

Detailed Test Report for the Static Acceleration Testing of a cRIO Data Acquisition System

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FOREWORD

This project was funded by Launch Test Capabilities (LTC) Control and Data Acquisition System (CDAS). This document evaluates the suitability of a National Instruments cRIO data acquisition system, in a quasi-static acceleration environment. The axial test was conducted on 5 August 2014. The bending test was conducted on 7 August 2014. This report was reviewed for technical accuracy by Chris Hoskins.

*S. BARLOW, Head
Weapons Airframe Division
1 October 2014*

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14. ABSTRACT (U) The purpose of this test series was to evaluate the suitability of a National Instruments Compact Reconfigurable Input/Output (cRIO) chassis and associated data acquisition cards (c-modules) for use in a mobile test device. The expected environment the VDAS will experience is a 68-g half-sine waveform (of duration approximately 45 milliseconds) followed by a diminishing load over the following 250 milliseconds. Two tests were conducted. The first resulted in ejection of c-modules at 114 g's. This test did not meet the success criteria as defined in the test plan. The second test was successful; no incidents were recorded by the cRIO data acquisition system. The c-modules were not ejected, nor any physical damage observed in the post test visual examination. The cRIO and associated c-modules have demonstrated the ability to survive in a static acceleration environment, tangent to the mounting plane, up to 136 g's.					
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1.0 PURPOSE OF TESTS

A series of tests were conducted to evaluate the suitability of a National Instruments Compact Reconfigurable Input/Output (cRIO) chassis and associated data acquisition cards for use in a mobile test environment (MTE) that will be subject to significant acceleration.

The expected environment the MTE will experience is a 68-g half cycle waveform with a duration of 300 milliseconds. The expected environment is plotted in Figure 1. To evaluate the suitability of the cRIO, personnel decided to subject it to the maximum acceleration that the test facilities centrifuge could achieve and no less than twice the peak acceleration of the expected environment.

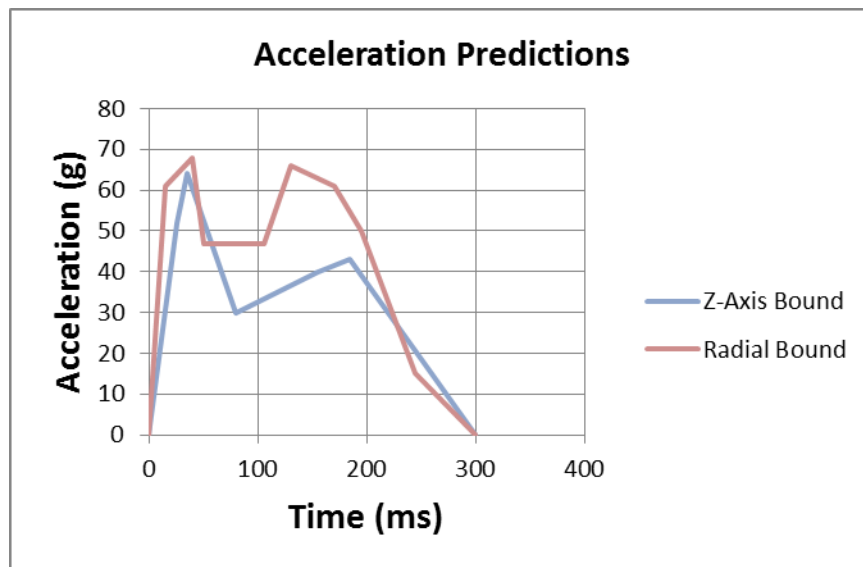


FIGURE 1. VDAS Expected Acceleration Load.

2.0 cRIO DESCRIPTION

The cRIO is a National Instruments Compact Reconfigurable Input/Output model 9014 chassis with four slots containing three C-module I/O cards and one filler module. The cRIO is mounted via two #10 screws.

3.0 DESCRIPTION OF TESTS

Two tests were conducted: the first test was conducted to subject the C-module cards to an acceleration that would tend to pull the modules from the cRIO (axial acceleration), and the second test was conducted to subject the C-module cards to an acceleration that would tend to bend the C-module cards. The cRIO was powered and programmed to record the acceleration from a monitoring accelerometer mounted on the centrifuge arm and output a signal that was recorded by an external data acquisition system. A schematic of the two tests is shown in Figure 2.

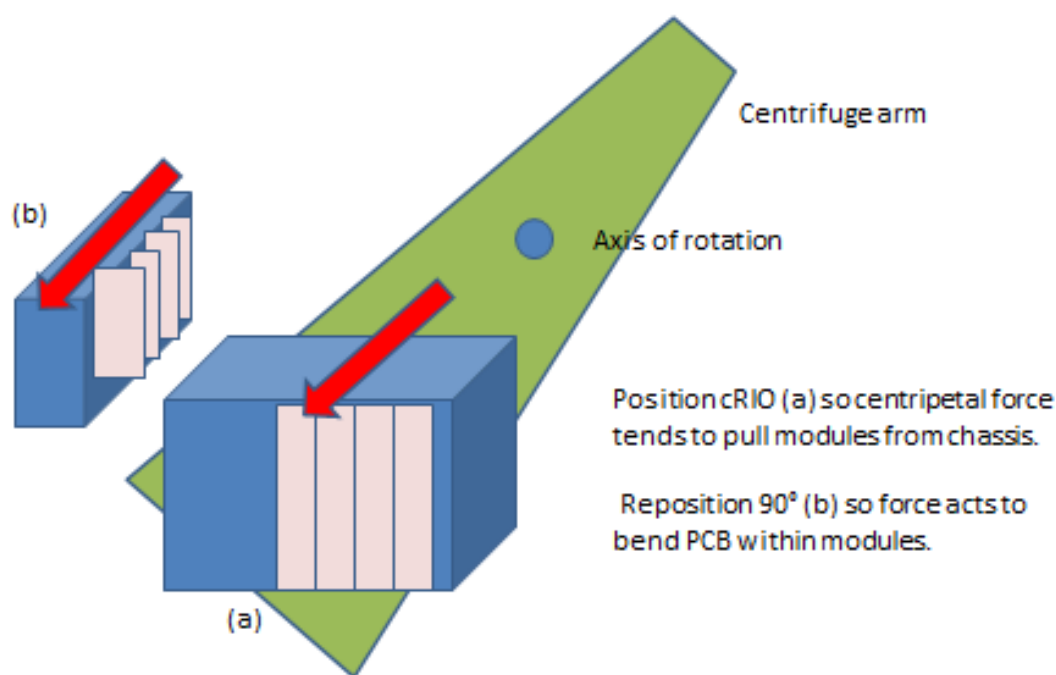


FIGURE 2. Schematic of the cRIO Chassis Testing Configurations.

