to the stow position in a clockwise upward direction.

Test 37 through 39 used the Gunter Box and signal generator to input 2, 4, and 6-milliamp pulses into the AZ & EL yoke coils while cage was proceeding from reload left to the stow position in a clockwise upward direction. Test 37 inserted 2 milliamps through the Gunter Box into the AZ & EL yoke coils and a small disruption (wiggle) in the cage movement occurred and then the launcher recovered. Test 38 inserted 4 milliamps through the Gunter Box into the AZ & EL yoke coils and a small disruption (wiggle) in the cage movement occurred and then the launcher recovered. Test 39 inserted a 9-milliamp pulse through the Gunter Box into the AZ & EL yoke coils and a larger disruption (more wiggle) occurred in the cage movement and then the launcher recovered.

5.3.3.14 Scenario 3 Tests 40 – 42 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ & EL yoke coils while the launcher was proceeding from stow to the reload left position in a counter clockwise downward direction.

Test 40 through 42 used the Gunter Box and signal generator to input 2, 4, and 6-milliamp pulses into the AZ & EL yoke coils while cage was proceeding from stow to the reload left position in a counter clockwise downward direction. Test 40 inserted 2 milliamps through the Gunter Box into the AZ & EL yoke coils and a small disruption (wiggle) in the cage movement occurred and then the launcher recovered. Test 41 inserted 4 milliamps through the Gunter Box into the AZ & EL yoke coils and the cage appeared to slow down, speed up, and then jerk to a stop. Test 42 inserted a 9-milliamp pulse through the Gunter Box into the AZ & EL yoke coils and the cage appeared to slow down, speed up, and then jerk to a stop.

5.3.3.15 Scenario 3 Tests 43 – 54 - The purpose of these tests was to insert a VME command into the servo coil. These events were an attempt to see how the launcher system responds to commands that appear on the VME BUS. In the process of running the insertion tests using the Gunter Box it was concluded that the VME insertion tests were not necessary or would not cause the launcher to respond any different than when the insertion was performed with the Gunter Box.

5.3.3.16 Scenario 3 Tests 55 – 57 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ yoke coil while the LLM was proceeding clockwise using boom controller.

Test 55 through 57 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp pulses into the AZ yoke coil while LLM was in boom control mode and moving in a clockwise direction. Test 55 inserted 3 milliamps through the Gunter Box into the AZ yoke coil and a small disruption (slowed then sped up) in the cage movement occurred and then the launcher recovered. Test 56 inserted 6 milliamps through the Gunter Box into the AZ yoke coil and the cage appeared to slow down, speed up, and then jerk to a stop. Test 57 wasn't performed. After the 6 milliamps stopped the LLM movement a 9-milliamp insertion was not necessary as the threshold had already been determined.

5.3.3.17 Scenario 3 Tests 58 – 60 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the AZ yoke coil while the LLM was proceeding counter clockwise using boom controller.

Test 58 through 60 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp analog pulses into the AZ yoke coil while LLM was in boom control mode and moving in a counter clockwise direction. Test 58 inserted 3 milliamps through the Gunter Box into the AZ yoke coil and a small disruption (slowed then sped up) in the cage movement occurred and then the launcher recovered. Test 59 inserted 6 milliamps through the Gunter Box into the AZ yoke coil and the LLM appeared to reverse direction, and then recover. Test 60 specified inserting a 9-milliamp pulse through the Gunter Box into the AZ yoke coil, which wasn't performed.

5.3.3.18 Scenario 3 Tests 61 – 64 - The purpose of these tests was to insert a VME command into the servo coil. These events were an attempt to see how the launcher system responds to commands that appear as a foreign signal on the VME BUS. In the process of running the insertion tests using the Gunter Box it was concluded that the VME insertion tests were not necessary or would not cause the launcher to respond any different than when the insertion was performed with the Gunter Box.

5.3.3.19 Scenario 3 Tests 65 – 67 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the EL yoke coil while the LLM was proceeding up using boom controller.

Test 65 through 67 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp pulses into the EL yoke coil while LLM was in boom control mode and ascending. Test 65 inserted 3 milliamps through the Gunter Box into the EL yoke coil and a small disruption (stopped momentarily) in the cage movement occurred and then the launcher recovered. Test 66 inserted 6 milliamps through the Gunter Box into the EL yoke coil and the LLM appeared to stop moving and then recover. Test 60 inserted a 9-milliamp pulse through the Gunter Box into the EL yoke coil and the LLM reversed direction, then recovered.

5.3.3.20 Scenario 3 Tests 68 – 70 - The purpose of these tests was to see how the launcher would respond to an external current pulse into the EL yoke coil while the LLM was descending using boom controller.

Test 68 through 70 used the Gunter Box and signal generator to input 3, 6, and 9-milliamp pulses into the EL yoke coil while LLM was in boom control mode and descending. Test 68 inserted 3 milliamps through the Gunter Box into the EL yoke coil and a small disruption (slightly noticeable bounce) in the cage movement occurred but then the launcher recovered. Test 69 inserted 6 milliamps through the Gunter Box into the EL yoke coil and a small disruption (noticeable bounce) in the cage movement occurred and then the launcher recovered. Test 70 inserted a 9-milliamp pulse through the Gunter Box into the EL yoke coil and the LLM experienced a very fast jump/bounce, and then recovered.

5.3.3.21 Scenario 3 Test 71 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Yoke Resolver. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the **as design** would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 71 was executed, the launcher entered into an uncontrolled mode and the emergency kill switch was used to stop LLM motion.

5.3.3.22 Scenario 3 Test 72 - The purpose of this test was to see how the launcher responds to opening the AZ yoke resolver sine function. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the **as design** would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 72 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.23 Scenario 3 Test 73 - The purpose of this test was to see how the launcher responds to opening the AZ yoke resolver cosine function. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the **as design** would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 73 was executed, the launcher entered into an uncontrolled mode and the emergency kill switch was used to stop it.

5.3.3.24 Scenario 3 Test 74 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Yoke Resolver. The yoke resolver is an integral link within the inner control loop; therefore the expected responses is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 74 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.25 Scenario 3 Test 75 - The purpose of this test was to see how the launcher responds to opening the EL yoke resolver sine function. The sine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 75 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.26 Scenario 3 Test 76 - The purpose of this test was to see how the launcher responds to opening the EL yoke resolver cosine function. The cosine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 76 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.27 Scenario 3 Test 77 - The purpose of this test was to see how the launcher responds to opening the excitation of the LLM AZ Resolver. The LLM resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 77 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.28 Scenario 3 Test 78 - The purpose of this test was to see how the launcher responds to opening the LLM AZ resolver sine function. The sine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 78 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.29 Scenario 3 Test 79 - The purpose of this test was to see how the launcher responds to opening the LLM AZ resolver cosine function. The cosine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 79 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.30 Scenario 3 Test 80 - The purpose of this test was to see how the launcher responds to opening the excitation of the LLM EL Resolver. The LLM EL resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 80 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.31 Scenario 3 Test 81 - The purpose of this test was to see how the launcher responds to opening the LLM EL resolver sine function. The sine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 81 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.32 Scenario 3 Test 82 - The purpose of this test was to see how the launcher responds to opening the LLM EL resolver cosine function. The cosine resolver function is an integral link within the launchers control system, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 82 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.33 Scenario 3 Test 84 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Shaft Resolver while using the boom controller. The shaft resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 84 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.34 Scenario 3 Test 85 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Shaft Resolver while using the boom controller. The EL shaft resolver is an integral link within the inner control loop; therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 85 was executed, it resulted in uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.3.35 Scenario 3 Test 86 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Yoke Resolver while using boom controller. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 86 was executed, the launcher entered an uncontrolled mode and the boom control kill switch was used to stop LLM movement.

5.3.3.36 Scenario 3 Test 87 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Yoke Resolver while in boom control mode. The yoke resolver is an integral link within the inner control loop; therefore the expected responses is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function. When test 87 was executed, the launcher reversed direction and launcher motion was terminated. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.4 Testing Scenario 4 - Test Scenario 4 established the criteria in which procedures were written in order to perform the corresponding tests. This scenario objective was to observe/evaluate the launcher's response when an event is inserted/interrupted during a fire mission. Test scenario 4 – LLM Motor Function Dynamic Tests used fire mission data to position LLM to aim point and fire six rockets.

