Cassini C-Kernels

Cassini C-Kernels are a record of Cassini spacecraft pointing during the mission. Reading C-Kernels extracts the spacecraft attitude and spacecraft body rate (angular rotation rate) as a function of time. Cassini C-Kernels are either "predicted" or "reconstructed." They can be found here. Predicted C-Kernels output 'ideal" pointing without any gaps or jumps or discontinuities. Reconstructed C-Kernels represent actual telemetry of the achieved pointing, which are derived from the onboard sensors (e.g. star tracker and gyroscopes). Reconstructed C-Kernels show "deadbanding" when in RCS control (for example, the actual attitude may drift between ±2 mrad about the commanded attitude in each spacecraft axis).

Reconstructed C-Kernels are very accurate because of the high quality onboard attitude estimation which incorporates precision sensor measurements and filters out noise. Cassini attitude telemetry is not a perfect copy of the estimated onboard attitude because of telecommunications "bits to the ground" limitations. The two biggest limitations are: (1) the "repeat cycle" of the attitude telemetry (how frequently the telemetry "samples" the onboard attitude); and (2) the "granularity" of the downlinked attitude estimate.

The telemetry repeat cycle of the attitude estimate during the Tour phase of the mission was typically 4 seconds. In terms of reconstructed C-Kernel accuracy, the repeat cycle, during the Tour phase of the mission, was not a significant factor because the NAIF toolkit C-Kernel reader does a very good job of "interpolating" anywhere inside the 4-second period, given a telemetry attitude estimate at each end of the 4-second "window". A more significant factor in pointing estimate accuracy was the granularity of the attitude telemetry. The attitude quantization was about 40 microradians throughout the mission. This was due to the telemetry flight software converting attitude values (floating point numbers onboard) into 16-bit signed integers prior to downlink. This quantization was noticeable, in some science analysis, during very precise "staring" periods, for example during stellar occultations. During long staring periods, the attitude telemetry quantization appears to hold a "constant attitude" exactly for a while, then "jumps" by about 40 microradians. It could go through a series of these little "jumps" (often back and forth between two attitudes about 40 microradians apart) when the actual attitude did not have any of these jumps. The jumps are purely an artifact of the telemetry quantization.

A method is available to "post-process" the attitude telemetry using the commanded attitude (available in the KPT predicted C-Kernel), and the "attitude control error" telemetry (downlinked as floating point without the quantization issue). This process is especially helpful when staring at a fixed inertial attitude. For a few of these cases, an "enhanced" reconstructed C-Kernel has been produced that improves the pointing estimate during some science observations by utilizing this additional telemetry. A more detailed explanation of this process is given here.

Cruise Reconstructed C-Kernels

These are telemetry-based C-Kernels from launch on October 15, 1997 through January 1, 2004. Each of these reconstructed C-Kernels spans about 90 days of flight data. Although downlink data was sparse during parts of Cruise, Cassini was quiescent and Sun-pointed throughout most of the inner cruise, and mostly Earth-pointed after January of 2000. So even though there are gaps in the attitude telemetry, the inertial attitude was relatively fixed during the missing portions, so interpolation between telemetry periods provides good attitude estimates if data is needed in the missing periods. These cruise reconstructed C-Kernels were constructed to allow interpolation between telemetry periods.

All final cruise reconstructed C-Kernels include the string "rc" in their filename.

Naming Convention

Example: 97288_98002rc.bc (Start: 1997 DOY 288, End: 1998 DOY 2)
The "rc" means:
"r" is "reconstructed" (telemetry)
The "c" is just a unique identifier
Cruise reconstructed C-Kernels span from:

97288_98002rc.bc -- From Launch through Jan 1, 1998
98002_98091rc.bc -- From January 2, 1999 to DOY 91 of 1998

and continuing through:

03274_04001rc.bc -- From DOY 274 of 2003 through January 1, 2004

For 2004 and beyond, see below.

Tour Reconstructed C-Kernels

These are telemetry-based C-Kernels from January 2, 2004, through end-of-mission on September 15, 2017. Each of these reconstructed C-Kernels spans about 5 to 7 days of flight data. These Tour reconstructed C-Kernels do not permit interpolation if there are more than 16 seconds between consecutive attitude telemetry time points.

Almost every final Tour reconstructed C-Kernel include the string “ra” in its filename. There are a few files where telemetry playback was delayed enough that a more complete reconstructed C-Kernel was created later, and these include the string “rb” in their filename.

