SAND2007-2486C

Isolation System for NLOS Cannon Laser Firing System

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This project is funded by BAE Systems

The NLOS-C Development Program is a multi-agency effort

ARDEC
BAE Systems
Benet Labs
Boeing
David Cain Enterprises
Kigre Inc.
Rayotek Scientific Inc.
Sandia National Laboratories

Within every one of these agencies I have had the pleasure of working with groups of exceptionally skilled, yet humble, individuals.

It is an honor to be part of this team.

Special thanks to BAE Systems and ARDEC for the use of their images in this presentation

Future Combat System (FCS)

Brigade Combat Team

(unit capable of supporting itself away from its parent division)

Manned

- The Non Line of Sight Cannon (NLOS-C) 1 of 8 ground vehicles
- Multifunctional Utility Logistics & Equipment Vehicle (MULE)
- Soldiers

Control Network Linked

brain

nerves and muscles

Unmanned

- Unattended Ground Sensors (UGS)
- Unattended Munitions (UM)
- Unmanned Aerial Vehicles (UAV)
- Armed Robotic Vehicle (ARV)
- Small Unmanned Ground Vehicle

The synergy of all these elements creates a flexible, potent, and most importantly, organic way to confront an enemy

NLOS Cannon

Howitzer on a diet, a current conventional Howitzer style cannons weigh around 60 tons.
The term Howitzer is Dutch and Czech based term for catapult or hurl.

Approximately 20 ton weight
(C-130 transportable)

Light weight 155mm bore 38 caliber barrel

24-100 pound projectile magazine

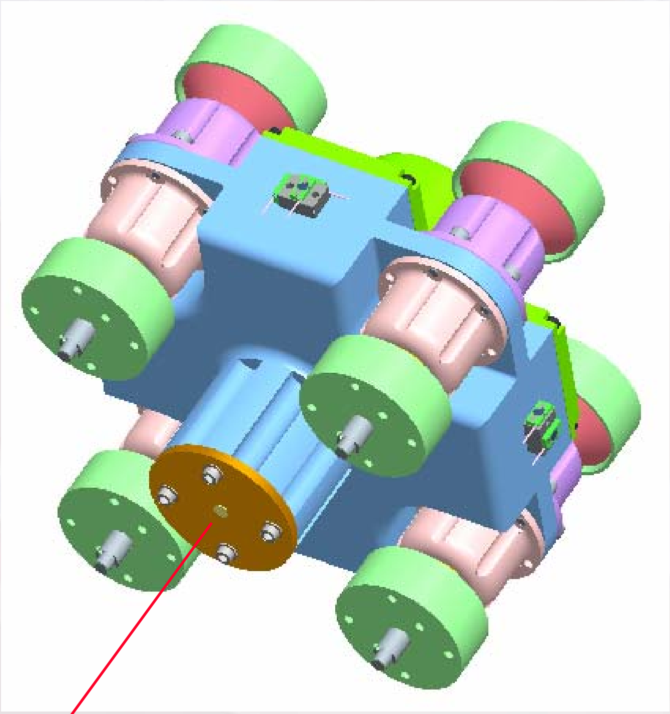
Auto-loading 10 rounds per minute

4-6 round simultaneous impact capability

Electronic laser firing system

Hybrid electric drive through band track suspension
90kph road speed

Laser Firing System Requirements



Timed delivery of energy

Accuracy

Pulse rate

Survivability

Problem Background

·The new lightened 155 barrel accelerates quicker during round firing

·The new barrel also incorporated an advanced muzzle brake to assist the recoil mechanisms

·Both of these new designs increase the magnitude of the shock events at the breech

This resulted in the breech mounted laser firing system experiencing failures

Sandia Deliverables

Enhance the Laser Firing System's Functionality

Laser System Hardening

Laser System Isolation

Design discovery based experiments

Reveal weak links

Quantify stress and strain in weak link components and correlate to g-level

Design a robust isolation system

Engineer isolator system

Model isolator system

Test isolator system

All test and experimental data is fed back into margin analysis

Discovery Based Experiments

Shock testing – Create a device and experimental methodology to systematically expose hardware to a variety of shock events and shock directions

Scanning Laser Vibrometer - Excite and monitor the natural resonant frequencies of trigger hardware in their actual mount geometries

Four Point Bend - Create a surface friendly four point bend test fixture to extract static bend stress and strain data from glass lamp components

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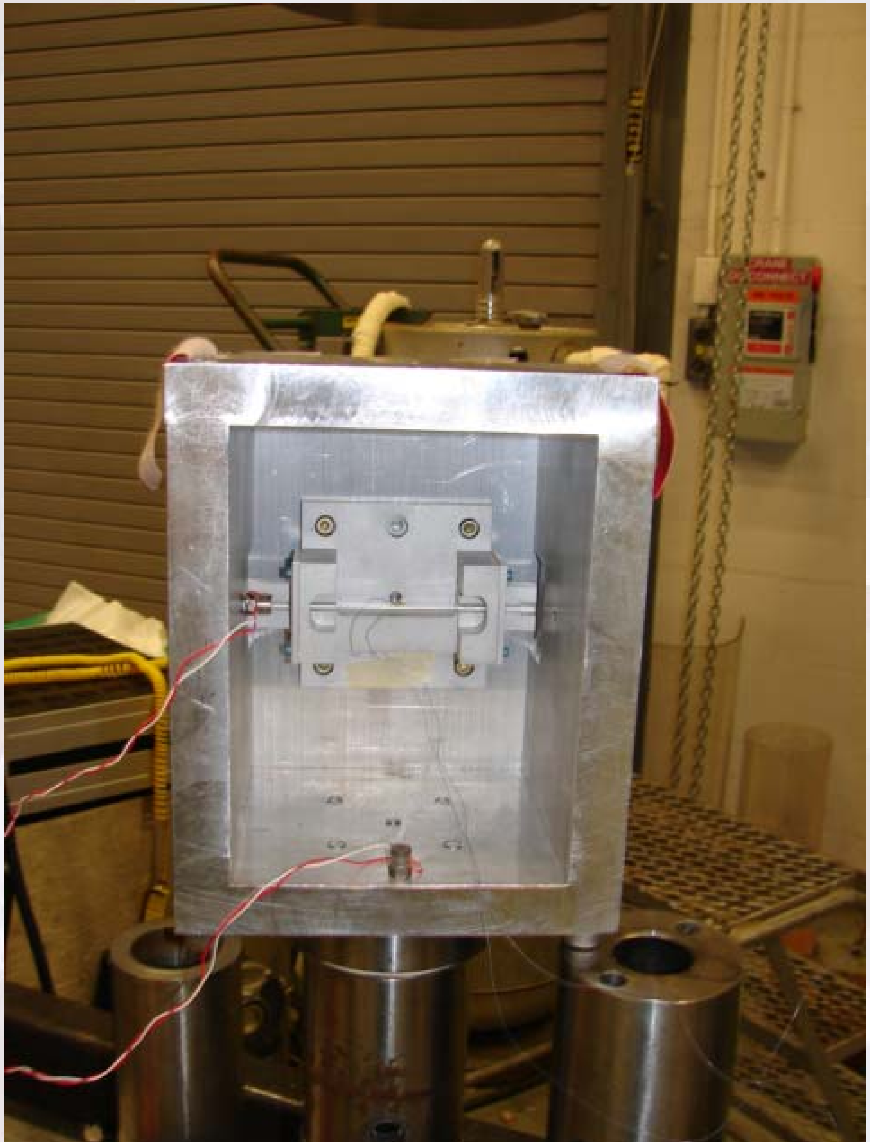

