AFLCMC/EBHJ

War-Winning Capabilities…On Time, On Cost

ACES II Harness Release System Failure Investigation

Cartridge NSN: 1377-01-368-5411
P/N: 9392046-2

CAD/PAD IPT

Hill AFB, UT

Allen Hancey

November 2015

U.S. AIR FORCE

Integrity - Service - Excellence

Overview

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- Sled Test Failure
- Harness Release System Operation
- Cause and Effect Diagram
- Specification and Test Fixture History
- Low Output Hi-Shear Cartridges
- Test Fixture Setup Error Discovery
- Hi-Shear lots in inventory
- Margin Study
- Thruster Dissection
- Thruster Configuration History
- Cold Gas testing
- Historical Performance Data
- Cartridge Installs
- Conclusions
- Path Forward

ACES II Harness Release Thruster and Cartridge

Sled Test Failure

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- **In June 2014 during a Modernized ACES Seat Sequencer (MASS) qualification sled test the FWD seat manikin failed to achieve seat-man-separation**

Manikin failed to release from seat

Sled Test Failure (cont)

- **Seat inspection revealed that the harness release cartridge was functioned, however, thruster was not activated**
  - **Upon cartridge removal gas pressure was heard releasing from the thruster**
  - **The bell-crank was functioned manually; it was estimated that it took <40 lbs to move crank (typical value)**
  - **Seat acceleration noted to be 0.97 Gs on peak axis at time of release (typical range with historic sled test data)**
- **Identified cartridge was from lot HST08D001-001**
  - **NSN: 1377-01-368-5411, P/N: 9392046-2, DODIC: MD87**

Harness Release System Operation

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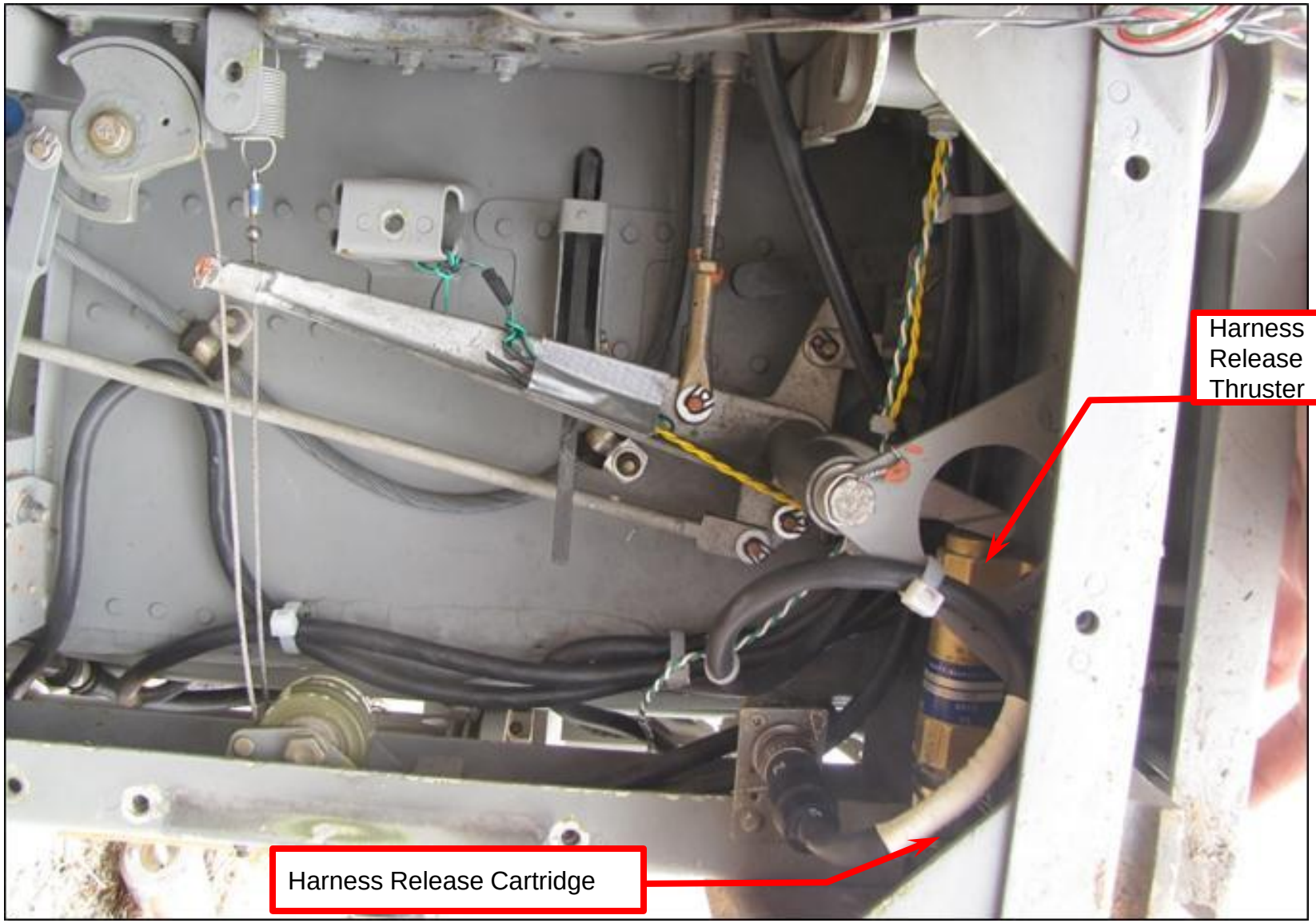