The acceleration of an item that is mounted to the arm of a centrifuge is dependent on the distance the item is from the center of rotation and the angular velocity of the centrifuge. The equation below relates acceleration (G in g 's) to the distance from the center of rotation (R in inches) and the angular speed of the centrifuge (ω in rpm).

$$G = \left(\frac{R}{386.4} \right) \left(\frac{2\pi\omega}{60} \right)^2$$

This equation was used to calculate the angular speeds to set the centrifuge at to achieve the required test acceleration of the cRIO. The maximum speed of the centrifuge is 400 rpm.

The monitoring accelerometer was calibrated in 1984. Prior to test, the monitoring accelerometer's output was compared with a 100-g accelerometer with a current calibration. The acceleration output of both accelerometers was quite similar.

4.0 TEST SUMMARY

4.1 TEST #1: AXIAL ACCELERATION

4.1.1 Description

This test subjected the cRIO and the C-module cards to an acceleration that would tend to pull the modules from the cRIO. The cRIO was powered and programmed to record the acceleration from a monitoring accelerometer mounted on the centrifuge arm and output a sine wave voltage that was recorded by an external data acquisition system. The accelerometer and sine wave voltage signals were routed out of the centrifuge via slip rings and recorded by an external Data Acquisition System (DAS).

The monitoring accelerometer was mounted 41.25 inches from the center of rotation and the cRIO was mounted 53 inches from the center of rotation.

4.1.2 Equipment and Instrumentation

Table 1 is a list of equipment and instrumentation used in this test.

TABLE 1. Equipment and Instrumentation, Axial Acceleration Test.

Item	Model	S/N	Description
Centrifuge	N/A	N/A	Centrifuge located in the Life Cycle Environmental Engineering Laboratory (BLDG. 00005, China Lake, CA).
Monitoring Accelerometer	Endevco 2262-200	EB14	200g Accelerometer to monitor the acceleration of the centrifuge. Calibration date circa 1984.
DAS	NI 9234	N/A	Analog to digital converter, sends data to an external data logger.
Power Supply	Hewlett-Packard DC Power Supply	N/A	Two DC power supplies to provide power to the monitoring accelerometer and the cRIO.
Centrifuge Controller	Shore Western Controller	N/A	Controls the angular speed of the centrifuge.

4.1.3 Specification

The cRIO was to be subjected to a static acceleration of 200 g's for a duration of at least 1 second. The centrifuge speed required for this acceleration is 365 rpm. The relevant parameters are given in Table 2.

TABLE 2. Test Specification.

Angular Speed (rpm)	cRIO Acceleration (g's)	Monitoring Accelerometer Acceleration (g's)
365	200	156

4.1.4 Procedure

The test procedure is described below.

1. The cRIO was installed on the centrifuge.
2. All fasteners were checked for tightness.
 - a. The one 1/2-13 monitoring accelerometer screw was checked.
 - b. The four 1/2-13 cRIO fixture mounting screws were checked.
 - c. The two 10-32 cRIO mounting screws were checked.
3. The four cRIO c-modules were installed.
 - a. Duct tape of an unknown manufacture was placed on the outside of the cRIO to secure the c-modules in place.
4. All appropriate cables were installed.
 - a. The monitoring accelerometer cables.
 - i. The cable from the cRIO to the monitoring accelerometer.
 - ii. The cable from the monitoring accelerometer to the DAS.
 - b. The cRIO power cable.
 - c. The cRIO sine voltage signal cable.
5. The cRIO was powered.
6. The cRIO was reset/initialized.
7. The centrifuge doors were secured.

- a. Personnel were cleared from the area.
8. The external DAS/data logger was set to record.
9. The centrifuge was powered.
10. The centrifuge controller was set to 365 rpm per test specification.
11. As the centrifuge increased speed, a loud pop was heard and the centrifuge was powered down.
 - a. The peak acceleration recorded by the monitoring accelerometer was 89 g's.
 - i. This corresponds to a peak acceleration for the cRIO of approximately 114g's.
12. After the centrifuge arm ceased movement, the chamber was powered down.
13. The DAS/data logger was set to stop recording.
14. The Hewlett-Packard Power supplies were switched off.
15. The centrifuge door was opened.

4.1.5 Observations

Prior to reaching the desired acceleration, a loud pop was heard. The sine voltage signal was lost from the cRIO. The centrifuge was powered down for an inspection of the cRIO. This loud pop and the loss of signal happened when the monitoring accelerometer reached 89 g's. This corresponds to a cRIO peak acceleration of approximately 114 g's and an angular speed of approximately 275 rpm.

Upon inspection, the four c-modules had become dislodged and flung away from the c-RIO, smashing against the walls of the centrifuge. At least one c-module impacted the cRIO power cable and possibly damaged the internal cRIO power receptacle.

As the desired test specification of 200 g's was not met, nor the minimum test specification of 136 g's met, the cRIO did not achieve its success criteria.

4.2 TEST #2: BENDING ACCELERATION

4.2.1 Description

This test subjected the cRIO and the C-module cards to an acceleration that would tend to bend the modules from the cRIO. The cRIO was powered and programmed to record the acceleration from a monitoring accelerometer mounted on the centrifuge arm and output a transistor logic (TTL) voltage that was recorded by an external data acquisition system. The accelerometer and TTL voltage signals were routed out of the

centrifuge via slip rings and recorded by an external DAS via a NI 9237 and NI 9234, respectively.

The monitoring accelerometer was mounted 41.25 inches from the center of rotation, and the cRIO's center of gravity was approximately 51 inches from the center of rotation.

Due to the failure of the axial test, the cRIO was inspected. No damage was found, and four new c-modules were supplied.

4.2.2 Equipment and Instrumentation

Table 3 provides a list of equipment and instrumentation used in this test.

TABLE 3. Equipment and Instrumentation, Axial Acceleration Test.