Shock Testing

-Impact cage design

-Accelerated by an MTS high rate test frame

-Impacting a steel reaction plate

-Decoupled with a shear pin fixture

-Instrumented with accelerometers

-Data captured with a high speed Nicolet oscilloscope

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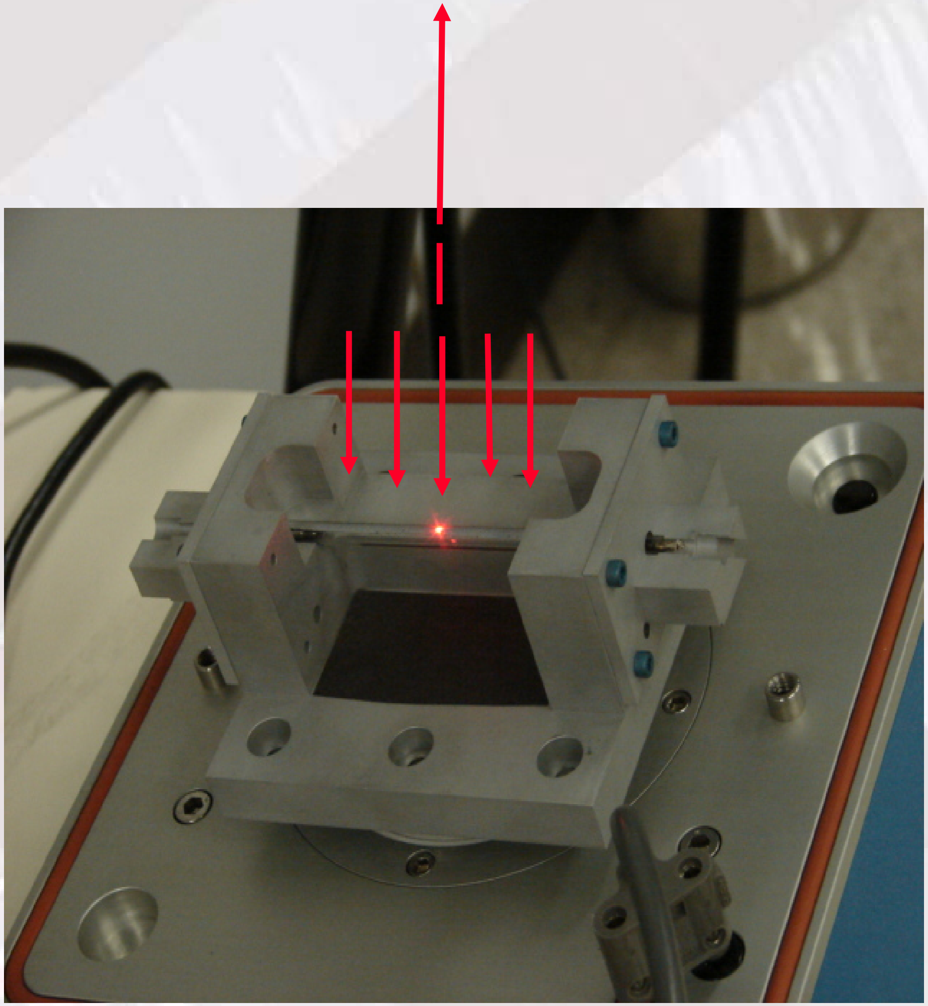
Scanning Laser Vibrometer

Polytech SLV

Doppler shift of beam indicates point velocity

Scan of length combined with excitation sweep determines the resonant frequency and mode



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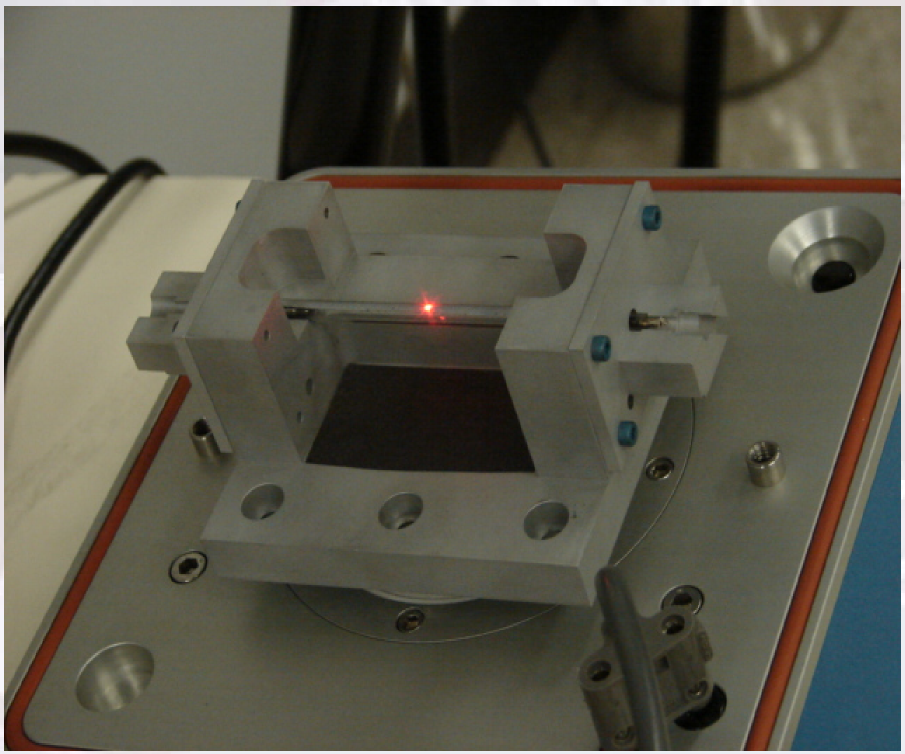
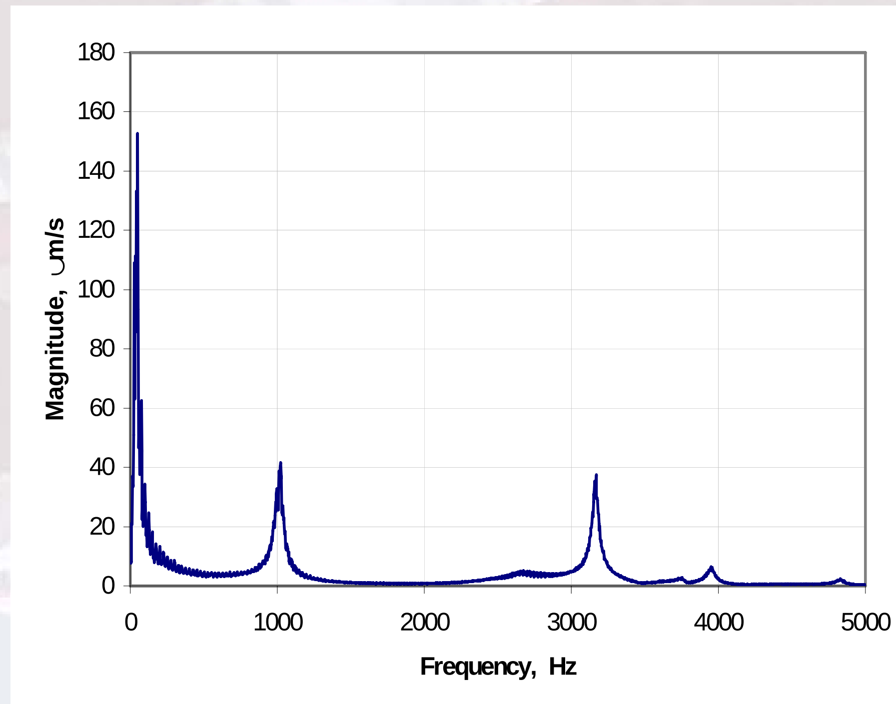
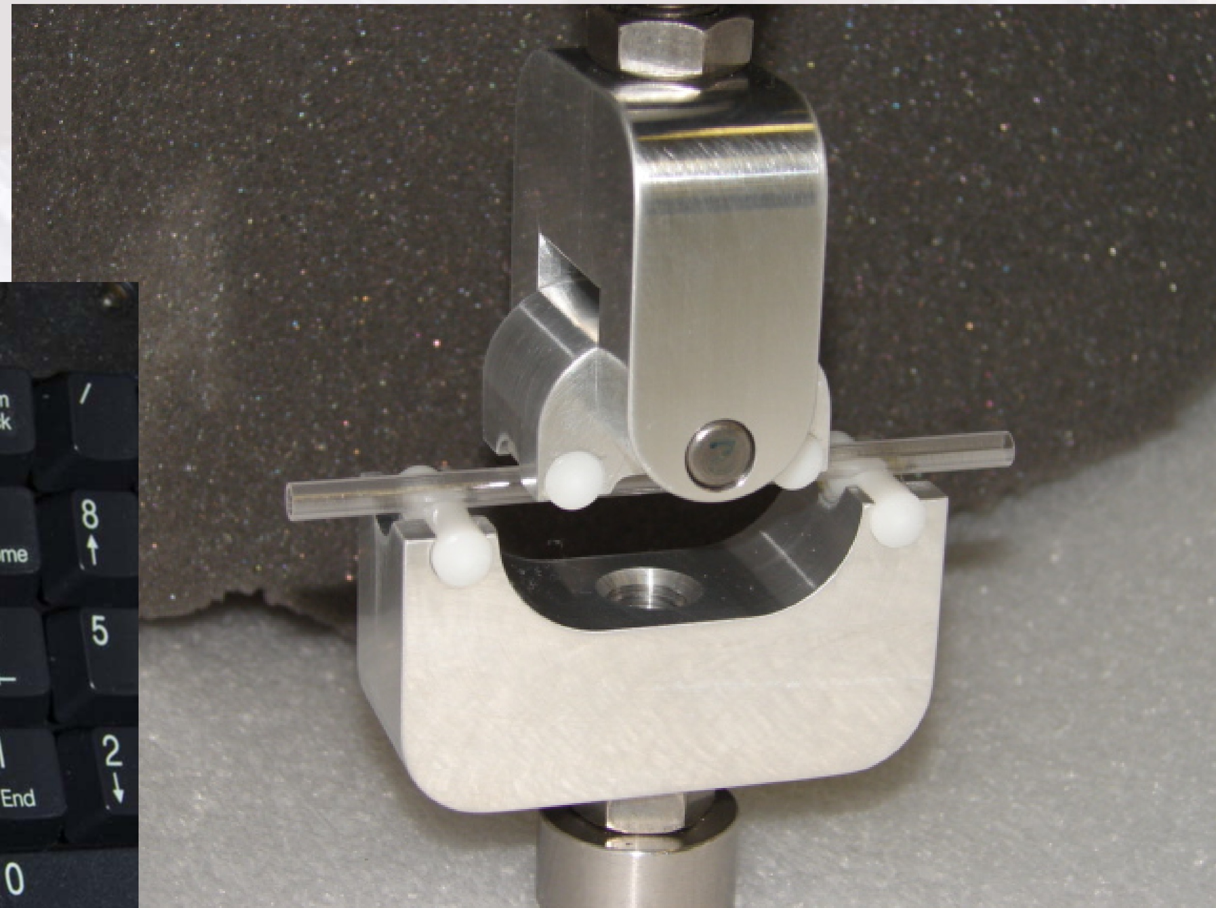
Scanning LASER Vibrometer
Excitation Sweep of Quartz Lamp
with electrodes no lead wires
conventional single o-ring mount
resonance @ *50hz, 1150hz, 3200hz
*50hz is the free body motion of the fixture and lamp



