



LGS-AO: Expected Brightness of Aircraft

In LGS-AO astronomy at night, it is imperative that the safety systems that protect civilian aircraft and their pilots and passengers are robust and reliable. For systems that are optically based, such as a CCD all-sky camera, we would like to know what limitations we can expect from the safety system.

For optical detection of aircraft, the brightness of the aircraft's position and anti-collision lights are relevant to the detectability of the aircraft. This technical note calculates the expected brightness, in a rough approximation to the V band used in astronomical photometry.

Assumptions

We will treat the V band in a relatively crude manner. We also make the simplifying assumption that the human eye is sensitive in the same way as a V -band measurement (i.e. the same bandpass). The FAA (Federal Aviation Administration) specifications provide for a light brightness in candela (cd), which refers to a monochromatic power measurement at 555 nm, similar to the wavelength for V . One cd represents a flux of 1/683 W/sr.

FAA Brightness Specification

In FAA Requirements document, Title 14, Section 25.1401, the minimum intensity of the anti-collision lights on an aircraft are given as a function of angle above of below the plane of the aircraft. For horizontal flights, the angle at which an observer sees the aircraft's lights is the same as the aircraft's elevation as seen by the observer. We are interested in values between 20° and 90° . Between 20° and 30° the minimum required brightness is 40 cd. At elevations above 75° (i.e. the aircraft nearly directly overhead) there is no requirement for brightness, and we might assume that the aircraft's lights would be invisible. In practice, however, we should have detected the aircraft before it got to such a high elevation. We will use a minimum requirement of 40 cd in the following calculations.

Section 25.1391 of the same FAA document gives minimum intensities of the position lights. For aircraft heading towards the observer and seen between 20° and 30° elevation, the minimum required intensity is only 12 cd. The position lights are fainter, and we will not use them in this calculation. There is an important point to be made here, however. Pilots have the authority to turn off the anti-collision lights if they feel it is interfering with their vision, for example, if they are flying through clouds and the backscatter from the lights is making it difficult to see. If they are flying through clouds, we can reasonably expect that we are not lasing in that area. However, should the pilot fail to turn on the anti-collision lights after emerging from clouds, we might have a problem. For instance, if halfway to Hawaii the pilot passes through clouds, and turns off the anti-collision lights, then emerges from the clouds and does not turn the lights back on, we would only have the position lights to identify the aircraft.



Calculations

A light emitting 40 cd of power produces 40 lumens/sr. If we assume an aircraft at an elevation of 45,000 feet (above sea level; 31,200 feet = 9.5 km above the observer), seen at 20° elevation, it will be 27.8 km distant. One steradian covers one square meter on the surface of a globe of 1 meter radius, so at a distance of 27.8 km, a steradian corresponds to 7.73×10^8 sq. m. An intensity of 40 lumens/sr seen at such a distance produces 5.18×10^{-8} lumens/m². A lumen/m² is called a lux, and a $V = 0$ star produces 2.54×10^{-6} lux outside the Earth's atmosphere (i.e. ignoring extinction). So, ignoring extinction for the moment, the 40 cd light appears as a $V = 4.2$ star.

Calculations for other ceilings take into account the inverse square law, so at a ceiling of 35,000 feet above sea level (21,200 feet = 6.5 km above the observer), the aircraft appears a magnitude brighter.

The MMT calculations (Lloyd-Hart et al. 1999) used a brightness of 400 cd, an altitude of 11,000 m, and a maximum zenith distance of 45°. The latter constraints imply a maximum distance of 15.6 km, so their calculation should yield a brightness that is 32 times (3.8 mag.) brighter. This implies $V = 0.4$, consistent with their claim that the aircraft should be first magnitude or brighter. Most of this (a factor of 10, or 2.5 mag.) is from an apparently incorrect use of the aircraft regulations.

Including extinction, a star seen through one air mass suffers roughly 0.2 mags of extinction. I have not looked up the equivalent value for a light source within the atmosphere, but presumably a distant aircraft would suffer a significant fraction of this. If the values are taken to be identical, then the V magnitude comparisons above would be the same (i.e. the aircraft would look the same as a $V = 4.2$ mag. star seen at 20° elevation).

Conclusions

We can expect to see aircraft as faint as V mag. 4.2 at elevations of 20°. This requirement opens up a set of new problems, as tracking moving targets at this brightness level could include numerous satellites and meteors. The possibility for false triggers increases dramatically. It seems likely that other discriminants need to be used, such as the apparent angular velocity of the detected object (to discriminate against satellites), or the short-lived nature of the object (meteors). For aircraft, the angular velocity correlates somewhat with brightness, so while fast-moving objects should be nearby and hence bright, slow-moving bright objects or fast-moving faint objects might be ruled out as possible aircraft.

References

Lloyd-Hart, M., Cheselka, M., & Hanson, R. 1999, PASP, 111, 1577.

Electronic version of Federal Aviation Requirements, Title 14: "Aeronautics and Space," Part 25: "Airworthiness Standards: Transport Category," Subpart F: "Equipment." URL: <http://ecfr.gpoaccess.gov/cgi/t/text/text->



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Web page, “*The Unit of Luminous Intensity: Candela (cd)*” at URL <http://www.electro-optical.com/whitepapers/candela.htm>.

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