# THE STARSHINE HITCHHIKER MISSION ON STS-96

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Project Starshine

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## ABSTRACT

A mirrored, spherical "Starshine" satellite was ejected by NASA into a circular low Earth orbit from a Hitchhiker canister in the cargo bay of Space Shuttle OV-103 Discovery at 07:21 Universal Time on June 5, 1999, near the end of Discovery's STS-96 mission to the International Space Station. Starshine's initial orbital altitude was 218 Nautical Miles (387 km), and its orbital inclination was 51.6 deg. The satellite is expected to orbit Earth until sometime in January 2000, when it will reenter the atmosphere and vaporize. Some 25,030 students in 700 schools around the world participated in the construction of this satellite by polishing 878 small, front-surface aluminum mirrors that stud its outer surface. A small fraction of those students is presently tracking the satellite and measuring its angular position at specific times.

The Naval Research Laboratory is combining the students' measurements with Naval Space Command radar tracking data to compute the satellite's orbit on a daily basis. From the rate of decay of the orbit, the students are able to calculate the density of the atmosphere at the satellite's present altitude. The students are also accessing the project's web site to observe ground-based and space-based images of the sun and other indices of solar activity. They are then using these data to make correlations between the intensity of solar storms and fluctuations in the density of the earth's upper atmosphere. The number of students participating in the tracking phase of the project is expected to increase dramatically at the start of the fall school term in the northern hemisphere. At the conclusion of the Starshine mission, the student team will attempt to predict when and where the satellite will re-enter the atmosphere, so they can compete for a cash prize for the best photograph of the satellite's fiery demise.

## INTRODUCTION

Our sun experiences substantial changes in activity during an approximately eleven-year interval known as the sunspot cycle. It is now approaching the peak of activity in its present cycle. As the peak approaches, the sun exhibits several interesting phenomena, such as an increase in the numbers of sunspots in its photosphere (Figure 1) and in the occurrence of plages, flares, prominences, and coronal mass ejections in which enormous quantities of ionized particles randomly erupt from its surface. Earth's upper atmosphere, ionosphere and magnetosphere respond to these outbursts of solar activity in various ways, including magnetic substorms, auroral displays (Figure 2) and fluctuations in atmospheric density. During the next year or so, aurora will be observed at latitudes unusually far south in the northern hemisphere and unusually far north in the southern hemisphere. In addition, it is possible that power blackouts will occasionally occur in northern locations, such as Canada, as they did in 1988 during the previous sunspot peak. Furthermore, unprotected commercial communication satellites may experience temporary or even permanent damage to their electrical circuits and processors following very large coronal mass ejections.

Project Starshine was initiated in 1997 by a volunteer consortium of individuals and institutions involved in educational outreach (Table 1), for the purpose of bringing this cyclical behavior of the sun and its effect on the earth's atmosphere to the attention of pre-college students and their parents around the world. In order to give them a sense of participation in an experiment designed to measure some of these solar-terrestrial effects, large numbers of students were recruited in 1998 to polish small aluminum mirrors (Figure 3), that were then mounted on the surface of a spherical satellite (Figure 4). This satellite was installed in a Hitchhiker canister in the cargo bay of Space Shuttle OV-103 Discovery (Figure 5). Discovery was launched on the STS-96 mission to the International Space Station on May 27, 1999, and its crew deployed Starshine into its own orbit on June 5, 1999 (Figures 6 and 7). This particular mission was chosen for the satellite deployment, because its orbital inclination to the equator was 51.6 degrees, and its orbital altitude at deployment was 218 nautical miles (387 kilometers). In this orbit, the satellite passes over almost all the populated regions of the globe (Figure 8) and is visible at civil twilight to all the students who polished its mirrors. The deploy altitude and the area-to-mass ratio of the satellite were chosen to insure that the satellite's orbit will be steadily reduced by atmospheric drag and will result in the satellite's fiery destruction by aerodynamic heating in approximately eight months. By observing the change in the satellite's orbital altitude (Figure 9), the students are able to measure the drag on the satellite and thus the atmosphere's density at the present altitude of the satellite.

## EARLY RESULTS

Many sunlight flashes from Starshine's mirrors have been observed and reported by a mixture of students, teachers and skilled amateur satellite observers all over the world. The brightness of these flashes is slightly greater than predicted, ranging from +5 to –2 in equivalent stellar magnitude, depending on the distance of the satellite from the observer and the phase of the mirror at the time of the flash. However, the frequency of the flashes is much lower than expected. The mirror pattern on Starshine was laid out with the expectation that its Hitchhiker deployment system would impart to it sufficient tip-off and spin torques to make it rotate about its principal axes at a combined rate of approximately five degrees per second, or one revolution per minute. The designers chose this approach, since similar motions had been experienced by the three previous satellites deployed by the Hitchhiker ejection system.