After writing the test procedures for scenario 4 tests were performed on the M270A1 launcher. In Test Scenario 4 various events were inserted into the launcher.

5.3.4.1 Testing Scenario 4 Tests Not Performed – There were a total of 62 tests written for scenario 4. As testing began certain tests within scenario 4 became invalid as the

SRRE team members became more educated about M270A1 launcher functions. After review of the tests only 15 were determined to be capable of producing valuable information. These 15 tests were run and will be described in the following sections.

5.3.4.2 Scenario 4 Test 3 - The purpose of this test was to see how the launcher responds to opening both AZ servo coils during a fire mission. Commands are issued across VME bus through LDS card to energize servo coils to control servo valves, which provide force for cage motion. The servo coil is an integral part of the control system on the launcher, therefore the expected response is that the launcher design would recognize a lack of control, if any, and terminate launcher movement without using the emergency shut down function.

On the first test, all of the rockets fired, thereby ending the fire mission. The operator issued a launcher stow command by pressing the stow prompt on the FCP. A partial stow (cage moved approximately ten degrees in elevation) occurred and after 40 seconds, the interrupt switches were reset to normal position, thereby allowing the system to complete the requested stow command.

Two additional tests were executed using the same procedure but having different results. The difference being that when the event was inserted into the system, it caused uncontrolled launcher motion, thereby creating a personnel safety hazard. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.4.3 Scenario 4 Test 6 - The purpose of this test was to see how the launcher responds to opening both EL servo coils during a fire mission. Commands are issued across VME bus through LDS card to energize servo coils to control servo valves, which provide force for cage motion. The servo coil is an integral part of the control system on the launcher, therefore the expected response is that the launcher design would recognize a lack of control and terminate launcher movement without using the emergency shut down function.

The first event consisted of opening both EL servo coils, preventing current from flowing to the coils. The coils were opened after the 2nd rocket was fired. The cage jerked or bounced down in elevation and the FCS aborted the fire mission.

5.3.4.4 Scenario 4 Test 9 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Shaft Resolver during a fire mission. The shaft resolver is an integral link within the inner control loop; therefore, the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 9 opened the AZ shaft resolver excitation during a fire mission; the launcher appeared to remain in a stable operating condition. The fire mission was completed, firing all remaining rockets. The stow prompt was presented and pressed. The LLM stopped after short movement. The launcher had to be powered down and up to finish stow. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.4.5 Scenario 4 Test 18 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Shaft Resolver during a fire mission. The shaft resolver is an integral link within the inner control loop; therefore, the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

Test 18 opened the EL shaft resolver excitation during a fire mission; the launcher appeared to remain in a stable operating condition. The fire mission was completed, firing all remaining rockets. The stow prompt was presented and pressed. The LLM stopped after short movement. The launcher had to be powered down and up to finish stow. A quick look at the online LIDAS data indicated the launcher motion was stopped through the emergency shutdown function.

5.3.4.6 Scenario 4 Test 25 - 27 - The purpose of these tests was to see how the launcher would respond to an external pulse condition into the AZ servo command while the launcher was performing a fire mission.

Test 25 through 27 used the Gunter Box and signal generator to input 1, 2, and 3-milliamp analog pulses into the AZ servo command during a fire mission. Test 25 inserted 1 milliamp through the Gunter Box into the AZ servo after the 2^{nd} rocket firing. The launcher wiggled, re-aimed and fired remaining rockets. Test 26 inserted 2 milliamps through the Gunter Box into the AZ servo during a fire mission. When 2 milliamps are inserted during rocket firing the brakes are applied, thus there is no launcher movement. On the 2^{nd} run 2 milliamps was inserted after the 2^{nd} rocket firing. The launcher wiggled and fire mission was aborted. Test 27 inserted a 3-milliamp pulse through the Gunter Box into the AZ servo. The launcher jerked/wiggled, tried to re-aim, but the fire mission was aborted.

5.3.4.7 Scenario 4 Test 31 – 33 - The purpose of these tests was to see how the launcher would respond to an external pulse condition into the EL servo command while the launcher was performing a fire mission.

Test 31 through 33 used the Gunter Box and signal generator to input 1, 2, and 3-milliamp analog pulses into the EL servo command during a fire mission. Test 31 inserted 1 milliamp through the Gunter Box into the EL servo after 2^{nd} rocket firing. The launcher bounced, re-aimed and fired the remaining rockets. Test 32 inserted 2 milliamps through the Gunter Box into the EL servo after 2^{nd} rocket firing and the launcher jerked/bounced, but completed the fire mission. Test 33 inserted a 3-milliamp pulse through the Gunter Box into the EL servo and the launcher experienced a large jerk/bounce and the fire mission was aborted.

5.3.4.8 Scenario 4 Test 51 - The purpose of this test was to see how the launcher responds to opening the excitation of the AZ Yoke Resolver during a fire mission. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

After the 2^{nd} rocket was fired, test 51opened the AZ yoke resolver excitation. The launcher fired 2 more rockets, but stopped short of firing the last one. The LLM slew and then came to a rapid stop.

5.3.4.9 Scenario 4 Test 54 - The purpose of this test was to see how the launcher responds to opening the excitation of the EL Yoke Resolver during a fire mission. The yoke resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

After the 2nd rocket was fired, test 54 opened the EL yoke resolver excitation. The launcher fired 1 more rocket, then slew to a damage zone and stopped.

5.3.4.10 Scenario 4 Test 57 - The purpose of this test was to see how the launcher responds to opening the excitation of the LLM AZ Resolver during a fire mission. The LLM AZ resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

After the 2nd rocket was fired, test 57 opened the LLM AZ resolver excitation. The launcher fired all 6 rockets, turned off pump, but gave no safe prompt.

5.3.4.11 Scenario 4 Test 60 - The purpose of this test was to see how the launcher responds to opening the excitation of the LLM EL Resolver during a fire mission. The LLM EL resolver is an integral link within the inner control loop, therefore the expected response is that the launcher design would recognize an interruption of the control loop and terminate launcher movement without using the emergency shut down function.

After the 2nd rocket was fired, test 60 opened the LLM EL resolver excitation. The launcher turned off pump and terminated the fire mission.

5.3.5 Testing Scenario 5 – This scenario identified conditions in which procedures were written to perform detailed tests to evaluate the launcher's response to the inserted event. The objective was to verify the three safety functions monitored during the SNVT (short-no-voltage-tester) test operations are satisfying the safety requirements. The SRRE team added three tests to the original scenario and concluded these three tests were an acceptable method for safety validation. The three tests are: Stray voltage, High impedance, and Low impedance. The SNVT tests the interface looking back into the WIU firing circuit.

5.3.5.1 Scenario 5 Test 51 - The purpose of this test was to verify that the SNVT will detect a 'stray-voltage' on any squib line, located in the WIU. The test circuit in the SNVT Box applied the 'stray-voltage' (50 mv to 1.5 volts) to a squib line, but the SNVT circuitry in the WIU did not detect the aberrant voltage consistently. Troubleshooting of the problem revealed that the 'external' system noise levels were too high and interfered with the test box and measuring equipment. This test was deemed not nearly as important as the other two SNVT tests, so correcting the problem at the time was 'put off till later'; the test never was repeated.

5.3.5.2 Scenario 5 Test 54 - The purpose of this test was to verify that the SNVT function in the WIU detects a 'low impedance' of less than 10 Kilohms between any one squib wire and all of the other squib lines. When the event was inserted into the firing circuits the SNVT detected the low impedance, as expected, and issued a failure alarm.

The testing demonstrated that 8.6 Kilohms is detected as a failure by the SNVT circuitry and that 20 Kilohms passes the test.

5.3.5.3 Scenario 5 Test 57 - The purpose of this test was to verify that the SNVT function in the WIU detects a 'high impedance' of more than 5 ohms between the signal and return lines of the squib conduit under test. When the event was inserted into the firing circuit, the SNVT detected the high impedance, as expected, and issued a failure alarm. The testing demonstrated that 5.7 ohms is detected as a failure by the SNVT circuitry and 0.5 ohms passes the test.