Cause and Effect Diagram

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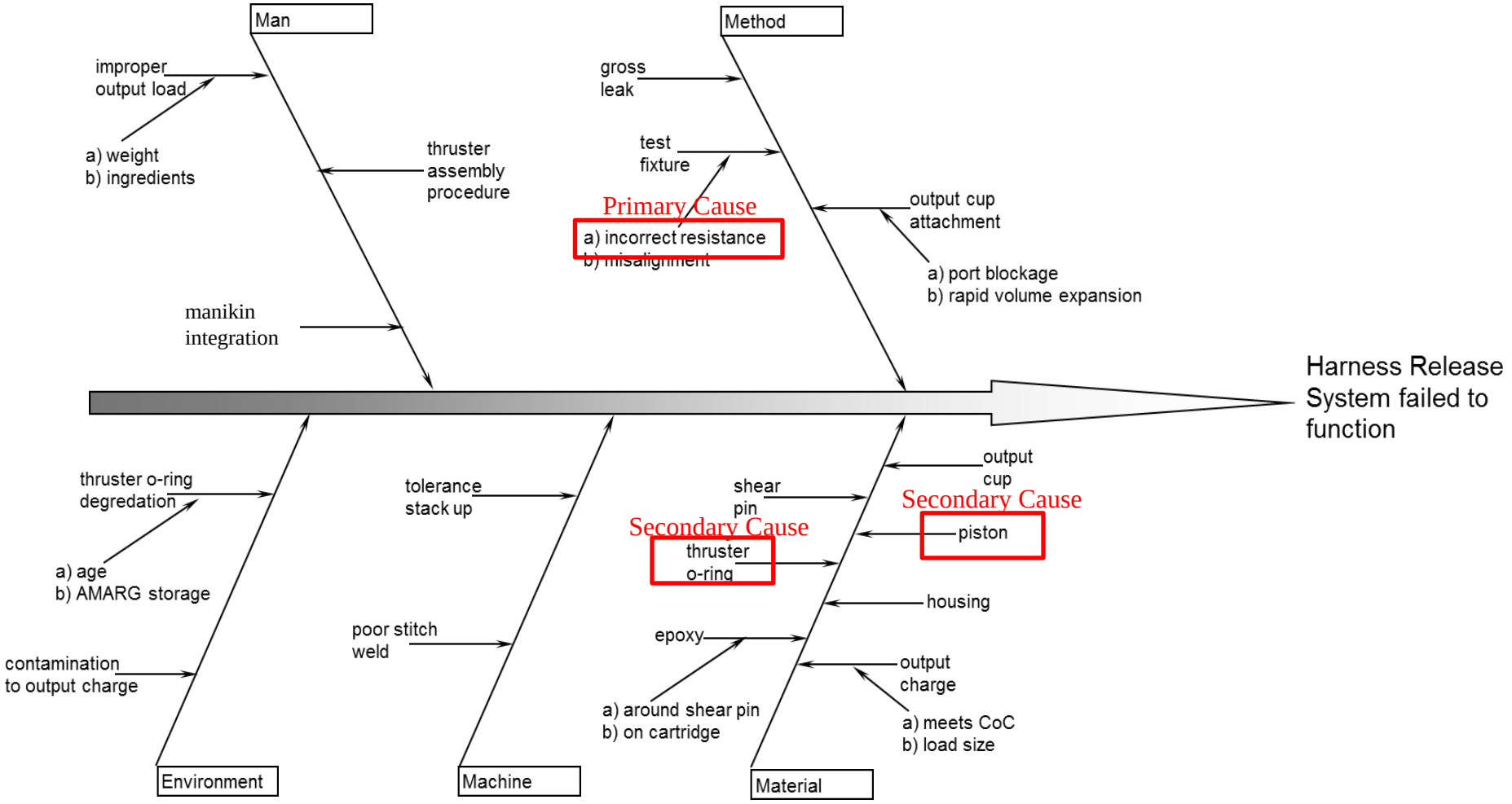

