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Paper Session III-B - The Photon Satellite: A Demonstration of Satellite Laser Tracking and Communications

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The Photon Satellite: A Demonstration of Satellite Laser Tracking and Communications

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Abstract

An alliance of Florida universities and companies are proposing to construct a small satellite to demonstrate the feasibility of laser communications for satellite to ground-airborne receivers and ground-airborne to satellite receivers. The possibility of using high-data-rate optical transmitters for satellite communications has generated a renew interest in laser communication systems for ground-airborne-to-space and space-to-ground-airborne data links. Here we describe a ground to satellite experiment to demonstrate the requirements of pointing accuracy and tracking for reliable communications and a novel technique to track a satellite with laser beams

Introduction

The possibility of using high-data-rate optical transmitters for satellite communications has generated a renew interest in laser communication systems for ground-airborne-to-space and space-to-ground-airborne data links. However , atmospheric turbulence causes intensity fluctuations or scintillations that can seriously degrade the reliability of such optical communication links. The scintillations as a function of the pointing error have been measured in the Strategic Defense Initiative Organization Relay Mirror Experiment data reported by Lightsey[1]. Recently a theoretical study has been published by Andrews, Phillips and YU[2] on the fading statistics of a laser beam propagating from ground to space and space to ground and the changes that arise as a result of transmission point errors for a satellite at geosynchronous orbit. The analysis shows that pointing errors of less than 0.5 μ rad are required to keep average fading times below 10 dB less than 100 microseconds for zenith angles of less than 45 degrees for the down link. For the up-link pointing errors of less than 0.5 μ rad are required to keep the average fading times below 10 dB less than 500 microseconds for zenith angles less than 30 degrees. This analysis shows that significant fading will occur for both the up and down link and thereby cause long strings of data bit loss for the geosynchronous orbit scenario analyzed. Currently we are studying the same effects of turbulence on fading for LEO satellite links. Here we expect to have fade times several of orders of magnitude less (~ 10 nanoseconds) for the same 10 dB of fade level and pointing error of 0.5 μ rad.