5.3.6 Testing Scenario 6 - Test Scenario 6 established the criteria in which procedures could be written in order to perform corresponding tests. The scenario objective was to verify that the launcher's processors "caught" and correctly reported a HANGFIRE or a MISFIRE if either occurs. Test Scenario 6 set conditions to create the Hangfire/Misfire criteria by connecting the SNVT Box between the WIU and the weapon pods. The tests consist in interrupting the squib lines, one at a time, and placing a load across the squib lines sufficient to cause the desired Hangfire or Misfire. The SRRE team added two tests to the original scenario and concluded that these two tests were an acceptable method for safety validation. The two tests are: Hangfire and Misfire.

5.3.6.1 Scenario 6 Test 61 - The purpose of this test was to verify that the FCS detects and properly reports a 'Hangfire' when it occurs. When the event was inserted into the firing circuit, the FCS detected a Hangfire condition, reported the abnormality, and terminated the fire mission.

5.3.6.2 Scenario 6 Test 62 - The purpose of this test was to verify that the FCS detects and properly reports a 'Misfire' when it occurs. When the event was inserted into the firing circuit, the FCS detected the Misfire condition, reported the abnormality, and terminated the fire mission.

5.3.7 Testing Scenario 7 – The purpose of this scenario was to evaluate the PNU operation as it relates to the system safety requirements. Scenario requirements were written, a test tool was designed/fabricated, and detailed test procedures were written to evaluate the PNU/FCS interface and to determine how the system responds when abnormal events are inserted into the system. These tests were not performed because of the availability of the launcher to the SRRE team.

5.3.8 Testing Scenario 8 - This scenario was to operate the launcher under normal and random modes without inducing any faults. The procedures for this testing (normal and random operation) were written as the tests were performed. Many of these tests revealed information that increased the knowledge of SRRE team members. Only four of the tests performed were determined to be critical to safety, as a result those were the only four tests that were documented. The following tests describe the four random operations that were documented as being safety critical functions.

5.3.8.1 Scenario 8 Test 1 – The purpose of this test was to demonstrate that the system would terminate the fire mission when the cage position violates the safety window (± 3 mils). The LLM was positioned to aim point and a 12 round ripple firing began. After 2nd round fires, the excitation voltage applied to the cage resolver was opened, and a manual rotational input was applied to the cage, resulting in azimuth cage motion.

5.3.8.2 Scenario 8 Test 2 – The purpose of this test was to demonstrate hanging commands in the buffers and their effect on launcher motion. This test examined how launcher motion was affected when the commanded stored logic connection is re-established. The test was accomplished with no induced fault. During normal and random operation the sequence of events were:

-position cage to reload right
-extend boom
-lower hoist with pod just off the ground
-hand brake off
-momentarily commanding azimuth CCW
-press resume on FCP
-hand brake on

5.3.8.3 Scenario 8 Test 3 – The purpose of reporting on this test was that an undesirable launcher condition existed, which resulted in cage motion (oscillation). This test examined how launcher motion was affected under a sequence of events:

-position cage to reload rear
-boom out with pod, do not hoist down
-momentarily command LLM CW (1 second)

5.3.8.4 Scenario 8 Test 4 – During normal and random operational testing the boom controller kill switch was activated (accidental or intentional) to terminate launcher cage motion; however, it did not stop launcher cage motion. This test was repeated several times with the same result occurring each time. This test examined how launcher motion was affected under the following sequence of events:

-LLM stow while in BC mode
-during stow activate kill switch (accidental or intentional)

6.0 Results – This result section will follow the outline established in the SRRE approach. There were many tests performed during the SRRE assessment. As each test was performed, the test conductor (TC) and technician made observations and notes about each test performed. A summary of these observations/notes is provided at the end of each test procedure, which are provided in the Appendices. If the data was reduced, specific parameters were plotted and evaluated to determine whether the system was performing in accordance with the safety definition established at the beginning of this task. Each test was designed to evaluate how the launcher responded to a specific event insertion. If the launcher responded as expected, the data was not reduced. Understanding the design was a key factor in developing the scenarios and test procedures. As the team gained more knowledge about how the system operated, it became obvious that testing the conditions for Scenario 1 and 2 would not provide useful information as it relates to safety. The reason is that after launcher software stops the cage motion, the brakes are applied, therefore no safety issue exists.

As a result of performing the normal and random operational tests (scenario 8), several undesirable conditions were identified as a safety concern. When the data was reduced and evaluated, it was determined that the effect was on both the munition firing and the cage motion. Therefore, the details of the results of scenario 8 will be addressed in both the launcher movement and munition firing sections.

6.1 Launcher Movement – The basic premise was that the cage control design was not adequate to provide sufficient personnel safety without major restrictions. Also, single point failures were a major focus in this assessment. Reduction of the data supported the stated premise (i.e. inadequate design). As the tests were performed, the launcher's response was observed, and the understanding of the control loop design improved, it became obvious that when the inner/outer control loops were interrupted, the cage movement became uncontrollable. The data analysis supported only two ways of stopping the launcher under this condition – Overspeed condition and Damage Zone violation. The sub-paragraphs of Section 6.1 will provide the detail to support this position.

6.1.1 Scenario 3 Test 3 Run 1 – This test was to evaluate the launcher's response when the system looses control of the Azimuth motor servo coil, which resulted in the launcher going to an uncontrolled state. Figure 1 provides a plot showing that the launcher is out of control for 2.885 seconds, resulting from design implementation (i.e. the servo motor valve can drift to a fully open position when this function is interrupted). Note that the software detection overspeed function (i.e. emergency stop) issued a brake command resulting from an overspeed condition. The launcher moved approximately 500 mils past the programmed stop position (1600 mils) and moved approximately 1300 mils in an uncontrolled state. The cage movement was less than 22 mils from brake command applied to launcher movement stop. See Figure 6-1

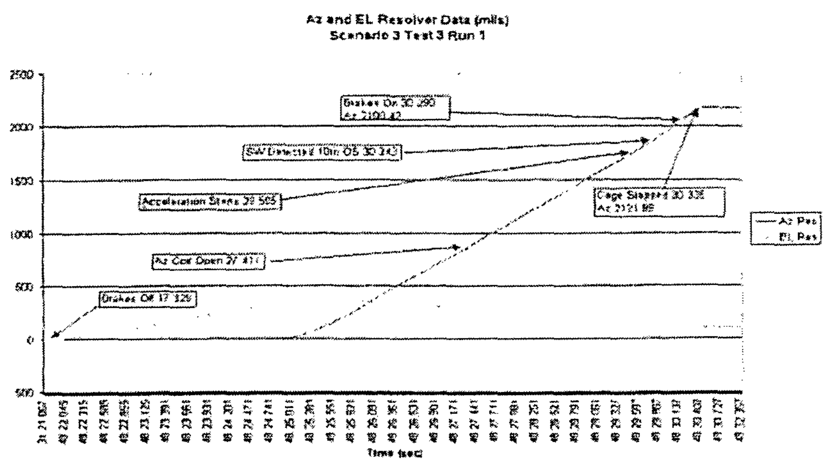

Figure 6-1

6.1.2 Scenario 3 Test 71 Run 1 – This test was to evaluate the launcher's response when the system looses control of the Azimuth yoke resolver function by interrupting excitation voltage which resulted in the launcher going to an uncontrolled state. Figure 2 provides a plot showing the launcher motion as a function of cage movement and time. The cage was commanded to a reload position but at 1500 mils the cage directions reversed, moving approximately 150 mils before the manual kill switch was energized, thereby terminating cage motion. The system as designed did not recognize the loss of this function allowing the launcher motion to continue probably until an emergency stop condition is satisfied (i.e. overspeed or damage zone condition). See Figure 6-2.