Specification & Test Fixture History

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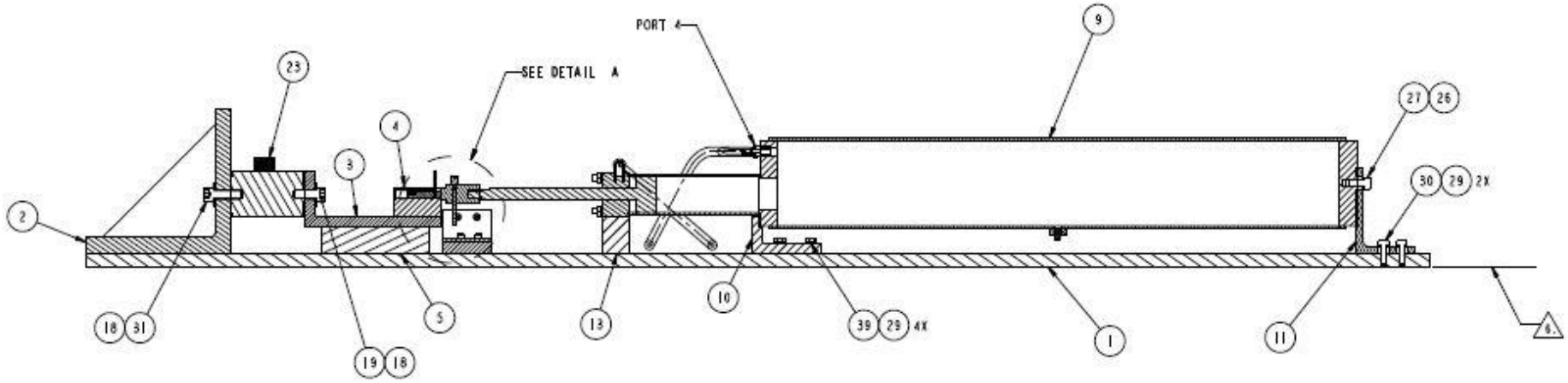
- **Due to variability between vendor's test equipment HAFB & Indian Head developed a Weapon Specification 34120 and standardized test fixture in early 2010 in accordance with McDonnell Douglas Specification A114304**
- **Fixture validation showed distinct performance difference between Hi-Shear and UTAS cartridges**
  - **Hi-Shear cartridges observed to produce lower thrust; 100-150 lbs < UTAS Ctgs**