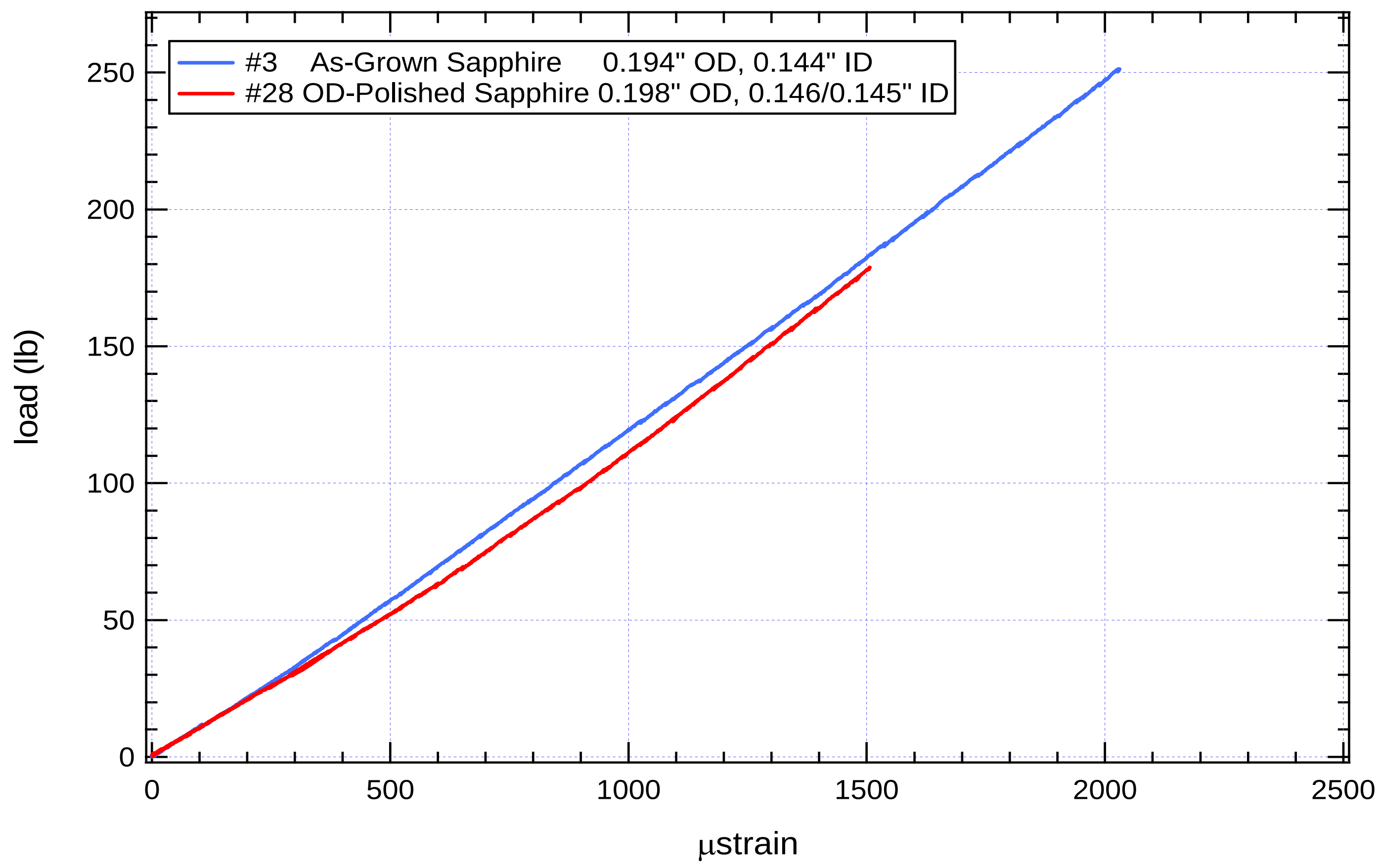


Four Point Bend

Polyethylene pivot pins provide a semi-soft, radius matched seat



4 Point Bend Results
#3 as-grown sapphire
#28 OD polished sapphire



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Laser Firing System Isolation Design Requirements

·Provide a significant reduction in transmitted firing and braking shock without a sacrifice in alignment accuracy

·The firing schedule and firing system design flux requires modular field tunable hardware

·Fit within existing gun space while utilizing existing mounting points/attachments

·Provide extended multiple round lifespan

·Complete the design and provide working hardware in a two month time frame

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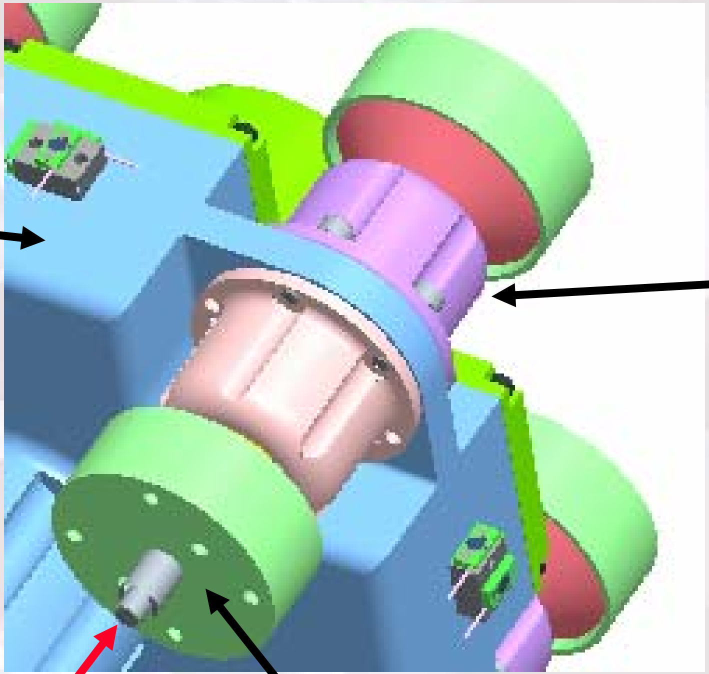
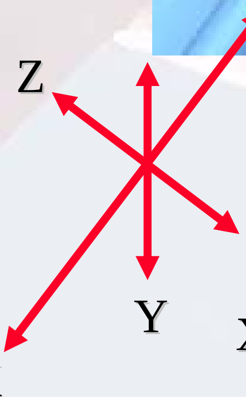
Isolator general function

Laser housing



Isolator unit (1 of 4)

