P 1.17 EVALUATION OF THE 2 FOOT-LAMBERT (FL) DAWN AND DUSK THRESHOLDS FOR RUNWAY VISUAL RANGE (RVR) AIRPORT APPLICATIONS

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1. INTRODUCTION

An analysis was conducted to probe the discontinuity in Runway Visual Range (RVR) values reported when the background luminance passes through the 2-ft-Lambert threshold used by the RVR computational algorithm to define nighttime conditions. These times provide general guidance on when step changes of RVR reports might occur due to a change in the RVR algorithm. Above 2-fL, RVR is the highest value of the daytime and nighttime values, whereas at or below 2-fL, RVR is based solely on the nighttime value.

Ambient Light Sensor (ALS) data were taken from the New Generation Runway Visual Range (NGRVR) system at the Otis Weather Test Facility on Cape Cod, MA from 03/01/06 to 07/28/07. These data are generally recorded at 10-s intervals. The readings have a resolution of 0.1 ft-Lambert. The times of 2-fL transitions were taken and compared against sunrise and sunset times for Falmouth, MA.

Definitions

Sunrise and sunset times are derived from the US Naval Observatory website:
http://aa.usno.navy.mil/data/docs/RS_OneYear.php

> "Sunrise and sunset conventionally refer to the times when the upper edge of the disk of the Sun is on the horizon, considered unobstructed relative to the location of interest. Atmospheric conditions are assumed to be average, and the location is in a level region on the Earth's surface."

Since the results indicate times generally a half hour or less before sunrise or sunset, definitions of the *horizon* and *twilight* are also relevant.

> "Wherever one is located on or near the Earth's surface, the Earth is perceived as essentially flat and, therefore, as a plane. The sky resembles one-half of a sphere or dome centered at the observer. If there are no visual obstructions, the apparent intersection of the sky with the Earth's (plane) surface is the horizon, which appears as a circle centered at the observer. For rise/set computations, the observer's eye is considered to be on the surface of the Earth, so that the horizon is geometrically exactly 90 degrees from the local vertical direction."

Sunrise and Sunset Times

Sunrise and sunset times are based on the times the solar disc center is 50' below the horizon, which accounts for atmospheric refraction (34') under average atmospheric conditions and the average angular radius of the Sun's disc (16').

The Glossary of Meteorology (Huschke, ed., 1959) gives the following definition related to *twilight*:

> "The intervals of incomplete darkness following sunset and preceding sunrise. The time at which evening twilight ends or morning twilight begins is determined by arbitrary convention; and several kinds of twilight have been defined and used. Civil twilight, nautical twilight, and astronomical twilight are in common usage, the limiting solar depression angle [angle below horizon] being, respectively, 6°, 12°, and 18° for those three."

The angles are based on the location of the center of the sun. Start and end times of civil twilight for Falmouth, MA may also be generated from the US Naval Observatory website.

Civil twilight typically starts in the morning at around a half hour before sunrise and ends just before sunrise; in the evening, it starts right after sunset and lasts for around the same duration. The duration of civil twilight is the shortest (a few minutes less than a half hour) near the spring and autumnal equinoxes and longest near the summer solstice (several minutes longer than a half hour). The illumination at the transition time between civil and nautical twilight is such that, under appropriately favorable conditions, the horizon is clearly defined, terrestrial objects are discernable and bright stars and planets are visible (US Naval Observatory).

1.1 Background

Reported values of RVR are always taken as the largest value derived from solutions of Koschmieder's Law (KL) and Allard's Law (AL), except at nighttime when the solution is based solely on AL. Fig. 1 shows solutions of possible reported RVR values for both for Edge Light Step settings 1 and 2. The KL result is in blue, while the AL solutions are in green and red for light settings 1 and 2, respectively. Since a background threshold luminance B of 2-fL is the basis for defining nighttime conditions (RVR is forced to depend solely on a pilot's ability to see runway lights when B ≤ 2-fL), RVR reports can change abruptly from results based on KL to ones based on AL. The curves show all the possible RVR reports as a function of atmospheric extinction coefficient. Under most circumstances of good visibility or low extinction coefficient, the transition at the threshold results in higher to lower RVR values. For example, when the extinction coefficient is 0.3-km^{-1}, RVR reports can switch between

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6,500-ft to 4,000-ft, depending on whether one is going from day to nighttime conditions or vice-versa. Note also that when the extinction coefficient is high, the AL solutions for these light settings become greater than the KL solution.

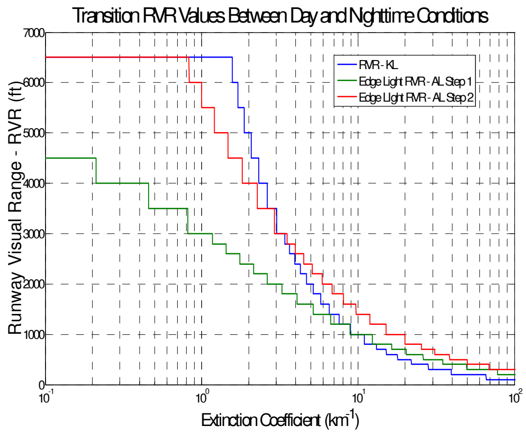

Fig. 1. Dependence of RVR reports as a function of Extinction Coefficient for Edge Light Steps 1 and 2. Note that the Allard's Law solutions can be much less than the Koschmieder's Law solutions at low extinction coefficients.