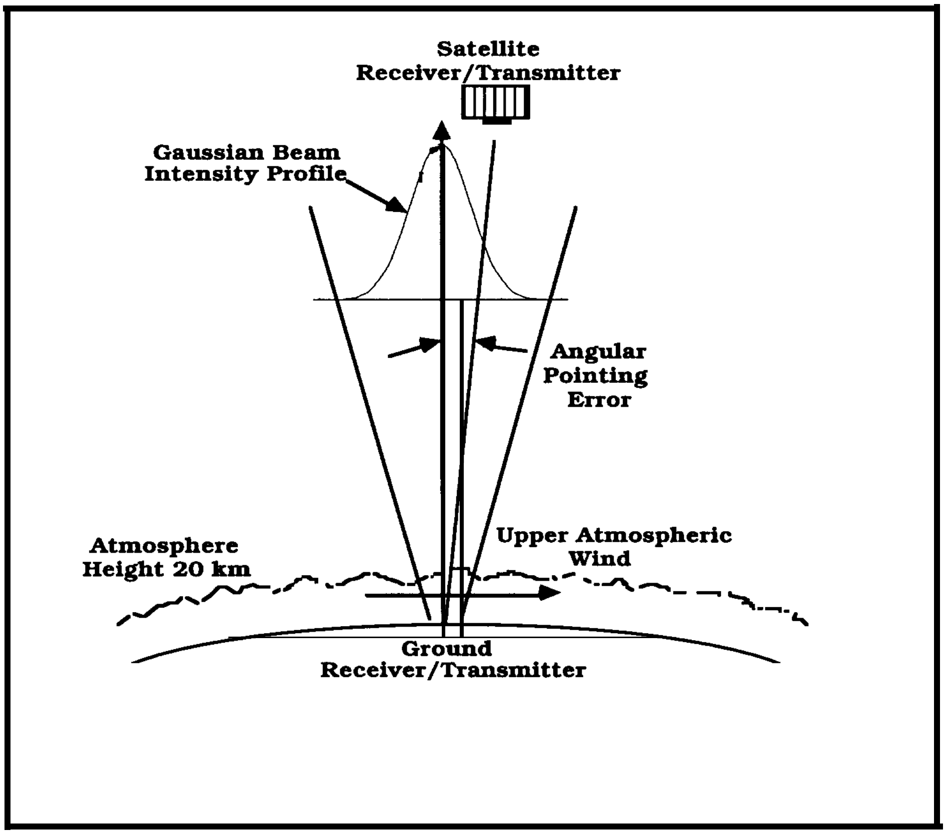

Fig. 1. Schematic of the up-link propagation channel, illustrating the Gaussian-beam profile of the mean intensity at the satellite and the relative pointing error. The satellite will orbit at 350 Km

A recent publication by Harvey, Reddy and Phillips[3] has shown a new technique for tracking. The technique exploited Reciprocal Path Scattering (RPS) resulting from reciprocal scattering paths when using active illumination of a target through atmospheric turbulence. The technique allows interferometric sensitivity in pointing accuracy when using a dual aperture and a polarization discrimination technique for suppressing the non-RPS return optical wave. The RPS phenomenon has been studied for use in imaging systems as well.[4]

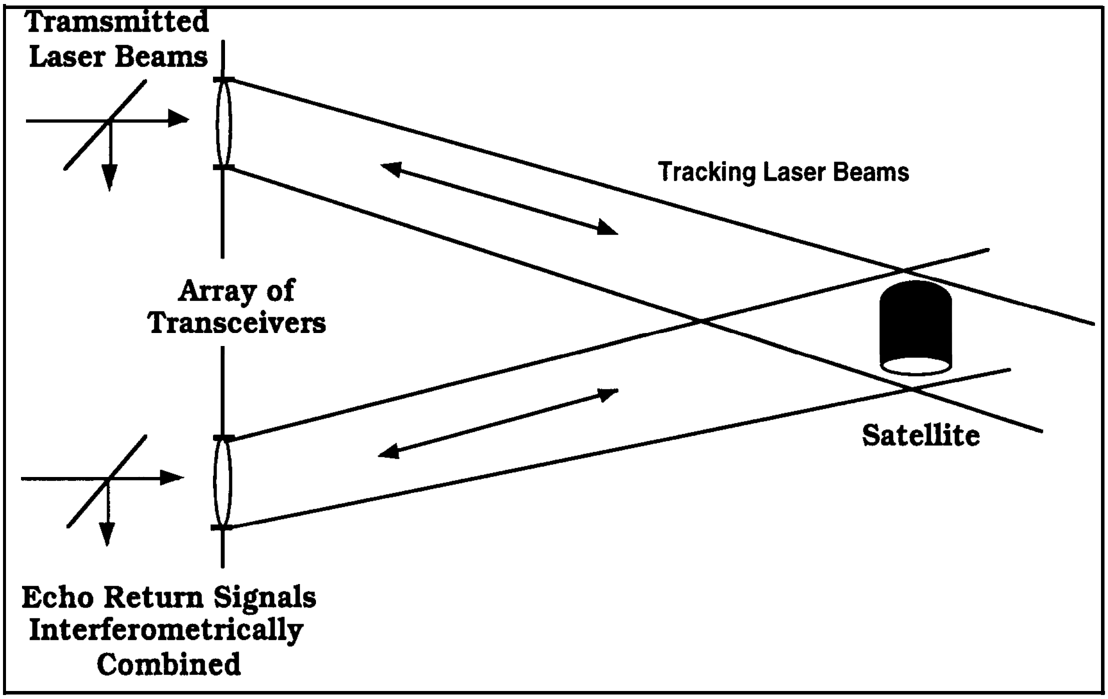

Fig. 2 Dual laser beams used for tracking of satellite using RPS beam. Only the signal from the opposite transmitter is used-and the signal from its own transmitter is rejected by polarization discrimination technique.

