GENESIS EARLY FLIGHT EXPERIENCE

Kenneth E. Williams and Roby S. Wilson
Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109-8099

Abstract

As the fifth Discovery mission, Genesis will collect solar wind samples for a period of approximately two and a half years while in orbit in the vicinity of the Sun-Earth L1 point. The samples will eventually be delivered back to the Earth, a formidable challenge in terms of both mission design and navigation. This paper discusses trajectory management strategies employed during the early phases of flight to accommodate spacecraft and instrument design constraints, while achieving the science objectives of the mission. Topics to be discussed include mission overview, spacecraft design and constraints, maneuver analyses and trajectory re-optimization studies, as well as other operational flight experience to date. The emphasis of this discussion is on launch, transfer and injection into the halo orbits where sample collection occurs

Extended Abstract

Genesis is the fifth mission selected as part of NASA's Discovery Program. The objective of Genesis is to collect solar wind samples for a period of approximately two and a half years around the Sun-Earth L1 point. At the end of this period, the spacecraft follows a free-return trajectory to deliver the samples to a specific recovery point on the Earth for subsequent analysis. This type of sample return has never been attempted before and presents a formidable challenge in terms of both mission design and navigation.

An overview of the Genesis trajectory is shown in Figure 1. One unusual feature of this trajectory is that it requires only one deterministic maneuver. After the transfer from Earth to the Sun-Earth L1 region, this single maneuver inserts the spacecraft into a series of five Lissajous or halo orbits where the bulk of the solar wind collection occurs. In practice more maneuvers are needed of course, particularly shortly after launch when an initial trajectory correction maneuver is necessary to correct the injection energy required for the transfer out to the L1 region. Additional station keeping maneuvers, three per halo orbit, are also planned to correct errors associated with the Lissajous orbit insertion maneuver at the end of the transfer phase, and to keep the spacecraft on course during the sample collection phase of the mission. After completing the five halo orbits, the spacecraft is on a free return to Earth that includes a loop around the Sun-Earth L2 point to position the science payload for a daylight entry over Utah and subsequent recovery via helicopter retrieval in early September 2004.

An overview of the spacecraft design, which will be explained in more detail in the paper, is shown in Figure 2. To achieve a level of cost-effectiveness consistent with a Discovery-class mission, a simplified spacecraft design was selected for Genesis. Spin stabilization was chosen for attitude control, in lieu of three-axis stabilization, with a star scanner and two types of sun sensors (near-Sun digital and spinning) providing the only means of attitude determination. Thrusters are located on the opposite side of the space vehicle from science instruments to minimize contamination of samples over the course of solar wind collection. Since thrusters so positioned do not produce balanced torques, all attitude control maneuvers contribute a translational Δv to intended propulsive maneuvers, which must be accounted for when designing these maneuvers. Power is provided by solar arrays with a battery in reserve.