2. RESULTS

In order to estimate the times when B passes through the 2-fL threshold, nearly 500 days of background luminance data (includes spring 2006 through mid-summer 2007) were examined. The resulting histograms of the transition times relative to sunrise and sunset are given in Figs. 2 and 3, respectively. The ALS readings typically cross the 2-ft-Lambert threshold twice a day: from ~5-24 min before sunrise and from ~5-28 min after sunset, respectively. These transitions generally occur during civil twilight. Anomalous events such as multiple transitions before sunrise or after sunset were also observed, most likely due to changing atmospheric conditions involving changes in visibility, cloud conditions and precipitation. Fig. 4 shows that the pre-sunrise 2-ft-Lambert threshold typically occurs a few minutes less before sunrise than the post-sunset 2-ft-Lambert threshold crossing is after sunset. This difference is attributed to the fact that poor visibility conditions at the Otis WTF usually occur in the morning, which would cause a concomitant reduction in luminance compared to similar solar conditions in the evening. The number of days that this occurs is considered enough to skew the symmetry between morning and evening time periods.

Figs. 5 and 6 show that the durations of the transitions (B = 2-fL) usually last less than a minute, with transition durations of 20-30-s being the most common. Figs. 7 and 8, respectively, show only a weak negative correlation between duration times and the time difference between the transition and the time of sunrise or sunset. Fig. 9 shows 2-ft-Lambert threshold crossings appearing to occur somewhat farther from sunrise and sunset in summer months than at other times of the year.

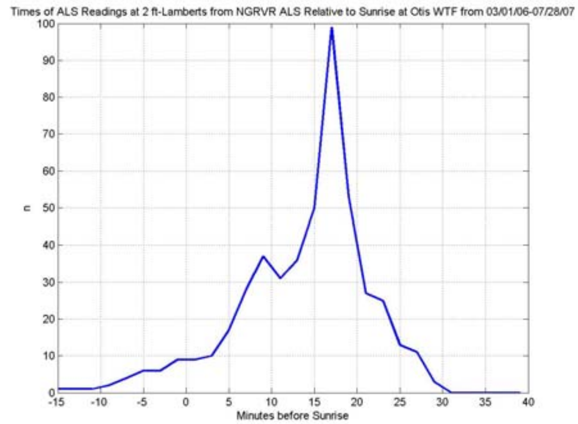

Fig. 2. Histogram of 2-fL Transitions before Sunrise.

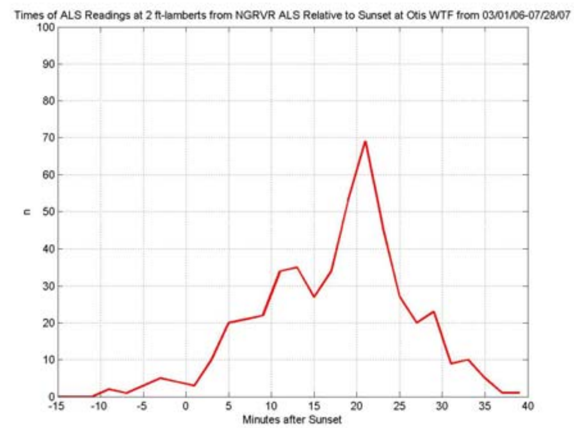

Fig. 3. Histogram of 2-fL Transitions after Sunset.

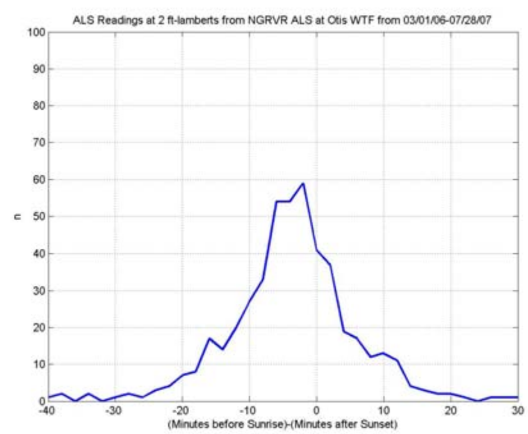

Fig. 4. Histogram of Differences between Sunrise and Sunset Transitions.

