JOURNAL OF SPACECRAFT AND ROCKETS
Vol. 46, No. 5, September–October 2009

Pointing-Stability Performance of the Cassini Spacecraft

Emily B. Pilinski* and Allan Y. Lee†
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109-8099

DOI: 10.2514/1.41675

The operations of Cassini optical remote sensing instruments require a high level of spacecraft-pointing stability to minimize image distortion during an exposure window. This paper summarizes the flight performance of the Cassini spacecraft's pointing stability with respect to mission requirements. Sources of spacecraft jitter, the Cassini spacecraft control modes, and pointing-stability metrics are discussed to provide a context for the results. In designing the Cassini attitude-control system, a pointing-stability performance metric that considered the frequency contents of the disturbance sources was employed. Cassini pointing-stability results using the root-mean-square stability metric are provided for both spacecraft control modes, using the reaction-wheel assembly or the reaction control system composed of eight thrusters. The pointing-stability results are then related to characteristics of the spacecraft and operations. For thruster-based control, the pointing-stability results are analyzed with respect to the per-axis dead band. Results from the scientific instruments onboard the Cassini spacecraft confirm that the pointing-stability results in either control mode have achieved high accuracy pointing capabilities critical to the success of the mission and have resulted in data to improve our understanding of Saturn.

Nomenclature

C = normalized frequency, dimensionless
e = deviation of line-of-sight vector from its windowed mean, rad
F = magnitude of thruster force, N
f = frequency of a time signal, Hz
I_{ZZ} = Z-axis moment of inertia of the spacecraft, $\mathrm{kg \cdot m^2}$
L = moment arm of the thrusters, m
m = windowed mean of the line-of-sight vector, rad
N = number of exposure windows in a telemetry sample, dimensionless
s_p = windowed peak stability, rad
T = exposure time of an imaging event, s
W = frequency weighting function, dimensionless
$\Delta T_{\mathrm{pulse}}$ = duration of thruster pulse, s
$\Delta\theta$ = rms pointing-stability performance defined in Eq. (10), rad
σ_{rms} = rms stability metric, rad
σ_{SP}^2 = squared peak stability metric, rad^2
σ_W^2 = windowed variance of the line-of-sight displacement vector, rad^2
Φ_{PSD} = power spectral density of the signal ϕ, $\mathrm{rad^2/Hz}$
ϕ = time history of the angular displacement of the line-of-sight vector, rad
Ω = Z-axis spacecraft rate, rad/s

I. Introduction

THE Cassini orbiter is a platform for extensive exploration of the Saturn system, including Saturn, its moons, and its rings. The spacecraft carries 12 scientific instruments on a seven-year, 1.5×10^9 km mission. The Cassini mission, the spacecraft, and the instruments are described in detail in [1]. The four-year prime mission concluded in July 2008 and is succeeded by a two-year extended mission. This paper will characterize Cassini's pointing stability from data collected during the prime tour operations during which the spacecraft was controlled by either the reaction-wheel assembly (RWA) or the reaction control system (RCS). Since Cassini's launch on 15 October 1997, spacecraft attitude has been routinely estimated onboard and telemetered to the operations engineering team. Using these data, this paper documents our effort to better characterize the pointing-stability performance of the Cassini spacecraft during the four-year prime mission. By studying the stability performance of Cassini in relation to the spacecraft design characteristics and operations, this work documents the practices that have resulted in precision jitter control to maximize science return.

The Spacecraft Operations Office (SCO) at the Jet Propulsion Laboratory focuses on protecting this scientific platform from the harsh space environment to ensure the reliability of the spacecraft's sensors and equipment on which the science return depends. A group within SCO, the Attitude and Articulation Control Subsystem (AACS) team, is responsible for guaranteeing that the pointing designs of each instrument execute safely and successfully onboard the spacecraft. The Cassini AACS estimates and controls the attitude of the three-axis stabilized Cassini spacecraft as it responds to ground-commanded pointing goals for the spacecraft's science instruments. To achieve the commanded targets within the required accuracy, AACS uses either RCS or RWA to control the spacecraft. Attitude determination sensors used by Cassini AACS include two stellar reference units (star trackers), two sun sensor assemblies, and two inertial reference units [2].

II. Attitude Control of the Cassini Spacecraft

A. Spacecraft Configuration

A sophisticated interplanetary spacecraft, Cassini is one of the largest spacecraft humans have ever built and launched. The orbiter, shown in Fig. 1, is about 6.8 m in height with a "diameter" of 4 m. The total mass of the spacecraft at launch was approximately 5574 kg, which included about 3000 kg of bipropellant. Cassini is a flexible spacecraft containing four structural appendages and three propellant

---

Presented as Paper 6810 at the AIAA Guidance, Navigation, and Control Conference and Exhibit, Honolulu, HI, 18–21 August 2008; received 17 October 2008; revision received 11 April 2009; accepted for publication 17 April 2009.

*Guidance and Control Systems Engineer; currently Mission Operations Lead, BioServe Space Technologies/University of Colorado, Boulder, Colorado 80309; Emily.Pilinski@colorado.edu.

†Project Element Manager, Attitude and Articulation Control System, Cassini Spacecraft Operations Office, Mail Stop 230-104, 4800 Oak Grove Drive; Allan.Y.Lee@jpl.nasa.gov.