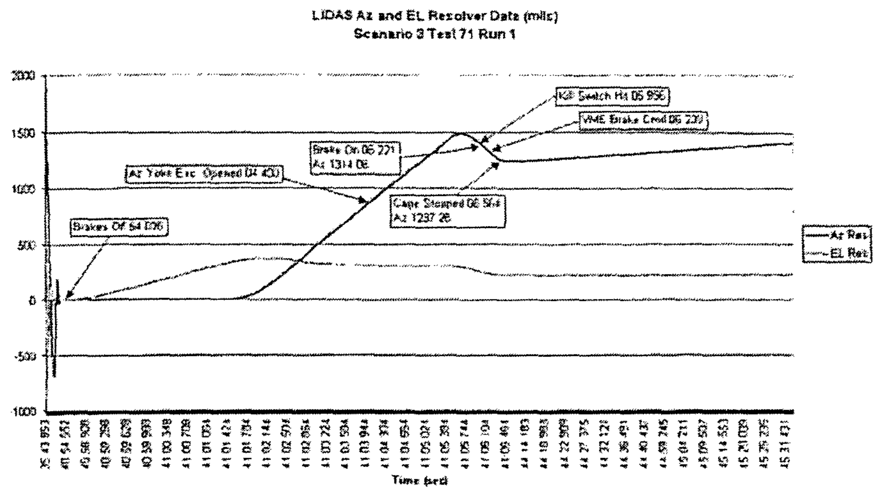

Figure 6-2

6.1.3 Scenario 3 Test 77 Run 1 – This test was to evaluate the launcher response when the system looses control of the Azimuth cage resolver function by interrupting the excitation voltage. Figure 3 provides a plot showing the launcher motion as a function of cage movement and time. When the event was inserted, this caused the cage resolver data to be corrupted. The software interpreted this corrupted data as a software damage zone condition, which resulted in issuing an emergency brake command (damage zone condition) to stop launcher motion. The nature of the event prevented the instrumentation from capturing the cage movement, allowing only a time evaluation coupled with the system as designed for understanding the results/system response. See Figure 6-3.

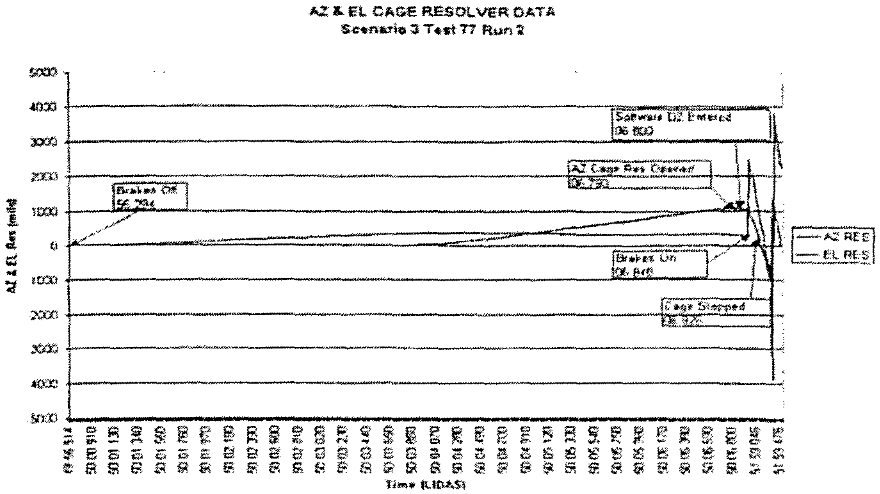

Figure 6-3

6.1.4 Scenario 3 Test 18 Run 1 - This test was to evaluate the launcher response when the system looses control of the elevation shaft resolver function by interrupting the excitation voltage which resulted in the launcher going to an uncontrolled state. Figure 3 provides a plot showing the cage motion as a function of movement and time. When the event was inserted, the launcher was in an uncontrolled state for approximately 0.5 seconds. The cage moved into a damage zone, which resulted in issuing a emergency brake command (damage zone condition) to stop launcher motion. The system as designed did not recognize the loss of this function allowing the launcher motion to continue into the damage zone. The software recognized damage zone violation, thereby issuing an emergency brake command that stopped the launcher motion. See Figure 6-4.

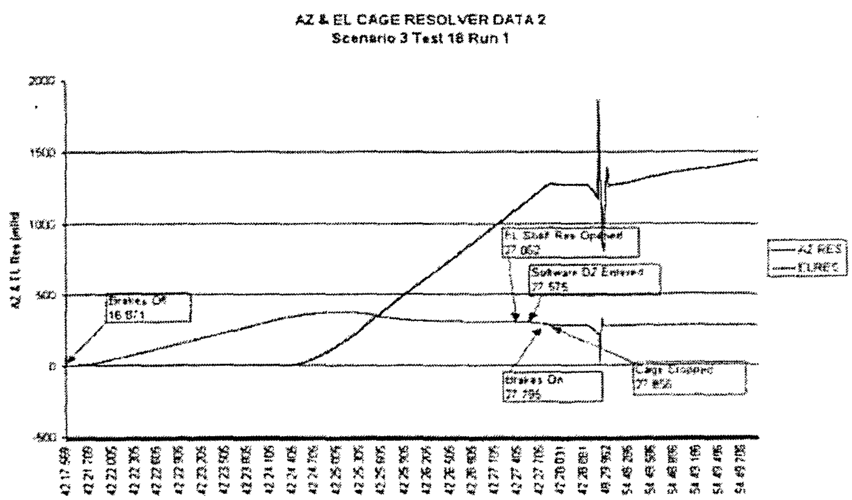

Figure 6-4

6.1.5 Scenario 3 Test 56 Run 1 – This test was to evaluate the launcher's response when a foreign signal was inserted into the control system to determine the stability of the launcher. An input signal (6mA for 1sec) was applied to the servo coils thru the Gunter Box. The event caused the launcher to slow down, the speed up and then launcher motion stopped. Data analysis indicated that an emergency overspeed brake command was issued. The initial launcher movement was being controlled by the boom controller (in maintenance speed) but the cage was driven to an overspeed condition without the software recognizing that the maintenance had been violated. See Figure 6-5.

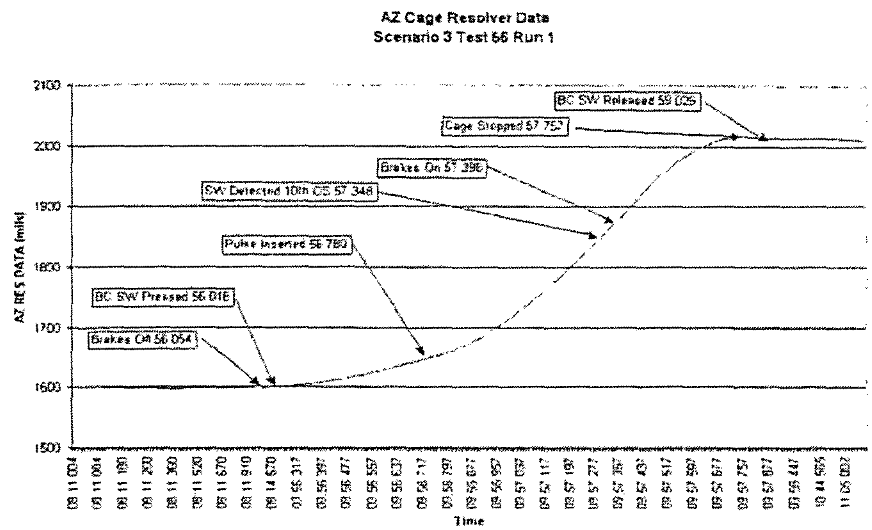

Figure 6-5

6.1.6 Scenario 4 Test 3 Run 1 – During this ripple round firing (eleven rocket) mission, the inserted event did not affect the completion of the eleven round mission. Upon completion of this mission, the stow prompt appeared on the FCP and was pressed. This caused the launcher to partially stow (i.e. elevation moved down approximately ten degrees) and the cage motion stopped. Since the event had opened the AZ servo coils (i.e. causing the inner loops to be interrupted) hence no AZ cage movement occurred. After approximately 40 seconds, the interrupt switches were repositioned to the normal position, resulting in the completion of the stow function. Analysis of the data showed that the servo yoke didn't move, thereby explaining no cage motion but the software terminated the stow function, but left a hanging command to the servo coils. Analysis of the circuit design explained why the cage functioned as observed. Since the launcher's response was different from similar event insertions in Scenario 3, the test conductor decided to rerun the test.

