Summary of OV-103 Flight 31 Landing Gear Rigging

The landing gear (LG) functional test for OV-103 was successfully performed on 03/21/05. This completed a 6-month effort to re-rig the main and nose landing gear in order to meet an environmental seal compression requirement that had not previously been addressed. The following is a summary of the work performed:

Due to concerns after the Columbia accident about the LG environmental seal compression, chit J5966 authorized Ground Ops to measure the seal compression on both the main and nose LG. There is no drawing or specification requirement for the compression of the seals, however nominal rigging of the doors to a +/- 0.030 in. inner mold line (IML) step will provide adequate compression. From previous rigging attempts in the early 1990s, there were recorded IML steps of up to 0.170 in. on the main landing gear (MLG). The seal compression was measured this flow, and it was found to be below the minimum required value per the certification requirement of the seals (CR 05-GS17M10C). This was partially due to the fact that the seals had taken a compression-set over time, but the excessive door to structure IML steps were what accounted for the majority of the compression problems. All the seals were replaced with new seals from stock or ones that had been recently procured from vendors. However, there were still areas around the perimeter of the MLG doors, and along the centerline of the nose landing gear (NLG) doors that did not meet the minimum compression value. STR engineering eventually built aluminum shims (LT-80 tape used for the NLG), which were installed on the sealing surfaces to meet the minimum seal compression requirements, taking into account the in-flight door deflections predicted by analysis. Problem reports (PR) STR-3-31-8699 (MLG) and STR-3-31-8840 (NLG) accomplished this work. The additional load from these shims required adjustments to the LG mechanisms to get the doors closed and the hooks properly positioned.

Main Landing Gear (PR MEQ -3-31-1429/1430)

During some initial rigging checks of the left main gear (LMG), it was discovered that the fwd door roller was not in contact with the door hook, and there was a large gap (greater than 0.020 in.) at the fwd-inbd door stop. Per the MLG installation and rigging spec ML0308-0029, the hook should be in contact with the roller and the door stops should be zero. The fwd-inbd door stop had previously been MR accepted in the early ‘90s with a 0.030 in. gap. During this flow, the fwd door roller position was adjusted to allow the fwd door hook to share the door load, and as a result the fwd-inbd stop gap was reduced.

After installation of the new seals, but prior to installing the shims, both MLG were retracted. Measurements of the door stops and the door hook mechanism indicated that neither MLG was closing properly. The load from the new seals was preventing the door hook mechanism from fully engaging the door rollers. During this same period, Glenn Research Center was conducting some off-line tests on the MLG seals. They determined that the way the seal was bonded affected the compression load. If

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July 2005

the excess RTV from the bond line was allowed to form a fillet along the outboard edge of the seal, it significantly increased the compression load. All the excess RTV was removed from the MLG seals, and another gear retraction was performed. The right main gear (RMG) closed properly, but the LMG had little improvement with regard to the hook engagement.

Since the higher seal compression (which was yet to be addressed) would likely further increase the loading on the door hook mechanism, two methods were considered to improve the door closure. The first involved increasing the preload in the door hook mechanism. When the preload was checked, it was found to be higher than permitted per the rigging spec. Instrumentation was installed on two of the hook mechanism links (ME162-0009-0011 and V070-510349-001), in order to monitor the loads and to evaluate a possible over-load condition when the first set of temporary shims were installed and the hook mechanism stalled. The loads were well within the limits of the latch mechanism, and the hook stall condition was determined to be due to a torsional deflection in the torque tube between the uplock mechanism and the door hook linkage. The stall was measured to be a 7 degree deflection, and the loads in the torque tube were verified to be well below the ultimate loads of the hardware.

The second method to improve door closure involved shortening the lengths of the V070-510452 door retract links. Due to concerns about the loads in these links and the upstream hardware, instrumentation was installed on the 452 links on both MLG. Boeing Stress had calculated an upper load limit of 5000 lbs in these links to prevent damage to the uplock mechanisms. Initial loads were 1700 lbs on the LMG and 2400 lbs on the RMG. Once the shims were installed to increase the seal compression, several rounds of adjustments were made to the 452 links to get the proper door closure and hook engagement. Overall, the 452 links were adjusted 2.5 turns shorter on the LMG and 0.5 turns shorter on the RMG. The final loads in both links were approximately 3000 lbs. After proper door closure was achieved, several adjustments/cycles were performed in an attempt to get the other rigging parameters within the requirements of the spec. Adjustments to the door stop bolts (LMG), hook stops (both MLG), and bungee striker (LMG) were performed. The following is a list of the MRs processed to accept the out of tolerance conditions after completion of the MLG rigging:

1. MEQ-3-31-1512 – restricted one flight – installation of an MD153-0016-2006 laminated washer at the LH fwd-inbd door stop bolt in place of a NAS1587-6L washer, and acceptance of a 0.0085 in. gap between stop bolt and door (s/b zero).
2. MEQ-3-31-1514 – restricted one flight – acceptance of RH door stop bolt gaps greater than zero (fwd-otbd: 0.004 in., fwd-inbd: 0.009 in., aft-inbd: 0.005 in.). Boeing Stress required that the gaps be 0.010 in. max for this flight, and is evaluating the requirement for zero gaps or possible door preload against the stops for future flights. The 0.010 in. max gap is to ensure loads on the tile are acceptable should the door be forced closed against the stops in flight.