Laser must be isolated from all planes of shock input



dark green surface mounts against gun breech

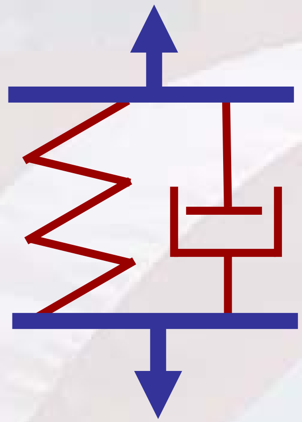
X is recoil/braking direction

Isolation Material Selection

Need a spring and a damper
which is simple and light

one option was to use a spring and
oil damper

time, complexity and weight ruled this out



Viscoelastic polymer

defined by its two components of response behavior

viscous

(damper) captures kinetic energy and converts it to heat

elastic

(spring) stores and releases energy

the spring component is necessary to maintain position and alignment

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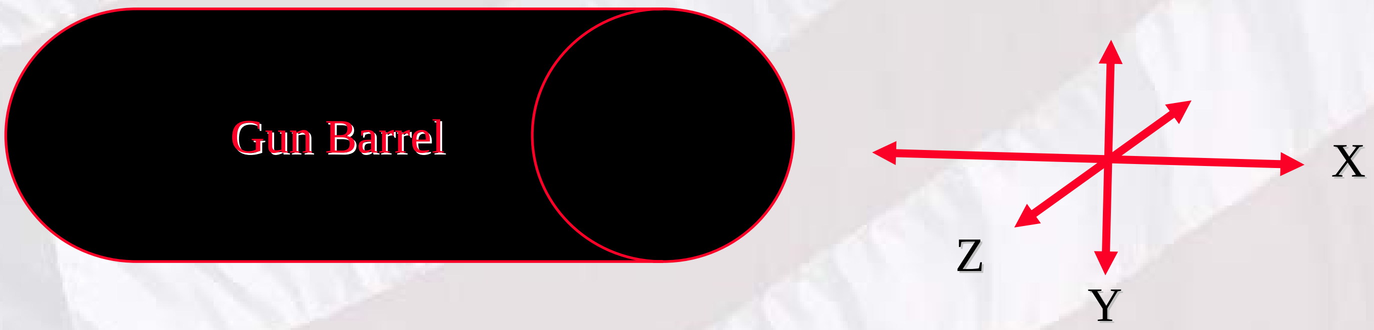
Further Isolation Requirements



Displacement is necessary to reduce transmitted shock

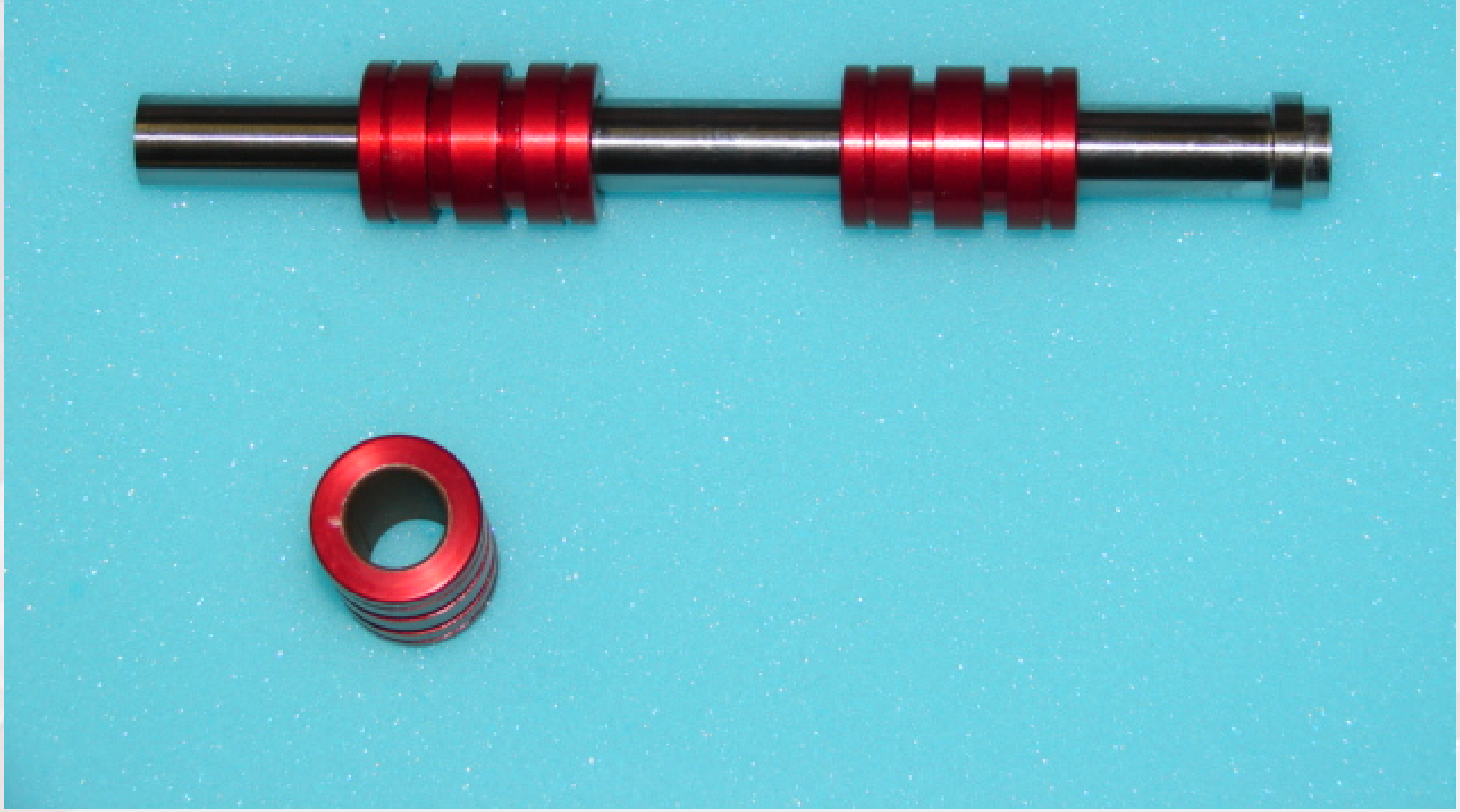
The firing/braking axis develops the highest shock loading thus requiring the greatest isolator travel

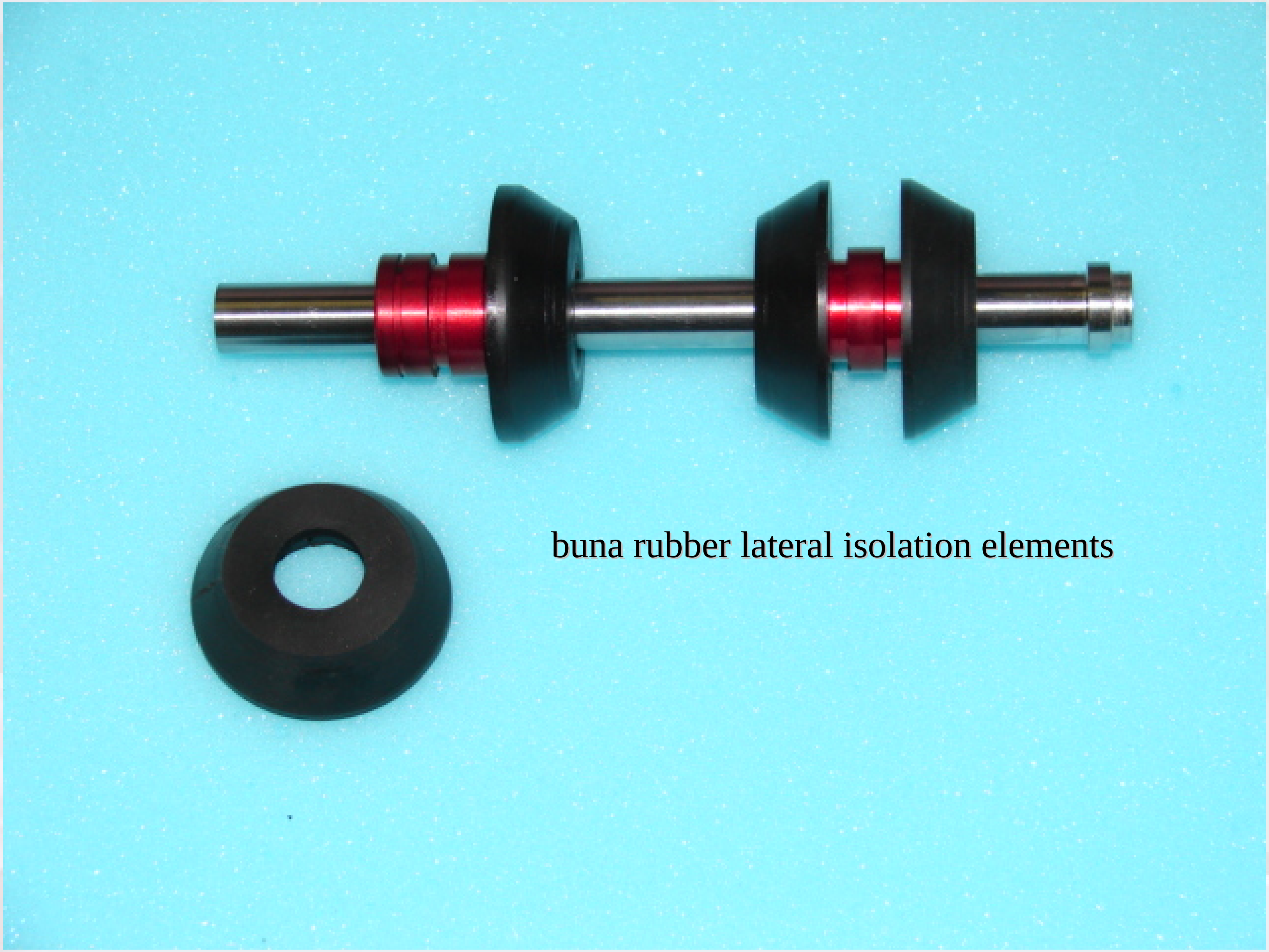
Allowed axial design space requirement +/- .600 inches