WS Test Fixture

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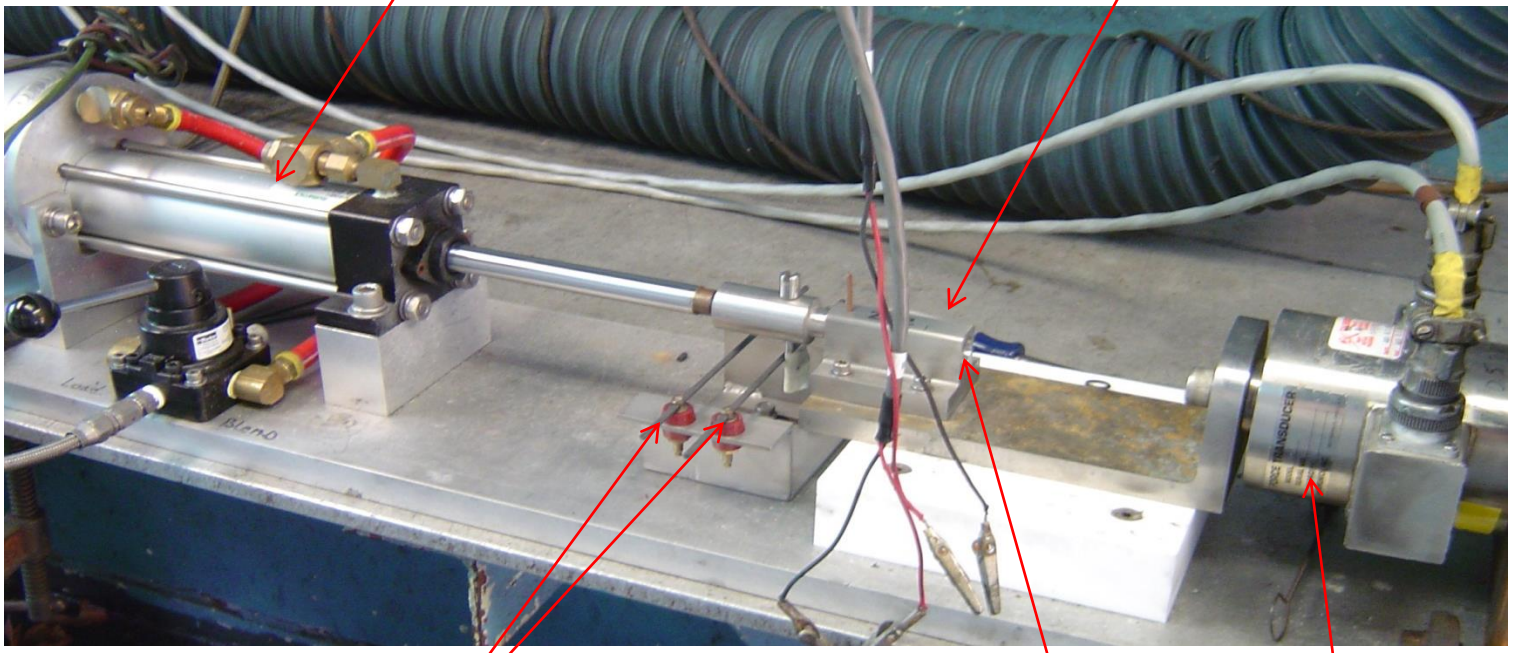
Air Cylinder; pressurized to 200 lbs resistance on thruster

Workhorse thruster; same geometry as seat thruster



Breakleads; indicate first motion and end of stroke ~1.07”

Harness Release Cartridge location

Load Cell; requirement < 780 lbs

Low Output Hi-Shear Cartridges

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- **Multiple 2008 Hi-Shear cartridges failed to produce sufficient output on the Weapon Specification fixture to fracture break-leads or even stroke at all when tested in 2010 at Indian Head (videos below)**


Completed Stroke.avi


SN1A failed BW2.avi


SN3A failed to move.avi

- **Results from Weapon Specification testing triggered CAD/PAD office to evaluate all Hi-Shear lots in inventory and identify lowest performing assets**
- **Initiated effort to conduct margin testing with actual seat/system and lowest performing cartridge lot**

Test Fixture Setup Error Discovery

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- **Hi-Shear Cartridge qualification was accomplished by Indian Head in 1990. It was noted in the qualification report that …**

> "cartridges were to have a resistive preload of 150 lbs. During Design Verification Testing at the manufacturer, the preload was only 150 psi., which equates to about 55 lbs. For test firing, the correct amount of pre-pressure was 460 psi. After it was determined what the correct pre-pressure was to be, performance firing began."
>
> (QTR 100205, para 4.2.16.4)

- **While the mistake was identified and corrected for qualification, updates to the vendors ATP were never made and Hi-Shear continued to test at 150 psi/55 lbs resistive load until late 2010 when the performance issues were identified; Weapon Specification fixture was implemented for all post 2010 contracts**

Hi-Shear lots in inventory

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- **The lot with the lowest thrust and highest standard deviation was identified as HST08M001-001**

Hi-Shear Cartridge Thrust Performance					
Lot Number	Out of Service HST02C001-007	HST04G001-009	HST08D001-001	HST08M001-001	HST10G001-001
Avg Thrust (lbs)	421.2	448.7	437.6	371.6	479.4
-65 °F	403	437.4	439.7	362.3	498.3
70 °F	**423.9**	**442.6**	**368.1**	**360.1**	**508.0**
200 °F	436.9	466.0	504.9	392.4	432.0
Standard Deviation	**34.0**	**40.5**	**143.3**	**164.7**	**112.4**
3σ	102.1	121.6	430.0	494.2	337.2

- **SOW developed and contract awarded to UTAS, Colorado Springs (seat developer) to analyze margin of Harness Release System**
  - **Perform system functional tests with worst case harness strap loads using HST08M001-001 cartridge samples**

