

# VIMS IR Pixel Timing

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*Summary: The VIMS EDR labels provide a set of time parameters that are internal to the VIMS instrument and measured in units of the VIMS internal clock (Integration Time, Interline Delay Time, and Interframe Delay Time). In geometric reconstruction (mapping the cubes into RA/DEC or LAT/LON etc.), these times must be converted to real time units (multiplied by 1.01725) to compute the time offset of each pixel from the start of a cube (recorded by a time stamp from the S/C clock as Native Start Time). These pixel times (then in Ephemeris Time units) can be used to derive geometric parameters for each pixel from the Cassini SPICE kernel database. Also note that the spectral radiometric response calibration coefficients (i.e. DN/Spectral\_Irradiance( $\lambda$ )/sec) of the VIMS IR were measured in units of the VIMS internal clock so the Integration Time should be left in the internal clock units when converting DN to radiometric units.*

The VIMS infrared channel uses an articulating secondary mirror to produce a raster scan of the scene being observed. Under normal operation, as a particular image mode is started by a trigger command from the Cassini spacecraft, it is initiated at a time which is recorded in the VIMS cube header as “Native Start Time”--a hybrid of the spacecraft clock for whole seconds and VIMS’ clock for fractional seconds. The downstream timing for the raster scan is, however, determined by the VIMS internal oscillator. The VIMS internal oscillator runs at roughly 16 kHz and is used to determine all instrument timing, including “Integration Time”, “Interline Delay Time” and “Interframe Delay Time”. Subsequent to the launch of Cassini, the VIMS team has determined that the VIMS internal clock runs “slow” when compared to a reference standard such as the spacecraft clock. That is, a second as reckoned by the VIMS internal clock has been measured to take 1.01725 seconds (see appendix 1). Using flight data spanning the period 1999-2013, obtained using a special mode of the instrument called “time insertion mode”, the VIMS clock has been compared to the spacecraft clock, and has been shown to be stable to about 1 ppm during that period. When combined with measurements of the VIMS clock rate determined during the construction phase of the instrument (roughly during the years 1992-1995), the VIMS internal clock has remained slow by a factor of 1.01725 but stable to about 1 ppm since launch.

The effects of this internal timing drift relative to a more accurate source such as the Cassini ultra-stable oscillator are mostly inconsequential, except when trying to perform accurate geometric reconstruction of infrared cubes taken with long integration times. (Note that: In the case of radiometric calibration, the responsivity of the instrument (i.e. DN/Spectral\_Irradiance( $\lambda$ )/sec) was measured in units of the VIMS internal clock, thus the Integration Time should be left in VIMS internal clock milliseconds when converting instrument data to specific intensity or I/F).