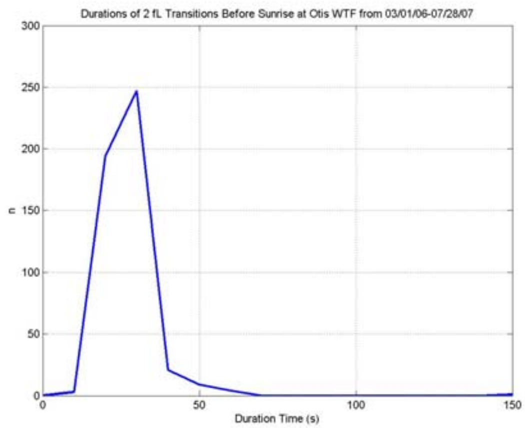

Fig. 5. Histogram of Durations of 2-fL Transitions before Sunrise.

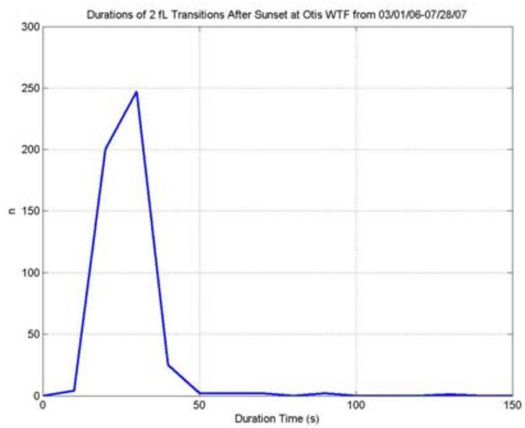

Fig. 6. Histogram of Durations of 2-fL Transitions after Sunset.

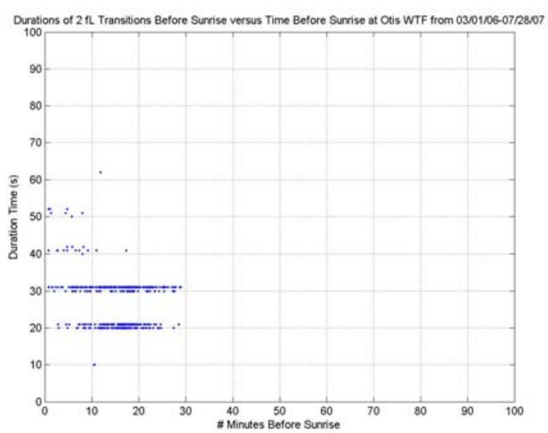

Fig. 7. Scatter Plot of Durations of Transitions versus Times before Sunrise.

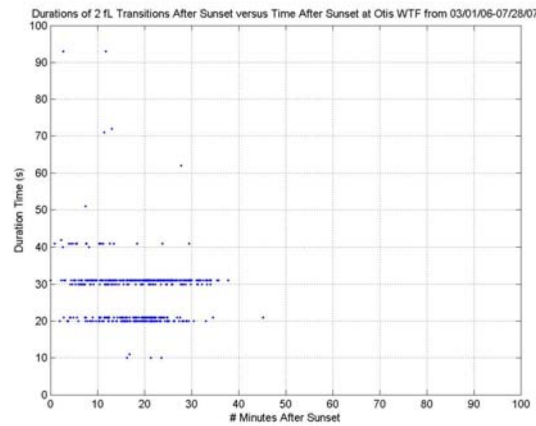

Fig. 8. Scatter Plot of Durations of Transitions versus Times after Sunset.

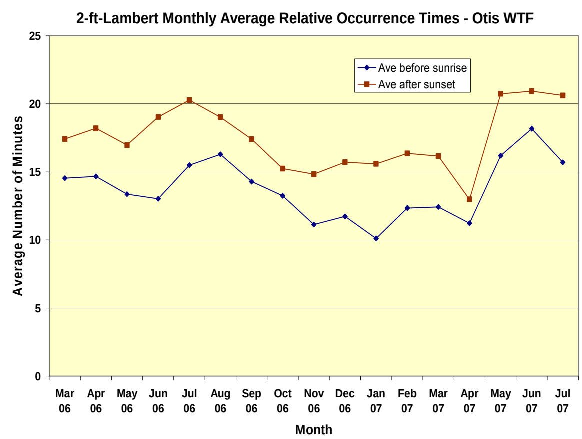

Fig. 9. Monthly Statistics of Relative Occurrence Times.

3. GENERAL FINDINGS

The RVR switching phenomenon observed by controllers when runway light setting steps are at Step 1 or 2 are consistent with expectations based on the transitions from day to nighttime that occur when the background luminance B ≤ 2-fL. Measurements of B at the Otis WTF indicate that this transition can be expected to occur primarily during civil twilight, shortly before sunrise and shortly after sunset. This time can change with the time of year and local atmospheric conditions. When good visibility conditions occur during twilight time, visibility based on contrast (KL) can be very good while visibility of low intensity runway lights can be much less. The switching of RVR values observed by controllers during such times is readily explained by the results of this paper.

References

Huschke, R. E. ed., 1959, Glossary of Meteorology, Amer. Meteor. Soc., p. 598.

US Naval Observatory web site

http://aa.usno.navy.mil/data/docs/RS_OneYear.php