Pointing Accuracy Requirement:

The pointing accuracy requirement of the CubeSat is determined by the desired collecting area of the detector. To measure X-rays from solar flares, the detector must face the Sun. If the photon flux is normally incident, the geometric area is maximized. Any pointing angle away from the CubeSat-Sun line results in a degradation of collecting area. We deem a collecting area of 90% the maximum to be acceptable because a 10% loss in number of photons is negligible for the statistical analysis of hard X-ray spectra. From the target area of 90% of the maximum, the required pointing accuracy can be determined.

Figure 1: Cone representing off-axis pointing angle. The orange line represents a line from the center of the detector to the center of the Sun. The angle theta is the off-pointing angle.

When determining the required accuracy, a possible pointing misalignment in one direction was considered; this is the half angle \( \theta \) of the cone shown in Figure 1. Parallel rays were assumed.

Figure 2: The diagram illustrates quasiparallel photons from the Sun incident on the CubeSat. The CubeSat's orientation as shown provides 100% of the maximum effective area. This is the ideal case. The blue face represents the detector.
With an off-axis angle $\theta$ a smaller number of photons intersect the detector as demonstrated by the following.

Figure 3: The diagram illustrates photons from the Sun incident on the CubeSat. The CubeSat’s orientation as shown is only able to see 60% of the incoming photons as compared with the “perfect pointing” case. As can be seen, having the CubeSat at different attitudes can greatly affect the number of photons incident upon the desired face. The blue face represents the detector.

The detector surface and the incoming photons can be used to make a right triangle which can be used to find the effective area that can accept photons; see Figure 4.

Figure 4: The diagram illustrates the right triangle that is created by a photon from the sun and the detector surface. $\theta$ is the angle that the detector surface makes with the horizontal plane in this depiction.

The hypotenuse in this triangle is the physical detector size. The horizontal segment, which can be defined as the variable ‘$Y$’, therefore varies with the cosine of theta:

$$Y = X \cos \theta$$

Next, an acceptable effective must be determined. In this case, 90% is acceptable for the purposes of the mission because a photon loss of 10% will not significantly affect the statistics that can be used for spectroscopy. If we set $Y/X = 90\%$, then $\theta = 25.8$ degrees. Therefore, in the worst case scenario, the maximum theta that is acceptable to maintain at least 90% effective area is $\theta = 25.8$ degrees. This off-axis angle limitation applies in any direction (i.e. it is the half-angle of the cone shown in Figure 1.

With 90% of the maximum possible collecting angle, the loss of photons due to imperfect pointing is negligible for the purposes of spectroscopy. However, it is essential to know the pointing so that an accurate model of the detector response can be constructed. We allow a 2% error budget in flux reconstruction due to pointing knowledge. (It is common for astrophysical detectors to have absolute efficiency calibrations at the 10% level; with a 2% flux error budget we leave allowance for other sources of error too.) To achieve a 2% flux error, using the same geometry shown in Figure 4, a pointing knowledge of 11.5% is required, which we conservatively round to 10%.