This rotation rate, combined with the pattern in which its 878 mirrors were installed on its surface, was expected to produce a reflected sunlight flash to an observer on the ground every two to five seconds. However, the Hitchhiker project office made several improvements to the Hitchhiker system following the deployment of MightySat I during the STS-88 mission in December of 1998. Those improvements apparently eliminated essentially all tip-off torques, with the result that Starshine experienced no observable motion about any of its principal axes following deploy, as can be seen in the deployment videos taken by the STS-96 crew. Consequently, the only motion now producing mirror flashes is the satellite's orbital translation across the sky. During the first few months of the mission, flashes are being seen by observers around the world at rates varying from once per five seconds to once or twice per pass, to no flashes at all, depending on how the rows of mirrors line up with the sun-satellite-observer plane during a given pass. Therefore, it is very difficult for observers to make precise measurements of the satellite's position.

It is anticipated that the flash rate will increase when the satellite descends into denser air later in the mission and begins to experience continuum-flow aerodynamic torques. The satellite is slightly asymmetric, due to the presence of the deployment foot at its base. It is therefore statically stable, but dynamically unstable, and should wobble in the manner of a badminton shuttlecock late in the mission and thereby produce the desired increase in flash rate. In the meantime, project officials have suggested to the observer team that they should concentrate on making and reporting observations of flash rates and help determine when it will be possible to return to the standard tracking procedures. In addition, they have suggested that the students practice tracking Mir and ISS, which are in orbits very similar to Starshine, so as to become adept at tracking by the time Starshine's flash rate improves. Near the end of the mission, an attempt will be made to increase the numbers of student observations greatly, since drag effects will ramp up sharply, and atmospheric density measurements will be at their most meaningful. A cash prize is being offered for the best photo of the flaming fireball that will occur at re-entry, as a means of focusing interest on this portion of the mission. Although the students have been advised that is extremely unlikely the satellite will come down over land on a non-cloudy day or night, many of them have exhibited great interest in making the attempt to obtain the prize-winning photograph.

## FUTURE PLANS

The interest expressed by students and teachers around the world in participating in this first mission would seem to justify a continuation of the Starshine project. The mirror-polishing phase has been very popular, since it is relatively easy to accomplish, and it produces a tangible piece of shiny space hardware. The tracking and reporting phase of the project has been more difficult to get underway, since it is intellectually more challenging and more esoteric in nature for the target audience. Additionally, the fact that the Shuttle launch and satellite deploy took place after many schools in the northern hemisphere had closed for the summer has delayed the start of most of the tracking effort till the beginning of the 1999 fall term. The degree of success of the tracking and atmospheric density determination phase will become apparent only near the end of the project, after the mirror flash rate has increased, and after a larger number of students has been recruited and trained to track the satellite at the start of the fall school term.

In anticipation of the successful conclusion of this first experiment, a request for flight assignment to a Space Shuttle mission in 2000 has been submitted to NASA. The external structure for a second satellite has been fabricated, and a self-contained, spin-inducing mechanism is being designed to insure proper spin at the start of the next mission. A full complement of mirror blanks has been machined for a second satellite, and mirror-grinding and polishing kits are being assembled. A deluge of applications to polish mirrors for this next satellite is expected to arrive at the start of the fall school term in the northern hemisphere, well in excess of the number of mirrors that can be flown. Selection criteria are being developed to insure fairness in assigning mirrors to the most deserving schools for Starshine #2.

Further details about the fabrication, launch, and tracking phases of the project may be found at http://www.azinet.com/starshine.