Ground to Satellite Laser Experiment

The proposed satellite experiment would demonstrate the requirements for very high data rate communications by measuring the fading time of the laser signal as a function of the pointing error of the ground communication laser beam. The fading of the ground communication beam will be measured by an intensity detector on board the satellite. A portion of the beam will be reflected by a retro-reflector on the bottom of the satellite. The retro-reflector-ed signal will be detected on the ground by an array of detectors. The signals from each of the detector in the array will be combined coherently. The average fade time of the combined signal will then be measured. The diagram of the proposed experiment is shown in Figure 3.

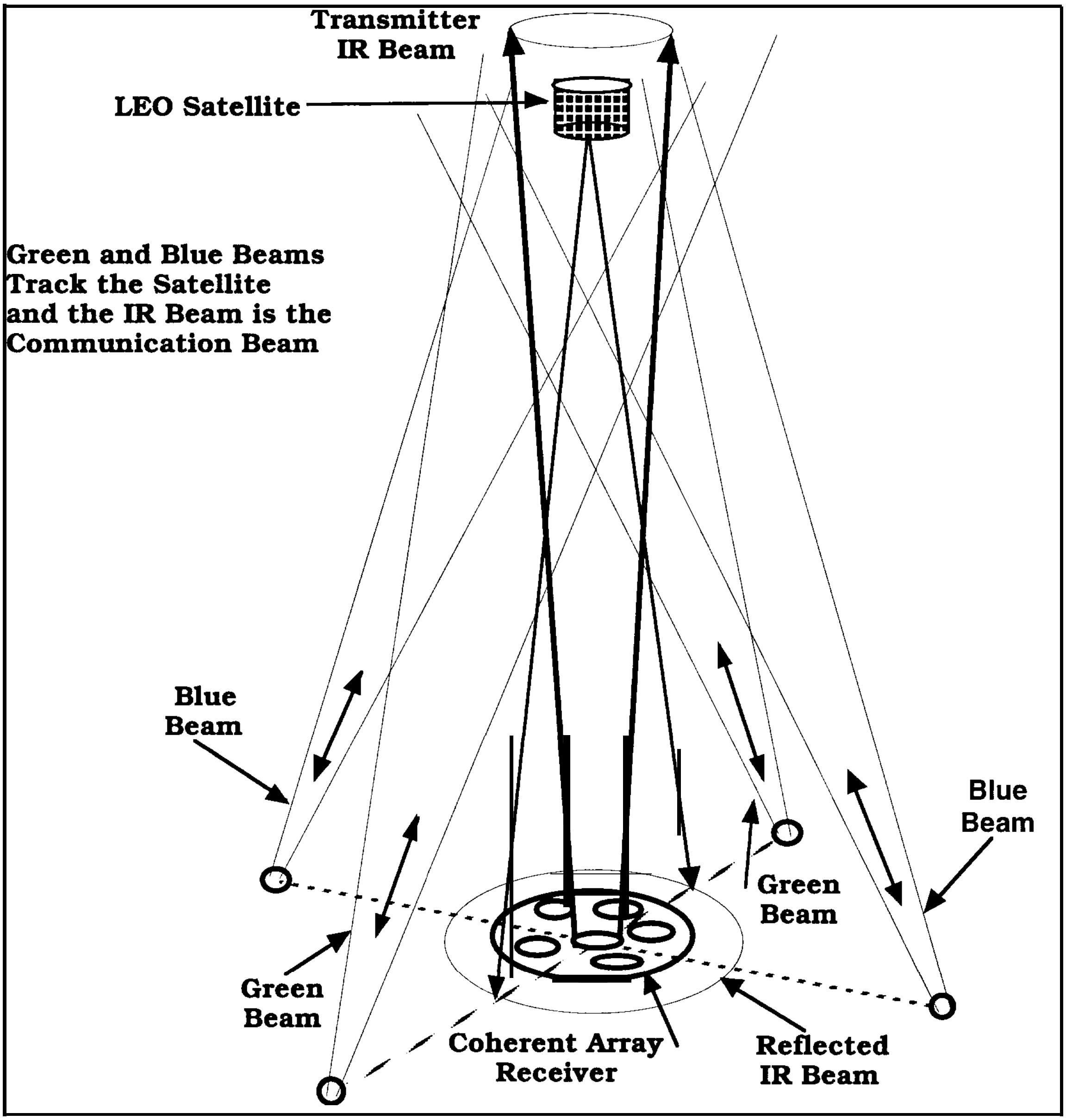

Fig. 3. Composite diagram of the satellite tracking and laser communication experiment.

The tacking of the satellite will be with two pairs of laser beams arranged in orthogonal planes. The four beams will use reciprocal path scattering to mitigate the fluctuations induced on the beams by atmospheric turbulence.