Run 2 and 3 – When the two reruns were executed and when the event was inserted into the system, the firing stopped but the **as designed** cage moved uncontrollably until the emergency damage zone function stopped the cage motion.

6.1.7 Scenario 8 Test 2 – When the data was reduced and analyzed, it was determined that a BC command was not cleared. (Specified by SRRE team as hanging command.) When a cage movement command switch is pressed, the system control loop sees this as a valid input, even though the kill switch has interrupted functions that prevent launcher motion. When the kill switch is repositioned back to the normal position and "resume" is pressed, uncontrolled cage motion occurred CCW and set the brake. The evaluation of the data indicated that the cage motion was terminated by the emergency stop function, therefore the system was in an uncontrolled state. When the SRRE team reran this test with 5.0 software, the boom controller hanging command was corrected.

6.1.8 Scenario 8 Test 3 – During the normal and random mode testing, the test conductor established a condition that allowed the launcher to oscillate in azimuth about $\pm$ 60 mils.

6.1.9 Scenario 8 Test 4 – When the SRRE team began using the 5.0 software, this update affected the operation of the kill switch in the boom controller mode. This kill switch, using 5.0 software, would not stop cage motion.

6.2 Munition Firing – The testing executed in Section 5.5.5 and 5.5.6 were to evaluate the launcher safety environment when abnormal events were inserted into the firing circuits and to determine if the launcher allows firing outside of the safety window requirement ($\pm$ 3 mils).

6.2.1 Scenario 5 Test 51, 54, 57 – These tests were to obtain data to determine that the firing circuits/SNVT circuits are working in accordance with the **as design** SNVT requirements. The data obtained from the SNVT testing verifies that the SNVT captured the abnormal conditions ("High/Low" impedance requirements) when the events were inserted into the launcher system.

6.2.2 Scenario 6 Test 61, 62 – These tests were to obtain data to verify all firing circuits work in accordance with the operational design requirements (Hangfire/Misfire). The data obtained in these tests verifies that the system captured the abnormal condition (Hangfire/Misfire) when the events were inserted into the launcher system. Also, these conditions were displayed on the Fire Control Panel (FCP) for the operator's information and/or action.

6.2.3 Scenario 8 Test 1 – This test was to demonstrate that the system would terminate the fire mission when the cage position violates the safety window ($\pm$ 3 mils). When the event was inserted, after the 2^{nd} rocket, the hydraulic pump shut off and a third round was fired. When the data was reduced and analyzed, it was determined that on the first test, the 3^{rd} rocket fired outside of the $\pm$ 3 mils safety window. Having determined this safety concern, the SRRE team repeated the same test many times (20-30 times), but was unsuccessful in duplicating the same results. Apparently the system bus traffic increased and the wrong "ok to fire" message was reported to the WIU for the 3^{rd} round

7.0 Conclusion – The SRRE team has identified three design deficiencies that effect the personnel safety environment of the M270A1 launcher weapon system. Two of the deficiencies are related to the launcher cage motion and the other is related to the munition firing.

7.1 Launcher – Figure 7-1 provides a functional flow chart of the M270A1 control system. Analysis of the control system logic and the understanding of how the design was implemented, the SRRE team concluded that when either the inner or outer loop is interrupted, the launcher cage becomes uncontrollable. When either of the loops are interrupted, regardless of what created the condition, the **as design** looses control of the cage movement, therefore the cage motion will depend upon how the control loop's logic responds to this condition. The analyses for Scenario 3 Test 18, 71, and 77 confirms that the launcher moves uncontrollably and is stopped only by the emergency shut down function. Since the **as design** system does not recognize that the cage is out of control, then cage motion ultimately is stopped by issuing a brake command, resulting from the emergency overspeed or damage zone function, thereby applying the cage brakes.

The hanging command was identified in Scenario 4 Test 3 and Scenario 8 Test 2. These tests interrupted the servo coils, which interrupted the control loop. The **as design** system did not recognize this condition, therefore allowed active commands to remain in the buffer creating a personnel safety hazard condition.

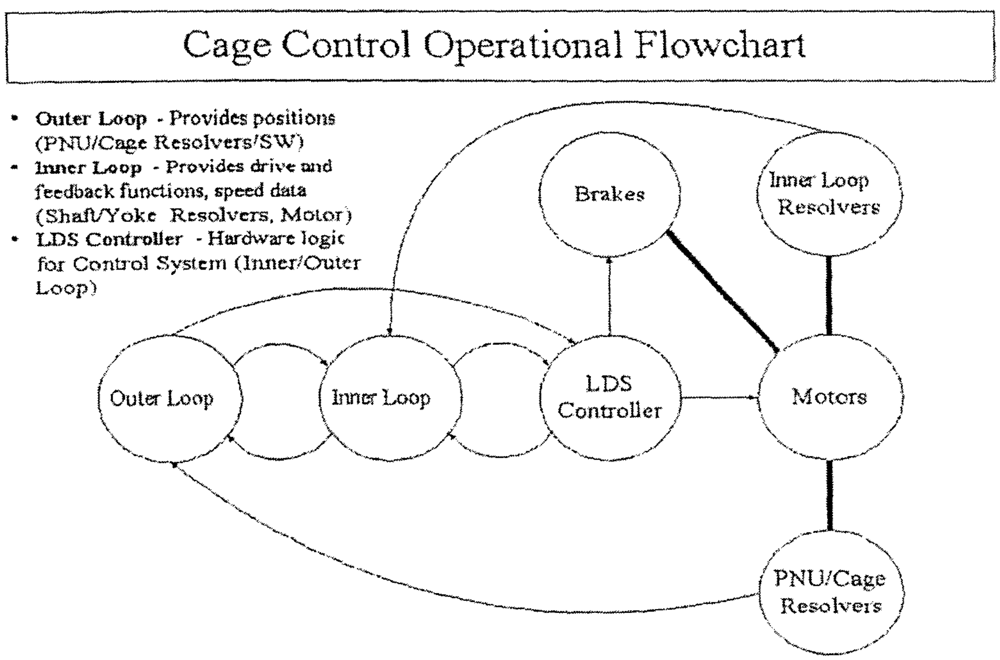

Figure 7-1

7.2 Munition Firing – During ripple firing, Scenario 8 Test 1 and the analysis of this test (section 6.2.3) determined that a rocket could be fired outside of the $\pm$ 3 mil window. This condition resulted from improper reporting of the "ok to fire" function to the WIM software logic.

7.3 Safety Launcher Criteria – The SRRE team concluded that when the launcher did not meet the definition of a safe launcher (reference section 1.0), a criteria must be provided to identify an acceptable level of safety. As a result of data analysis, cage movement speed, and circuit design analysis, the following criteria is provided:

- Launcher cage movement control is regained within 81 milliseconds or 2 degrees of cage movement.
- FCS informs operator of fault condition before next action.
- Launcher software does not rely on brake application for control.
- Firing circuits do not make uncommanded firing pulse.

8.0 Recommendations – The SRRE team has two recommendations:

1. Place restrictions upon the use of the launcher to provide an acceptable personnel environment for the user of this weapon system.
2. The design deficiencies should be corrected as soon as possible, thereby removing the launcher restrictions.

9.0 Design Considerations – During the SRRE team assessment of the M270A1 weapon system, the safety office requested that the team note any areas/concerns that were not safety related but would increase the understanding of the M270A1 operation and any future upgrades and/or new systems that might be produced. The team concluded from observations and preliminary data analysis that the control system algorithm had not been optimized and the hardware design did not have an independent means to verify position and speed (truth), thereby resulting in hardware single-point failures and allowing uncontrolled cage motion. It was also determined through analysis that minor hardware design changes would enhance the cage movement performance. The design approach for stopping the cage at aimpoint is less than desirable (i.e. not an optimal design), but the hardware selection/implementation might have been a major design element, thereby allowing a decision to be based upon program cost and schedule, resulting in poor performance.