System Margin Study

- **The margin study consisted of two phases, analysis and test**
  - **Analysis included evaluation of worst case loading for leg restraints, left and right lap belts, inertia reel release and seat pan release with worst case packed survival kit**
  - **Test phase included using worst case analyzed scenarios and functioning cartridges from lot HST08M001-001 and then either increasing or decreasing loads until failure/success identified**
    - **Used F-22 seat with manikin**
    - **Functioned 20 cartridges**
    - **Load ranged from 316 to 473 lbs**
    - **Pressure recorded for each shot with workhorse thrusters**
    - **High speed video of release**

Margin Study Results

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	Number	HMTF RUN #	Plunger Diameter (in)	Area (in^2)	Targed Load (lbs)	Applied Load (lbs)	Thruster Pressure (lbs/in^2)	Thruster Force (lbs)	Harness Release System Condition
	1	1486	0.373	0.109	310	316	4571	499	Fully Released
	2	1487	0.373	0.109	310	317	4739	518	Fully Released
	3	1488	0.373	0.109	310	325	3999	437	Fully Released
	4	1489	0.373	0.109	310	324	3552	388	Fully Released
	5	1490	0.373	0.109	310	316	4530	495	Fully Released
	6	1491	0.373	0.109	341	351	4337	474	Fully Released
	7	1492	0.373	0.109	341	357	3214	351	Fully Released
	8	1493	0.373	0.109	341	349	3295	360	Fully Released
	9	1494	0.373	0.109	372	380	4005	438	Fully Released
	10	1495	0.373	0.109	372	379	No Data		Fully Released
	11	1496	0.373	0.109	372	377	4408	482	Fully Released
	12	1497	0.373	0.109	403	418	5007	547	Fully Released
	13	1498	0.373	0.109	403	412	4376	478	Fully Released
	14	1499	0.373	0.109	403	413	4046	442	Fully Released
	15	1500	0.373	0.109	434	439	5026	549	Fully Released
	16	1501	0.373	0.109	434	440	3166	346	Fully Released
	17	1502	0.373	0.109	434	445	4859	531	Fully Released
	18	1503	0.373	0.109	465	469	5000	546	Fully Released
	19	1504	0.373	0.109	465	473	4743	518	Fully Released
*	20	1505	0.373	0.109	500	505	5935	649	Fully Released

- **All 19 ea HST08M001-001 successfully functioned harness release system at all loads**
- **1.5 safety factor estimated based on analysis and test**
- **No action taken to remove/restrict Hi-Shear cartridges**

*** UPCO Cartridge Sample Firing #20 (WS compliant cartridge)**

Thruster Configuration

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- **Dissection of thrusters identified multiple configurations in service**
  - **Pistons with and without chamfer around shear pin hole**
  - **Different O-ring types**
    - **Archived documentation revealed that UPCO notified USAF of an improved O-ring change to ‘eliminate observed post-firing O-ring damage and gas leakage’**
    - **Changes approved by McDonnell Douglas in 1992; however, existing thrusters in service were not updated to latest configuration**
      - **USAF currently does not serially track or time change inert thrusters**
      - **Configurations can only be observed by disassembly of thrusters**

Incident Thruster Dissection

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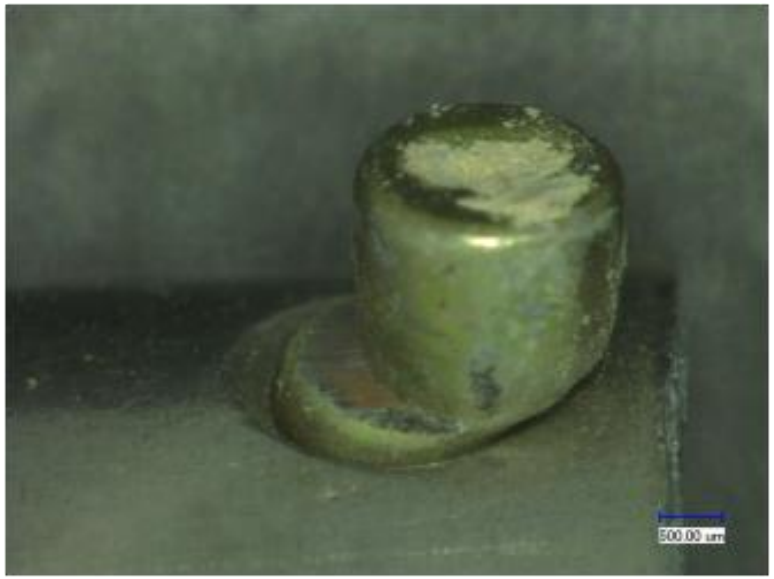
- **Inspection of the through hole identified bevel edges rather than sharp edges around the shear pin hole**
- **Copper shear pin shows material deformed to chamfer and contributed to the pin not fully shearing**