Item	Model	S/N	Description
Centrifuge	N/A	N/A	Centrifuge located in the Life Cycle Environmental Engineering Laboratory (BLDG. 00005, China Lake, CA).
Monitoring Accelerometer	Endevco 2262-200	EB14	200g Accelerometer to monitor the acceleration of the centrifuge. Calibration date circa 1984.
DAS	NI 9237 NI 9234	N/A	Analog to digital converter, sends data to an external data logger.
Power Supply	Hewlett-Packard DC Power Supply	N/A	Two DC power supplies to provide power to the monitoring accelerometer and the cRIO.
Centrifuge Controller	Shore Western Controller	N/A	Controls the angular speed of the centrifuge.

4.2.3 Specification

At the direction of the MTE engineers, Barry Neal Navarro and Chris Hoskins, the test specification was altered. The cRIO was subjected to a static acceleration of 136 g's for a duration of at least 1 second. The centrifuge speed required for this acceleration was 307 rpm. The relevant parameters are given in Table 4.

TABLE 4. Test Specification.

Angular Speed (rpm)	cRIO Acceleration (g's)	Monitoring Accelerometer Acceleration (g's)
307	136	110

4.2.4 Procedure

The test procedure is as follows.

1. The cRIO was installed on the centrifuge.
2. All fasteners were checked for tightness.
 - a. The one 1/2-13 monitoring accelerometer screw was checked.
 - b. The four 1/2-13 cRIO fixture mounting screws were checked.
 - c. The two 10-32 cRIO mounting screws were checked.
3. The four cRIO c-modules were installed.
 - a. Duct tape of an unknown manufacture was placed on the outside of the cRIO to secure the c-modules in place.
4. All appropriate cables were installed.
 - a. The monitoring accelerometer cables.
 - i. The cable from the cRIO to the monitoring accelerometer.
 - ii. The cable from the monitoring accelerometer to the DAS.
 - b. The cRIO power cable.
 - c. The cRIO TTL voltage signal cable.
5. The cRIO was powered.
6. The cRIO was reset/initialized.
7. The centrifuge doors were secured.
 - a. Personnel were cleared from the area.
8. The external DAS/data logger was set to record.
9. The centrifuge was powered.
10. The centrifuge controller was set to 307 rpm per test specification.
11. The centrifuge achieved 307 rpm.
12. 307 rpm was held for several seconds.
13. The centrifuge controller was set to 0 rpm.
14. After the centrifuge arm ceased movement, the chamber was powered down.
15. The DAS/data logger was set to stop recording.
16. The centrifuge door was opened for the cRIO to be inspected.

4.2.5 Observations

The test was successfully executed, and the cRIO operated without incident throughout the test.

5.0 TEST SUMMARY

5.1 AXIAL ACCELERATION

Due to the ejection of c-modules at 114 g's, the cRIO did not meet the success criteria as defined in the test plan. Restraint of the c-modules by the tool-less latching system and duct tape is insufficient to retain the c-modules in place to survive and operate in a static acceleration environment, normal to the mounting plane that is greater than 114 g's.

5.2 BENDING ACCELERATION

The cRIO met the success criteria as defined in the test plan. No incidents were recorded by the cRIO or the external data acquisition system. The c-modules were not ejected, nor any physical damaged observed in the post test visual examination. The cRIO and associated c-modules have demonstrated the ability to survive in a static acceleration environment, tangent to the mounting plane, up to 136 g's.

Appendix A

AXIAL ACCELERATION TEST DATA AND PHOTOGRAPHS

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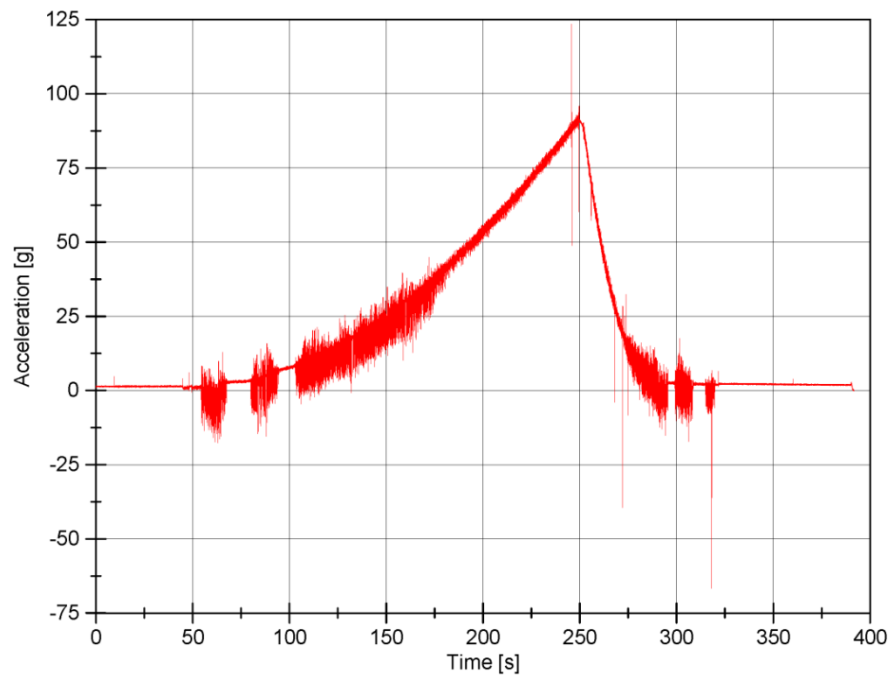


FIGURE A-1. Monitoring Accelerator Data, Low Pass Filtered at 50 Hz.

