Surface integration text, V0

The pixel detector was designed to be the last element to be integrated with the rest of ATLAS, yet it is trapped at the center of the much larger Inner Detector (ID). This late integration was accomplished by assembling on the surface a "pixel package" to be inserted into a Pixel Support Tube (PST) that had been previously integrated. The pixel package contains the pixel detector proper, spanning the region |Z|<65cm, the "internal services" spanning the region 65<|Z|<350cm, the optical drivers (receivers) for all pixel data (control), the ~7m long Beryllium beam pipe, the Beam Conditions Monitors (BCM), plus environmental sensors and installation hardware. The PST is a ~7m long, 48cm diameter structural tube with built in electrical and thermal shielding.

The assembly of the pixel package took place on an Integration and Transfer Tool (ITT) to hold each element coaxially as it was added (allowing axial relative motion), and to finally safely deliver the full package into a transport box (DST for Dummy Support Tube) to in turn carry the detector underground to the waiting PST. The position of the pixel detector within the ID was predetermined by kinematic mounts on the inside of the PST. These mounts were surveyed and the PST adjusted at the time of PST integration. Features on the pixel detector support frame engage these mounts with a measured repeatability of +/- ??? in X-Y and +/-??? in Z. There is no adjustment of the pixel detector position after insertion.

Elements were added to the ITT assembly in the following order: Barrel support frame, Barrel Layer 2, Barrel Layer 1, Be beam pipe, Barrel Layer 0, Endcap C, Endcap A, beam pipe and services support structure, BCM system, Inner services quarter panels (4 per side), traction system and mounts. The relative position and circular shape of each barrel layer end were surveyed after mounting on the global support frame. The results are shown in figure ???. Each layer was in turn constructed by clamping two carbon fiber half-shells holding all the bistaves. The loading of bistaves proceeded for the two half shells of a given layer in parallel. Each bistave was formed by joining two nominally identical staves with PEEK mechanical supports and a U-link connecting the cooling tubes from both staves a one end. A bundle of micro-cables (1 cable per module) was added to each half stave just prior to joining the two staves. All micro-cables have different lengths to match the final location of the bistave in the detector with 5mm tolerance and 15mm over-length. For layers 1 and 2 exhaust pipes and capillaries were added only after the shells were clamped and loaded in the support frame on the ITT. For layer 0 exhaust pipes had to be added prior to loading the shells because of reduced access to fittings due to the proximity of the beam pipe. The Layer 0 half shells were clamped together around the beam pipe after the beam pipe was loaded on the ITT.

The endcaps were fully integrated into their respective support frames, including attachment of exhaust pipes and capillaries, prior to transport to CERN and loading on the ITT. Endcap A was connected to prototype services and operated with evaporative cooling prior to loading on the ITT (see section ???). This served as a 10% vertical slice test to validate the full system design and operation. The position of each disk within the support frame is determined by 4 mounts per disk on the frame. No survey was done of the fully loaded endcap frame. Instead, the repeatability of the mounts was validated to ??? microns with empty disk rings prior to integration. The 3 disks of each endcap were loaded with 8 sectors each and independently surveyed prior to mounting inside the support frame. The RMS deviation from nominal of the module positions within an endcap (from optical survey) is 2.6 microns in X and Y, and ??? in Z.

Describe load transfers here.

Electrical and leak check testing were carried out after each major operation: after integrating bistaves, after loading bistaves into half-shells, after clamping half-shells, after loading sectors into disks, after loading disks into endcaps, and after integrating components on the ITT. The electrical testing was operated using surface air flow at room temperature for cooling during the disk and half-shell integration stages, when access was open. All module features were tested at this point except for response to ionizing radiation. The integrity of bump bonds was evaluated by examining the pixel noise with and without sensor bias voltage. Because pixels are on the ohmic side of an unirradiated sensor, they are electrically shorted until the sensor is depleted, which leads to small but measurable noise increase. After layers and endcaps were loaded on the ITT, however, such air flow was not possible and the electrical testing was more limited. Full digital functionality could be tested to assure the integrity of all connections, but analog measurements to monitor the bump integrity were not possible. Nevertheless at this stage there was no handling of modules that could result in bump damage. The final electrical testing on the ITT included the optical transducers mounted on the service panels. Thus the connectivity of package in its final form was tested on the surface, but not the analog operation or the cold operation of the full detector.

Cooling pipe circuits underwent vacuum leak checks after each fitting connection. Within the pixel package each cooling circuit has a U-link with two fittings ganging staves or sectors, one exhaust tube with two fittings connecting a bi-stave or bi-sector to a service panel heat exchanger exhaust, and one capillary with two fittings connecting to the same heat exchanger. The leak test was passed if no sensitivity to helium was found with a background reading of 10E-9 mbar.l/s or less. A pressurization at 4 bar absolute using dry air was carried out for 1 minute after the capillaries and exhaust pipes had been added and for 24 hours after the full package had been integrated, always followed by the vacuum leak check. This was the highest pressure for which the local supports (sectors and staves) had been qualified. While this pressure should not be reached in the exhaust circuits during normal operation, all inlet circuits must operate at 12 bar, and therefore have not been individually tested at final pressure in the full package.

Failures were encountered and repaired during integration. Where do we talk about stave pipe corrosion? The breakdown of new pipe vs. inserted pipe staves should probably be given or repeated here. A systematic failure in the micro-cables for the barrel modules was uncovered soon after bi-stave integration and half-shell loading started. This led to additional quality control tests on all existing micro-cables and manufacture of new cables of with a revised process. Approximately 50% of the original micro-cables and

>95% of the new ones passed the final quality control. To minimize delay, the accepted original cables were used for layer 2, while layers 0 and 1 were assembled with new cables. The disk micro-cable design is different and was not subject to this failure mode. Accidental damage to random micro-cables during handling affected 9 modules. The damage was accessible and could be repaired in 5 cases, and could be bypassed to recover full module operation for 3 of the inaccessible cases, leaving only 1 module lost for operation due to an open sensor bias line. Electrical contact failures were also detected in 7 service panel connections, but the exact point of the fault could not be isolated. These were all bypassed using spare connections or by adding single wires.

Active component failures not caused by handling were encountered at a low level in the integrated package. One front end readout chip failed in a disk module by developing an internal short. The module functionality except for this chip was recovered by breaking wire bonds to isolating the failed chip. Two optical components failed: one cannel of a laser diode array and one channel of a photodiode array. In both cases the failure was confirmed to be internal to the component and could not be repaired. However, in both cases the affected modules were moved to spare service slots. One module was discovered with an unusual defect that prevents it from operating with the final optical communication, yet it operated with a pure electrical readout as used for production testing.

Cooling circuit leaks occurred during ITT integration after pressurization. One leak appeared in a Layer 0 stave exhaust fitting, one leak in a disk capillary wall, and 3 leaks in fittings connecting to the service panel heat exchangers. The latter 3 were due to damaged sealing surfaces and this was recovered by sealing these fittings with glue. The capillary leak was a manufacturing defect in the capillary material that was activated as the capillary was routed in a coil. It was repaired by cutting the capillary and soldering it back together with a copper sleeve. The barrel fitting leak may have been caused by a stuck strain relief clamp that applied a large de-mating force, but this is not certain. The fitting was re-tightened in place using a special extension clamp to reach the barrel through the endcap. The full package remained leak tight after 24 hour pressurization before it was transferred to the PST.