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John M. Fitzgerald

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Honeywell Federal Manufacturing & Technologies
P.O. Box 419159
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John M. Fitzgerald, Project Leader

Project Team:
John Fanska
Matt Willoughby
Aaron Seaholm
Tom Bender
Jody Brown
Greg Thompson
Andrea Lawson
Matt Clark
Kelly Bennett

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Abstract

This project funded production process and tooling improvements to meet and sustain rate production for the W76-1 mechanism assemblies. Techniques were developed to allow evaluation and disposition of sealed stronglinks that resulted in prevention of the scrapping of numerous stronglinks and firesets. Improved processes and tooling allowed D-Test rates to be reduced in favor of E-Test, thus saving millions of dollars over the life of the program. Future system mechanisms will likely be smaller with tighter toleranced parts that will require improved inspection equipment and techniques. During the latter phase of this project, a method of improving inspection was developed that will have benefits for existing and future system mechanical assemblies.

Summary

The W76-1 LEP mechanical assemblies that this project supported are: the MC4710 Intent Stronglink (*see* Figure 1), the MC4711 Trajectory Stronglink (*see* Figure 2), the MC4713 Launch Accelerometer (*see* Figure 3), and the Forward Mount. Processes and tooling were improved and additional tooling was procured to support First Production Units (FPU), rate production, and schedule pull ups to support the new building (KCRIMS). All FPU schedules were successfully met for these components because of efforts supported by this project. Likewise, rate production schedules are also being supported.

Figure 1. MC4710 ISL

Figure 2. MC4711 TSL

Figure 3. MC4713 LA

The Level 2 Milestone associated with this project was to meet FPU schedules, develop processes, and improve tooling to support rate production. Grading criteria was as follows: to keep scrap costs under $1M, reduce MC4710 standard hours by 10%, and reduce MC4711 standard hours by 5%. The Level 2 milestone and grading criteria were all successfully achieved.

Other milestones were to develop processes to allow disposition of units that exhibited problems after they were welded shut, design and procure an improved dry film lubricant spray machine, achieve and maintain W76 stronglink cost targets, and to investigate lower cost and improved inspection techniques and vendors. These milestones were also achieved.

Discussion

Scope and Purpose

The scope of this project only included W76-1 LEP mechanical devices with upgrades and additional copies of tooling and test equipment needed to support rate production. The scope did not include the day to day support of production, which was funded by a separate account. Concurrent engineering with SNL/NM was used to suggest and incorporate design improvements as well as improve processes and tooling.

The scope also included preliminary investigation into improved inspection techniques and outside vendor support to lessen costs and prevent future inspection bottle necks.

Activity / Accomplishments

Standard Hour Reductions

The MC4710 ISL achieved a 10% reduction in standard hour content from the baseline of 68.75 standard hours on August 21, 2006. This included 45.65 manufacturing standard hours and 23.10 inspection standard hours. As of July 28, 2008, the total has been reduced to 60.16 standard hours for a 12.49% reduction. Examples of standard hour reductions include: incorporation of Fact Based Quality (approx. 2 std hr), elimination of 100% in process low and one ambient test (approx. 2 std hr), elimination of one of 3 leak tests (approx. .4 std hr), change to a Vespel cam (approx. .3 std hr), and various tooling improvements.

MC4711 TSL achieved a 5% reduction in standard hour content from the baseline of 70.94. Because of the change to E test from D test (reported on below), standard hours for the E test are charged to the top assembly instead of the D test hours being charged to a D test part number. Therefore, the actual standard hour decrease appears less than 5%, but the actual savings is over 5%. Some of the activities that led to the 5% reduction include eliminating some tests because of improved process controls, improving laser marking tooling and processes, and simplifying gap measurements from taking variables data to using a go / no-go method. For example, an inductance test elimination for a Clockplate assembly resulted in a savings of 1.065 standard hours (FY08 savings of $25.5K). The gate and drive solenoid stator and coil assembly drawings each had a note to re-clean prior to next assembly. This was an unnecessary extra cleaning since the parts are already cleaned, handled, and stored in a clean environment. The extra cleaning would also increase the chance for rusting. The request to remove this drawing note was accepted and saved 0.176 standard hours.

Scrap Reduction

The grading criteria of $1M in scrap reductions was exceeded with a total savings of approximately $2.79M.