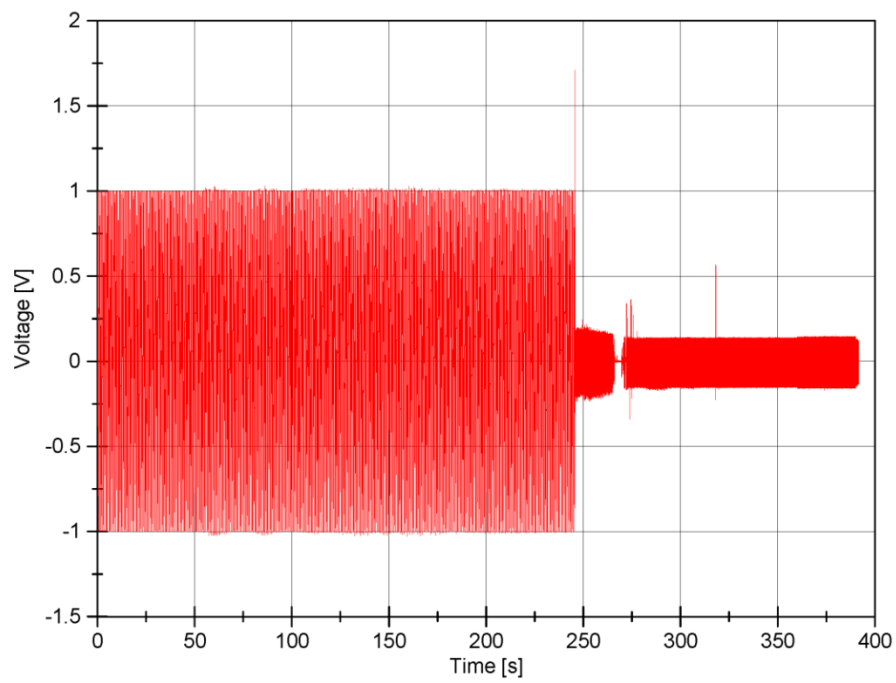


FIGURE A-2. Voltage Output.

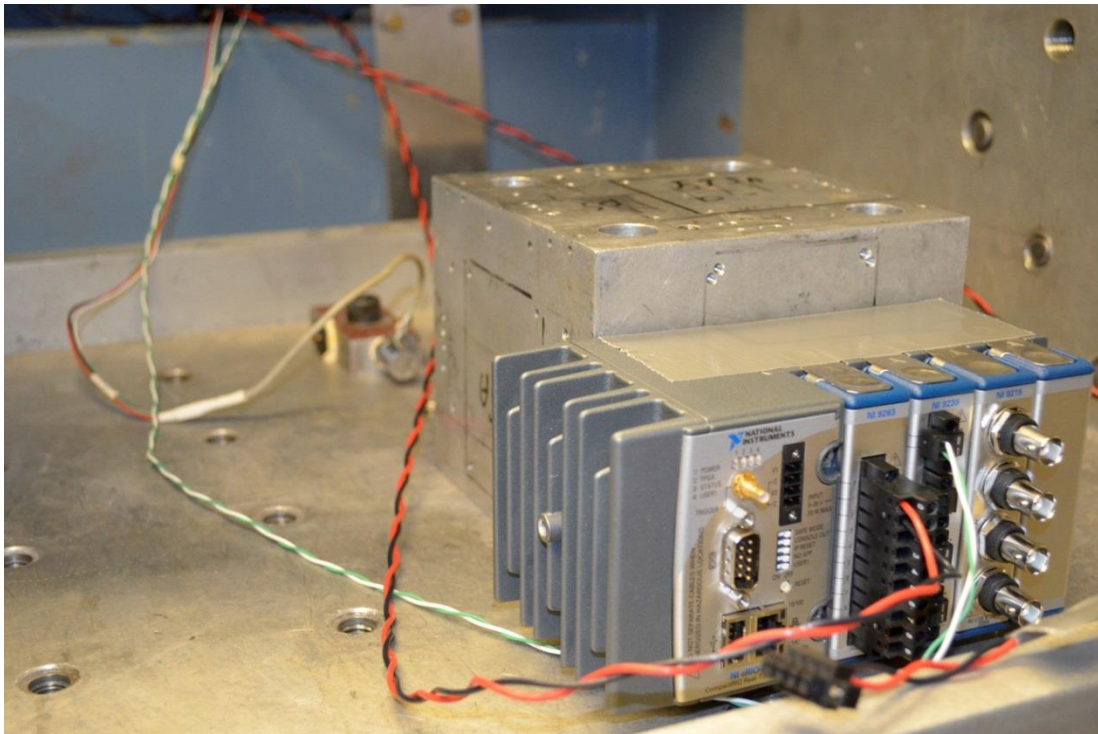


FIGURE A-3. Pre-Test.

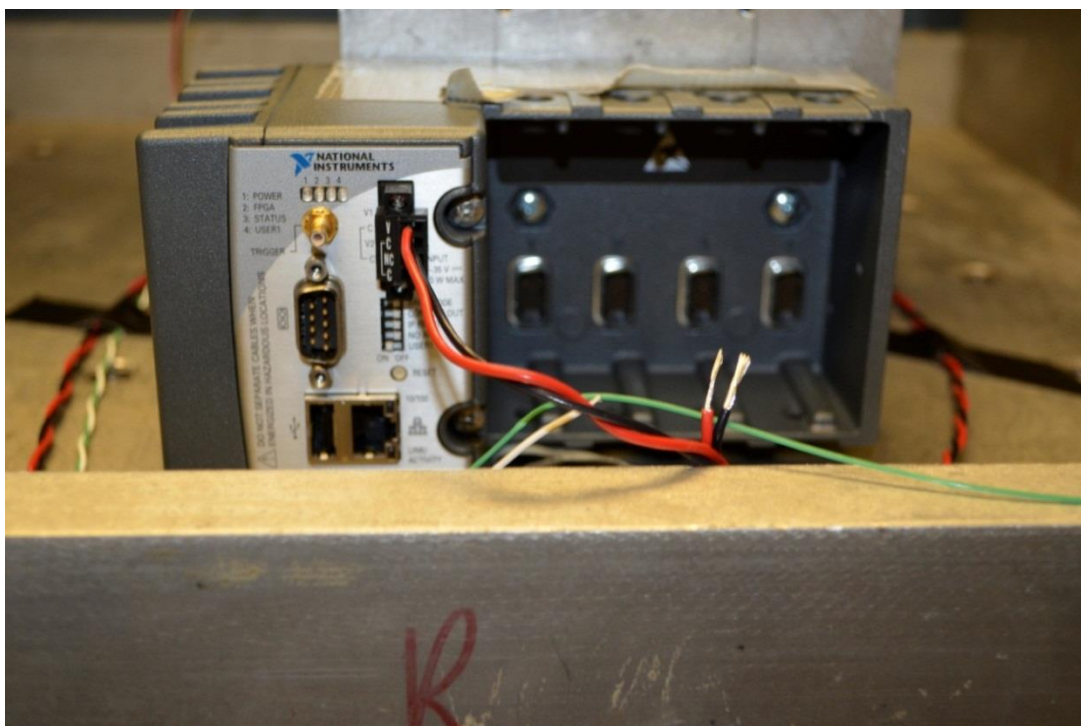


FIGURE A-4. Post-Test.

