Pixel Local Supports FDR

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ATLAS PIXEL LOCAL SUPPORT REQUIREMENTS

The design requirements for the ATLAS Pixel System Local Supports are presented. The Local Supports are barrel staves and disk sectors. Requirements common to both are given and the requirements applying only to staves or sectors are also provided.

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Distribution List

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1 Introduction

This note summarizes the requirements for the Local Supports of the ATLAS Pixel System. A general description of the ATLAS Pixel System and the definition of Local Supports are given elsewhere.[1] There are two types of Local Supports: barrel staves and disk sectors. These may have different dimensional, survey and stability requirements, but have common thermal, material, operating pressure, transient or fault tolerance and miscellaneous requirements. Requirements given here apply to barrel layers 1 and 2. Special B-layer requirements are under development.

The common requirements for both barrel staves and disk sectors are summarized in Table 1. The other requirements for barrel staves and disk sectors are summarized in Table 2 and Table 3, respectively. Details of the requirements are provided in subsequent sections.

Item	***Requirement***
Normal Thermal Conditions	
ΔT from coolant to face of local support(^{O}C)	*≤12*
Temperature uniformity on local support(^{O}C)	*≤10*
Meet all requirements after T cycles(+20^{o}C ↔ -20^{o}C)	*30 cycles*
Minimum temperature of silicon sensor	*-20^{O}C*
Normal Pressure Conditions	
Maximum normal operating pressure(bar absolute)	*4.0*
Pressure cycling of ± 0.1 bar about 2 bar absolute	*TBD cycles*
Radiation Conditions	
Total dose	*500,000 Gy(50,000,000 Rads)*
Material	
Radiation length(active) region - goal in %X_0	*≤0.7*
Transient and Fault Conditions	
Minimum temperature on start-up of cooling	*-35^{o}C*
Once-per-lifetime pressure fault for one hour	*8 bar absolute*
Once-per-lifetime temperature fault for 30 sec.	*50^{O}C*
Miscellaneous Conditions	
Vibrational stability as supported	*≥ 100Hz*
Conducting particles from carbon or other materials	*Not allowed*
Corrosion from all sources	*Prevent*
Erosion from fluid flow	*Prevent*
Repair after complete assembly	*Not required*
Surface characteristics	*Compatible with module attachment*

Table 1. Common requirements of barrel staves and disk sectors. See text for explanation of conditions.

Item	**Requirement**
Envelopes and As-Built Tolerances	
Max deviation from nominal shape (along Z)(mm)	*0.25*
Max deviation from nominal shape (along X)(mm)	*0.25?*
Max lateral tilting of each step(Y) displacement)(mm)	*±0.05*
Single step planarity(mm)	*±0.05*
Survey tolerances	
Z (mm)	*± 0.184*
Y(R) (mm)	*± 0.035(worst case)*
X(ϕ) (mm)	*± 0.023*
Stability Tolerances	
Z (mm)	*± 0.146*
Y(R) (mm)	*±0.028*
X(ϕ) (mm)	*± 0.018*

Table 2. Requirements applying only to barrel staves. See text for explanation of conditions.

Item	***Requirement***
Envelopes and As-Built Tolerances	
Faceplates as cut(mm)	*± 0.25*
Thickness of sector not including support buttons(mm)	*≤ 5.0*
Faceplate planarity(mm)	*± 0.05*
Survey Tolerances	
Z (mm)	*± 0.485*
Y(R) (mm)	*± 0.229*
X(ϕ) (mm)	*± 0.028*
Reference targets front-to-back sides(mm)	*± 0.025*
Stability Tolerances	
Z (out-of-plane)(mm)	*± 0.10*
Y(R) in-plane(mm)	*± 0.065*
X(ϕ) in-plane(mm)	*± 0.006*

Table 3. Requirements applying only to disk sectors. See text for explanation of conditions.

2 Dimensional Requirements

The dimensional requirements for barrel staves and disk sectors are covered in this section. Survey and stability requirements are also included here. Whenever possible tolerances are given. These represent hard limits that the design and fabrication of the Local Supports must meet. Some of these tolerances (i.e. those related to stability) are derived from the impact of misalignments on track reconstruction in the Pixel System, which are more naturally expressed in terms of root-mean-square (rms) deviations. In these cases, the tolerance is related to the rms by the following formula: tolerance range = +/- rms deviation x $(12)^{1/2}$ *where deviation means difference of a given dimension from the undeformed to the deformed conditions due to a given action or load. Tolerances are expressed in the local coordinate system appropriate to survey measurements so that Quality Control procedures may be applied.*

2.1 Barrel Staves

2.1.1 Geometry

The geometry of the barrel stave is given in Figure 1.