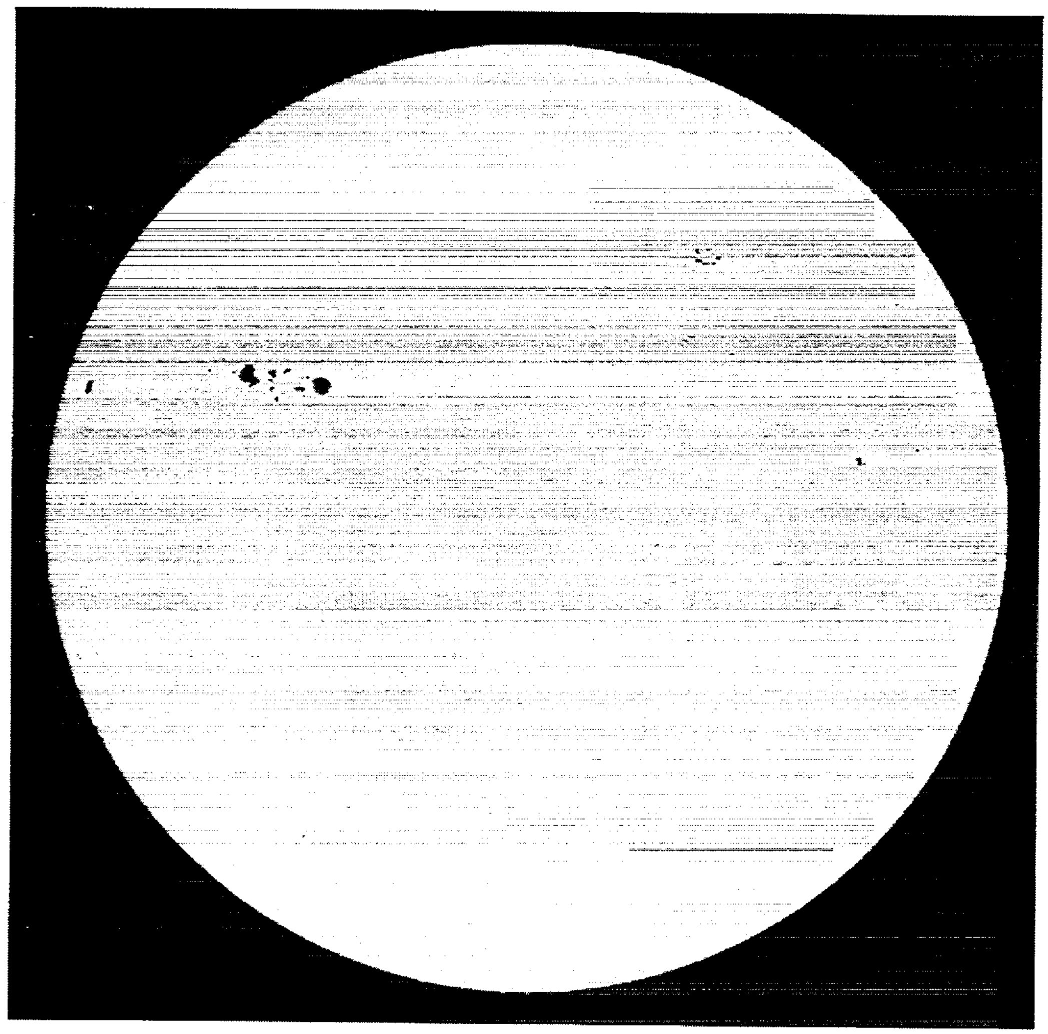


**Figure 1**
Sunspots
SOHO Image

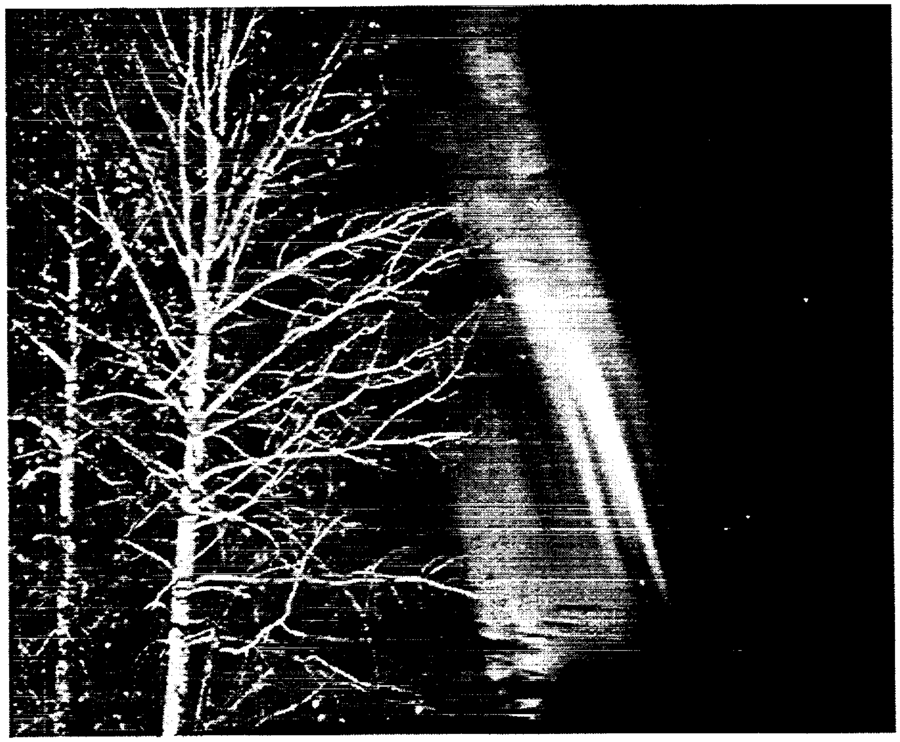