In FY07, savings of $1.33M were approved. Ten early production units of the MC4710 ISL and 14 MC4702 Firing Sets were in jeopardy of being scrapped because of a misalignment problem of the MC4710 discriminator monitor. A process was developed using CT scan to view inside the welded up sealed units to analyze the monitor alignment (*see* Figure 4). This allowed 9 of 10 ISLs and all 14 Firing Sets to be used, thereby saving $994,234. A redesign to change materials to Vespel, as explained in the ongoing activities section below, will prevent electrical shorting due to misalignment or wear during shock and vibration.

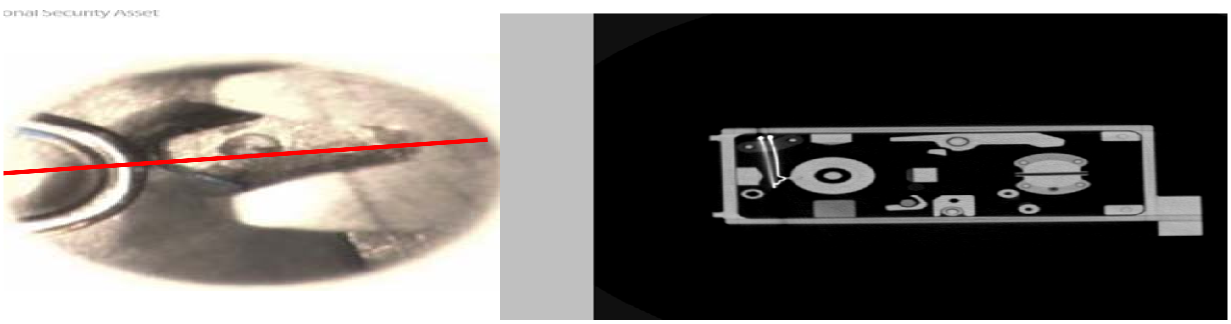

Figure 4. CT Scan of MC4710

Also in FY07, seven early production units of the MC4711 TSL were in jeopardy of being scrapped because of an orientation problem of the reset monitor being closed at the Reset +1 position. The team developed an x-ray process to determine if welded up units had acceptable monitor alignment, thus saving $283,822. A drawing change was made to clarify the monitor adjustment procedure to prevent recurrence.

Removal of a nylon button in the W76 Forward Mount was a very time consuming and costly process. The previous process involved soaking one Forward Mount at a time in solvent vapor for 48 hours to remove the button (*see* Figure 5). A process was developed to use a solvent that would allow 19 parts to be run at once for 6 hours, resulting in a cost savings of $699 per Forward Mount. This resulted in a FY07 savings of $13,279. Discoloration was also a problem and a process was developed to remove the discoloration without causing damage to the part (*see* Figure 6).

Figure 5. Button Removal

Figure 6. Discoloration Removal

Yields for the MC4711 solenoids were running at 90% until March, 2007. A study was performed to prove that by improving the method of measuring torque the drawing torque requirement could be lowered (*see* Figure 7). This avoided scrapping nine solenoids, saving $12,293 and a future improvement of yield from 90% to 97% for the remainder of the program schedule. The FY07 savings was a total of $39,612

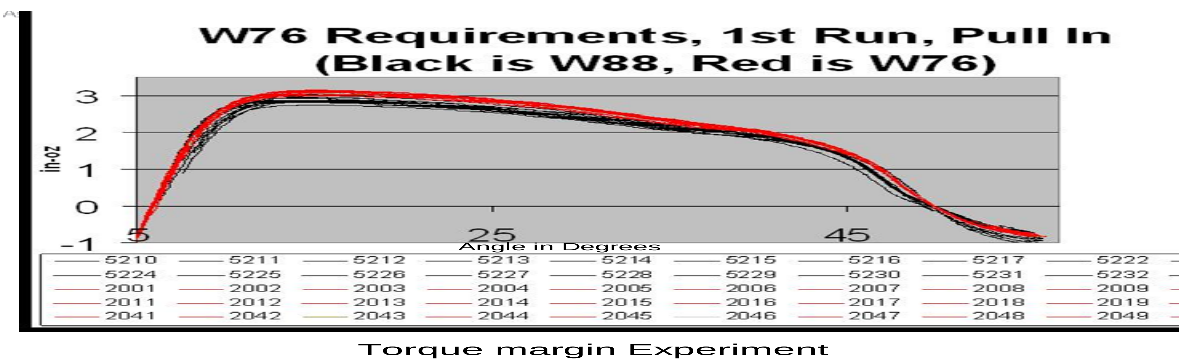

Figure 7. Torque Margin Curves

Additional savings for FY07 that were not submitted as productivity savings included a rework process developed to allow replacement of broken ferrite C-Cores in MC4711 housing assemblies. This saved 14 assemblies for a cost savings of approximately $35K.