Incident Thruster Dissection

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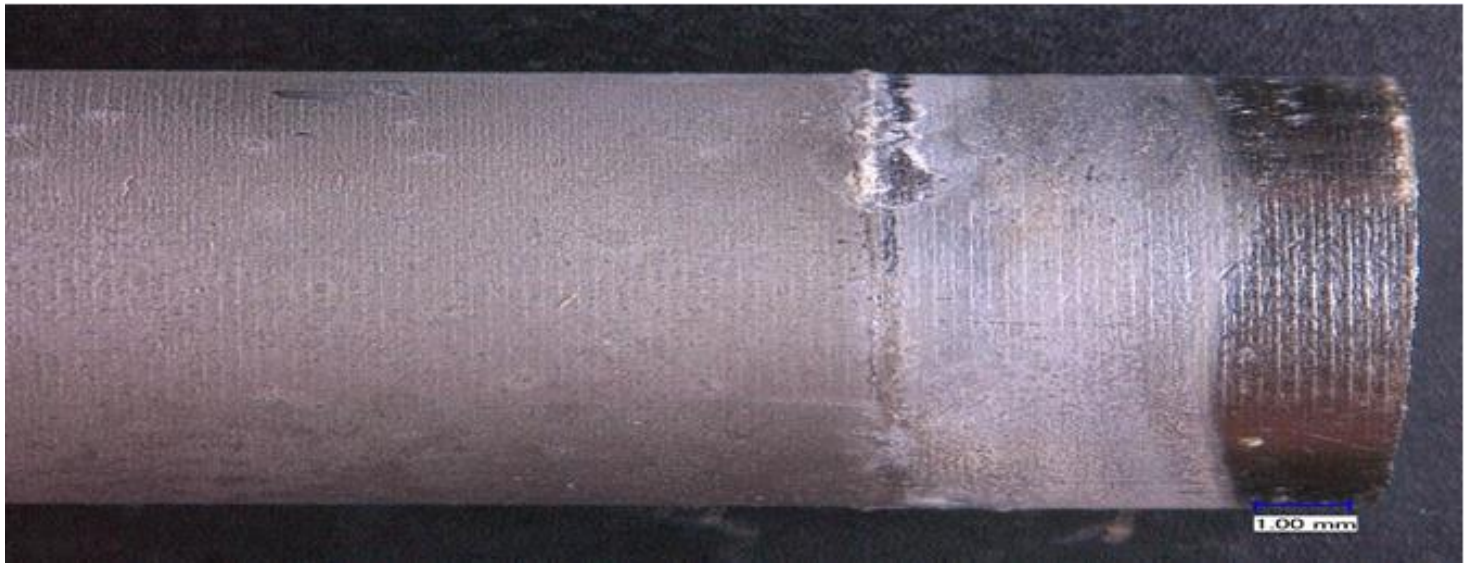
- **Hill AFB Science and Engineering Laboratory conducted Energy Dispersive Spectroscopy**
  - **Both Zirconium and Potassium were found on the downstream side of the O-ring, evidence of gas blow by**
  - **Cartridge uses Boron Potassium Nitrate ($BKN0_3$) and Zirconium Potassium Perchlorate (ZPP)**

Incident Thruster Dissection

- **Based on EDS results it is believed that the O-ring allowed initial gas pressure to escape**
  - **Further evidence is the curved line where the O-ring appears to have rolled or twisted about the piston**



Cold Gas Testing

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- **To quantify the effects of the chamfer and O-ring change (both present on failed unit) cold gas testing was completed at Hill AFB.**
  - **Inert thrusters were initiated with cold gas under water with high speed video to observe escaping gas**
  - **26 units manufactured between 1979 and 2008**
  - **Initially pressurized with 500 psi to determine if O-ring leaked**
  - **Re-pressurized to 3000 psi with pressure traces used to determine shear pressure**
    - **Pressure application mimicked Hi-Shear cartridge performance**
  - **Since none of the units selected had chamfer present a chamfer was added to piston and units were reset with shear pin and retested**
    - **Original shear pin long enough to re-use if reversed**