In summary, it is very important that lessons learned be applied to the next generation design (new or upgrades). Having concluded this, here are some antidotes that if applied to any application will produce an effective program/product:

- Never use software to fix a hardware problem.
- Software and Hardware should always be designed and selected together from a systems approach.
- Hard decisions early in a program make for easier decisions later; the reverse is also true.
- Changes in the initial design without determining full impact throughout the system and operation usually causes unforeseen problems downstream.
- Identifying the root cause of a problem eliminates speculation on the solution.
- Good management will sort out the essentials from the non-essentials.
- Design decisions based solely on cost and schedule are doomed to fail.
- All hard design decisions follow this rule: Correct deficiency now or pay much more (ten times and up) later.

Appendices

Appendix 5

SRRE Acronym List

AZ – Azimuth
BC – Boom Controller
COTS – Commercial Off the Shelf
CSV – Comma Separated Values
CCW – Counter Clockwise
CW – Clockwise
EL – Elevation
FCP – Fire Control Panel
FCS – Fire Control System
GB – Gunter Box
GPS – Global Position System
HW – Hardware
LDS – Launcher Drive System
LIDAS – Launcher Instrumentation and Data Acquisition System
LIU – Launcher Interface Unit
LLM – Launcher Loader Module
LM – Lockheed Martin
MLRS – Multiple Launch Rocket System
MSD – Mass Storage Device
PNU – Position Navigation Unit
SNVT – Short No Voltage Test
SPF – Single Point Failures
SRRE – Safety Risk Reduction Effort
SW – Software
TC – Test Conductor
TCC – Test Control Counter
VME – Versa Module Europa
WIU – Weapons Interface Unit

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TAB 76

Time of intervals between strokes (ms)	60
Peak Current [first stroke] (kA)	200
Time to peak [all strokes] (µs)	1.5
Max dI/dt (A/s)	2×10^{11}
Action integral $\int i^2 dt$ (A^2s)	2×10^{6}
Peak current [subsequent stokes] (kA)	100
Action integral $\int i^2 dt$ [subsequent stroke] (A^2s)	0.25×10^{6}
Amplitude of continuing current average (A)	400
Duration of continuing current (ms)	400
Charge passing in continuing current (coulombs)	160
Charge per stroke (coulombs)	166
Total charge in flash (coulombs)	200
Flash duration (second)	0.5

3.2.7 Transportability. M270A1 Launcher shall be capable of being transported without damage by appropriate commercial and military transportation systems. Transport shall be by rail, aircraft (C141B and C17), highway, ships, barges and Army lighterage. Preparation time for the M270A1 Launcher shall not exceed 12 hours for removal and 12 hours for replacement of those components needed to meet weight restrictions of the aircraft. Removal of components to satisfy the aircraft weight restrictions will be limited to operator and organizational level maintenance personnel and will be accomplished without the aid of any support equipment (i.e., cranes, hoist lifts, etc.). The M270A1 Launcher will be loaded and transported with a maximum of 1/4 tank of fuel.

3.2.8 Identification and marking. Identification and marking of end items and components shall be consistent with those already in the Army inventory.

3.2.9 Interchangeability. All major components, assemblies and replacement parts shall be physically and functionally interchangeable without modifications of the items or the equipment.

3.2.10 Safety.

3.2.10.1 General requirements. Protection shall be provided against hardware and software catastrophic and critical hazards for operating and maintenance personnel and associated equipment. Mechanical and electrical/electronic safety, to include safety factors/margins, shall be equal to or exceed those of the Basic M270 MLRS Launcher hardware as defined in Section 6. Weapon controls and circuits shall prevent unintentional firing, and safety critical electrical and mechanical control circuits cannot be actuated in improper sequence.

3.2.10.2 Critical hazard. Single-point failures which may result in catastrophic or critical safety hazards or mishaps, shall be precluded from the system except for those identified in Safety Assessment Reports (SAR) as defined in paragraph 6.

3.2.10.3 Electrical and electronic safety. The electrical and electronic safety requirements shall be as follows:

a. Personnel and equipment safety shall be as delineated in applicable commercial electrical standards/codes to prevent catastrophic and critical safety hazards and mishaps.

b. Personnel shall be protected from contact with voltages greater than 30 volts root mean square or direct current.

c. The launcher shall incorporate cable connectors so wired that the pins arming and firing signals in the connectors are separated to avoid critical malfunctions resulting from bent pins. Cable connectors shall have positive measures to prevent mismatching or loosening.

d. The system shall ensure that all monitoring circuits are isolated from functional (firing) circuits by using separate circuits leading back to or from separate contacts, relays, or switches.

3.2.10.4 Mechanical safety. The mechanical safety requirements shall be as follows:

a. The launcher shall prevent the inadvertent reversing or mis-mating of fittings or couplings on liquid, hydraulic and pneumatic lines and mechanical linkages. Pneumatic systems shall have a minimum burst pressure of 4 times normal operating or fill pressure and a proof pressure of 1.5 times normal operating or fill pressure.

b. Sharp corners and edges, projections, and hot surfaces that personnel will be exposed to in the operation of the weapon system shall not be included in the launcher. Shielding may be used only in those areas where eliminating the hazard is not possible.

3.2.10.5 Environmental safety. The environmental safety requirements shall be as follows:

a. Toxic materials as identified by OSHA shall not be used in the system or support of the system. Toxic gases resulting from rocket firings shall not exceed industrial hygiene standards in the vehicle cab when it is properly sealed and ventilated. Operating and maintenance personnel exposure to toxic gases resulting from the heating of any component shall not exceed industrial hygiene standards.

b. Cancer suspect agents identified by OSHA standards shall not be used in the system or support of the system.

c. The launcher shall have a man-rated crew cab and shall provide crew protection from the rocket firing environment, e.g., blast overpressure, exhaust gases, thermal energy, blast debris and acoustic noise (when double ear protection is used). The man-rated crew cab

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TAB 77

AMSAM-SF (385-16a) 31 Jan 02

MEMORANDUM FOR AMSAM-MMC-MA-NI
SFAE-MSL-PF-SE-P

SUBJECT: M270A1 Safety Assessment/Safety and Health Data Sheet (S&HDS) in Support of a Milestone III Decision

1. **References:**

   a. M270A1 Safety Risk Reduction Effort (SRRE) Final Executive Summary, Jan 02.

   b. M270A1 LRIP III Final Safety Assessment Report (SAR), Lockheed Martin Report No. 3-53420/2001R-5003, 20 Dec 01.

2. **System Description.** The M270A1 Launcher is an upgrade to the standard version M270 Launcher. The improvements consist of a new Fire Control System (FCS) and new Launcher Drive System (LDS). The FCS functions with all the LDS sub-systems to provide overall control of the M270A1 Launcher. The FCS is equipped with a Global Positioning System (GPS) that provides the launcher with precise location information and fully supports munitions with embedded GPS receivers. The FCS features Built-in-Test (BIT) and Built-in-Test-Equipment (BITE), for isolating malfunctions to the Circuit Card Assemblies (CCA). The M270A1 hydraulic system is an upgrade to the hydraulic system of the current version M270 Launcher. The launcher cage moves simultaneously in azimuth and elevation for firing and reload operations. The speed in azimuth has been increased 5 times that of the current system and elevation has been increased 8 times. The aim to fire time has decreased from 93 seconds with the current system to 16 seconds and the reload has been decreased from 260 seconds to 160 seconds. From a System Safety perspective, it is this launcher cage speed increase and change in the software and hardware which controls the cage movement that is considered to be the primary safety critical areas of concern during development of the M270A1 Launcher.

3. **Prime Contractor Safety Assessment.** During the critical development period of the M270A1, Lockheed Martin cut their safety program to apply needed resources to problem areas considered crucial to completion of the program, particularly in the software area. It wasn't until the LRIP 3 contract that agreement was secured for Lockheed to complete their Safety Assessment. Per reference 1b, Lockheed has performed a top level Safety Assessment and provided their position on the safety of the M270A1 Launcher. Although not currently documented in their Safety Assessment, they have recently agreed to the following statement: The M270A1 Launcher is considered safe for fielding provided strict adherence to established safety procedures are followed. No other agreements, statements or conclusions regarding system safety of the M270A1 Launcher may be directly or indirectly implied or inferred without prior review and consent by the Lockheed Legal department.