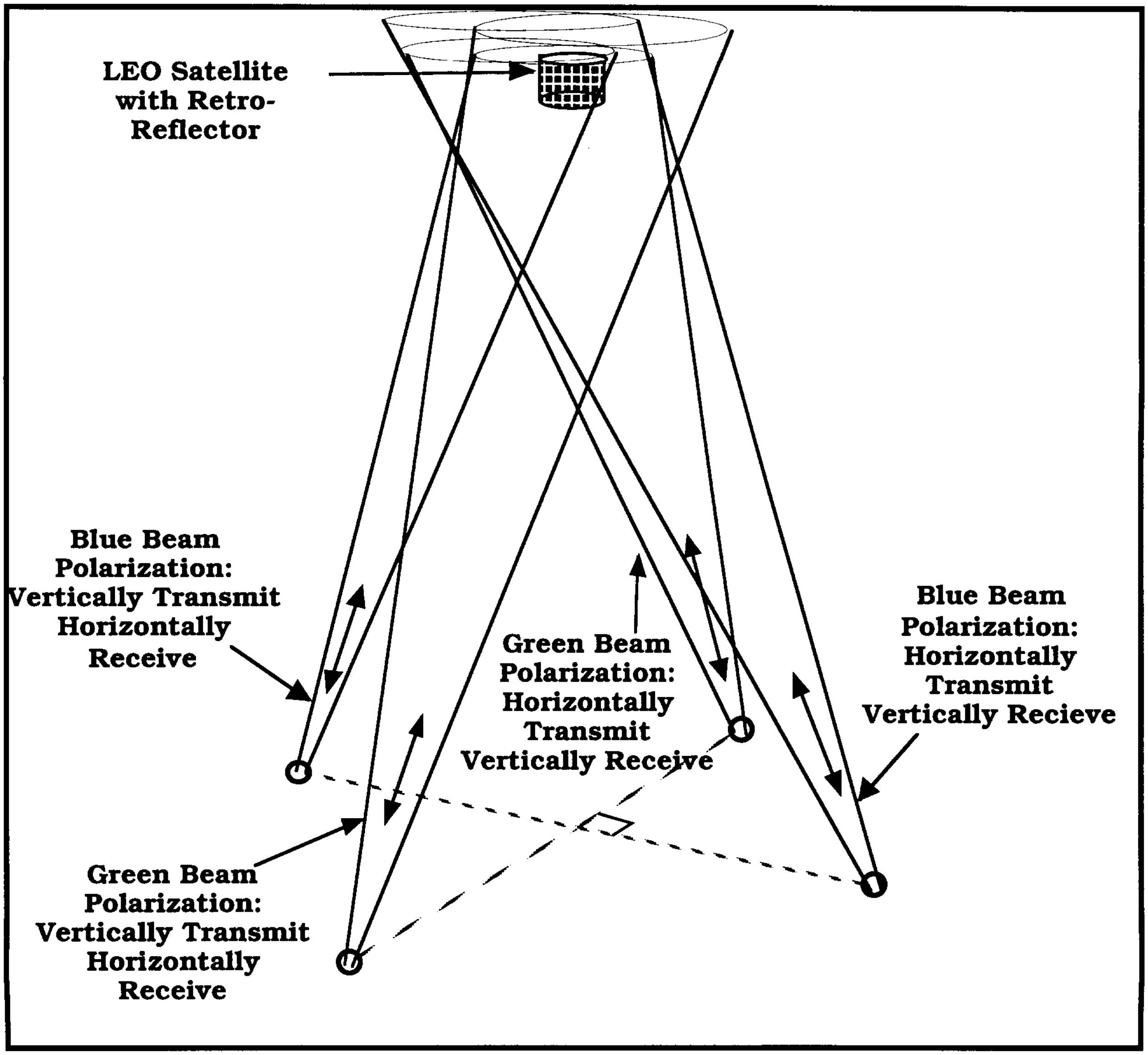

Fig. 4. Two pairs of laser beams in orthogonal planes will be used to track the satellite. The scheme will use Reciprocal Path Scattering (RPS) to suppress jitters of measured position due to atmospheric turbulence.

The receivers on the ground will be an array of detectors arranged in a circle about the transmitter aperture which will be a mono static receiver. The transmitter laser beam will have a wavelength in the near infrared (1.06 micron wavelength). The transmitted beam will be detected at the satellite and a portion will be reflected back to the ground. The received signals from each aperture will be coherently detected and coherently combined to produce a composite signal. Because the signals are coherently combined the fading time of the composite signal will be much smaller than the individual signals.