**Figure 2**
Aurora Borealis
Jan Curtis Image

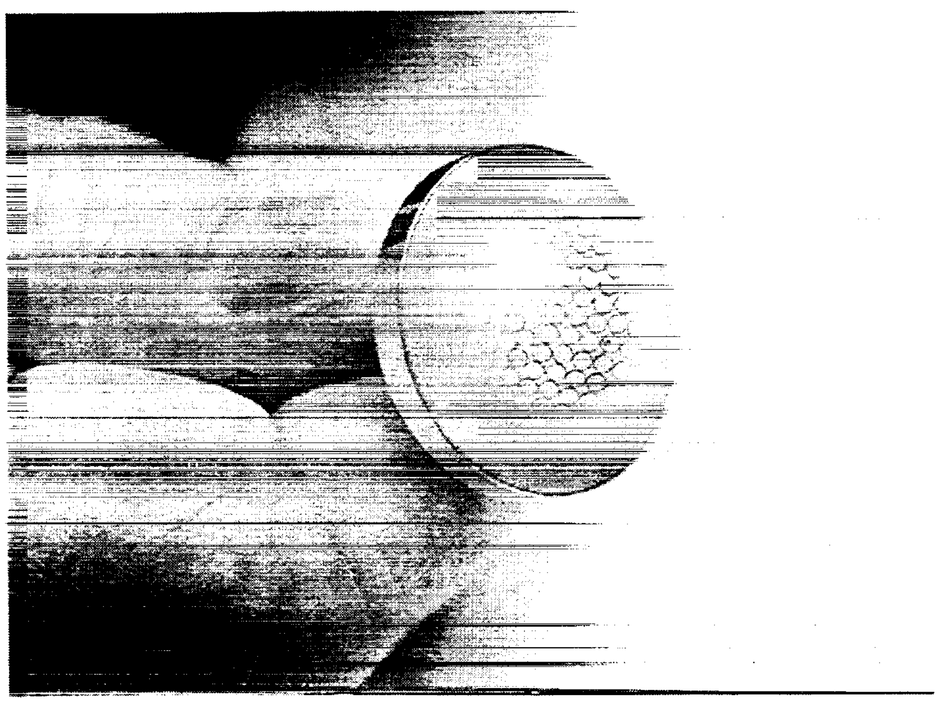


**Figure 3**
Student Mirror
USAFA Image