4. **Government Safety Assessment.** As a result of contractual and Government requirements to certify that the M270A1 Launcher is safe for Fielding not being able to be met approximately a year before the Fielding decision, agreement between the AMCOM Safety Office and PFRMS PMO was secured to establish an independent Government Team to address this issue. This Team, called the Safety Risk Reduction Effort (SRRE), was formed to make a safety assessement of the M270A1 Launcher, specifically to evaluate the level of safety, identify risks, and make recommendations to the PFRMS PO in support of a Materiel Release Decision. The focus of the SRRE was on Munitions Firing/Circuits and Launcher Movement concerns related to Personnel Safety issues only. An extensive assessment and testing effort consisting of insertion of events/faults/interruptions in the Launcher software control loop and firing circuits during the operational mode was accomplished to capture the Launcher's reaction. No safety issues were discovered in the safety critical Firing Circuits/SNVT/PNU areas, but normal design operational characteristics and software control loop single-point failures that could present hazards to operating personnel were identified. Two software changes and six specific design related fixes were recommended by the SRRE for incorporation into the design of the M270A1 Launcher to enhance safety or correct the identified deficiencies. Five of the design related fixes are the subject of a Get Well Plan for Fielding the Launcher. Operating restrictions were also identified to lessen the impact of these deficiencies and allow Fielding of the M270A1 Launcher. These operating restrictions define a 3 meter rule for personnel safety while the Launcher Drive System (LDS) is on, and also restrict the M270A1 LLM from moving or unloading rocket pods from a HEMTT/HEMAT/PLS. The complete list of SRRE identified deficiencies and recommended changes/fixes, and which form the basis of a Pre-Fielding Plan and a Post-Fielding Get Well Plan, are described as follows:

a. FCS Software changes:

1) Double-Tap. For the Fire Control Panel (FCP) operator, the intent is to require two deliberate actions, including prompts with a FCS message, to move the Launcher cage to a desired position at tactical speed. This prevents accidental movement of the cage by inadvertent action and requires deliberate knowledge and action by the operator to move the cage at tactical speed.

2) Maintenance Default. Upon FCS start-up and initialization, the Launcher cage speed defaults to a slower maintenance speed, and requires a deliberate operator action to move the cage at tactical speed.

b. Specific Launcher control and safety related design changes (in order of priority):

1) Launcher Movement/Control – As a result of identified single-point failures in the software control loop, an independent means for the Launcher control software to perform a parity check against known position and speed at all times is recommended to remove the potential for uncontrolled behavior potential with the Launcher. It was further recommended that this improved process of monitoring and regaining control be held to within 3.5 degrees or 81 msec, with the ability of the FCS to inform the operator of a fault condition before resuming.

2) Boom Control Kill Switch – The current M270A1 boom controller has a kill switch that is only active in boom control mode. It was recommended that this switch be changed to be active full time and inhibit three functions: the Azimuth brake, Elevation brake, and PTO. This active full time function will add an increased level of safety for Launcher personnel when not in boom control mode, and add increased reliability and safety by wiring this switch directly to the Az/El brake and PTO, instead of shorting a low voltage power supply as currently configured.

3) Stale Message and Hanging/Latent Commands – An issue was discovered during the SRRE whereby it was possible to fire a rocket outside of the 3 mil safety window. Although this is a very low probability and not likely in-the-field event in and of itself, it uncovered a characteristic of the type of message traffic delay issues and system bus used which may have ramifications in other undetermined areas. It was recommended that to prevent stale messages or hanging/latent commands from causing potential safety issues, essentially due to a Launcher event using an old or late message check, that a form of time/event tagging be implemented on each message to prevent this issue from creating a problem in areas not currently identified.

4) Timeout of Last Command in Buffer – An issue was discovered whereby commanding the Launcher cage to stop and then resuming at the FCP could cause a sudden uncontrolled movement then sudden stopping of the cage. The cause of this is a command left stored in the buffer from a previous action, and when resume is pressed after operation with the boom controller, the cage performs the action left in the buffer instead of resuming in a ready for next command mode. The version of FCS software scheduled for fielding corrects this problem by clearing the buffer before pressing resume command. It was recommended that this issue receive further assessment since time restrictions prevented the SRRE from a complete evaluation of this deficiency for all operations, and the fact that other unusual behavior was noted related to correction of this problem in the latest version of software.

5) Launcher Cage Oscillation – In the left or right load/reload position and booms extended, pressing boom left or right then stop sets the cage into an oscillation of about 24 inches at the forward end. A safety hazard is created if pods are hanging from the hooks and off the ground. Although it is an easy condition to stop with the boom controller once noticed, it is a control issue that should not exist for the long term in a Fielded Launcher.

6) Additional Kill Switches – As a result of the dismounted crew not having a capability to kill the Launcher cage movement in an emergency situation, it was recommended to add an additional kill switch to each side of the base of the Launcher LLM in the event uncontrolled motion of the cage was experienced. As stated in the recommendations for the Get Well Plan below, the PFRMS PM and User made the decision to not pursue incorporation of these kill switches since this was not considered practical in a tactical military rocket Launcher, citing possible mission performance related issues.

5. **Conclusions.** Based on all safety assessment documentation available to date, especially the results of the Government Safety Risk Reduction Effort (SRRE) conducted on the M270A1, several conclusions are made as follows:

a. No safety issues or unacceptable risks have been identified in the safety critical areas of the M270A1 Firing Circuits/SNVT/PNU, therefore, no further recommendations are required.

b. The M270A1 Launcher has sufficient design safety incorporated to protect itself from mechanical damage via the Damage Zones, therefore, no further recommendations are required.

c. The M270A1 has several identified normal design operational characteristics and software control loop single-point failures that present potential hazards to operating personnel requiring action to be taken. These identified safety issues are considered residual hazards that require either acceptance of risk or correction prior to Fielding and/or Post-Fielding in a Get Well Plan. These actions are defined below in the Recommendations paragraph. In addition, until all residual hazards are corrected or the risk properly accepted by the required decision authorities, M270A1 Operating Personnel must strictly adhere to Operating Procedures developed and approved by the PFRMS PMO, the User and the AMCOM Safety Office. Any deviation in the recommended Operating Restrictions and Procedures of the SRRE must also be included in any Risk Acceptance process and signed by the appropriate decision authority.

d. A Health Hazard Assessment has been completed on the M270A1, to include a revised Noise Hazard survey as a result of the changes and upgrades in hardware from the basic M270 Launcher. No additional Health related hazards were identified over that already known for the basic M270 Launcher.

6. **Recommendations:** Based on the conclusions above and all safety assessment documentation available to date, especially the results of the Government Safety Risk Reduction Effort (SRRE) conducted on the M270A1, several recommendations are made as follows:

a. Pre-Fielding. Two Software changes (paragraph 4.a.) have been recommended to improve operating personnel safety by requiring deliberate FCP operator action in key cage control areas (Double-Tap and Start-up Maintenance Default). These changes have been accepted and are currently planned for the March FCS Software drop.

b. Fielding/Post-Fielding:

1) Implementation of identified operator restrictions/procedures is required for the fielded Launcher. Strict adherence to these procedures is absolutely mandatory to ensure an acceptable level of safety is maintained during operation of the M270A1 Launcher. In addition, the User and PFRMS PMO is required to accept any risk associated with deviation from the recommended restrictions/procedures identified by the SRRE.

2) Establish and implement a Get Well Plan to address and correct safety deficiencies identified by the Government SRRE. Agreement has been obtained from the PFRMS PMO on 5 of 6 SRRE recommendations (paragraph 4.b.) to correct identified safety deficiencies, and a Get Well Plan is being formulated with a not to exceed end date of 24 months from Materiel Release. The one safety recommendation, addition of a kill switch on each side of the external base of the Launcher, was considered by the User and PFRMS PM to be undesirable for a tactical vehicle and a decision was made to not implement this design modification. The remaining 5 SRRE recommendations, identified above in the Get Well Plan under paragraph 4.b., are currently being assessed and actions to begin development work are in process with the PFRMS PMO decision that they will be handled in a priority and ASAP fashion. At the end of the 24 month Get Well Plan period, if any of the five recommendations are not completed and incorporated into fielded launchers for cost and/or technical reasons, an amended Safety Assessment will be prepared and will consider the necessary action to take, or a request for acceptance of risk by the required decision authorities will be coordinated.