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3. MEQ-3-31-1515 – unrestricted – Item 1: LH door hook mechanism linkage has and extra half turn of preload. This condition has been in place since the early 90s when the gear was re-rigged. The hook mechanism performance is nominal and the linkage loads were measured to be 1690 lbs max (ultimate loads for weakest link were calculated to be 4951 lbs). Item 2: LH V070-510452 link is shorter than allowable per spec. This was necessary to achieve proper door closure, and the measured load of 3000 lbs is below the 5000 lb upper limit calculated by Boeing Stress
4. MEQ-3-31-1516 – unrestricted – Item 2: RH door hook mechanism linkage has and extra 1.5 turns of preload. This condition has been in place since flight 18 when the link was adjusted to arm the door bungee properly. The hook mechanism performance is nominal and the linkage loads were measured to be 680 lbs (ultimate calculated to be 4951 lbs). Item 3: RH V070-510452 link is shorter than allowable per spec. This was necessary to achieve proper door closure, and the measured load of 3000 lbs is below the 5000 lb upper limit calculated by Boeing Stress.
5. MEQ-3-31-1429/1430 – unrestricted – application of corrosion protection to surfaces of the RH/LH V070-510452 links after removal of the strain gauges.

<u>Nose Landing Gear (PR MEQ-3-31-1457)</u>

Prior to any adjustments to the NLG mechanisms, the minimum thickness shims (LT-80 tape) were installed on the sealing surfaces of the doors. The subsequent cycles of the NLG revealed that the doors were not closing properly due to the additional loads from the seals. Several door stop bolts had gaps that were out of spec (greater than 0.010 in.). Additionally, the door hooks were not fully engaging the door rollers, and the tile steps between the LH and RH doors exceeded 0.120 in. (s/b 0.060 in. max).

A similar approach to that used on the MLG was utilized to attempt to get the doors properly closed. In the design of the NLG, the LH door overlaps the RH door. It also contains the door rollers that are engaged by the door hooks. Since the position of the RH door was acceptable from a tile and mechanism perspective, the LH V070-510684 door retract link was shortened to pull the LH door further closed. Initial measurements of the 684 link indicated that it was already a half turn shorter than permitted in the rigging spec. The first couple of adjustments (shortened in half turn increments) provided some improvement. However, additional adjustments resulted in no improvement in the door position or hook travel. It was then discovered that the nose wheel well vent plug had been installed for the previous four cycles. This was done to support the PVD positive pressure test of the NLG, but had a negative affect on the ability to properly close the NLG doors. Once the vent plug was removed, and additional adjustments were made to the 684 link, the hook engagement was measured to be within the tolerance of the rigging spec (ML0308-0028). Overall, the 684 link was shortened 1.5 turns during the rigging process. Stress analysis verified that the final loads in the retract link and the upstream hardware were acceptable. Stop bolts along the centerline were adjusted to obtain the proper gaps (0.010 in.

max) with the exception of the mid-aft stop bolt. There was evidence that this stop could contact the LH door during closure (dynamic interference), resulting in structural damage. LT-80 tape was used to reduce the stop gaps at the mid-aft location and, and at the two aft centerline door stops. These two stops are riveted pads, and cannot be easily adjusted.

After completion of the NLG rigging, some of the tile steps across the door centerline were still out of spec. Thermal evaluation determined that several areas could not be accepted, and some of the tiles along the centerline were shaved to reduce the steps. Additionally, several mechanical items were out of spec at the completion of the NLG rigging. The following is a list of the MRs processed to accept the out of tolerance conditions:

1. MEQ-3-31-1498 – restricted one flight – Item 1: NLG perimeter seal has silicone rubber outer layer over fabric (not per drawing, s/b fabric outer surface). Inspect post-flight for wear/damage. Unrestricted – Item 2: Bulb seal diameter on perimeter seal is out of tolerance in several locations.
2. MEQ-3-31-1500 – unrestricted - Bulb seal diameter on centerline seal is out of tolerance in three locations.
3. MEQ-3-31-1513 – unrestricted – Item 1: LT-80 tape applied to three door stops, and acceptance of the mid-aft centerline stop with a gap of 0.012 in. (s/b 0.010 in. max). Item 2: LH and RH door bungee striker gaps out of tolerance. RH is 0.004 in. (s/b zero) and LH is 0.018 in. (s/b 0 to 0.016 in.). A minimum half turn adjustment would preload the strikers against the door, and possibly prevent proper door closure. Item 3: LH V070-510684 door retract link is two turns shorter than allowable per the rigging spec. This was necessary to obtain proper door closure, and the loads were acceptable per Boeing Stress analysis.

Due to the degradation of the environmental seals and the affect the seals have on the LG mechanisms, there will need to be some new requirements generated to address these issues. There will likely be requirements to periodically verify the seal compression, and requirements to re-verify the LG rigging after significant rework is done to the seals or perimeter TPS. Additionally, there is a need to create field-rigging specifications for the LG. Most of the initial rigging is done without the TPS installed, and it is often difficult to interpret the spec for re-rigging type work post delivery. Boeing is investigating this topic.

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