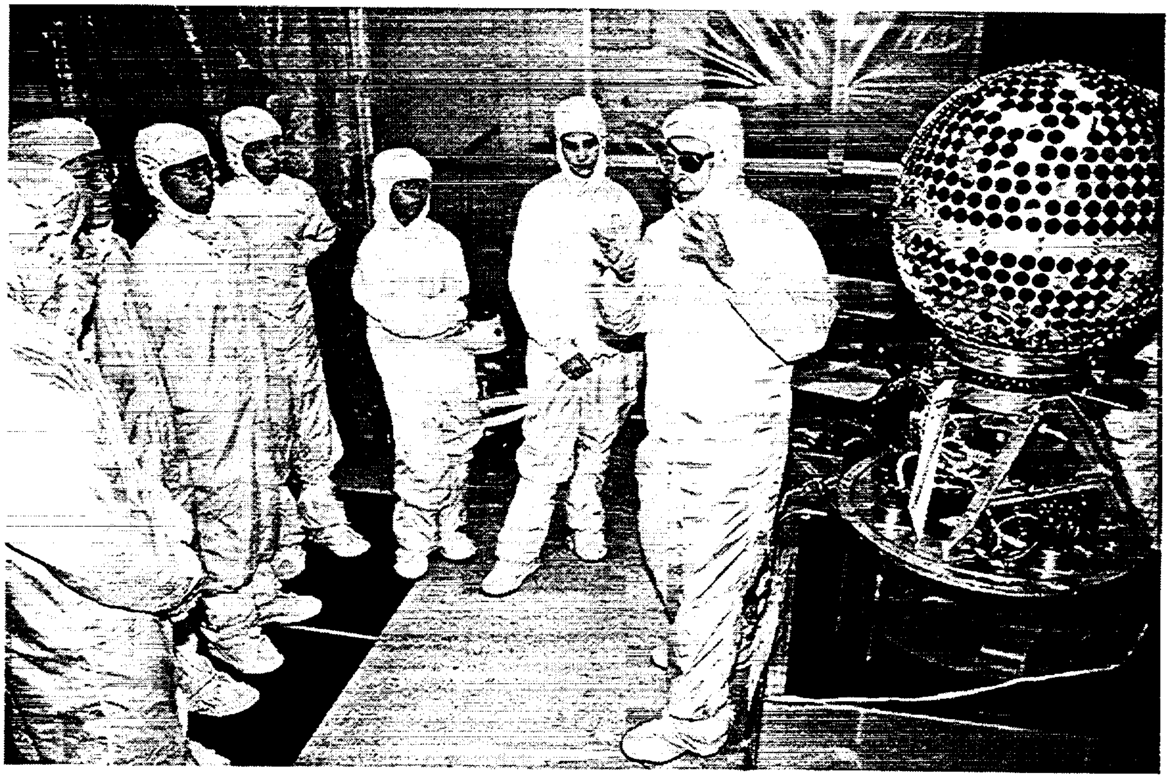


**Figure 4**
Starshine Satellite
NASA Image

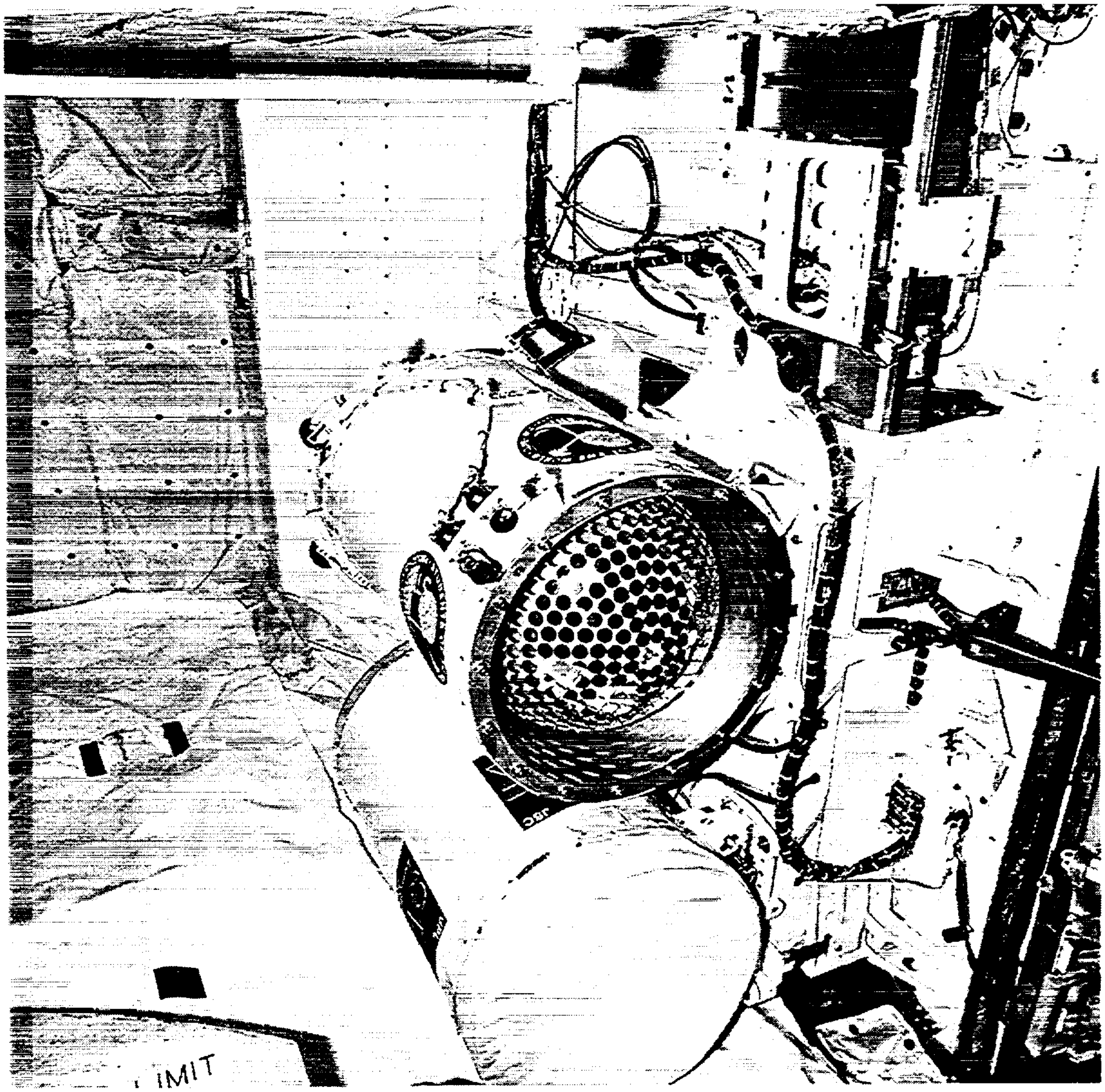