Naming Convention

Example: 17202_17207ra.bc (Start: 2017 DOY 202, End: 2017 DOY 207)
The “ra” means:
“r” is “reconstructed” (telemetry)
The “a” is just a unique identifier

Tour reconstructed C-Kernels span from:

04002_04009ra.bc -- From January 2, 2004 to January 9, 2004
04009_04019ra.bc -- From January 9, 2004 to January 19, 2004
04019_04026ra.bc -- From January 19, 2004 to January 26, 2004
and continuing through:
17247_17252ra.bc -- From DOY 247 of 2017 to DOY 252 of 2017
17252_17257ra.bc -- From DOY 252 of 2017 to DOY 257 of 2017
17257_17262ra.bc -- From DOY 257 of 2017 to final plunge on September 15, 2017

All cruise and tour reconstructed C-Kernels should be read in conjunction with the final Cassini SCLK Kernel and Leapsecond file. The SCLK Kernel filename is: cas00172.tsc and the Leapsecond filename is: naif0012.tls.

Final “As Flown” Predicted C-Kernels

These are C-Kernels generated by the Kinematic Predictor Tool (KPT) and span from January 2, 2004 through the end of mission on September 15, 2017. Each C-Kernel spans one complete background sequence (e.g. S101). These Tour predicted C-Kernels represent “ideal” pointing (no deadbands or controller errors). They are smooth and continuous without any gaps in data. The “as flown” designation means the predicted C-Kernel include orbit trim maneuvers (OTMs) and any other “real time” activities that affected pointing in the sequence. These “as flown” predicted KPT C-Kernels are the best predictions available for the mission.

All final “as flown” KPT predicted C-Kernels were built using the final Cassini SCLK Kernel and Leapsecond file. These same files should be used in reading these C-Kernels. The SCLK Kernel filename is: cas00172.tsc and the Leapsecond filename is: naif0012.tls. These C-Kernels were generated using the final and most up-to-date version of KPT called Version 14.5.

Naming Convention

Example: 17191_17258py_as_flown.bc (S101)

All include the "py_as_flown" character string in their filename.
The "p" in "py" stands for "Predict" (i.e. generated by KPT)
The "y" in "py" is just a unique identifier. No previous predicted C-Kernel used "y", so all "py" C-Kernels are the final, and best, KPT predicted C-Kernels available.

Tour KPT predicted C-Kernels span from:

04009_04051py_as_flown.bc (C42)
04051_04092py_as_flown.bc (C43)
04092_04135py_as_flown.bc (C44)
04135_04171py_as_flown.bc (S1)
and continuing through:
17191_17258py_as_flown.bc (S101)

C-Kernel Intervals and Gaps and Comparisons of Predicted and Reconstructed C-Kernels

Cassini C-Kernel summary information is available here. All Tour reconstructed C-Kernel intervals and gaps are summarized in these files. Each file has the ".txt" suffix.

Comparisons of all the as-flown KPT predicted C-Kernels with the corresponding reconstructed C-Kernels are in the same PDS directory as the C-Kernel interval/gap summary information. These comparisons are in two forms: (1) a plot (in PDF format) that depicts the angular difference (in milliradians) between the predicted and reconstructed C-Kernels, expressed in the spacecraft body (X, Y, Z) frame; and (2) a digital summary of the angular differences between the predicted and reconstructed C-Kernels. This digital summary includes the maximum, the mean, and the 1-sigma angular differences, per axis, for each 24-hour period.

Each comparison plot spans a 24-hour window, and there are three plots per page (one for each spacecraft body axis). The angular difference in each plot is the angular change "from" the predicted (KPT) attitude "to" the reconstructed (telemetry) attitude. In most cases, the angular difference is much less than one milliradian and is often within 40 microradians, per axis.

On a separate plot are the predicted (KPT) spacecraft body rates that spans the same 24-hour window as the attitude difference plot. This allows the user to rapidly identify whether a turn was in progress during the periods of interest.

A third plot depicts whether there are any "gaps" in the telemetry during with period. The comparison plots omit the angular comparison when the telemetry is missing from the reconstructed C-Kernel

Naming Convention for C-Kernel Comparisons

Example: 12284_12289ra_vs_py.pdf
12284_12289ra_vs_py.txt
The "final" comparison files will always include the "ra_vs_py" character string at the end of the filename, denoting that the comparison is based on the "final" KPT predicted C-Kernel (with "py" in the name of the name of the C-Kernel).
The "12284_12289ra" string denotes that the comparison spans the 5-day period between DOY 284 of 2012, and DOY 289 of 2012. This string matches the name of the reconstructed C-Kernel used in the comparison.
The PDF file includes the plot data, and the ".txt" file includes the interval/gap information, and the mean, max, and 1-sigma angular differences during that 24-hour period.