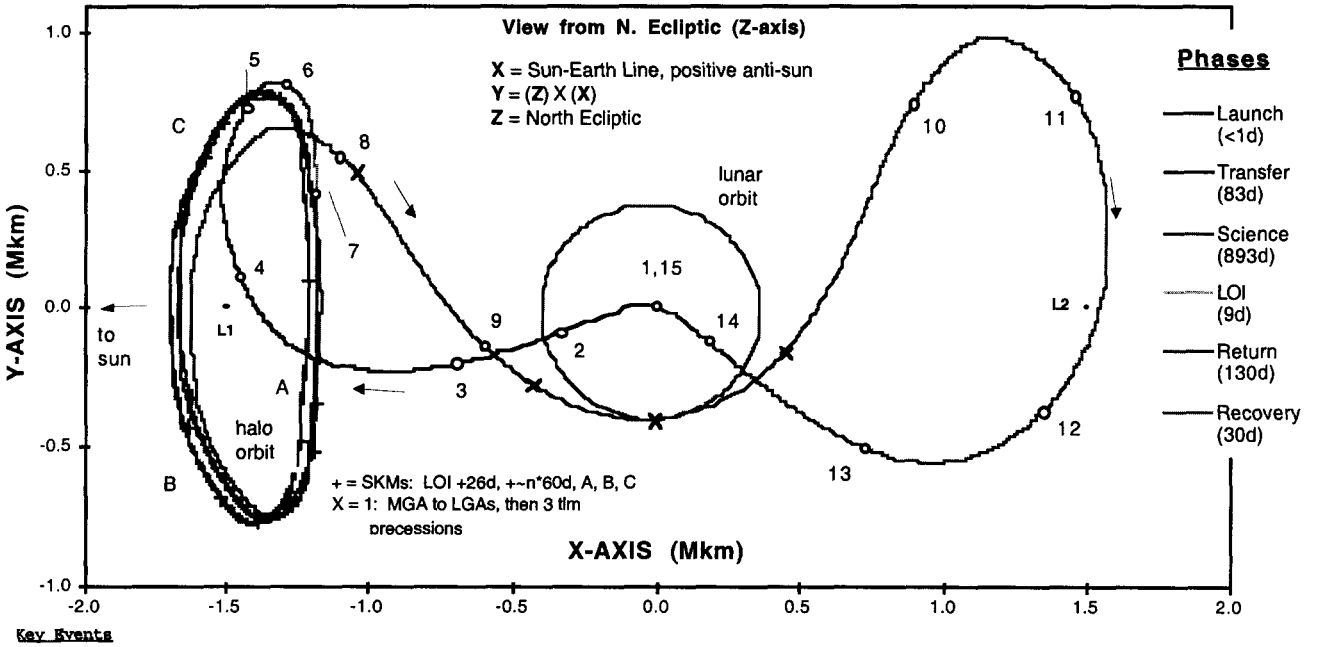
There are a number of constraints arising from the spacecraft design and limitations that arose from star scanner performance tests, which have a significant impact on flight operations. To avoid battery power depletion, solar arrays are normally pointed to within 10° of the sun with a time limit of about 85 minutes during which the spacecraft is allowed to point more than 30° off sun. This limits the magnitude of any large off-sun maneuvers to less than 110 m/s based on pre-launch thruster performance estimates.

In pre-launch testing, the star scanner could only guarantee identification of one star per spacecraft rotation. As a result, the star scanner must be used in combination with the digital sun sensor to obtain a three-axis attitude fix in an attitude control mode designated "Spin Track". Because the digital sun sensor was designed for use only when near the Sun, this effectively limits the use of the star scanner to within about 30° of the Sun. At all other attitudes, and when at higher spin rates (required for propulsive maneuvers to guard against consequences of a failed thruster), only the spinning sun sensors can provide attitude information. Because of the presence of wobble and nutation, which is exacerbated by any maneuvers, keep-out zones must be observed for spinning sun sensors at attitudes near the sunward and anti-sunward directions to ensure that sun crossing times are accurately measured and spin rate knowledge is maintained. Furthermore, the star scanner had to be calibrated before being brought on line early in flight. This precluded use of the star scanner altogether for the first trajectory correction maneuver.

Another constraint which arose from pre-launch testing involves the primary science instrument, known as the concentrator, which collects nitrogen and oxygen ions onto a target via electrostatic grids. The concentrator cannot be pointed more than 60° or so away from the sun when exposed to space or the grid becomes shaded, introducing a large thermal gradient with respect to the container that can cause irreparable damage to the instrument. This limits the ability to perform off-sun maneuvers with the science canister in the open or deployed configuration.

This paper will discuss maneuver strategies employed to accommodate all of these operational constraints, as well as monte-carlo analyses performed and flight performance experienced to date covering the early portions of the Genesis mission. For instance, to simplify early flight operations the post-launch trajectory correction maneuver for each launch opportunity was planned for one of two fixed directions, depending on whether the injection was an overburn or an underburn. Also, as a primary means of avoiding excessive turns away from the sun, all halo station keeping maneuvers are biased towards the sun. The paper will also discuss trajectory re-optimization which was used prior to the Lissajous orbit insertion maneuver to provide a more favorable Earth view angle for that maneuver, as well as to adjust the trajectory to better meet the aforementioned constraints and Earth entry requirements downstream.

GENESIS TRAJECTORY OVERVIEW



Key Events

1. Launch	30jul01/000	6. Start Science	21oct01/083	11. TCM-8	30jun04/1066	or	
2. TCM-1	01aug01/002	7. LOI (TCM-5)	16nov01/109	12. TCM-9	09aug04/1106		
3. TCM-2	06aug01/007	8. End Science	01apr04/976	13. TCM-10	29aug04/1126	Divert	07sep04/1135
4. TCM-3	03sep01/035	9. TCM-6	22apr04/997	14. TCM-11	07sep04/1135	B. Entry	16oct04/1174
5. TCM-4	03oct01/065	10. TCM-7	25may04/1030	15. Entry	08sep04/1136	[backup orbit TBR]	

Figure 1. Genesis Mission Trajectory.