A weld penetration-to-temperature study was completed on the ISL utility header that resulted in preventing the scrapping of 5 units worth $140K.

In addition to the $1.33M scrap reduction achieved in FY07, another $1.463M in savings was achieved for FY08. D-Testing stronglinks creates a significant cost to the W76-1 program ($41.4K for each MC4710 and $31.4K for each MC4711). Because of process, tooling, and test equipment improvements which resulted in consistently good test results through the first 40 D-Test units, the PRTs reduced the D-Test rates from the requirements in the product specification.

The rate was reduced from 20% to 5% until 100 units are D-Tested. The remaining 15% are now E-Tested instead of D-Tested and sold to WR. Then, after 100 D-Test units, the rate was reduced from 5.5% to 1.375% D-Test and 3.625% E-Test. This resulted in a savings for the last 7 months of FY08 of $786.6K for the MC4710 and for the last 8 months of $470.6K for the MC4711.

Another productivity savings for FY08 of $180,101 was achieved for the TSL Housing Assemblies (1A2412 and 1A2413). In FY07 a scrap rate of approximately 15% was experienced due to voids and cracked ferrite C-Cores. After redesigning the fixturing and process to fully seat the C-Core and not induce stresses, the scrap has been eliminated (*see* Figure 8).

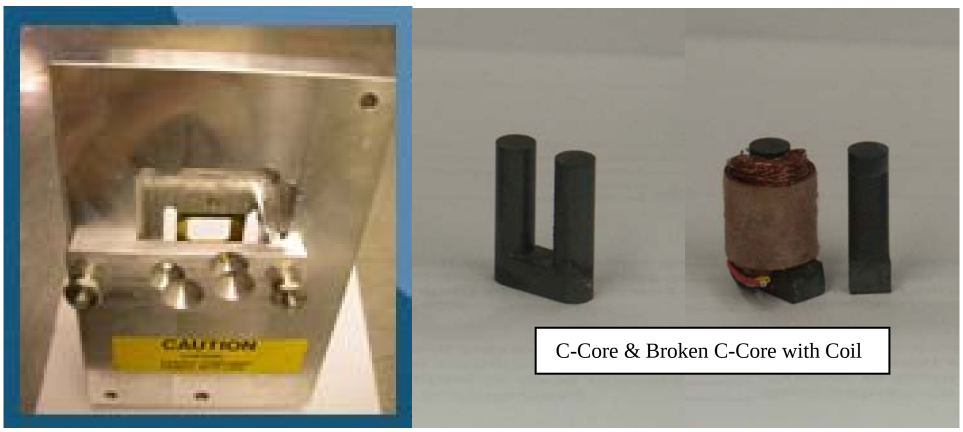

Figure 8. Improved Potting Fixture and Ferrite C-Cores

The final productivity savings submitted for FY08 resulted in a savings of $25,534 for eliminating an inductance test in April, 2008. This test had been required for engineering information and was eliminated because of good operator performance and controls that prevented failures. Final assembly testing verifies that inductance is acceptable.

<u>Mistake Proofing Tooling</u>

The MC4710 Idler Gear assembly was controlled by a fixture that could be misaligned and cause scrap (*see* Figure 9). KCP recommended that an orientation pin (*see* Figure 10) be added to the assembly which mistake proofed the assembly so that it could not be assembled incorrectly.