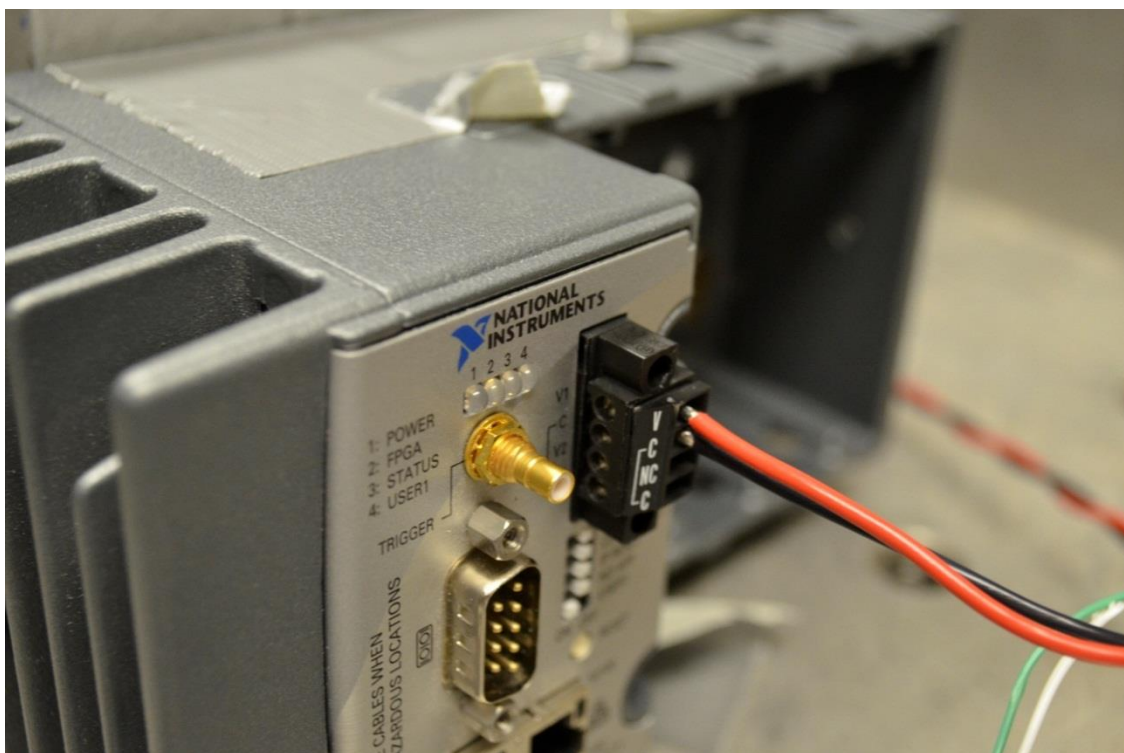


FIGURE A-5. Connector Damage.

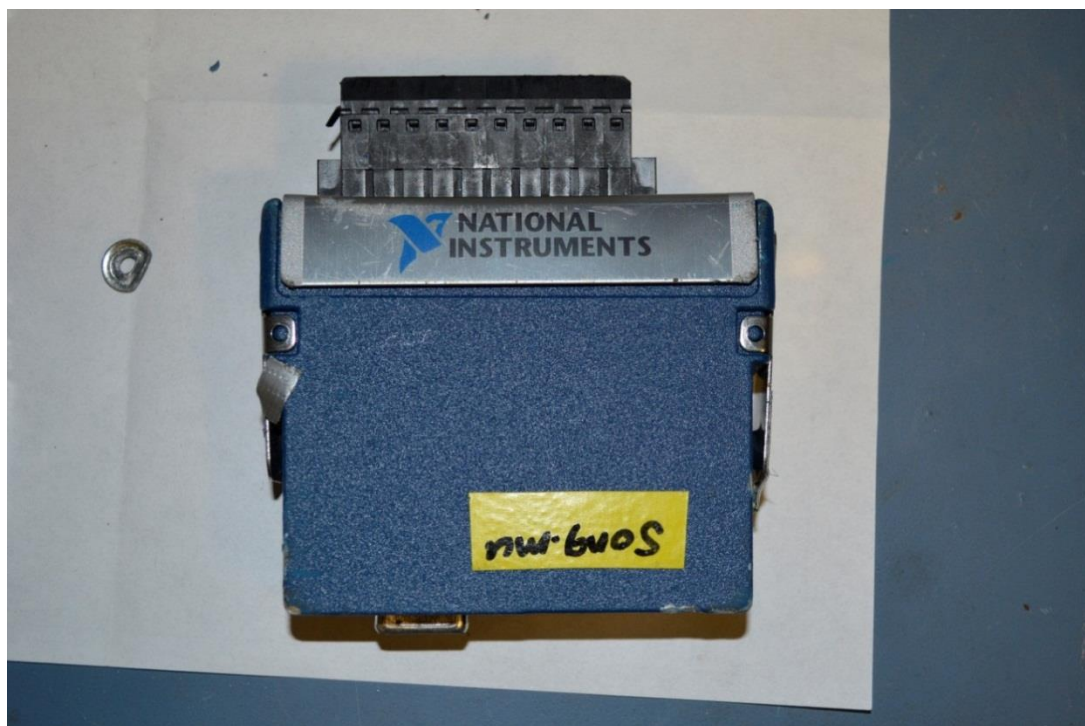


FIGURE A-6. Damaged c-Module, 1st Slot.



FIGURE A-7. Damaged c-Module, 2nd Slot.