**Figure 5**
Hitchhiker Canister
NASA Image

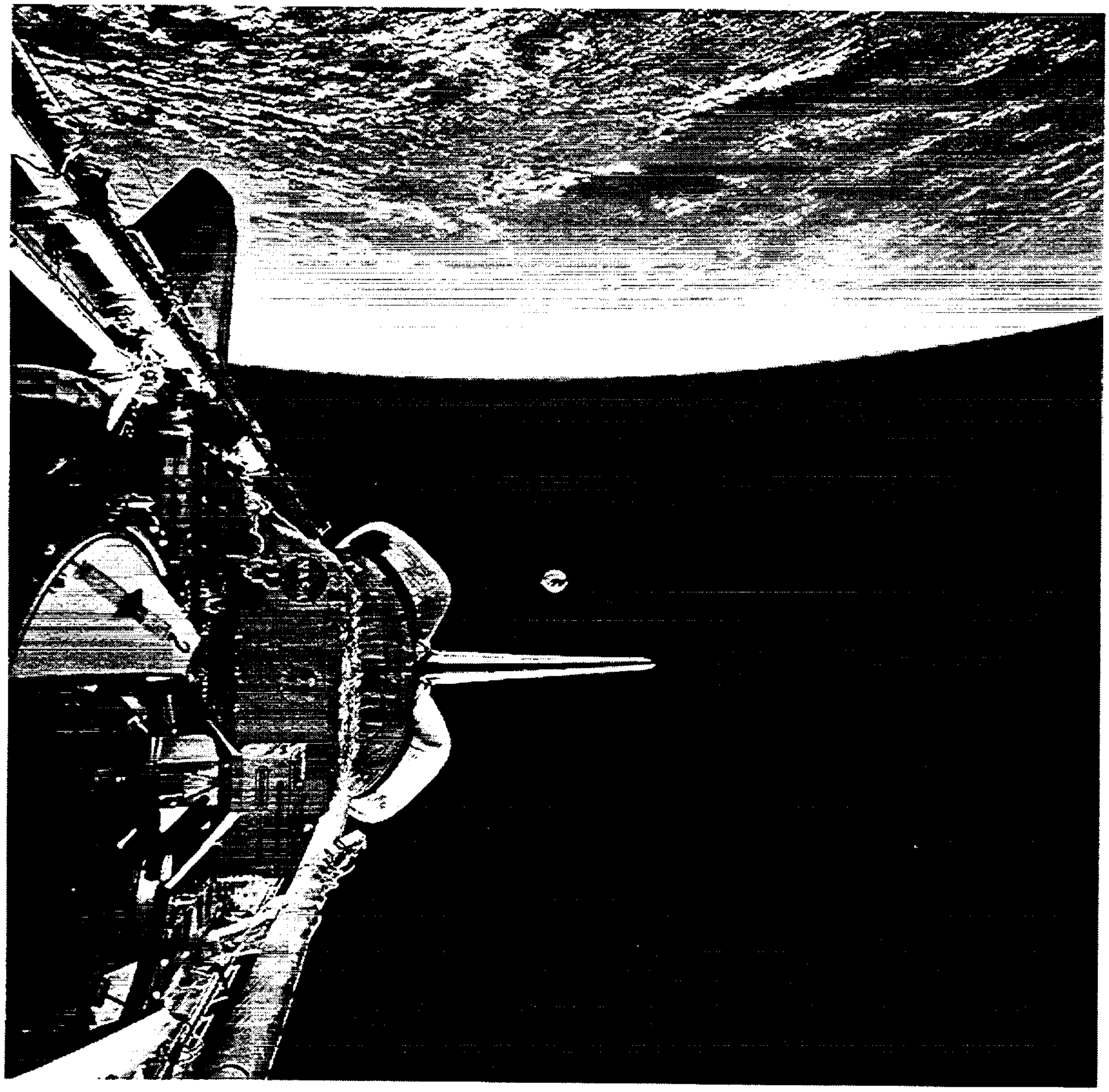


**Figure 6**
Starshine Deploy / NASA Image