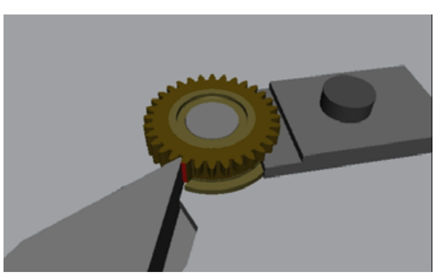
Figure 9. Idler Gear Fixture


Figure 10. Mistake Proofing Pin Added

The MC4710 solenoid rotor assembly was a welded assembly that required a fixture for orientation. However, the rotor is a Hiperco 50 (*see* Figure 11) which cracks during welding and does not yield a robust weld. KCP recommended that a bolted assembly with a mistake proofing pin for orientation between the rotor and the shaft be incorporated (*see* Figure 12). The recommendation was accepted.

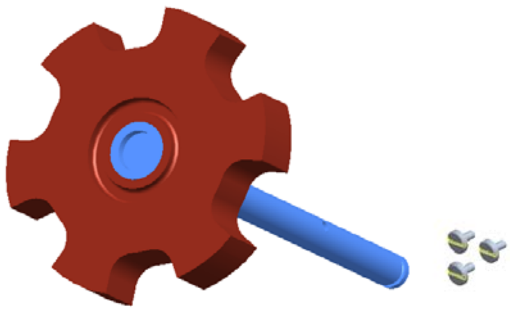

Figure 11. Hiperco Welded Rotor Assembly

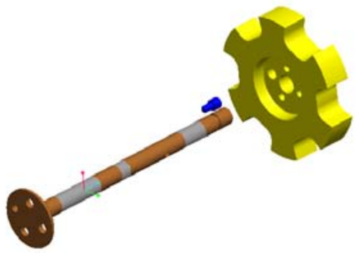

Figure 12. Bolted Assembly With Mistake Proofing Pin

The MC4710 Pattern Wheel Assembly required a difficult to use orientation fixture (*see* Figure 13), so KCP recommended changing to a design with a mistake proofing pin to control orientation, thus eliminating the need for the fixture (*see* Figure 14). This recommendation was incorporated as well.

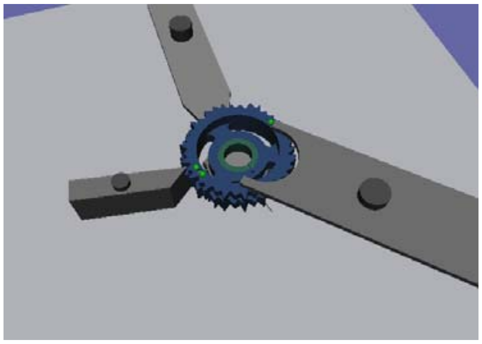

Figure 13. Pattern Wheel Orientation Fixture

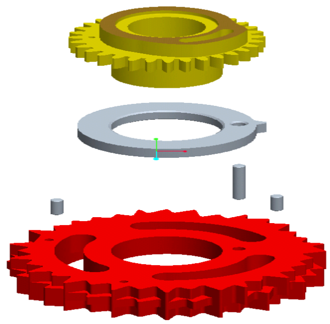

Figure 14. Self Orienting Design

The MC4711 transformer coils had multiple wires that had small tags to identify the wires (*see* Figure 15). This led to miswiring because the wires and tags had to be cut off to obtain the correct length. KCP recommended using different color wires to reduce the chances of mistakes, thus greatly reducing miswiring (*see* Figure 16).

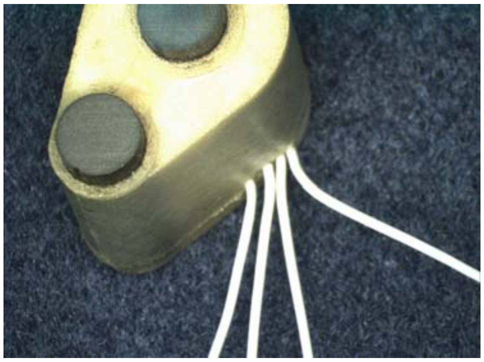
Figure 15. Original Coil Wire Design

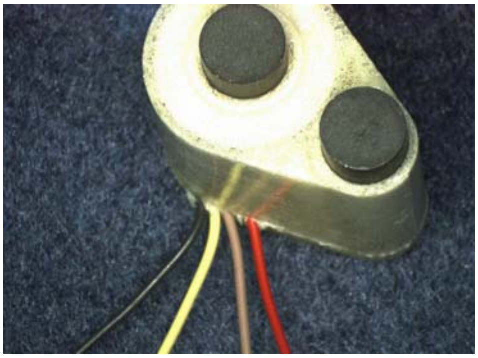
Figure 16. Color Coded Coil Wires

The MC4711 discriminator wheel originally was a multi-piece assembly requiring careful orientation before being welded together (*see* Figure 17). KCP's recommendation for changing to a one piece machined part (*see* Figure 18) to help eliminate scrap because of misalignment was incorporated.