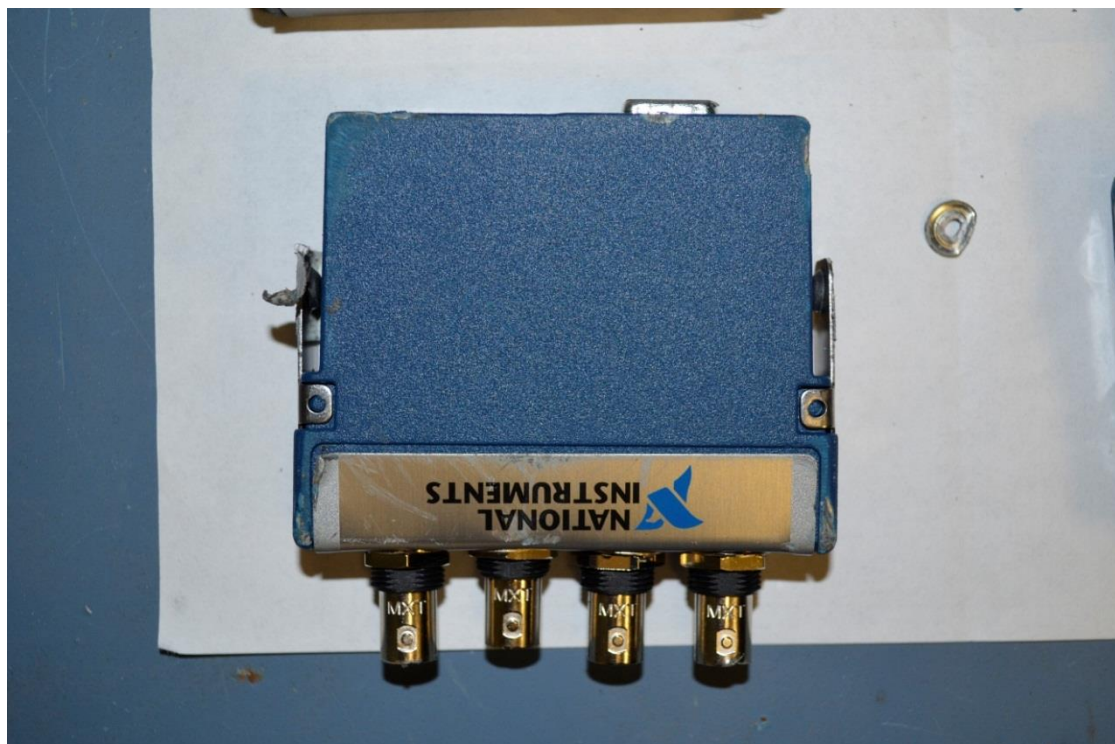


FIGURE A-8. Damaged c-Module, 3rd Slot.



FIGURE A-9. Damaged c-Module, 4th Slot.

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Appendix B

BENDING ACCELERATION TEST DATA AND PHOTOGRAPHS

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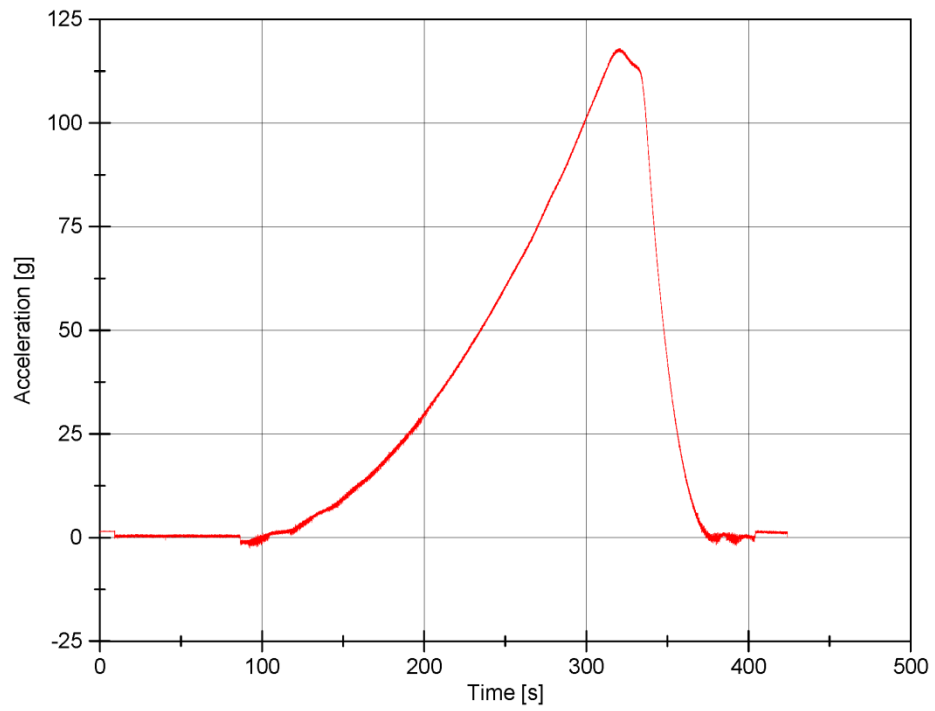


FIGURE B-1. Monitoring Accelerometer Data, Low Pass Filtered at 50 Hz.

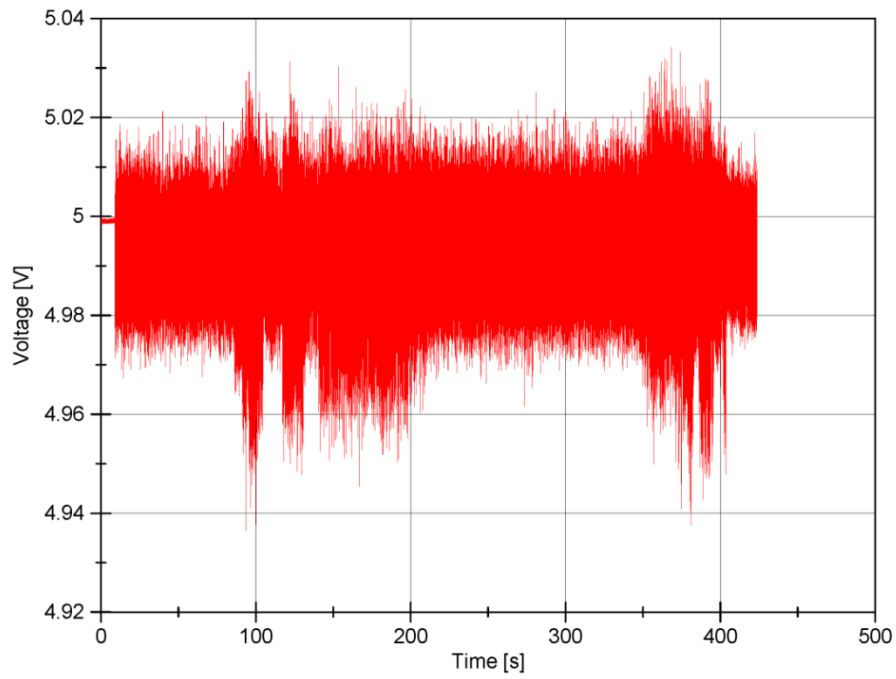


FIGURE B-2. Voltage Output.