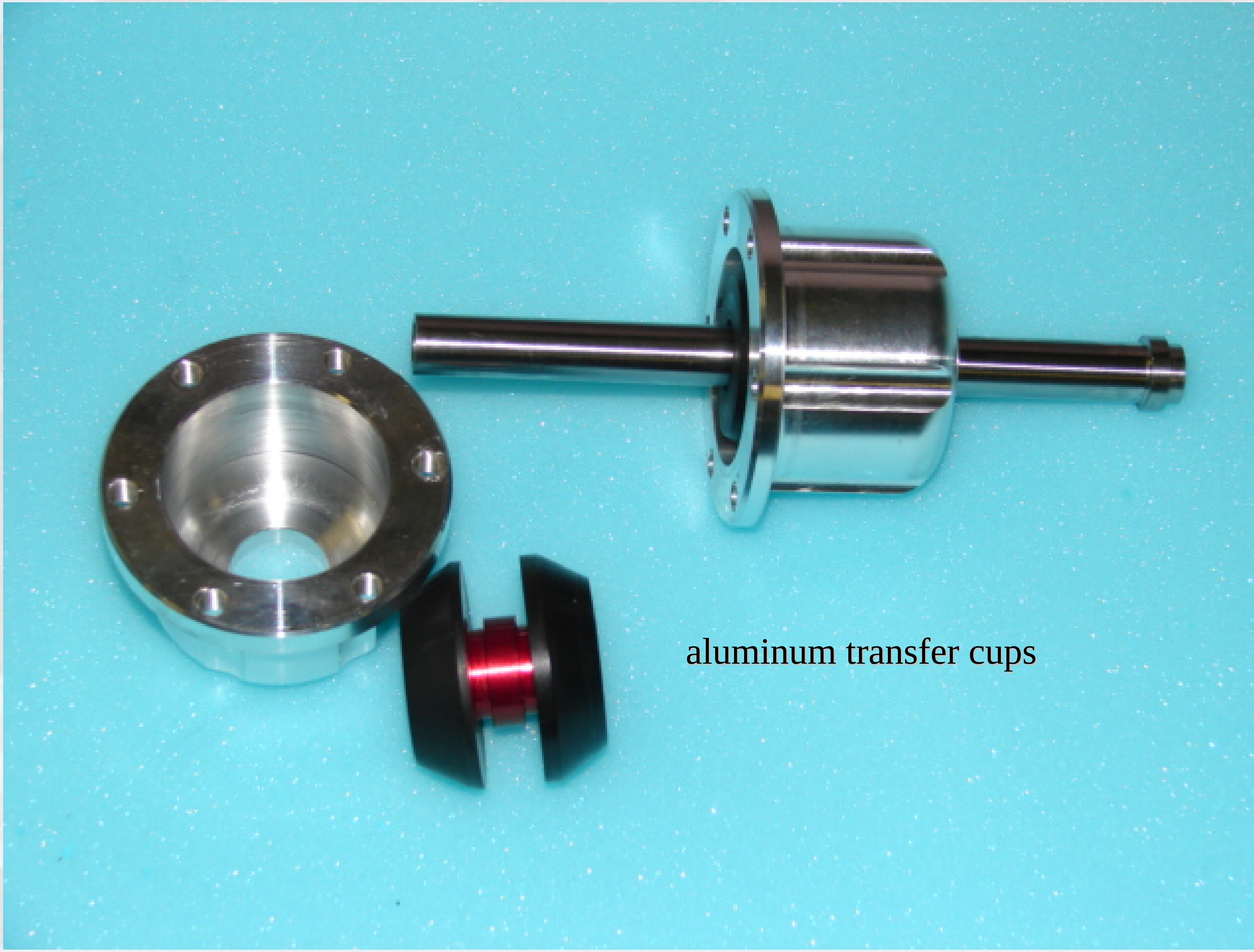
Lateral shock loads are considerably lower so the Y & Z Directions require less design space. Allowed +/- .250 inches

Alignment Accuracy

linear bearings on a custom ground hollow shaft




buna rubber lateral isolation elements


aluminum transfer cups

buna rubber axial isolation elements


shims effectively lengthen
or shorten the hollow
shaft establishing preload
and allowing for alignment
correction
aluminum hoop cups
for axial element containment
creates a progressive resistance

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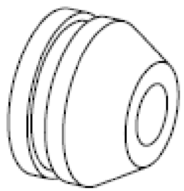
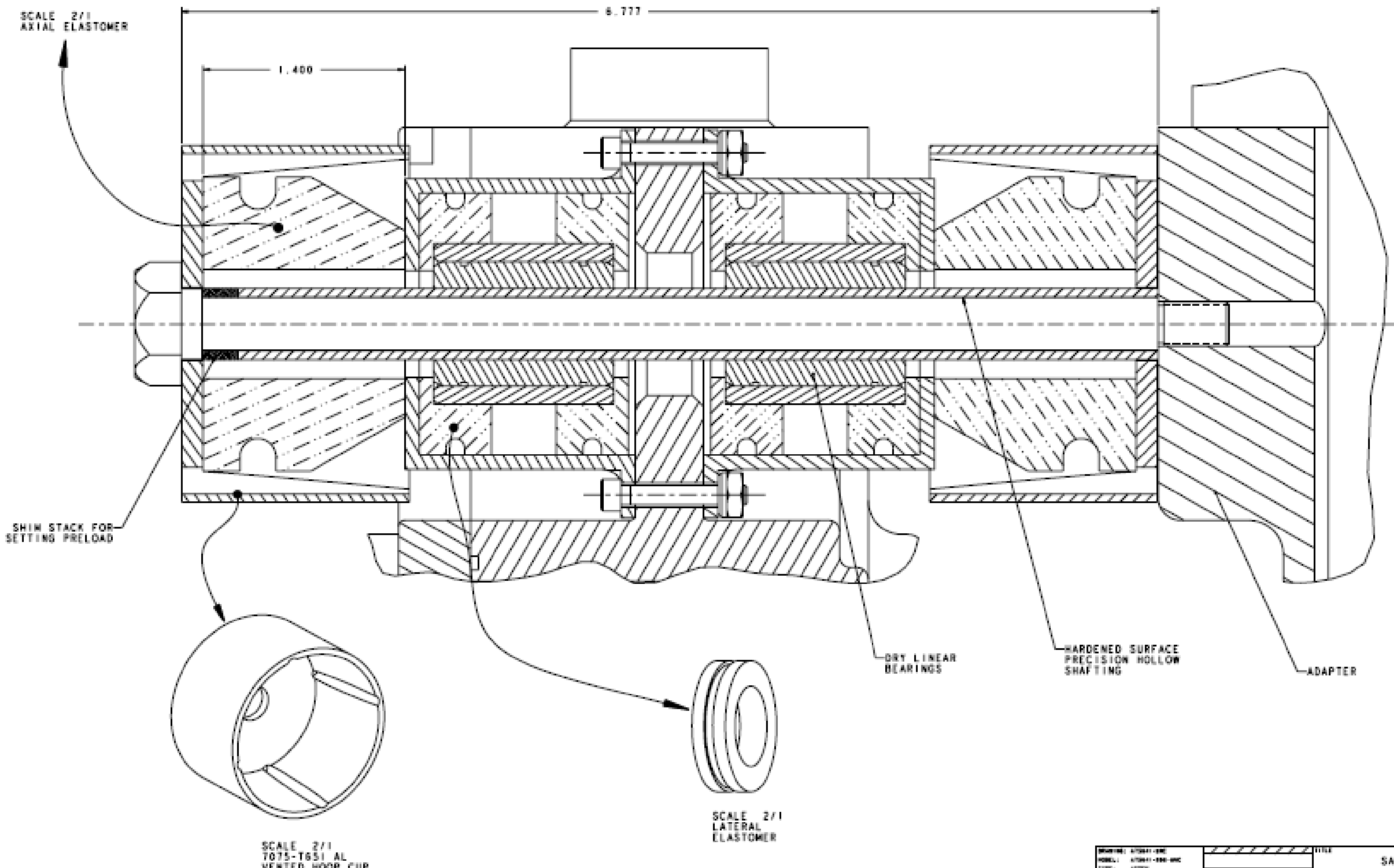
PART NUMBER	REVISIONS			
	LTR	SHEET ZONE	DESCRIPTION	DATE
A75641-000	A		ORIGINAL ISSUE	07/11/06

TUNING FUNCTIONS:

1. ELASTOMERIC INSERTS ARE NOT BONDED NOR VULCANIZED IN PLACE FOR QUICK CHANGE OUT.
2. ELASTOMERIC VARIABLES WILL INCLUDE, COMPOSITION AND GEOMETRY (GROOVES AND TAPERS).
3. HOOP CUPS WITH BREATHING VENTS.
4. SHAFT SHIMS FOR AXIAL LOCATION AND INITIAL PRELOAD.