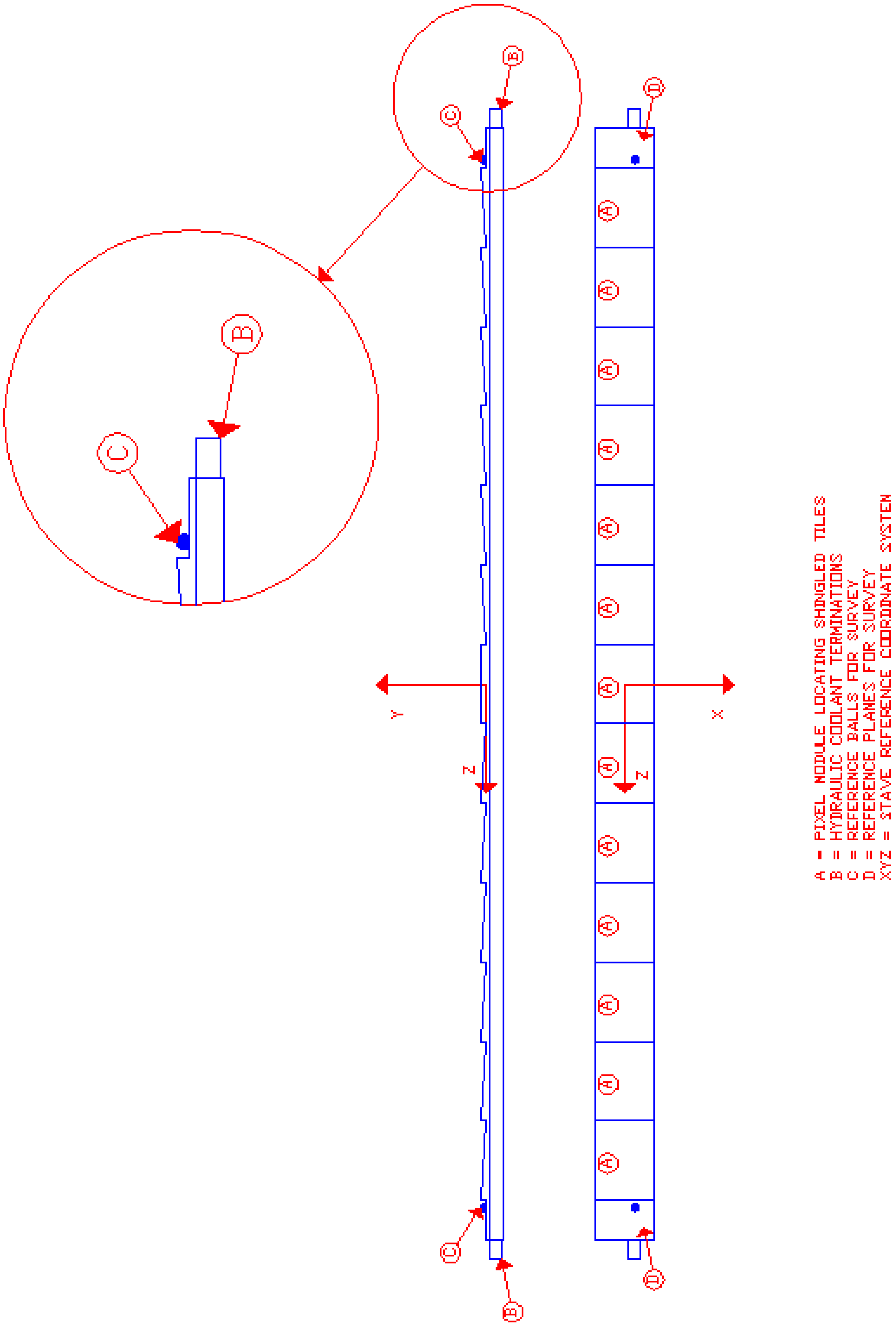

Figure 1. Barrel stave geometry.

2.1.2 Envelopes and As-Built Tolerances

The envelopes and as built tolerances are shown in Table 2. The total allowable deviation in Y from the nominal shape (longitudinal combined with lateral tilting) is such to allow for adequate clearance in-between adjacent staves. The tolerance in X also arises from the need to allow adequate clearance.