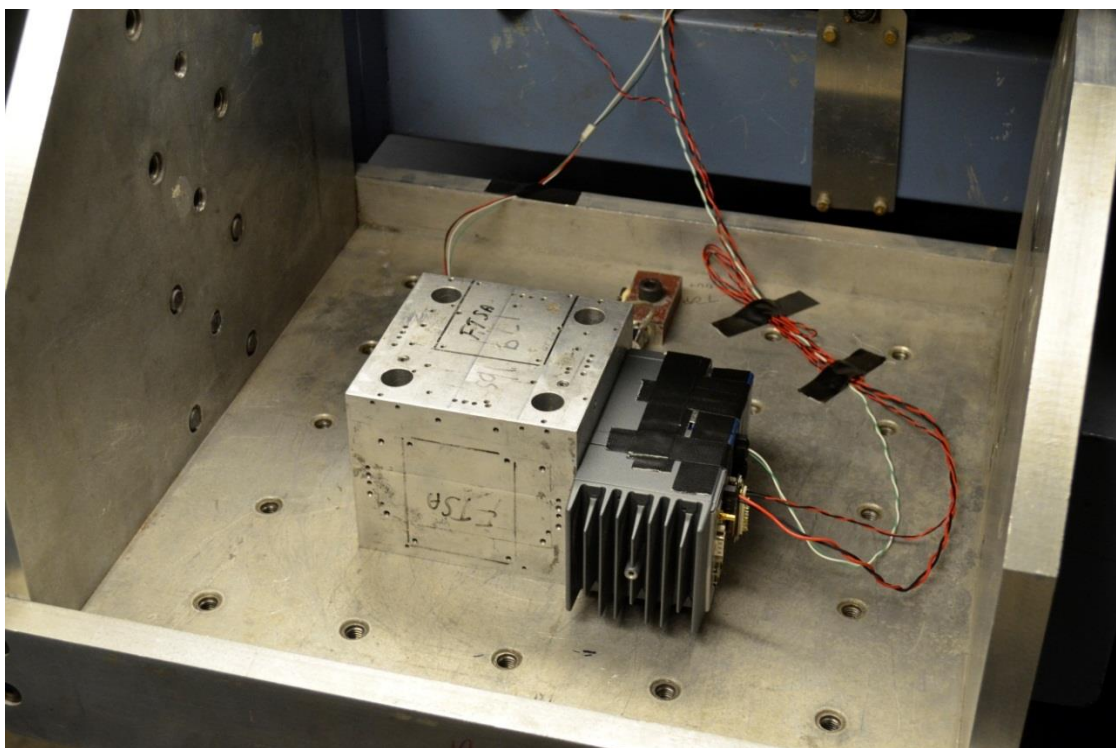


FIGURE B-3. Pretest.

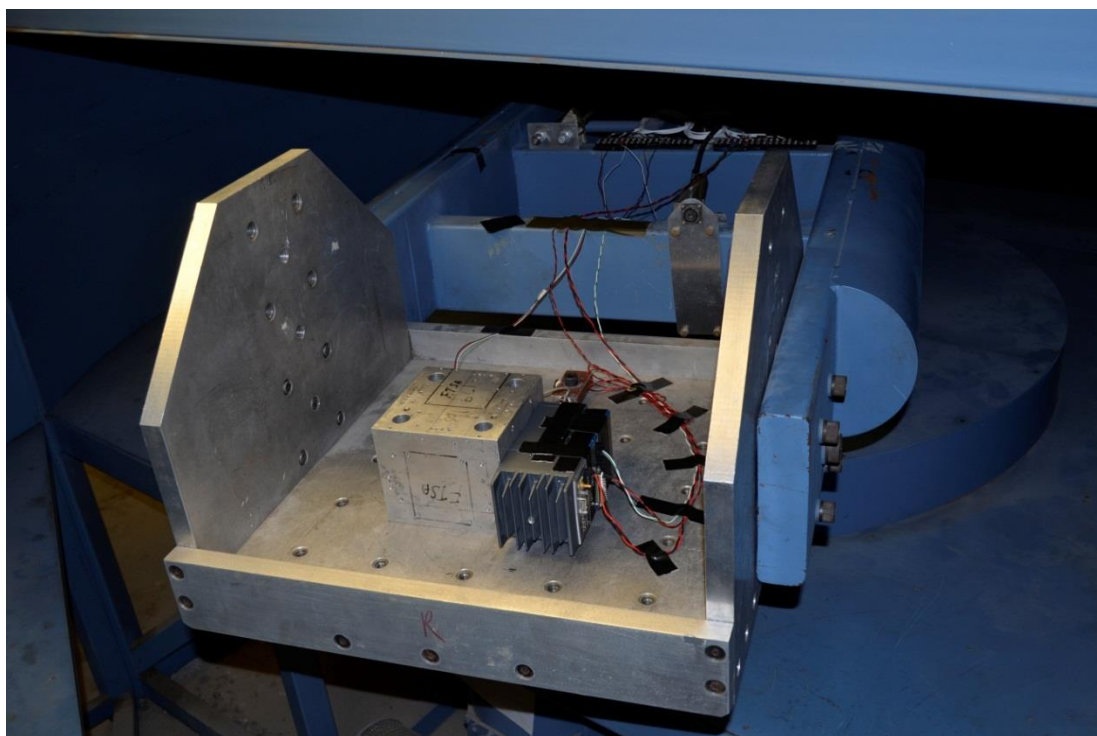


FIGURE B-4. Post Test.

Appendix C

TEST PLAN

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**Vehicle Data Acquisition System Static Load
Test Plan
August 4th, 2014**

Synopsis

This test of CDAS gear will simulate the worst case impulse load expected on the system by applying a 2X static load on the most-susceptible component. The most-susceptible component in the VDAS is expected to be the National Instruments Compact Reconfigurable Input/Output (NI cRIO) chassis and associated data acquisition cards.

