STEREO Mission Design Requirements

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The scientific objective of STEREO is to study the origin and propagation of CMEs, and their resultant interaction with Earth, within the mission lifetime (2 years). The mission design requirements must be consistent with this objective.

Symmetric or Asymmetric Drift Rates

After reviewing the imaging from symmetric and asymmetric drift rate designs, I am not convinced that that advantages for imaging along the Sun-Earth line outweigh the potential loss in data rate. In order to minimize the data transmission problems, I recommend that we take symmetric drift rate, i.e. the same nominal rate for both the leading and lagging spacecraft.

This has the disadvantage that if the two drift rates are exactly the same, then they arrive at 90 degrees from the Sun-Earth line at exactly the same time and both show exactly the same image of a limb CME. I recognize that this would be during an extended mission, and is therefore a lower priority requirement. However I think that the arrival time at 90 degrees should be slightly staggered. This can be done by a combination of slightly different (1-2 degree/yr) differences in the drift rate, and the fact that they leave the Moon 40 days apart. Therefore for the rest of this document, consider only a symmetric drift rate mission profile.

Science Requirements

In talking to Peter Sharer (APL Mission Design), he felt confident that the mean drift rate can be achieved with an accuracy of about 5 degrees/year. With that in mind, we should not consider granularity in the mean drift rate of less than 5 degrees. I think an accuracy of +/-2 degrees in the mean drift rate is likely to be achievable. Therefore it makes little sense, given the other uncertainties, to tweak the mean rate by small amounts.

The question remains, what is the optimum value for the mean drift rate? This comes directly from the science objectives for the mission.

In Situ Instruments

For the in situ instruments, we want to observe a reasonable number of CMEs, say 10, where both spacecraft are close enough together to sample the same event. The angular extent of a CME in the interplanetary medium is approximately 60 degrees. At the time of the launch of STEREO the total CME rate is about 0.3-0.5 CME/day. Out of this total approximately 0.10-0.12 of these events will be directed toward Earth. If the observing time is 300 days, then approximately 9-18 CMEs will be well observed by the particle instruments during this time. This leads to the drift rate requirement that the spacecraft separation shall be less than or equal to 60 degrees (30 degrees from the Sun-Earth line) for at least the first 300 days of the mission. Using these numbers one arrives at a drift rate

$$DriftRate \leq \frac{30}{300/365} = 37 \text{ degrees/year}$$

Imaging Instruments

During the early phase of the mission, the EUV imagers will be used to obtain stereo image pairs of solar magnetic structures. The optimum angle for this viewing is of order 20 degrees. We want to assure

sufficient time to obtain a reasonable data set of stereo image pairs of quiet Sun and active region fields. There is approximately 1 active region on the surface at a time during this phase of the cycle. Therefore if we require that the spacecraft be separated by no more than 30 degrees for 5 months we will have to opportunity to observe >5 active regions. The drift rate requirement is

$$DriftRate \leq \frac{15}{5/12} = 36 \text{ degrees/year}$$

The coronagraphs are most sensitive to CMEs at the limb, i.e. +/- 60 degrees from the plane of the sky. For both coronagraphs to observe the same Earth directed CME as a limb event (i.e. not a halo event) each spacecraft must be separated from the Sun-Earth line by 30 degrees or more for the last 300 days. This will result in 9-18 well observed events at the end of the mission. The drift rate requirement is

$$DriftRate \geq \frac{30}{(2*365-300)/365} = 26 \text{ degrees/year}$$

The requirements for the Heliospheric Imager (HI) are similar to those of the coronagraph.

These drift rates obtained above are summarized in the following table. Examination of the numbers shows that the minimum drift rate for a symmetric mission profile to accomplish the objectives described above is for both the leading and lagging spacecraft to have a minimum drift rate of 26 degrees/year. This will satisfy the requirements from all instruments.

Table 1 Mission Design Requirements (not in priority order) as derived from the scientific objectives of STEREO.

Scientific Objective	Mission Design Requirement	Implied Symmetric Drift Rate	Justification
Stereo In Situ observations of at least 10 events	Spacecraft separation must be less than 60 degrees for at least 300 days	≤ 37 deg/yr	In Situ instruments will observe an estimated 9-18 events during the first 300 days of the mission
Stereo observations of at least 10 CMEs leaving the Sun toward Earth	Each spacecraft must be more than 30 degrees from the Sun-Earth line for at least 300 days	≥ 26 deg/yr	Coronagraphs will observe 9-18 Earth directed events during the last 300 days of the mission
Observation of stereo pairs of active and quiet Sun loops in EUV imager	Spacecraft separation must be less than 30 degrees for at least 5 months	≤ 36 deg/yr	Imager will observe 5-10 active regions while spacecraft are in optimum position

How to Proceed

In talking with the orbit people at APL, there are basically only two parameters that can be varied, the speed of lunar escape, and the direction. This really gives you control of only two characteristics in the mission design. With this in mind, I suggest that

1. We settle on a mean drift rate of 26 degrees/year (parameter 1) using arguments above, and that
2. We optimize to minimize the radial variation (parameter 2) of the orbit for the desired drift rate. This makes the thermal design of the spacecraft and instruments easier, and will make the coronagraph design much easier.

Once this orbit is determined we compare with the requirements shown in the table, and decide where to go from there.