Cold Gas Test Results

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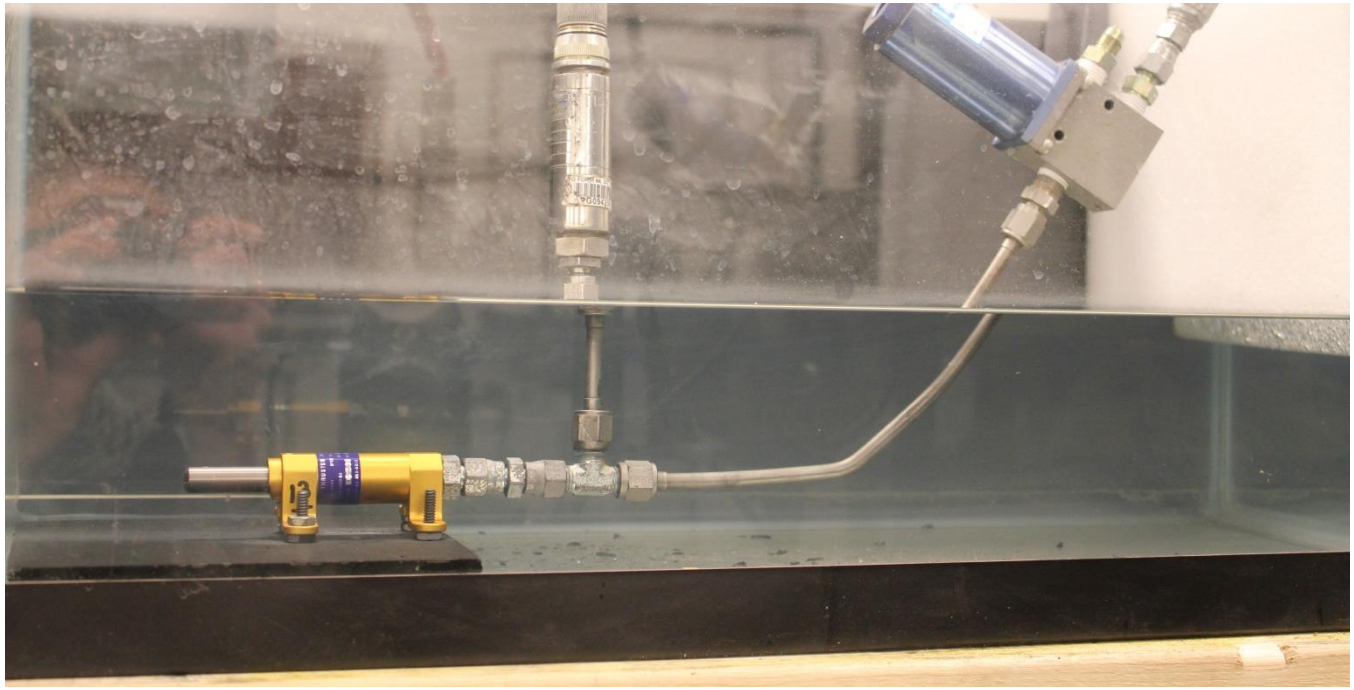
- **O-ring Effects**
  - **Units manufactured prior to 1992 required 217 psi more to overcome the shear pin than those with the improved O-ring**
- **Chamfer Effects**
  - **Reset units showed an average increase of 277 psi to overcome the shear pin when chamfer was present**



HRC video.mp4

Historical Performance Data

- **Seven ACES II sled tests with HST08D001-001 lot; one failure observed (Jun 2014)**
- **Two ACES II high altitude drop tests performed with HST08D001-001; no failures (conducted Apr 2012)**
- **USAF has identified eight successful A/C ejections using HST08M001-001 lot and two successful ejection using HST08D001-001 lot; no failures observed (2010 through 2015 ejections)**
- **Observed system failure rate of 5.3% with Hi-Shear**
- **Risk assessment "I-E" estimated for various ACES II platforms until replacement parts fielded per MIL-STD-882**
  - **Harness release system failure could result in serious injury or death at time of Parachute Landing Fall (PLF)**
  - **System does have manual release if pilot has physical/mental capacity and sufficient altitude/time to pull handle**