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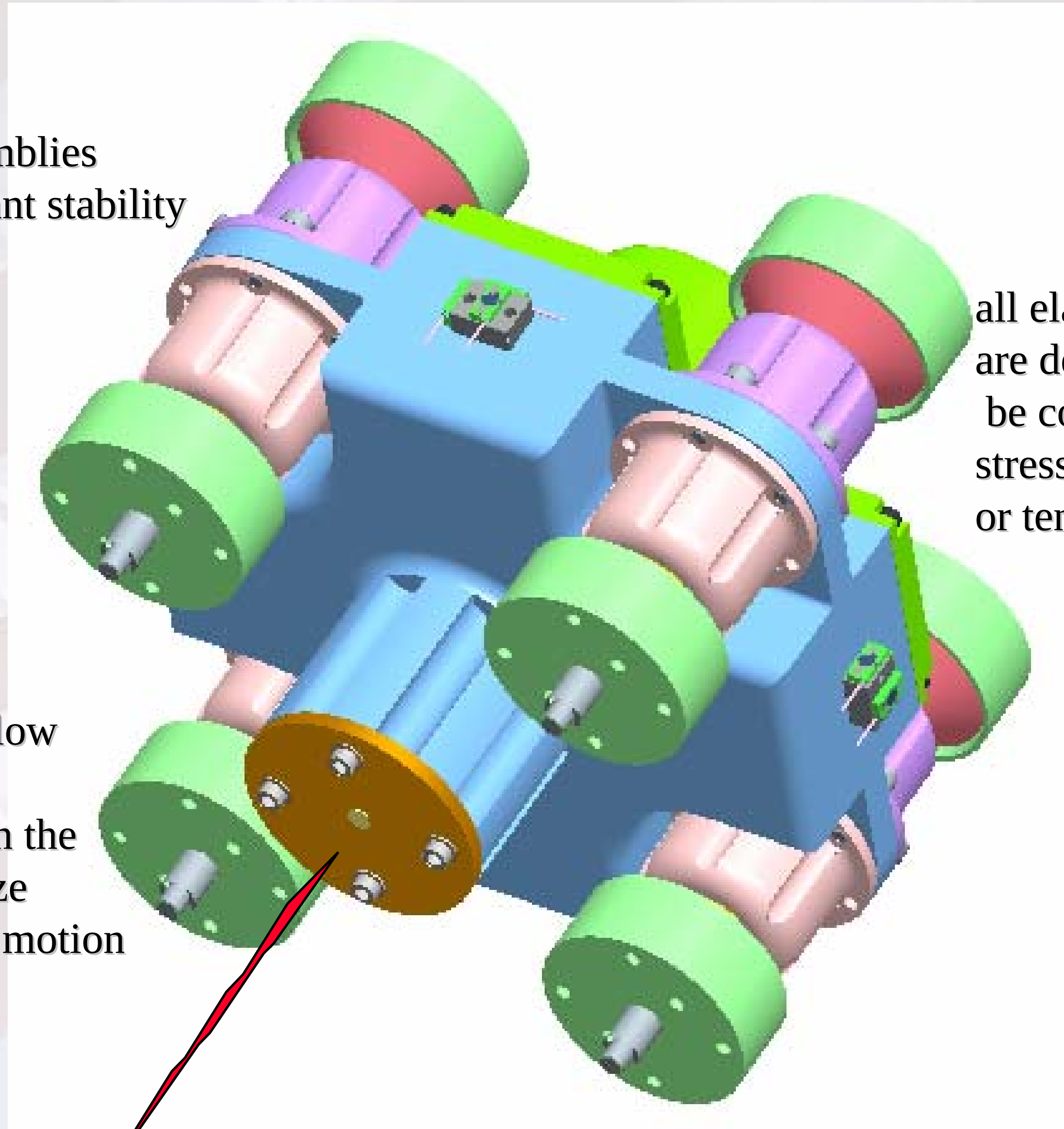
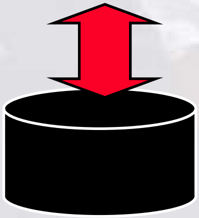
4 isolators assemblies
provide compliant stability



all elastomers
are designed to only
be compressively
stressed (no shear
or tension)

long press fit
pilots on the hollow
shafts eliminate
bending stress on the
bolt and minimize
non-elastomeric motion

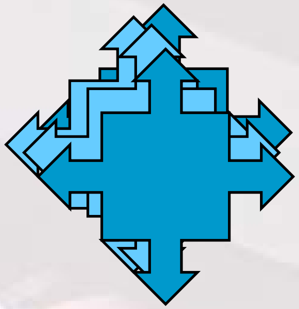
Isolation System Laboratory Testing



Materials testing: elastomer load rate response at field temperatures

Hardware testing: fastener strength, assembly stiffness

Shock isolation testing: isolation effectiveness



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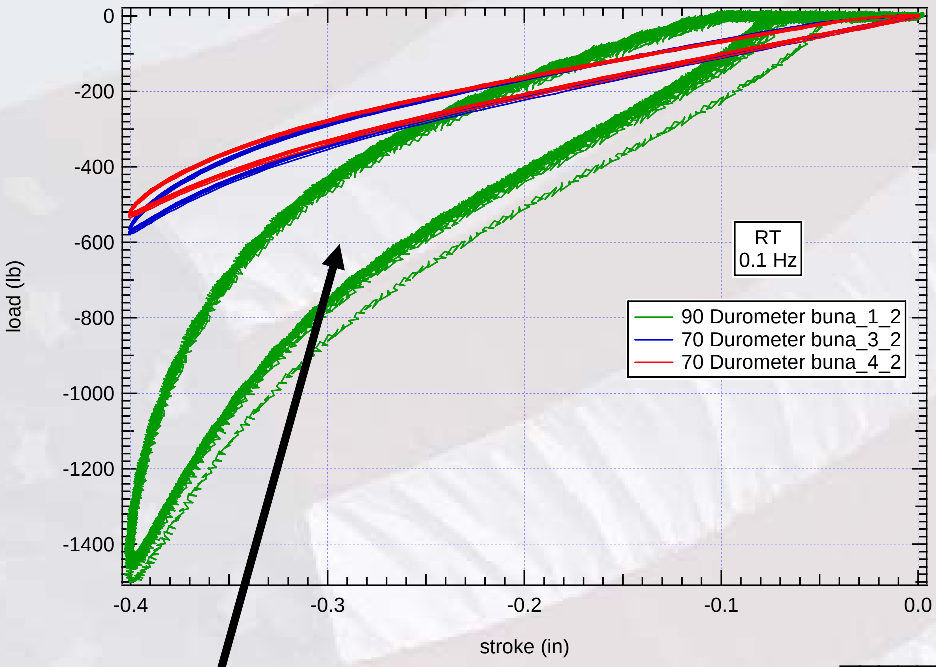
Compression testing for load deflection hysteresis temperature data



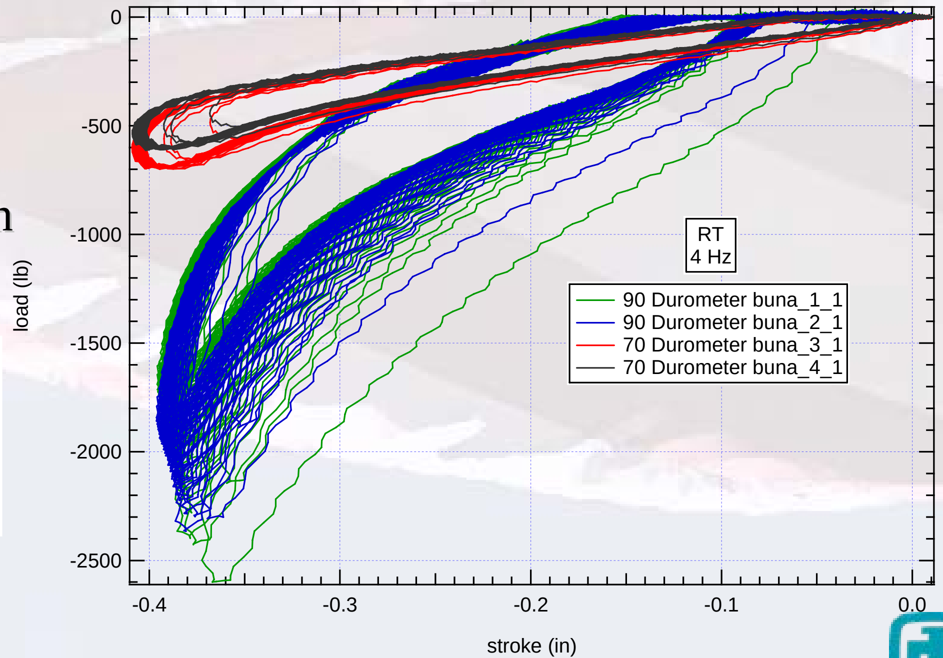
Load deflection curves (elastic–spring)

of Buna rubber

70 and 90 durometer

0.1Hz and 4hz

Hysteresis (visco-damper)
is represented by
the area inside the load/deflection curve



The word hysteresis is of Greek origin, meaning deficiency or to fall short.