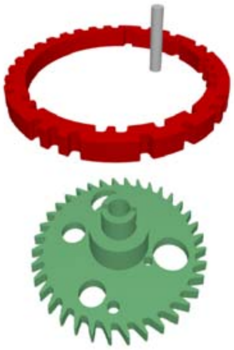
Figure 17. Multipiece Discriminator Wheel

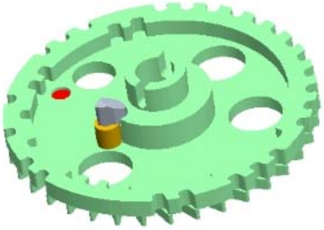
Figure 18. One Piece Discriminator Wheel

The MC4711 Flex Cable Assembly is required to have the header pins centered within the lands for soldering. Previously this was done using an open setup. A new fixture was designed to properly orient the header prior to soldering, eliminating the chance for error.

The MC4711 Reset Mechanism is laser marked with a serial number prior to assembly. Previously this was done using an open setup. A new fixture was designed to properly orient the mechanism prior to laser marking, eliminating the chance for error.

Snap Plate Weld Samples

KCP developed snap plates and recommended changing from WR qualified parts or simulated WR qualified part weld samples to using snap plates for before and after shift weld samples (*see* Figure 19). This has been implemented on the W76 mechanisms by replacing approximately half of the WR qualified parts or simulated samples with snap plates. The snap plates allow real time evaluation of the welds by welding the joint between two snap plates and breaking them apart to view the welds. Penetration can be determined without sending off expensive WR qualified parts or simulated part weld samples for metallurgical testing. This will save well over $1M for the life of program.

Figure 19. Snap Plates vs Simulated Samples

MC4710 Shutter Gear Modeling

Stress modeling at KCP on a shutter gear was done that showed that more than adequate engagement strength margin existed in gears that were machined to a diameter smaller than the drawing requirement (*see* Figure 20). This resulted in a design change that moved the lower limit so it accepted 111 of 112 gears, thus saving $58.8K and improving later yields.

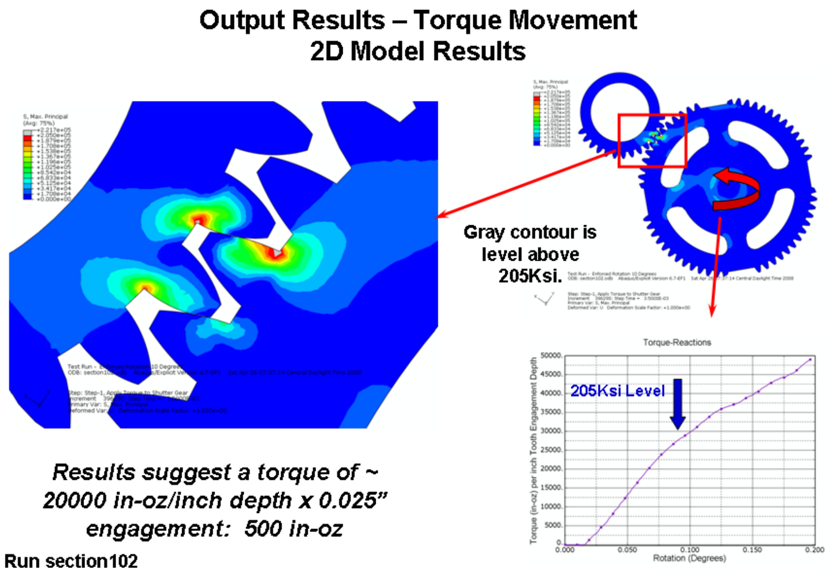

Figure 20. Stress Modeling of Shutter Gear Engagement

Bearing Push Test and Radial Play Fixturing and Process

Bearing push test and radial play fixturing and processes were developed, resulting in drawing changes to inspect bearings (*see* Figure 21). This eliminated the expensive and time consuming bearing disassembly and hardness testing procedure. There was also subjectivity due to hardness test variability where the vendor would accept and then KCP would reject parts.