2.1.3 Survey Tolerances

The X-Z plane is defined by two reference planes at the ends of the stave (marked with "D" in Figure 1). The Z axis is defined by the line that joins the centers of the two reference balls located on the reference planes (marked with "C" in Figure 1). Both reference balls and planes are always accessible with a touch probe, also when the modules are on the stave. The origin of the system is placed in the middle of the stave, both in the X and in the Z directions It is desired to use the coordinates of the local support as the starting point for the track reconstruction. Thus we impose a requirement that the location of modules on the local support be surveyed with respect to the local support coordinate system within a tolerance such that the resolution is degraded by no more than 20%. This leads to the survey tolerances given in Table 2. The intrinsic resolutions assumed are given in the section on stability requirements.

2.2 Disk Sectors

2.2.1 Geometry

The geometry of the disk sector is given in Figure 2 along with a summary of the key requirements.

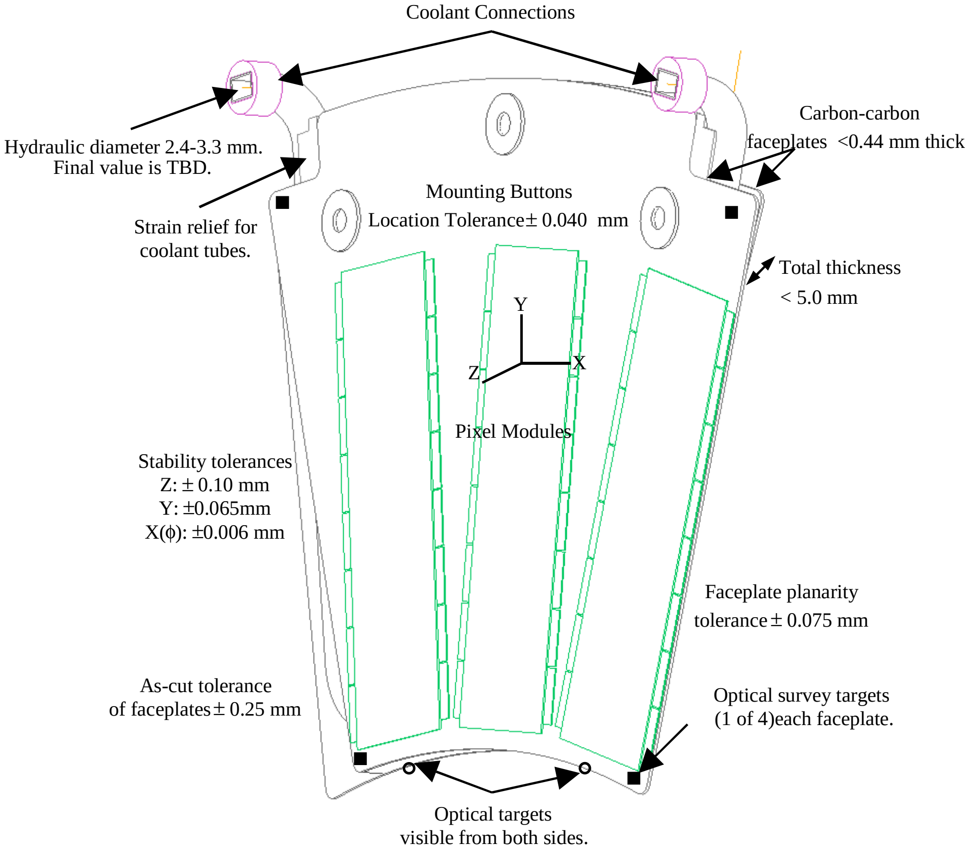

Figure 2. Geometry of disk sector and summary of key requirements.

2.2.2 Envelopes and As-Built Tolerances

The as-built dimensions of the faceplates of the sector have a tolerance of + 0.25mm to allow adequate clearance at the inner radius of the sectors when the sectors are mounted on disk support ring. The as-built dimensions of the faceplates of the sector have a tolerance of -0.25 mm so that carbon-carbon material is always present under all modules. The thickness of the sector, not including mounting buttons/washers, shall not exceed 5.0 mm. The thickness of the sector is limited by material considerations well before reaching any interference limits with neighboring (in Z) disks. The Z positions of modules on the sectors are referenced to a plane defined by the (average) Z values of the faces of the three mounting buttons on the face of the sector mounted to the disk support. The deviation from planarity of each faceplate relative to this plane shall not exceed ± 0.050 mm. This is set by the thickness of the material used for module attachment.