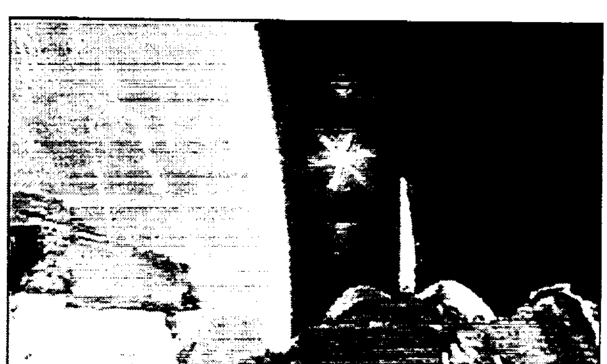
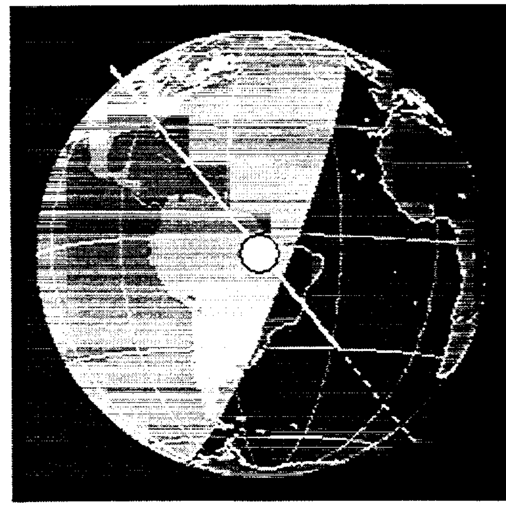
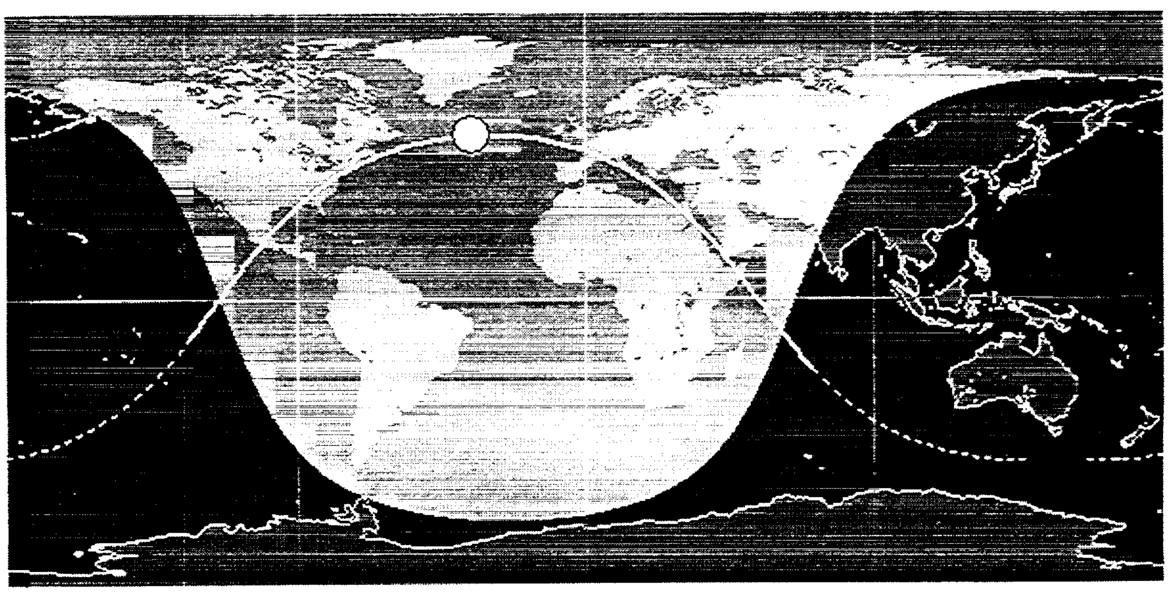