7. **Final Safety Statement.** Fielding of the M270A1 Launcher with the residual hazards identified, the associated Operating Restrictions, and implementation of a Get Well Plan requires the Materiel Release to be classified as Safety Conditional. It should be noted that satisfactory completion and incorporation of the M270A1 operating control recommendations under the Get Well Plan will remove the added safety operating restrictions and remove the Safety Conditional for Materiel Release. A System Safety Risk Assessment (SSRA) per Army Regulation addressing these safety issues for Fielding is currently in preparation concurrent with the conduct of the Materiel Release process, and must be signed by all decision authorities up to the PEO prior to Materiel Release. The Operating Restrictions identified by the SRRE are currently in process of being revised by the User and any delta changes considered necessary by the User will be incorporated based on an understanding of acceptance of risk in the changed areas. **In Summary, based on all the defined agreements for Fielding and Post-Fielding and acceptance of risk identified in the Recommendations above, the M270A1 Launcher is approved for Fielding, and is therefore considered safe for Fielding provided strict adherence to established operating restrictions/procedures are followed.**

8. The POC in this office and preparer of this Safety Assessment is Mr. Gary Indihar, AMSAM-SF, 842-8638, Email gary.indihar@redstone.army.mil.

/S/
JOHN C. FROST
Chief, AMCOM Safety Office

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TAB 78

REDSTONE ARSENAL, ALABAMA 35898-5000

REPLY TO ATTENTION OF

January 24, 2002

Precision Fires Rocket and Missile
Systems Project Office
Letter No. 2138

[redacted]
Lockheed Martin Missiles and Fire Control - Dallas
Mail Stop: MM-25
P.O. Box 650003
Dallas, TX 75265

Dear [redacted]

The following contract data item, submitted for approval via NOA - 3-53530/2002NOA-5010 on 24 January 2002, is disapproved:

Document Title: M270A1 LRIP III Final Safety Assessment Report
Document Date: 20 December 2001
Government Document Number: N/A
Government Document Revision: None
Contractor Document Number: 3-53420/2001R-5003
Contract: DAAH01-00-C-0109 - M270A1 LRIP 3,4,5
Data item: A001 - SAFETY ASSESSMENT REPORT (SAR)

Rationale for disapproval: This M270A1 LRIP 3 Safety Assessment Report (SAR) is not in compliance with DI-SAFT-80102B. It does not provide an adequate and sufficiently in-depth or detailed safety analysis and assessment of the M270A1, and contains many errors and misstatements. This SAR is considered more of a preliminary SAR expected at the beginning of a development program than one required of a final product at the end of development and production. This SAR does not reflect the level of effort required to properly assess the safety and risks associated with the design of the M270A1. In addition, very little substance has been provided in the SAR IAW DI-SAFT-80102B that supports the conclusions, recommendations, and safety statement of Sections 10, 11, and 11.3. As a matter of fact, these sections provide contradictory statements and errors, some of which are nonsensical.

I am furnishing a copy of this letter to [redacted] (SFAE-MSL-PF-BM-AP), [redacted] (AMSAM-AC-TM-C), [redacted] (SFAE-MSL-PF-PES-PDM), DCMA PT-03 (LMMFC-D), and [redacted] (LMMFC-D).

If you have any questions regarding this letter, you may contact [redacted] at [redacted] or the PFRMS Data Management Branch POC, [redacted], [redacted].

Sincerely,

[redacted]

Lieutenant Colonel, U.S. Army
Product Manager, Improved Launcher

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TAB 79

Commanding General's Determination

Having reviewed the U.S. Army Aviation and Missile Command Materiel Release Review Board's recommendation and having considered all factors required by AR 700-142, I hereby approve a conditional and training release of the Multiple Launch Rocket System M270A1 Launcher. The conditional release consists of 38 launchers, with 26 going to the U.S. Army Forces Command and 12 going to the National Guard Bureau. The training release consists of six launchers going to the U.S. Army Training and Doctrine Command.

FEB 2002

LARRY J. DODGEN DATE
Major General, USA
Commanding

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TAB 80

FEB 02

MLRS MAINTENANCE INFORMATION BULLETIN (MIB) #02001
SUBJECT: SAFETY BULLETIN FOR M270A1

1. **This MIB applies only to M270A1 fielded units.**

2. MIBs should be filed for future reference. MIBs will be used to expedite selected information to the field through Logistics Assistance Representatives (LARs) supporting M270A1 units.

3. The attached Safety Bulletin should be distributed to all M270A1 users and must be adhered to by all military and other personnel during the operation of the M270A1 launcher.

4. As safety precautions, a 3-meter rule has been put into place due to the higher speed of the LM and as a result of uncommanded cage movement that occurred during system development, which could not be re-enacted.

5. These procedures have been incorporated into the IETM and must be adhered until further notice.

6. The POCs for this action are [redacted] or [redacted], AMSAM-MMC-MS-MMA.

FEB 02

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SUBJECT: SAFETY BULLETIN FOR M270A1

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5. These procedures have been incorporated into the IETM and must be adhered until further notice.

6. The POCs for this action are [redacted] [redacted] or [redacted], [redacted], AMSAM-MMC-MS-MMA.

Safety Bulletin for M270A1

The following IETM procedures must be adhered to until further notice. The M270A1 reload procedures have been modified from the current M270 reload procedures.

3-Meter Rule

No personnel will be within a 3-meter safety zone around the LM while it is moving regardless of whether it is at Tactical or Maintenance speed. This applies to all LM movement regardless of whether it was commanded from the Fire Control Panel (FCP) or the Boom Controller (BC).

No personnel are allowed within 3 meters of the LM while the LDS is on except during reload operations. During all operations other than reload, the carrier engine must be turned OFF before entering the 3-meter safety zone. Crewmembers in the cab are excluded from the 3-meter rule as long as they remain in the cab.

No personnel will violate the 3-meter rule if an LM hardware failure occurs, LM moves in an uncommanded direction, or LM moves faster than maintenance speed with the BC until the FCS has been recycled. Prior to the FCS being recycled, personnel may be within the 3-meter safety zone if the carrier engine is off.

During BC operations, the operator must hold the boom controller in hand until the carrier engine is off. The BC operator must maintain the 3-meter distance and will ensure that all personnel comply with the restrictions above prior to initiating LM movement.

The 3-meter safety rule does not apply if;

- Carrier engine is off.
- Carrier engine is on but the LM is stowed and the LDS is off.

Reload Procedures

Once the LM is positioned for reload, only the Gunner may step into the 3-meter zone to remove the BC from its storage bracket. Once the Gunner has the BC in hand and has stepped back out of the 3-meter safety zone, the other crewmembers may step into the safety zone to perform reload procedures. All crewmembers must step out of the 3-meter safety zone while the Gunner is repositioning the LM.

The Gunner must have the boom controller in hand and must maintain a 3-meter distance from the LM during the entire reload operation except when removing or replacing the BC from its storage bracket. No other personnel will be in the 3-meter safety zone while the Gunner is removing or replacing the BC from its storage bracket.

Pod Handling

The LM will not be slewed in azimuth with either or both booms extended and the pod(s) attached (on the ground, hanging, or raised against hoist carriage assembly) except during combat operations.

The launcher will not be used to move/unload pods from a HEMTT/HEMAT/PLS (i.e. any re-supply vehicle/trailer) except during combat operations.

Override Prompt

If FCS OVERRIDE is selected to override a POD LOCKED, POD UNLOCKED, JURY STRUT PRESENT or BOOMS EXTENDED condition, the warning will not display again until the LM is stowed. Caution must be taken during subsequent operations to prevent damage to the LM and hoists. Once the LM is stowed, the OVERRIDE is reset and all warnings will display the next time the LM is moved.