2.2.3 Survey Tolerances and Requirements

The location of every pixel module on sector will be measured. The reference coordinate system on the sector for these measurements is defined by the location of the mounting buttons. Four optical survey targets are mounted on each sector face. These are surveyed relative to the location of the mounting buttons and are used to define the coordinate system for module placement. The location in the X-Y plane and in Z of fiducial marks (at least four) on the backside of the silicon sensor on each pixel module are measured relative to this coordinate system and recorded. The two sides of the sector may be referenced by using the through holes in the mounting buttons. Again for convenience, two small tooling balls that are visible from either side of the sector will be precisely located at the inner radius of the sector. These will provide a secondary means of referencing the modules on the front and back sides of the sector. Each optical survey target on a sector is required to be referenced to the coordinate system defined by the mounting buttons within a tolerance of ± 0.010 mm to provide a good starting point for the track finding process. Each of the tooling balls on a sector is required to be referenced to the coordinate system defined by the mounting buttons within a tolerance of ± 0.025 mm to ensure a well understood overlap of front and back modules. As for the staves, it is desired to use the sector location as a starting point for the track reconstruction. The survey tolerances required to limit the degradation in resolution to 20% are given in Table 3.

3 Thermal Requirements

3.1 Introduction and Background

The temperature of the pixel silicon sensors is determined by the heat load generated by the integrated circuit electronics attached to the sensors, leakage currents in the sensors, heat flow from the surrounding power and cooling services and heat flow from/to outside the pixel detector volume. Since the heat transfer efficiency (convection) to the surrounding environmental gas is very low, the temperature of the sensors is driven by the heat dissipation efficiency of the cooling structures. The local supports are designed for a maximum power of 50W per disk sector and 107W per stave, except for the B-layer in which case the maximum power is 134W.

The primary thermal requirement of the local supports is to achieve an operating temperature of the pixel silicon detectors of ≤ -6^{0}C. The operating temperature of the silicon detectors must by maintained at or below -6^{0}C in order to achieve an acceptable lifetime after irradiation.[2]

The temperature at the local support inlet is driven by the pressure drop in the stave or sector. A maximum temperature difference of 2.5 °C is a reasonable compromise between allowable pressure drops in the local support, and the maximum allowable temperature difference between coolant and modules. This corresponds to a maximum pressure drop in a stave of around 170 mbar. Two local supports are currently assumed to be cooled in series. Therefore, given a minimum temperature at the outlet of the local support of –25°C, the maximum temperature at the inlet of the first local support will be –20°C.

The temperature of the silicon sensors is determined by the (local) coolant temperature, the temperature gradient between the average (local) coolant temperature and the face surface of the local support and the temperature gradient between the face of the local support and the sensor, through the coupling adhesive or grease, the electronics integrated circuits and bump bonds. Assuming a maximum inlet coolant temperature of -20^{o}C, the allowed temperature gradient from the average (local) coolant to the face of the local supports should be ≤ 12^{O}C.

The local pressure (boiling conditions) determines the temperature of the coolant in the stave. The minimum practical temperature at the inlet of the compressor and the pressure drops in the return pipe limit the outlet temperature of the stave (or sector). We assume the minimum inlet pressure of the compressor to be above the atmospheric (to avoid contamination of the coolant in case of leaks). Assuming a minimum pressure drop in the return pipes (consistent with an acceptable piping layout and sizes) of 650 mbar, the minimum temperature that can be realistically achieved at the outlet of the local support is –25°C. During the start up of the cooling system lower temperatures could be temporarily reached in the local support, a minimum transient coolant temperature of –35°C is assumed.

3.2 Maximum Operating Temperature

The maximum normal operating temperature of the pixel silicon sensors is -6^{0}C.

3.3 Minimum Operating Temperature

The minimum normal operating temperature of the pixel silicon sensors is -20^oC, but during transient conditions the minimum temperature may reach -35^OC.

3.4 Temperature Uniformity

The temperature uniformity under power is given by three contributions: uniformity of the heat transfer efficiency from the local support cooling channel to the face surface (≤5^{o}C); uniformity of the module-to-support adhesive interface (≤2^{o}C); and the temperature distribution along the local support cooling channel (≤5^{o}C for two local supports in series). Thus the desired uniformity of temperature of the pixel silicon sensors on a <u>single</u> local support is about ≤10^{o}C.