Hi-Shear cartridge installs with potential for low output

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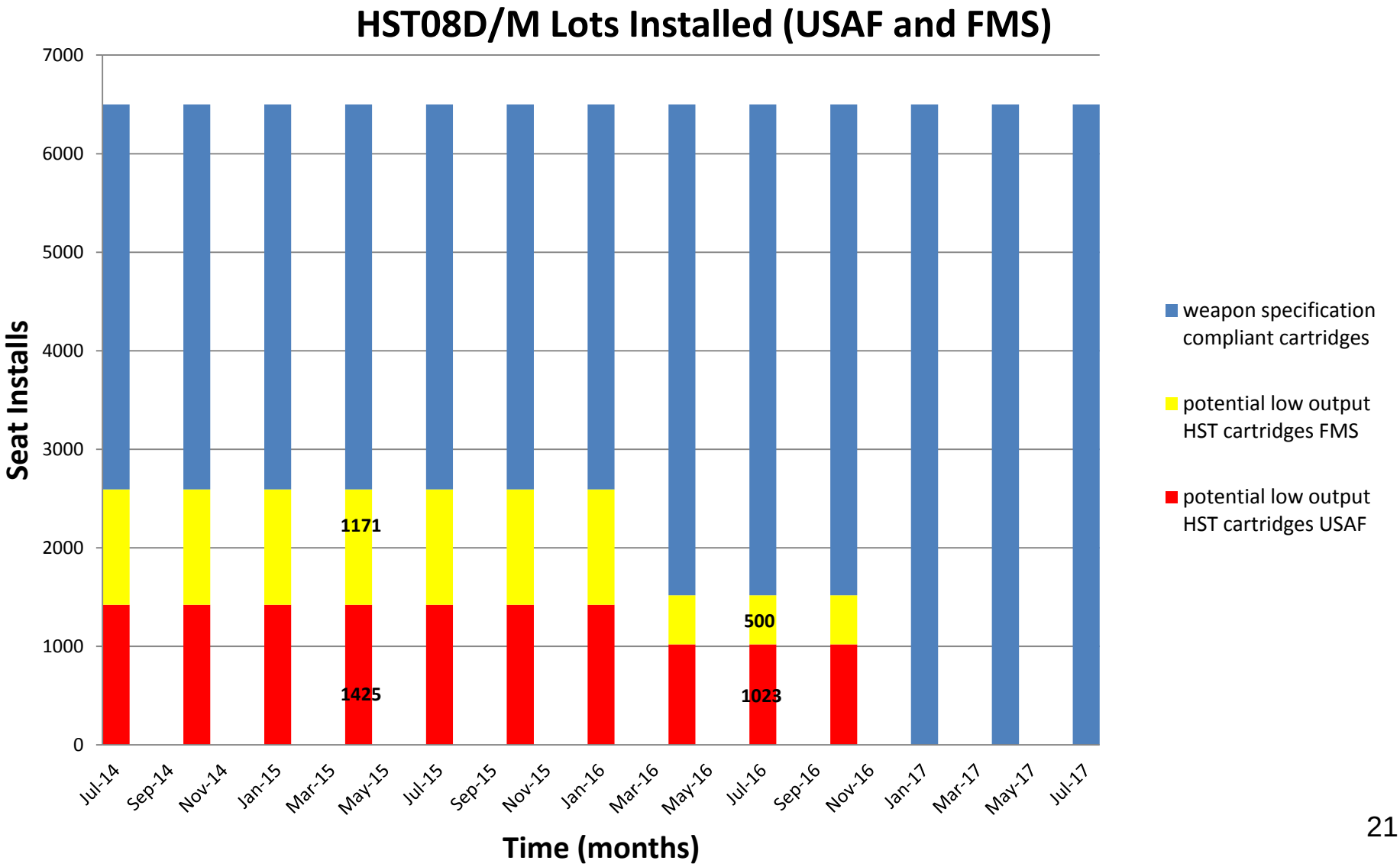

Conclusions

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- **The combined results of the O-ring and chamfered piston hole require an average of 494 psi more to overcome the shear pin and stroke the piston**
- **A weapon specification compliant Harness Release Cartridge provides nearly 1000 psi more output in the thruster than a pre-2010 Hi Shear cartridge and is capable of stroking the thruster**
- **Original margin study didn't take into account the variability of thruster configurations (new hardware)**

Path Forward

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- **Replacement cartridges that are weapon specification compliant are on order with an EDD of October 2016**
- **A TCTO will not be implemented for all affected HST cartridges as expiration date is January 2017**
- **Future procurements will be of cartridge and thruster combination (new NSN)**
  - **This will ensure that all thrusters in field are replaced with the latest configuration**
  - **New ‘single’ unit will be time changed based on existing cartridge shelf/service life**
  - **Replacement through attrition expected to begin mid 2017**

Questions?

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