The expected quasi-static load on the equipment is expected to be an impulse of up to 68 Gs applied over a time of 300 milliseconds. The shape of the maximum loads of this impulse is shown in Figure C-1. The maximum expected acceleration load is derived from a series of modeled acceleration curves that represent the worst-case arrestment trajectories for the unit under test in which the cRIO is mounted. Because the magnitude of the load cannot be easily reproduced for the expected impulse time, a method using static acceleration will present the worst case impulse load as described by a “Dynamic Load Factor” (DLF) as outlined in John M. Biggs text “Introduction to Structural Dynamics.” The worst-case DLF in this case is 2, the maximum an impulse DLF can take. This assures a conservative test and increases the chance of a successful outcome during testing (assuming the cRIO unit survives this acceleration test). The Environmental Engineering Branch (EEB) will use a centrifuge to apply a load of no less than 136 g’s for one second to provide the 2X impulse worst-case load event.

This document describes the test parameters and criteria for success and failure. It defines the data that are required by CDAS when the test is complete.

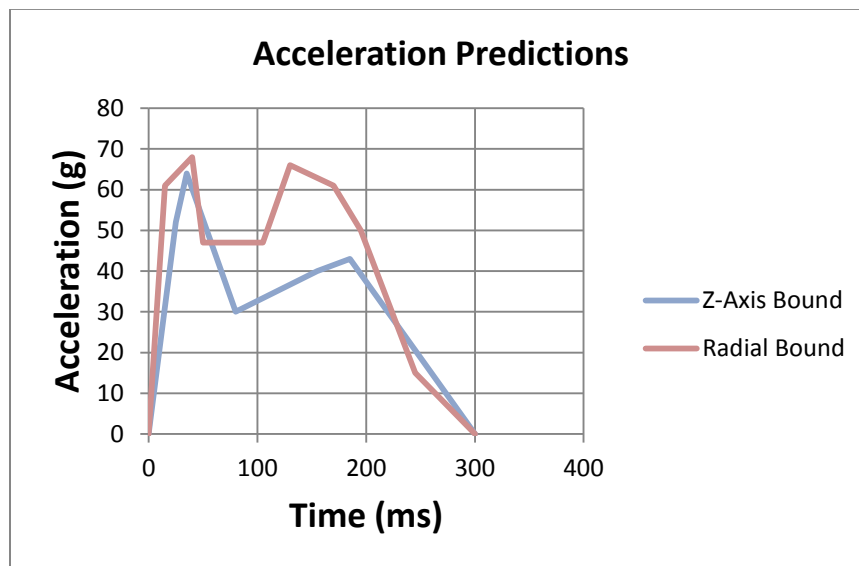


FIGURE C-1. Expected Acceleration Load for cRIO.

Test Parameters

- Applied acceleration load shall be 200 g's or as high as possible within the capabilities of the centrifuge, and in any case no less than 136 g's at any point in the cRIO.
- Applied acceleration load shall be applied for no less than 1 second.
- Applied acceleration load shall be in worst-case directions, expected to in a direction that would tend to remove the data acquisition cards from their chassis sockets, and in a direction that would tend to bend the data acquisition cards and cause them to fail. Loading directions are shown in Figures C-2.
- Acceleration data will be acquired locally by the cRIO unit, using an accelerometer attached to the cRIO unit or test fixture.
- Acceleration data will be acquired remotely by an external EEB data acquisition system (DAS).
- A cRIO unit health monitoring sine wave will be generated by the cRIO unit and transmitted to the external EEB DAS.
- Acceleration data will be acquired via another accelerometer attached to the cRIO unit or test fixture, via slip rings in the centrifuge, on the external EEB DAS.
- Data sampling rate shall be 2,000 samples per second.
- The cRIO unit will be powered by DC voltage via the centrifuge slip rings.

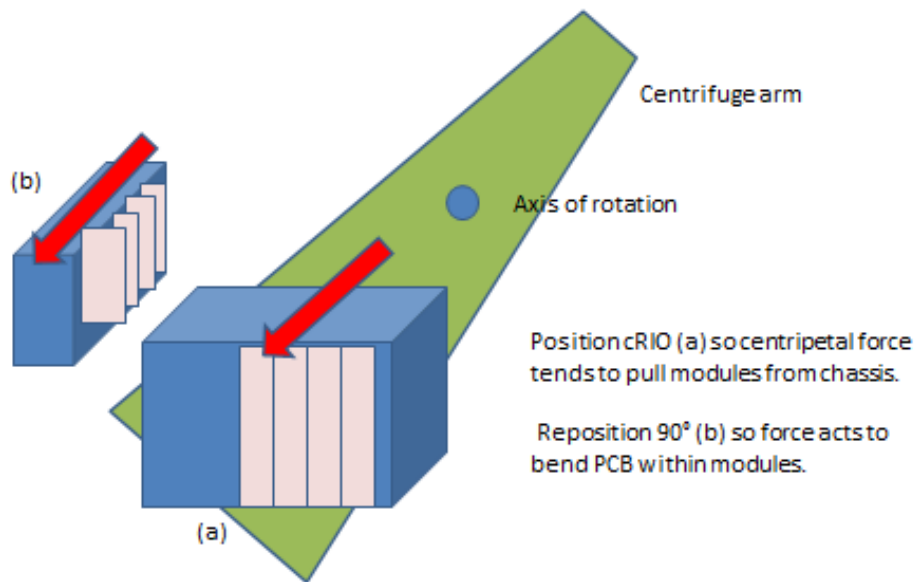


FIGURE C-2. Notional View of the cRIO Chassis and Cards Mounted in Centrifuge.

Success/Failure Definition

Success of this test series is defined as the acquisition of acceleration load on the cRIO unit at levels greater than or equal to 136 g's, for 1 second, in the most susceptible load orientations, resulting in proof that the cRIO unit has operated properly in the presence of the applied acceleration load, or can show at what applied load (and direction) data loss occurred.

In the event that failure of the cRIO unit occurs and data is not acquired or recoverable from the cRIO unit, the external DAS test data will show when the loss occurred. The magnitude and direction of the load that caused the failure (or that were applied at the moment of failure) will be noted and reported.

Deliverables

A report of findings will incorporate a summary of results, test setup, data reduction technique, and data in engineering units. The report will provide photo-documentation of the test setup.

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