Figure 21. Bearing Push & Radial Fixture

Backup Welding Machines qualified

To ensure support of rate production, backup welding machines were qualified. The second of two LaserDyne YAG (*see* Figure 22) continuous weld machines has been qualified for the W76 mechanisms. A new pulsed YAG weld machine has been qualified to replace older machines that are not as well suited to smaller tack welds on newer mechanisms. A second copy of this machine will be procured and qualified in the future.

Figure 22. LaserDyne YAG

Coil and Stator Assembly Process Improvement

The epoxy bonding process for the MC4711 solenoids had produced unacceptably bonded assemblies resulting in rework. This process was characterized and improvements made that have resulted in eliminating defects and rework through the next 250+ assemblies.

MC4711 Safing Wheel Production Capability at KCP

Production capability for manufacturing the TSL Safing Wheel (*see* Figure 23) was developed at KCP. This was done to serve as a backup for the WR vendor who was having high cost, low yields, and schedule problems when this effort began. A process was developed to assemble the ferrites in compression by using a shape memory alloy ring (SMA) that is shrunk around them. Ferrites are much stronger in compression than in tension (*see* Figure 24). The vendor has since improved yields and is meeting cost and schedule requirements. The PRT decided to not expend the resources at this time to qualify production at KCP and this effort is currently on hold.

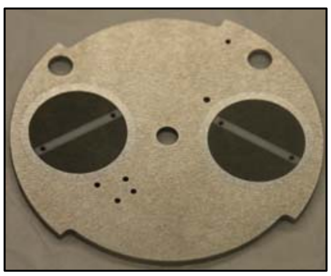
Figure 23. KCP Safing Wheel

Figure 24. SMA Captured Ferrites

Retrofitted W80 In-Process Tester

The PT3750 in-process testing on the MC4710 would be a bottleneck during the schedule build ahead. To alleviate this problem, a similar W80 tester was retrofitted to meet the W76 requirements. This prevented higher expenditures to build another copy of the PT3750.

Nuclear Safety Review

The NNSA Kansas City Site Office noticed drawing inconsistencies on the W76 LEP assemblies. A joint Sandia/KCP 90 day Pentagon S (/S/) review was then completed on the W76 mechanisms (Intent Stronglink, Trajectory Stronglink , and Launch Accelerometer) as well as the Arming Fusing & Firing (AF&F) Mechanism and Firing Set. The review was needed because time constraints and design changes to meet FPU precluded optimization of Nuclear Safety requirements. Over 2000 /S/ features were reviewed which resulted in changes to the Nuclear Fault Tree, /S/ Maps, and production routings. No critical shortcomings were found. This review ensured that Nuclear Safety had been adequately assessed and necessary controls were in place.

Future System Manufacturing Review

KCP placed contracts with two of our WR machine shops to review the Dual Stronglink Mechanism (DSM) drawings for the WR-1 system. They were asked to list drawing changes that would save costs, scrap, and improve quality. After receipt of their reports, KCP and Sandia engineers visited the two shops and discussed the suggestions. Several drawing changes resulted to the twenty-one more difficult parts reviewed. Datum schemes, tolerancing, radii callouts, and reduction or elimination of lengthy heat treat callouts were changed. This activity early in the development phase will result in drawings that are more manufacturable, resulting in considerable future cost savings because of lower machining times, inspection times, tooling costs, scrap, and ability to machine some parts on less costly equipment.

Improved Inspection

New concept mechanisms are smaller and require tighter tolerances. This requires inspection techniques that can handle contour tolerances down to .0008". An optical measurement system has been designed and is on order that can inspect these small parts. This system cannot only inspect edge features that can be detected optically (which can be done on existing equipment), but also non edge features that have not previously been inspectable by optical means. Some of the future system parts are so small and flexible that touch probe coordinate measuring machines (CMM) can not be used. This system is the first capable of automatically discerning which side of an edge break is the actual edge of the feature. The equipment was received at the end of FY08. Prove in and programming activities will be done in FY09.

Two inspection houses were visited by a team of KCP and SNL engineers as a preliminary investigation as to whether they could support mechanism piece part inspection when or if greater capacity is needed. QCI and AIS in Minneapolis both appear to be able to inspect many of the mechanism parts with some training for our specific requirements. Currently, QCI has been contracted by KCP to inspect some non mechanism parts.