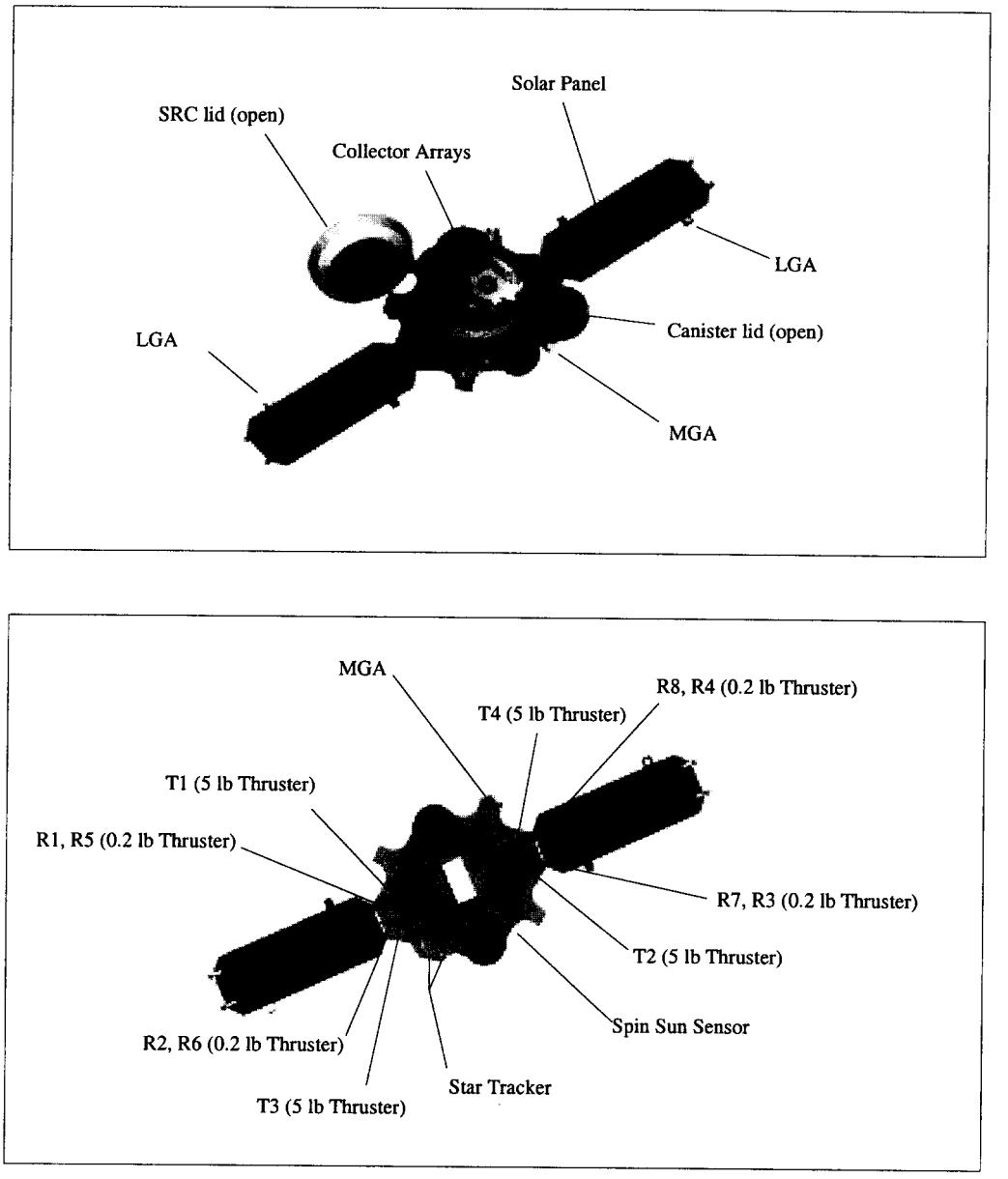


Figure 2. Forward Deck View (Normally Pointing Toward Sun) and Rear Deck View.