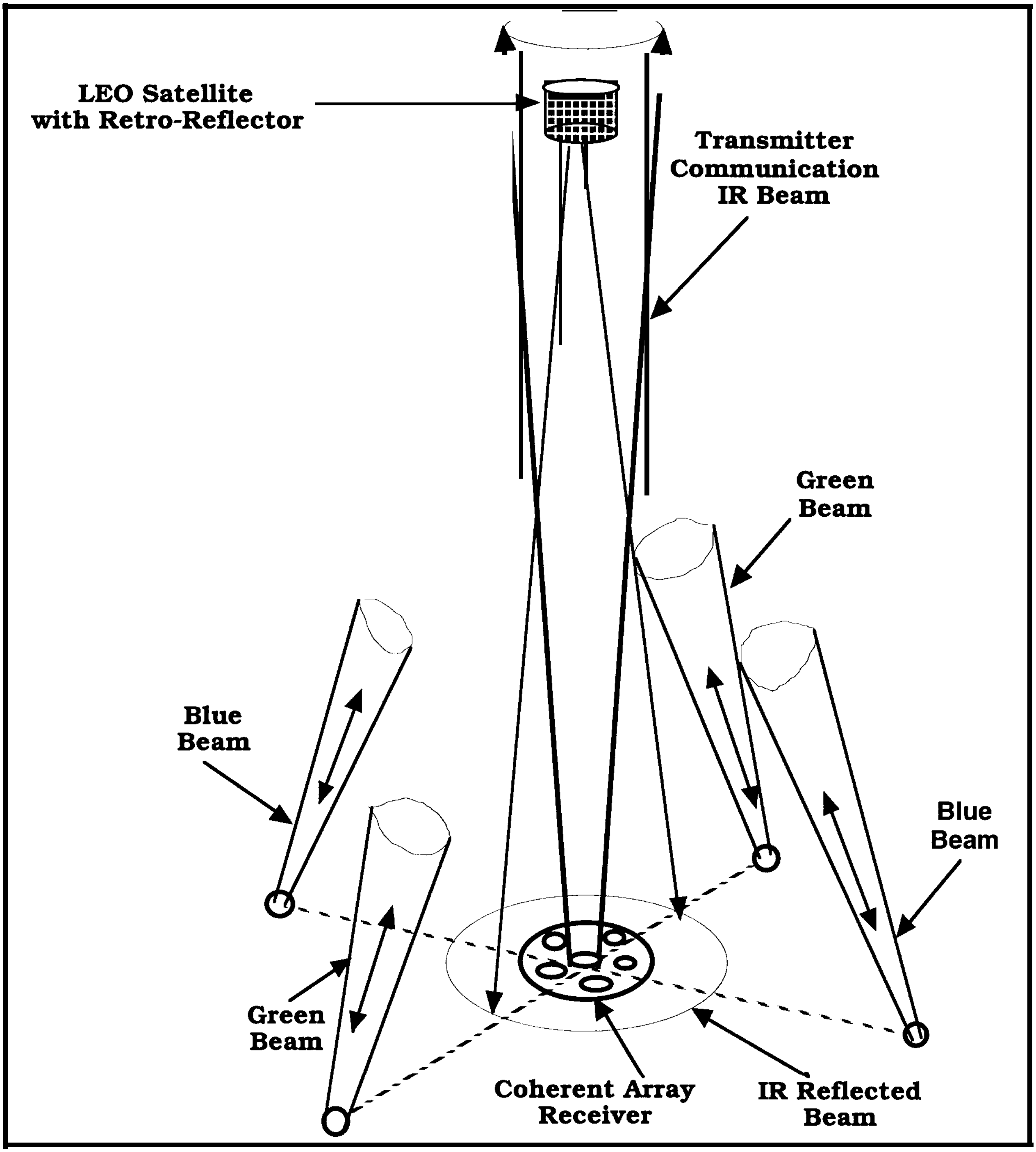

Fig. 5. A reflected signal from retro-reflectors on the bottom of the satellite will be detected by an array of receivers on the ground.

The satellite will have a mass of about 200 Kg with a volume of 1 m^3. The satellite will fly down-looking with magnetic torque ring stabilization. An on board GPS system will be used for the position sensing of the satellite. An RF radio communication system will be used for control of the satellite.

Photon Satellite Project

The proposed small satellite will be launched on rocket called a Multi Service Launch System (MSLS). The vehicle is a retro-fitted Minuteman ICBM. The Air Force has a charter to use these rockets for government research projects. Spaceport Florida has proposed that the Air Force use LC 46 for several launches of this vehicle.

The ground receiver and transmitter will be located at the Ballistic Missile Defense Organization facility at Kennedy Space Center called the Innovative Science and Technology Experimentation Facility (ISTEF). ISTEF is facility constructed to explore the application of new and innovative systems and applications of electro-optic systems.

The proposed satellite will be entirely constructed by a consortium of Florida universities and Department of Defense agencies. The Center for Research and Education (CREOL) at the University of Central Florida and the Florida Institute of Florida will be construct the satellite payload. E-Systems and the University of South Florida will be build the RF radio link for the satellite control and command. Florida Atlantic University will participate in the communication portion of the experiment with a demonstration of the transmission of a High Definition TV from the ISTEF ground station to the orbiting satellite and back. If available to Spaceport Florida Authority, the building of the satellite bus will be at cleanroom facilities at LC 20. The University of Central Florida will have the primary responsibility for the construction of the satellite bus but with participation of Bathune-Cookman College, University of South Florida and E-Systems. The ground equipment will be constructed by ISTEF. Other Department of Defense agencies involved in the development of the satellite will be Eglin Air Force Base, Florida and the Navy's Research and Development (NRAD), San Diego

Reference

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3. J. E. Harvey, S. P. Reddy and R. L. Phillips, "Precision pointing and tracking through random media by exploiting the enhance backscatter phenomenon", accepted for publication, Appl. Opt. 1996
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