Future Work

The ceramic Interconnect Terminal Assembly (ITA) (*see* Figure 26) in the MC4713 Launch Accelerometer is expensive and has had yield problems from the vendor. Replacement of the ceramic ITA with a molded DAP (Diallyl Phthalate) plastic ITA (*see* Figure 25) is being evaluated and initial results look very promising. This change would save approximately $1600 per MC4713.

Figure 25. DAP ITA

Figure 26. Ceramic ITA

This project funded initial activities to replace the three ceramic brazed headers in the MC4710 ISL (*see* Figure 27). These ceramic headers are also very expensive (approximately $8,000 for the three headers) and leaks developing in the headers have been a problem after they are assembled into the stronglink. A glass ceramic header design (*see* Figure 28) with a high temperature glass is being evaluated and will save approximately $5000 per MC4710 and a life-of-program savings of approximately $12M. This activity is a substantial undertaking and was moved during this FY to its own NNR project for completion.

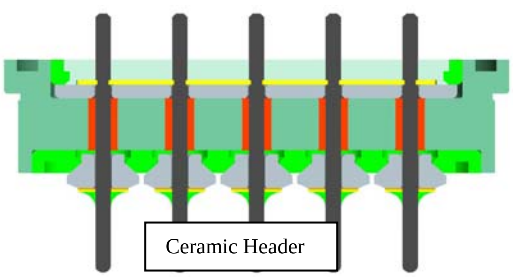

Figure 27. MC4710 Ceramic Header

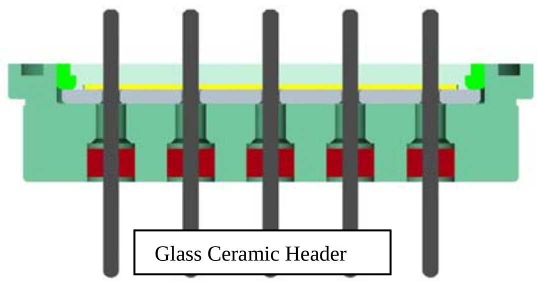

Figure 28. Proposed Glass Ceramic Header

Both the MC4710 experienced problems with monitor switches shorting out in final assemblies when the Teflon S coated features either wear through or are indented during shock and vibration testing (*see* Figure 30). A MC4711 post mortemed unit showed a thinning of the Teflon S coating where the monitor contact rubs. Therefore, work has been ongoing to develop machined Vespel plastic parts to eliminate the Teflon S coated stainless steel parts (*see* Figure 29). This will improve tolerance control and eliminate the possibility of internal shorting.

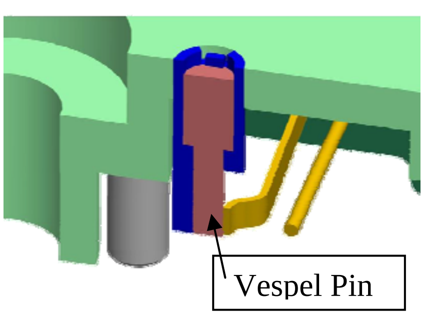

Figure 29. MC4711 Vespel Pin

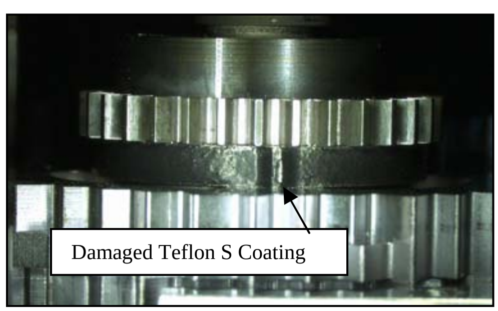

Figure 30. MC4710 Teflon S Coated Cam

A new special design automated solid film spray machine was designed and procured to improve process control of AS Mix moly-graphite sprayed lubricant film application and thickness. This machine will reduce the amount of parts that do not meet solid film thickness requirements and require reprocessing. This machine replaced a 27-year-old machine in department 99 and was to be installed during FY08. However, because of requalification and ES&H requirements, installation will take place in the new building (KCRIMS).

Future work to develop new technologies and processes for new mechanism designs will continue in FY09.