GENESIS TRAJECTORY AND MANEUVER DESIGN STRATEGIES DURING EARLY FLIGHT

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As the fifth Discovery mission, the Genesis spacecraft was launched on August 8, 2001 with a science objective to collect solar wind samples for a period of approximately two and a half years while in orbit in the vicinity of the Sun-Earth L_1 Libration point. These samples will eventually be delivered back to the Earth for analysis, posing a formidable challenge in terms of both mission design and navigation. This paper discusses trajectory and maneuver design 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, and operational flight experience to date.

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 in the vicinity of the Sun-Earth L_1 Libration point. At the end of the science collection 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.

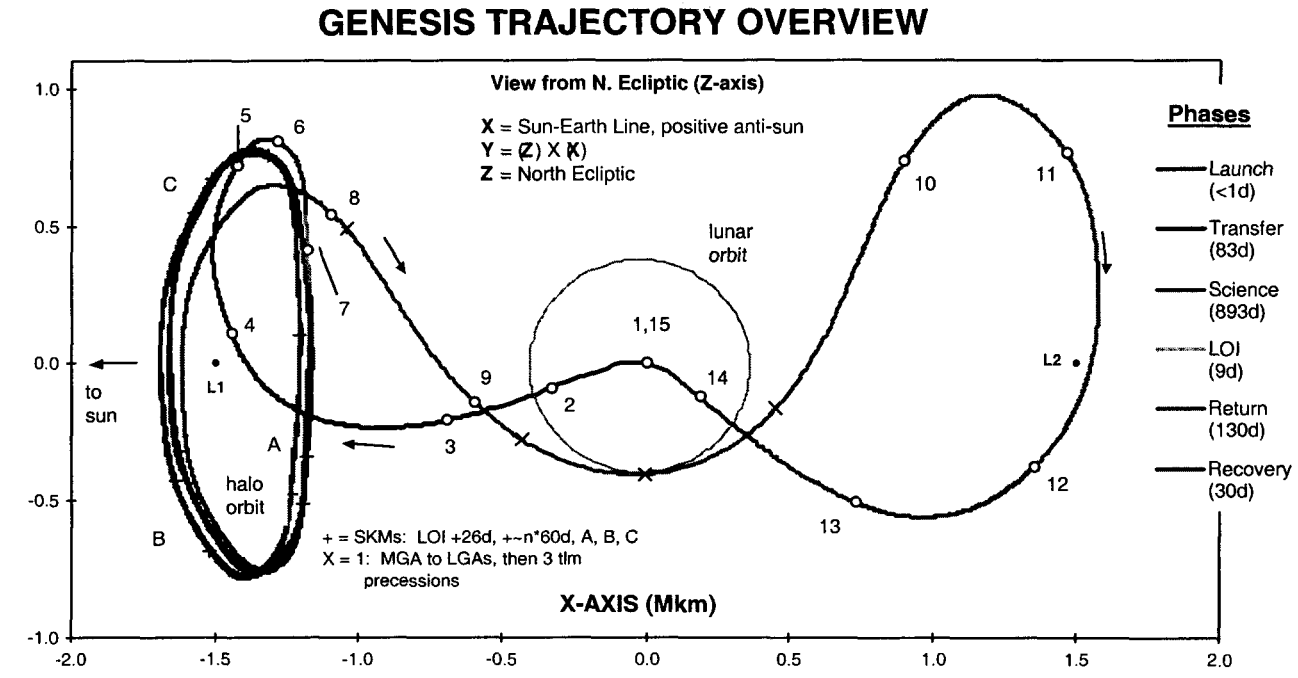
An overview of the pre-launch Genesis trajectory is shown in Figure 1. One unusual feature of this trajectory is that it requires only one deterministic maneuver. After the transfer from Earth to the Sun-Earth L_1 region, this single maneuver inserts the spacecraft into a series of five Lissajous or halo orbits where the bulk of the solar wind collection occurs. In practice, more maneuvers are needed, particularly shortly after launch when an initial trajectory correction maneuver is necessary to correct the injection energy required for the transfer out to the L_1 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 L_2 Libration 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 configuration is shown in Figure 2. The spacecraft design will be explained in more detail in the paper. 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. Maneuvering in this configuration produces unbalanced torques, so that all attitude control maneuvers contribute a translational Δv, 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 and limitations arising from the spacecraft design and from pre-launch star scanner performance tests, which have a significant impact on flight operations. For instance, to avoid battery power depletion, solar arrays are normally pointed to within 10° of the sun. This imposes a 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. 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 the science canister is open 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. Other constraints affecting the mission design will be explained in the paper as well.