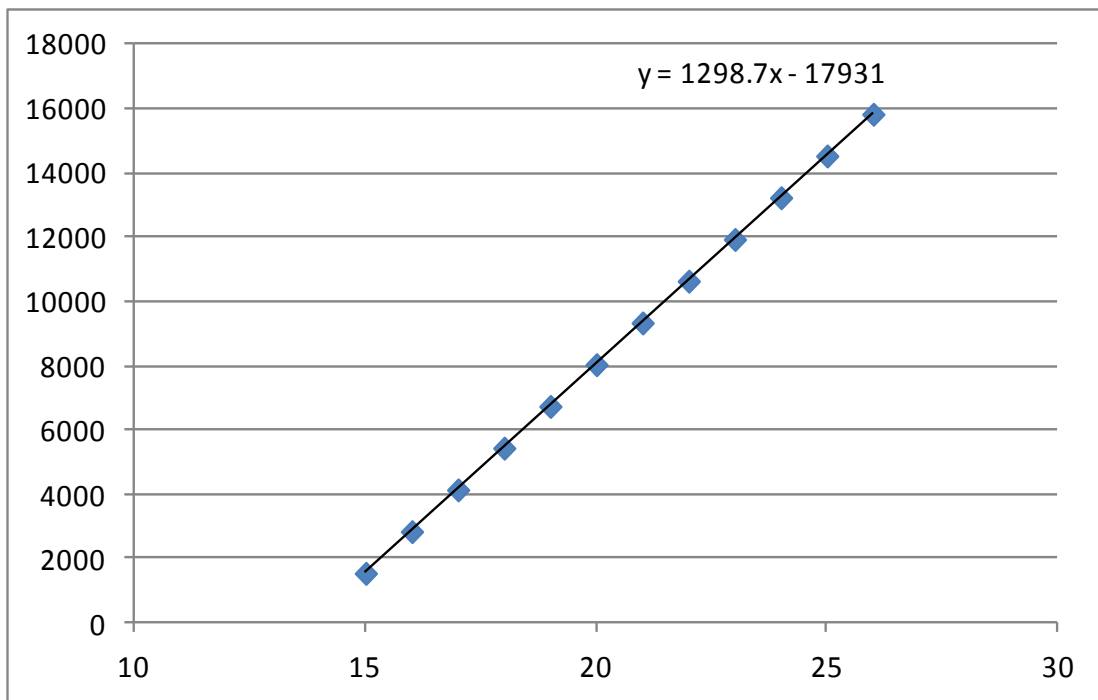
Accurate geometric reconstruction, however, requires that the timing drift of the VIMS internal clock be taken into account. For example, a 64x64 cube employing a 1-s integration time should require roughly 4100 s to complete, whereas the cube actually takes about 4171 s to complete. As such, the true time of acquisition of the last pixel in the cube is roughly 71 s later than is expected, with each previous pixel

offset in time by a proportionally smaller amount (the offset time is, of course, proportional to the number of pixels and lines completed since triggering the start of the cube).

As one might expect, accurate geometric reconstruction of the pointing of a given VIMS pixel requires, among a number of things, accurate measurements of when a pixel was exposed. Thus, if a user requires such, at the very least a timing conversion multiplier of 1.01725 must be included when the pixel timing is reconstructed from the specifications of pixel timing in the VIMS header. That is, an accurate reconstruction of the pixel timing requires calculating an offset from the "native start time" encoded in the cube header, and for the first and every subsequent pixel, using a multiplier of 1.01725 applied to the "Integration Time", "Interline Delay Time", and, if multiple cubes are obtained within a single trigger, conversion of the "Interframe Delay Time" as well. For example, if an integration time of 1 s has been used, the end of the first pixel and the start of the second pixel will occur at the "Native Start Time" plus 1.01725 seconds. By analogy, the end of the second pixel will occur at "native start time" + 2 \* 1.01725 seconds. When a line is completed, and the scanning mirror is repositioned for the next line (i.e., flies back to the starting position of the next line), one must add 1.01725 times the "Interline Delay Time" to the end time of the last pixel in the previous line to obtain the start time for the first pixel in the next line. Similarly, at the end of a cube, 1.01725 times the "Interframe Delay Time" must be added to the end time of the last pixel to determine the start time for the first pixel in the next cube. Equivalently, one may use the "Native Start Time" of the next cube if it has been encoded in the cube header.

## Appendix 1

The count rate of the VIMS clock was determined using several cubes taken over several years obtained using time insertion mode. Time insertion mode inserts the time as reckoned by the spacecraft clock and the time as reckoned by the VIMS clock in the last 8 channels of the spectrum for a given pixel. Under normal operation, the VIMS clock counter is reset each second using a 1 Hz update from the spacecraft clock. Using that knowledge and the data from a single cube, one can then determine that the VIMS counter runs at a rate of  $\sim 15958.4$  Hz. The timing drift can then be determined by the number of “ticks” of the VIMS clock that occur during the integration time of a given pixel (see fig. 1 for an example of the number of ticks during an interval of 80 msec as determined by the VIMS clock). The result of many such determinations for observations spanning the period 1999-2013 gives a drift rate of  $1.01725 \pm 0.00001$ .



**Figure 1: Timing for pixels in a VIMS cube using an 80 millisecond integration time. The x axis is pixel number and the y axis is the value of the VIMS internal counter at the start of a pixel**