4 Normal Operating Pressure Requirements

Cooling by evaporation of C_3F_8 is assumed. The typical operating pressure within a local support is 2 bar absolute. The normal operating pressure within a local support will not exceed 4 bar absolute. The fluid channels within the Local Supports and the connections to them must be leak tight to 4 bar absolute under normal operating conditions and after fault conditions.

Pressure cycling around the normal operating pressure of 2 bar absolute is assumed to be ± 0.1 bar. However, more experience with the baseline evaporative cooling system is required to better establish this requirement and the corresponding number of cycles expected over the life of the detector

5 Temperature and Pressure Cycling

All requirements must be met after pressure and temperature cycling of the local supports and the interfaces according to the following table (Table 4):

TRANSIENT MODE	*PRESSURE CYCLE (bar)*	*TEMPERATURE CYCLE (°C)*	*NUMBER OF CYCLES (LIFETIME)*
Single module On-Off	*-*	*20*	*750 (*)*
Cooling circuit On/Off	*3*	*30*	*750*
Detector warm-up	*3*	*45*	*30*

(*) It is expected to have one On/Off transient per day over the whole detector, the worst case for an individual module would be realistically to have 1 cycle per week.

Table 4. Local support temperature and pressure cycling conditions.

6 Transient Conditions Requirements

Transient conditions are those conditions that occur under normal operating circumstances during e.g. start-up or shutdown of the cooling or power system. The types of transients and their frequency are given in Table 5.

TRANSIENT TYPE	*EXPECTED FREQUENCY*	*ΔTmax (°C) ON LOCAL SUPPORTS*	*ΔTmax (°C) ON GLOBAL SUPPORTS*	*Δp (bar) IN LOCAL SUPPORTS AND COOLING PIPES*
Local module power ON/OFF (cooling always ON)	***daily***	***20*** *(-25 to –5)*	***0***	***0***
Cooling circuit(s) ON/OFF	***weekly***	***30*** *(-35 (*) to –5)*	**0**	***3***
Detector warm-up	***6 months***	***45*** *(-25 to +20)*	***30*** *(-10 to +20)*	***3***

(*) minimum expected temperature during the start up of the cooling system

Table 5. Temperature and pressure transients.

7 Material Requirements

It is desirable to minimize the amount of material as measured in radiation lengths (X_0) for the local supports. The desired goal for the radiation length of a local support, averaged over the (active) region covered by a pixel module is to be <0.7% X_0.

8 Radiation Requirements

All requirements must be met after a total dose of $5x10^5$ Gy(5×10^7 Rad).

9 Fault Condition Requirements

9.1 Pressure fault

The design of the local supports and interfaces to them will assume a once-per-lifetime single system failure resulting in a maximum pressure of 8 bar absolute for a duration of one hour.

9.2 Temperature fault

The design of the local supports and interfaces to them will assume a once-per-lifetime single system failure resulting in partial or complete loss of coolant with power on that raises the average surface local support temperature to 50^oC for 30 seconds.

10 Stability Tolerances and Requirements

10.1 Introduction

The ultimate alignment of the pixel modules will be done with charged particle tracks. In principle, it is possible to do this (there are enough tracks) on about a daily basis. However, this imposes severe requirements on the software reconstruction process and it is desirable that the system be as stable as possible and meet other requirements. The stability tolerances of the local supports cannot be separated easily from system stability requirements. The stability tolerances for the barrel staves may be, and are, different than for the disk sectors because of the different geometry and support of the two structures.

The total stability requirements are comprised of module attachment, local support, intermediate support structures (disk rings and barrel shells) and intermediate supports-to-global support frame stability requirements. It is not possible to entirely separate these from each other from current (or future) measurements or finite-element analyses. Thus some judgement must used to apportion the "stability budget" among these contributions. The stability of module attachment will be excellent and is ignored here.

Practically, the local support stability is assessed by measuring motions under thermal and pressure changes, including the ability to meet requirements after transient and fault conditions. If these motions are less than the tolerance allocation, then the stability requirements are judged to be met. Similarly, the frequency response of the local supports is measured and judged to be acceptable for peak motion above 100 Hz(including support conditions).