**Figure 7**
Mirror Flash / NASA Image

View from above orbital plane



View from above satellite



Ground Track

**Figure 8**
Starshine Orbit
GSOC Web Site

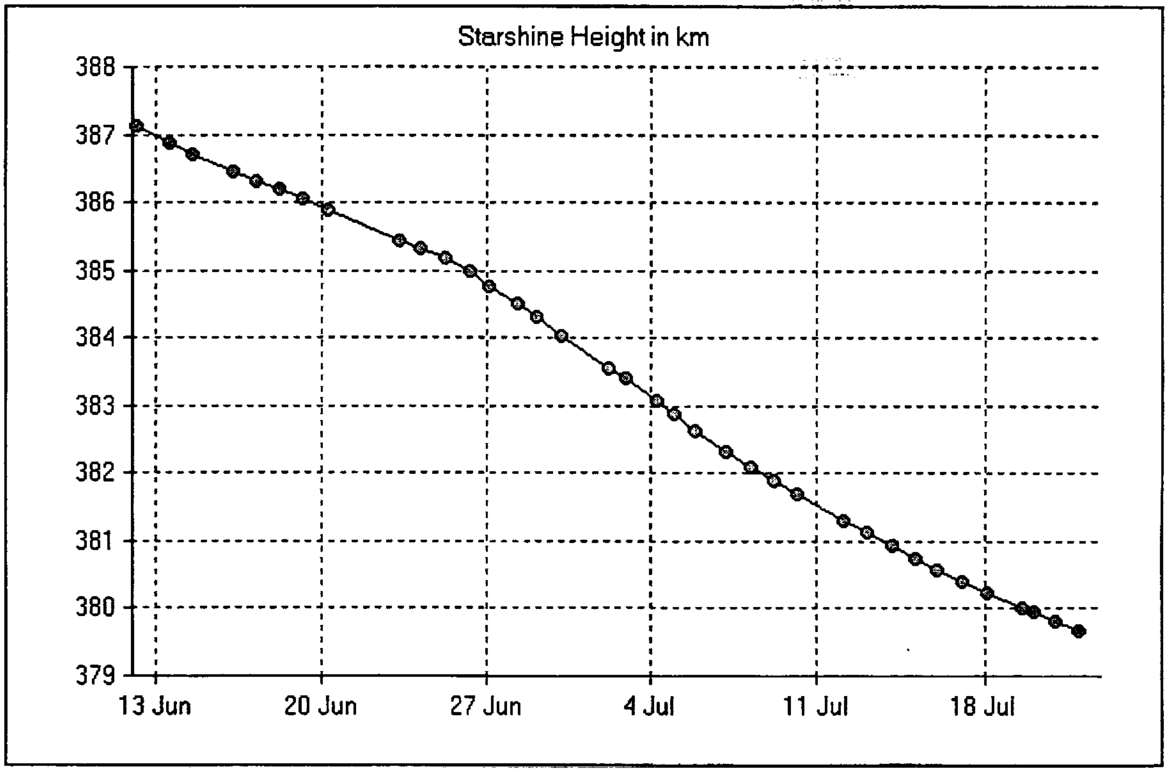



**Figure 9**
Starshine Orbit Decay
GSOC Web Site

**Table 1**
Participating Institutions

| Institution | Responsibility |
|---|---|
| NASA Headquarters | Provision of Shuttle launch at no charge to project, coordination of launch attendance by students, parents, teachers, addition of Starshine web page to Spacekids web site |
| NASA Goddard Space Flight Center | Mission management, Hitchhiker system modification and testing, satellite integration, cargo bay installation, L minus 2 week press briefing, coordination of launch attendance by students, parents and teachers |
| NASA Kennedy Space Center | Satellite installation and checkout, Shuttle launch, provision of facilities and tours for students, parents and teachers, pre-launch press briefing |
| NASA Johnson Space Center | Cargo integration, astronaut deploy training, Shuttle launch and on-orbit operations, satellite deploy, post-deploy press briefing |
| Naval Research Laboratory/Naval Center for Space Technology | Satellite structural design, fabrication, testing, mirror mounting, orbit determination |
| Naval Space Command | Satellite tracking |
| Air Force Space Command | Software development for orbit determination |
| Starshine Headquarters | Project direction, mirror polishing kit assembly and shipping, data base management, signature sheet scanning |
| Rocky Mountain NASA Space Grant Consortium | Project coordination, web site development, data base management, mirror-coating liaison, monetary support |
| Utah State University | Mirror design |
| Bridgerland Applied Technology Center | Machining of mirror blanks |
| White Sands Missile Range | Development of mirror polishing methodology |
| Students & Teachers in 700 Schools in 18 Countries | Mirror polishing, satellite visual tracking |
| Packager, Inc. | Manufacture of shipping boxes for polishing kits |
| Lightpath Technologies | Manufacture of optical inspection flats |
| Hill Air Force Base | Inspection and coating of polished mirrors |
| U.S. Air Force Academy | Mirror flatness measurement, photographic support |

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| German Space Operations Centre | Web site development, orbit determination, generation of sighting opportunities and orbit decay analysis |
| Azinet Internet Business Solutions | Web site development and operation |
| Gates Planetarium | Teacher education |
| Hansen Planetarium | Teacher education |
| U.S. Space Foundation | Teacher education |
| Starfire Optical Range | Teacher education, satellite optical tracking |
| U.S. Space and Rocket Center | Teacher education, monetary support |
| Albuquerque Chapter of Optical Society of America | Teacher education, monetary support |
| Aerospace States Association | Monetary support |
| Clark Foundation | Monetary support |
| Young Oak Foundation | Monetary support |
| Utah Section of American Institute of Aeronautics and Astronautics | Monetary support |