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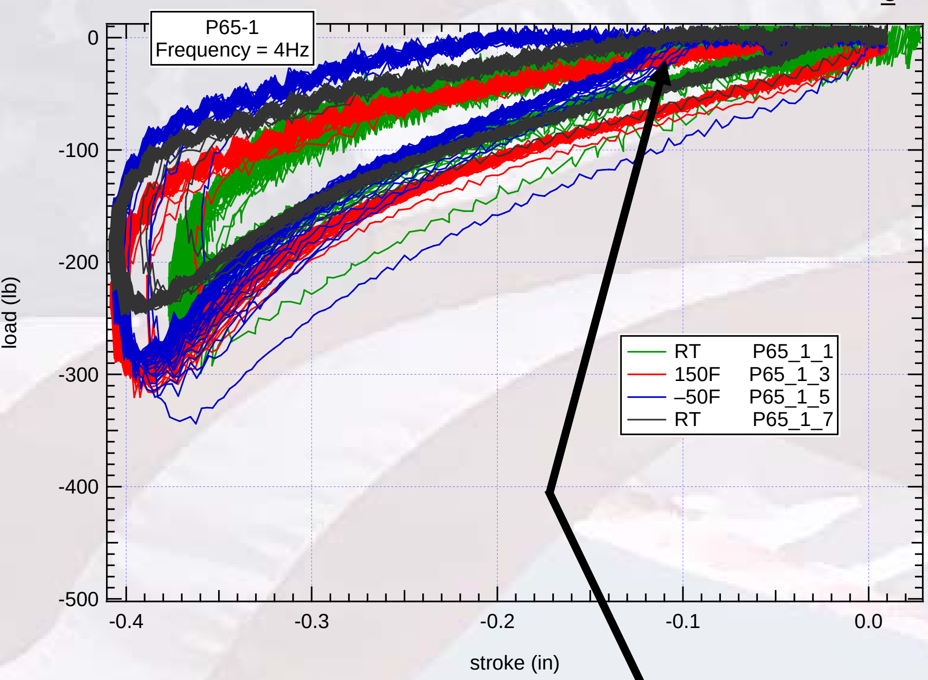
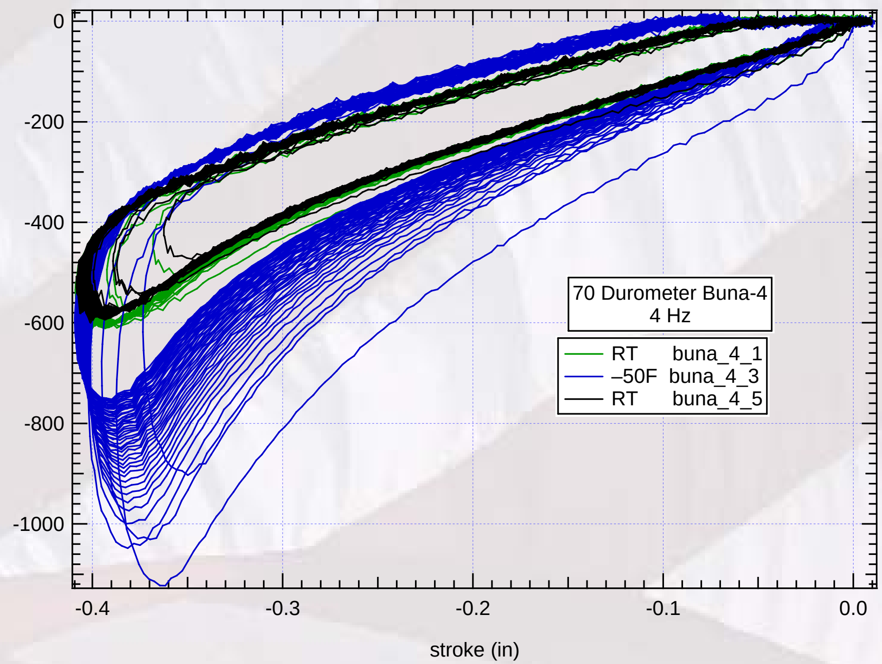
PVMQ Silicone 65 durometer





Buna rubber 70 durometer

zero shift indicated permanent deformation/damage

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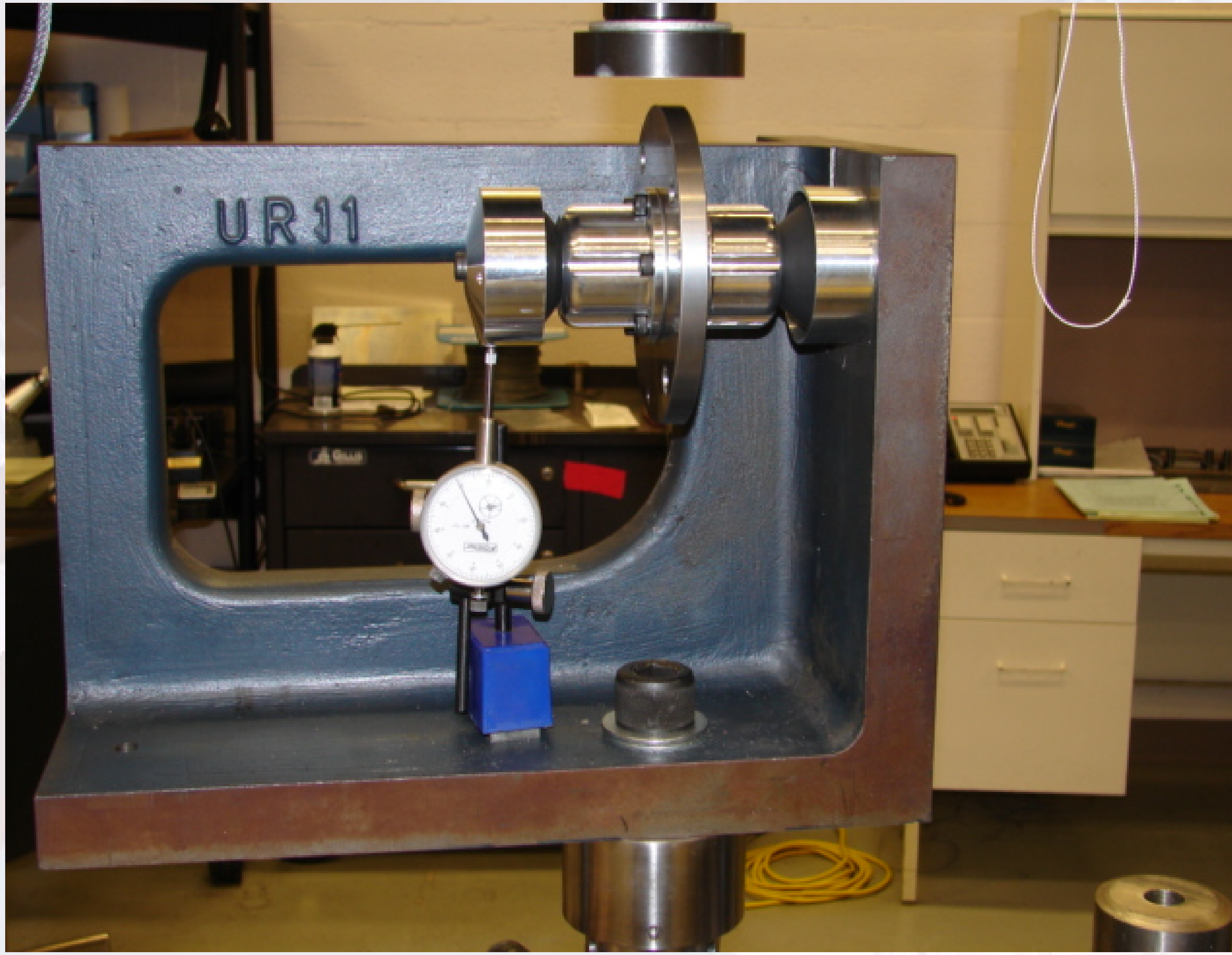
lateral stiffness testing