The reference conditions for stability measurements are ultimately defined by the ability to align elements of the system with particle tracks. The system must be stable on a timescale long enough to perform this type of alignment. We assume that transient and fault conditions occur rarely enough that alignment by tracks would be possible afterwards. A reference condition for the stability requirements is a temperature cycle of 20°C, although tests are typically performed over a larger temperature range. This value (20^OC) arises from the module on/off conditions given in Table 4. The reference condition for pressure stability is ±0.1 bar about 2 bar absolute, which we expect to be the variation during stable operation. However, measurements of stability under pressure variations are typically done over a much wider range of pressures.

10.2 Stave Requirements

The intrinsic resolution for the barrel is assumed to be 0.010 mm in ϕ and 0.080 mm in Z. The stability tolerance is calculated to keep the degradation of the intrinsic resolution to less than 20%. Therefore the stability requirements are 0.0066 mm(rms) in ϕ and 0.053 mm(rms) in Z for the barrel system. Motion in R at the most sensitive location at the end of the stave on the layer 1 nominally must be kept within 0.010(rms). However, the uniformity of the active thickness of the silicon sensor becomes important at this level as does the actual distribution of hit pixels in Z. A more sophisticated analysis will be available for the PRR. This is particular important for the B-layer, which covers a larger angular range.

Assuming a stability budget for the stave to be about 80% of the total stability budget, the stability tolerance for a stave have been calculated, and are given in Table 6.

	R (mm)	ϕ (mm)	Z (mm)
Total barrel module stability (rms)	0.010	0.0066	0.053
Stave stability(rms)	0.008	0.0053	0.042
Stave stability tolerances	±0.028	±0.018	±0.146

Table 6. Stave stability requirements summary.

10.3 Disk Sector Requirements

The intrinsic resolution in the disk region is assumed to be 0.012 mm in ϕ and 0.100 mm in R. An rms deviation of 0.140 mm in the Z location of a module at the most sensitive location in the disk system (disk closest to the interaction point at outer radius) results in a degradation of the resolution in R by about 20%. Measurements in the more accurate ϕ coordinate are even less sensitive to a local distortion (rotation about the local Y axis of a module) and thus deviations in Z of a sector by roughly a factor of three. However, motions of the sector in the plane of the faceplate of a sector must be less than an rms of about 0.008 mm to have less than a 20% effect on the intrinsic ϕ resolution. The total stability requirements for modules on a disk sector are summarized in Table 7.

The stability of disk sectors in Z and in the plane of the faceplates can be and has been estimated via measurements under the operating conditions. Similarly, the stability of a complete disk has been and can be roughly measured before final assembly, although all forces from service connections cannot be imposed. Stability of a disk within the global support frame has not been measured and will not be easily measured with precision. Thus it makes sense to apportion the "stability budget" with tighter restrictions on the sector, then the disk support ring and finally the attachment of the disk ring to the global support frame. We also assume the deviations from initial locations in each case may be added in quadrature. The sector stability requirement is estimated from the total stability budget by assuming the contribution from the disk ring/disk is twice the sector and the contribution from the disk-to-frame stability is four times the sector contribution. The tolerances are summarized in Table 7 under these (arbitrary) assumptions.

	R (mm)	ϕ (mm)	Z (mm)
Total disk module stability(rms)	0.066	0.008	0.140
Sector stability(rms)	0.0144	0.0017	0.0306
Sector stability tolerances	±0.050	±0.006	±0.106

Table 7. Disk sector stability requirements summary.

11 Miscellaneous Requirements

We summarize here miscellaneous requirements common to both staves and sectors.

11.1 Conducting Particles

The Local Supports shall be coated or impregnated to prevent conducting particles from being liberated, which might cause electrical breakdown in the pixel modules or connections to them.

11.2 Corrosion

The materials in the Local Supports and connections to them shall be such as to prevent corrosive effects that would prevent the Local Supports from meeting the requirements. This includes corrosive effects that might be induced by galvanic action between metallic and carbon materials, by coolant contact with coolant channels or connections to them, including adhesives, and environmental effects (e.g. humidity).

11.3 Erosion

The materials in the Local Supports and connections to them shall be such as to prevent erosion of material that might be caused by passage of the coolant fluid.

11.4 Repair

Repair of barrel staves and disk sectors after assembly is not required.

11.5 Surface

The surface of the local supports is required to meet the interface requirements for pixel module attachment. The surface must be clean of volatile residues and residual particles. There is no specification for surface roughness.

[1] ATL-IP-EM-0026, Pixel Local Supports Overview.
[2] Pixel Technical Design Report, CERN/LHCC/98-13, May 1998. See Chapter 4 for background information.