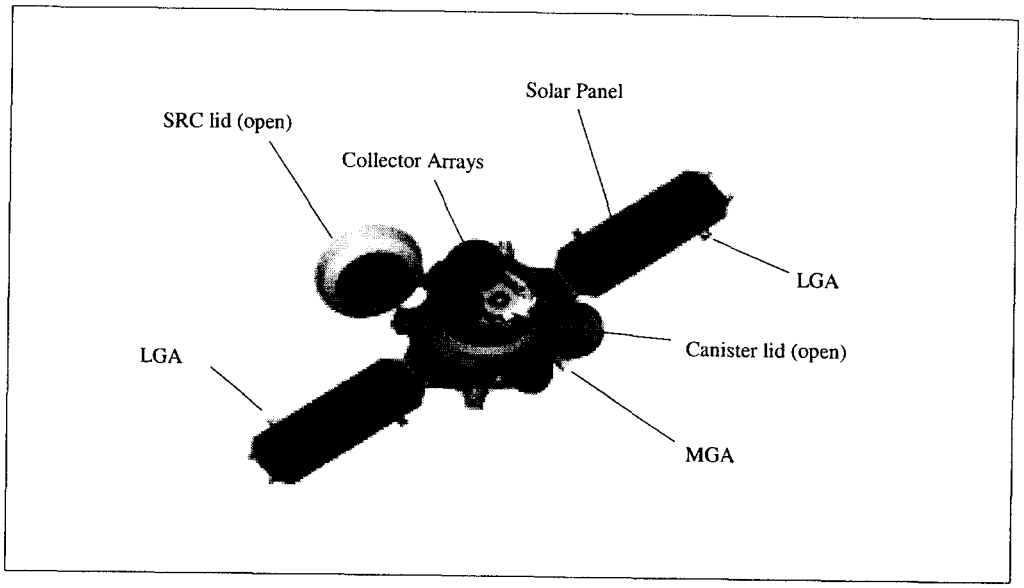
The trajectory and maneuver design strategies employed to accommodate all of these operational constraints will be described. For example, as a primary means of avoiding excessive turns away from the Sun, all halo station-keeping maneuvers are biased towards the Sun. The trajectory re-optimization to keep these biases pointed in the most favorable directions, while still meeting the aforementioned constraints and Earth entry requirements downstream, will be explained in detail. Additionally, the various types of maneuver modes will be discussed that have been designed to satisfy the constraints imposed upon the mission. These maneuver modes cover a variety of attitude configurations, maneuver magnitudes, and directions, and can be quite complex. Finally, the flight performance experienced to date covering the early portions of the Genesis mission will be presented including predicted results through the rest of the flight and lessons learned thus far.



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



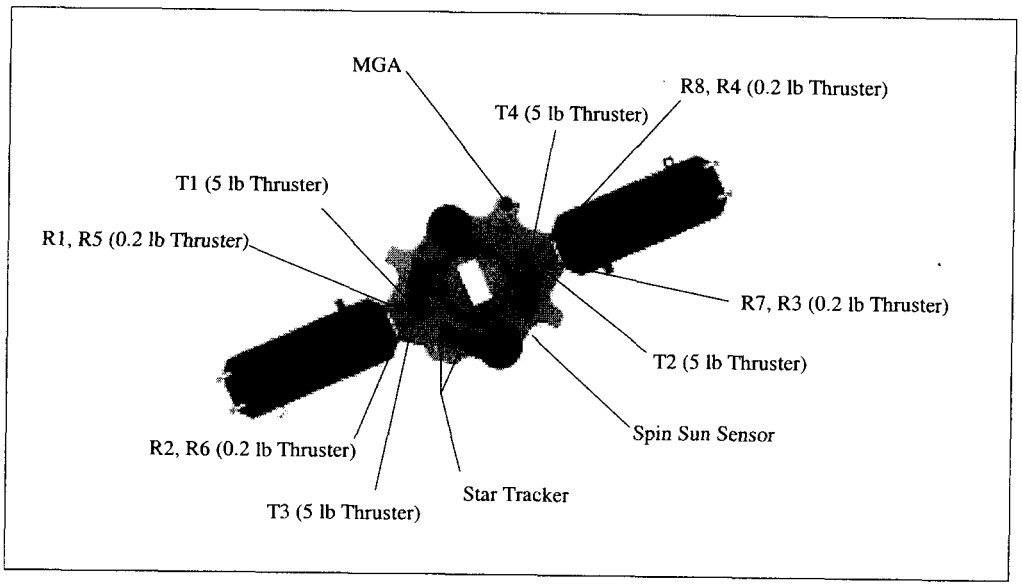


Figure 2. Forward Deck View (Normally Pointing Toward Sun) and Rear Deck View