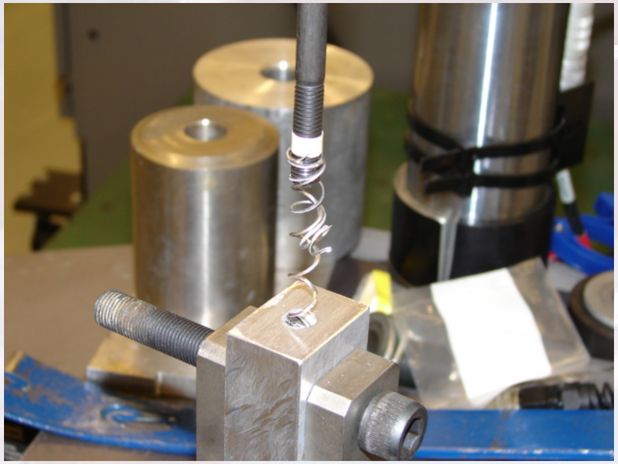
crosshead deflection minus the centered rod deflection equals the lateral elastomer deflection



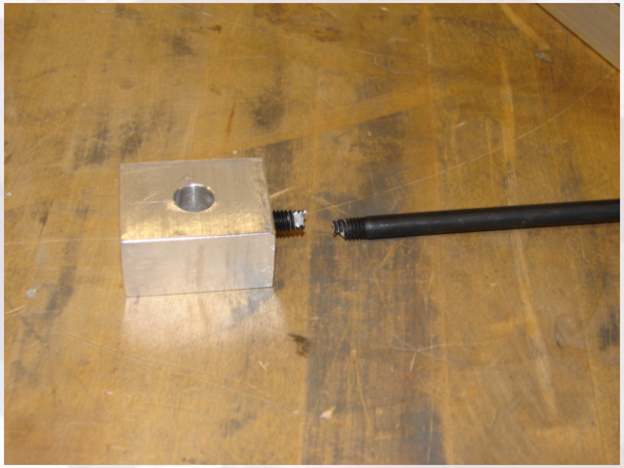
Isolator 8mm Main Bolt Test to Failure

Bolt - 8 x 1.25 200mm length socket head cap screw class 12.9 alloy steel 174,000 psi minimum tensile strength

Helicoil – stainless steel
16 mm (.629") long inserted into 6061- T651 aluminum



Bolt thread engagement 8mm (.315)
Helicoil failure at 8198 lbs.



Bolt thread engagement 16mm (.629")
bolt thread failure at 10853 lbs.

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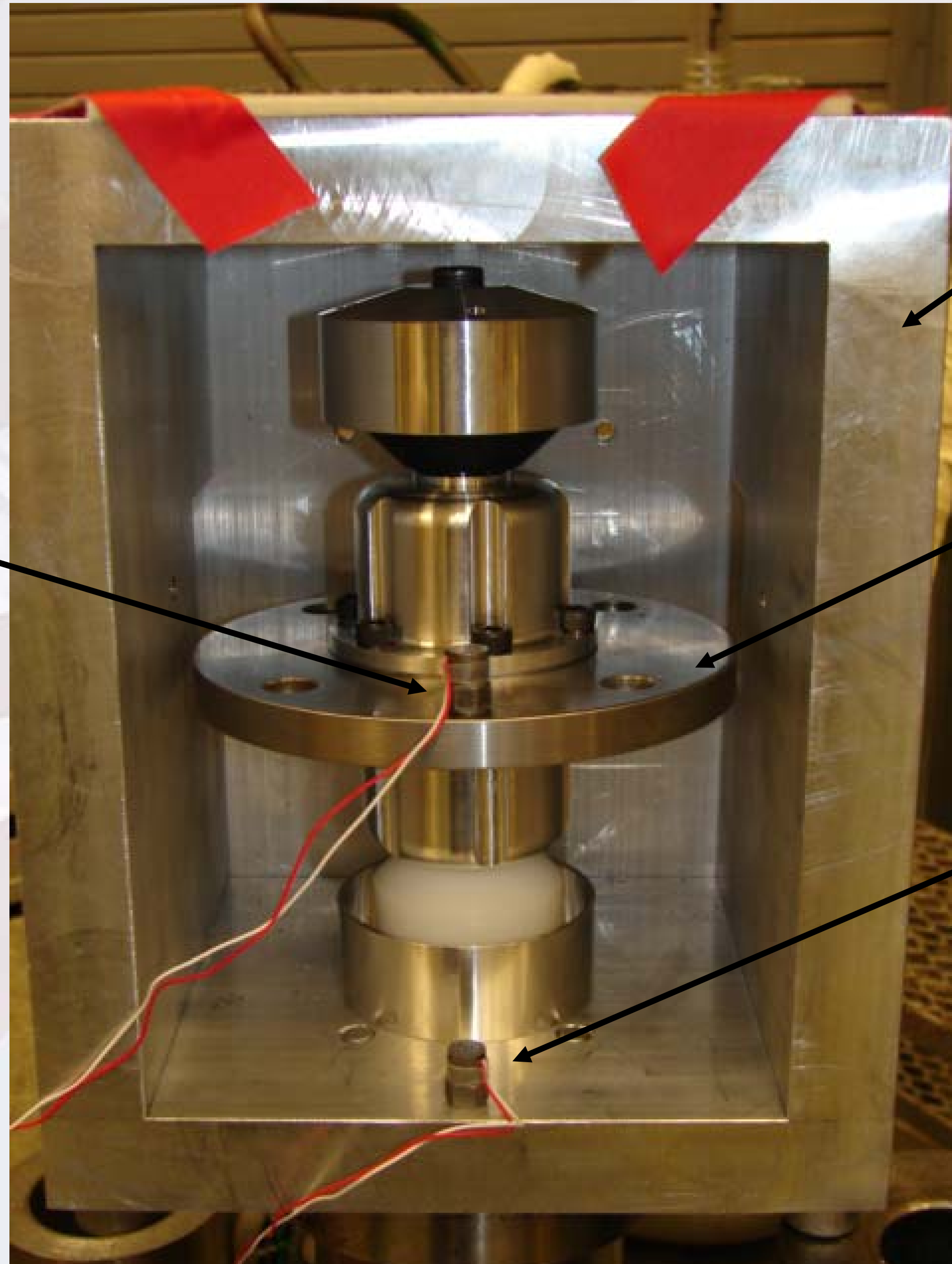
Shock Testing



acceleration impact cage

laser mass/mount simulator

input accelerometer

isolated accelerometer (what laser sees)

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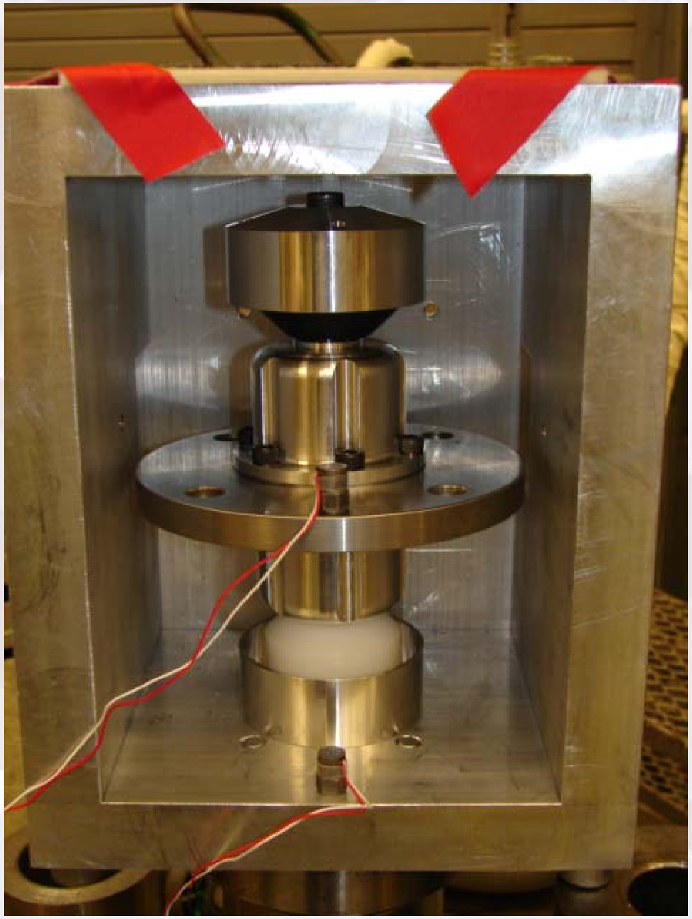
Isolator Shock Response

Input Shock level/duration	Isolated response
1kg/2ms	623g .2” preload
1kg/2ms	570g no preload
1.7kg/1.1ms	607g no preload
3kg/.55ms	574g no preload



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Project Accomplishments

Weak links have been experimentally discovered
in the laser firing system and design fixes have been put into place

Component shock margins have been established through laboratory experimental data incorporated into analytical and statistical modeling

The Sandia designed isolation system has been successfully protecting the NLOS-C firing system at the Yuma Proving Grounds since October 2006 through the maximum charge zone four shots

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