Applications of the Precision Expandable Radar Calibration Target (PERCS) to Laser Imaging and Tracking Systems

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Abstract

A large (10 m) diameter sphere, with conducting edges composed of open-faced polygons, is being planed for launch in low earth orbit. The primary purpose of the Precision Expandable Radar Calibration Target (PERCS) is calibration of high frequency (3 to 30 MHz) backscatter radars used for geophysical studies of the upper atmosphere. The PERCS sphere with 180 vertices and 360 edges provides about 200 square-meters radar cross section at HF frequencies [Bernhardt et al., 2008]. Measurements of radar backscatter from a sphere with known radar cross section will calibrate ground-based HF radars to permit absolute measurements of the strength of meteor trail echoes and scatter from auroral disturbances in the ionosphere. The addition of corner cube retro-reflectors at the 180 vertices enhances the use of PERCS by permitting (1) high accuracy measurements of the target position, (2) determination of its orientation, and (3) estimation of the PERCS rotation rate. With these measurements using laser backscatter from the retro-reflectors permits studies of the electrodynamic drag of the conducting wire-frame sphere moving in low-earth-orbit (LEO) across magnetic field lines. Currents induced in the conducting struts of PERCS will interact with Earth's geomagnetic field yielding forces that affect both the orbit and the rotation of the sphere. A mechanical model for deployment of the 10 meter diameter sphere from a 1-meter stowed configuration has been developed at NRL and Hoberman Associates. The model also includes corner reflectors at vertices of polyhedral wire frame with design considerations of the diffraction pattern of the reflected laser signals as well as the effects of the velocity aberration from the orbiting sphere. Some vertices will be vacant of reflectors at selected wavelengths so that the unique orientation of the PERCS can be determined from ground laser observations. The PERCS sphere is being considered for launch in the 2011 to 2012 time period.

Introduction

The Naval Research Laboratory in conjunction with Hoberman Associates of New York has developed a new concept for deployment of large satellites in space. The Precision Expandable Radar Calibration Sphere (PERCS) was first designed to provide an HF radar calibration target using spherical wire frame. The primary purpose of the PERCS sphere in orbit is to calibrate the antenna patterns and system sensitivity for space weather radars. For this objective, extensive numerical simulation of radar cross section (RCS) in the 3 to 30 MHz frequency band was performed a reported in a paper by Bernhardt et al. [2008]. Future activities for PERCS will be to construct (1) a scale mode for RCS testing, (2) a mechanical section for structural testing and (3) the spaceflight version for launch into orbit. The final PERCS satellite will 10.2 meters in diameter with an orbit altitude of 600 to 800 km in a high inclination (> 80 degrees) orbit.

Once the large wire frame structure was conceived, it became immediately obvious that corner-cube retroreflectors could be added to the structure to provide calibration for laser satellite tracking. Currently the PERCS satellite has 180 vertices and each vertex will have a holder for 3 retro-reflectors both on the inside and outside of the satellite frame. These corner cube reflectors can provide precision data on both the position and orientation of the orbiting sphere.

The next step in the PERCS concept was that the retro-reflectors could provide precise measurements of the electrodynamic drag of the satellite. As the conducting wire frame passes though the ionosphere crossing magnetic field lines, currents will be induced in the edges. The Lorentz (J cross B) force from the satellite motion will affect the satellite position and rotation rate. The optical tracking of the satellite orientation and position is essential to determine the effects of these forces. The orbit of the satellite will also be determined by the solar illumination. In darkness, the wire frame sphere will polarize to about 2 Volts across the 10-meter diameter structure. In sunlight, electrons will be removed from the conducting edges so that the satellite will charge positive. The deflection forces of this charged object crossing magnetic field lines will perturb the orbit. The least important force for the PERCS satellite could be the collisional drag. The 10-meter diameter sphere will have a drag cross section of less than 2 square meters because of its wire frame structure. Each edge on the sphere is less than 2 cm in diameter.

Status on the PERCS Design.

For the PERCS project, Hoberman Designs the creator and manufacturer of the famous Hoberman Sphere has been contracted to design the expandable satellite. Figure 1 illustrates the current design for the PERCS sphere. The stowed configure for the sphere starts out at 1.25 meters diameter. Torsion springs in each of the three scissors that comprise an edge cause the sphere to open with a distributed force.

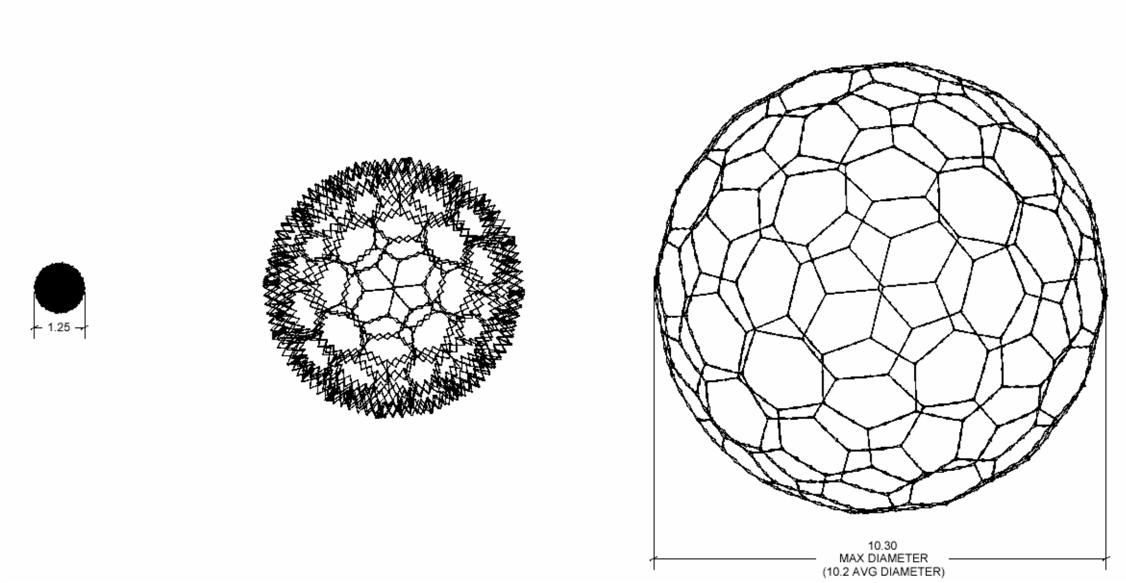

Figure 1. Expandable structure for the PERCS satellite with 180 vertices.

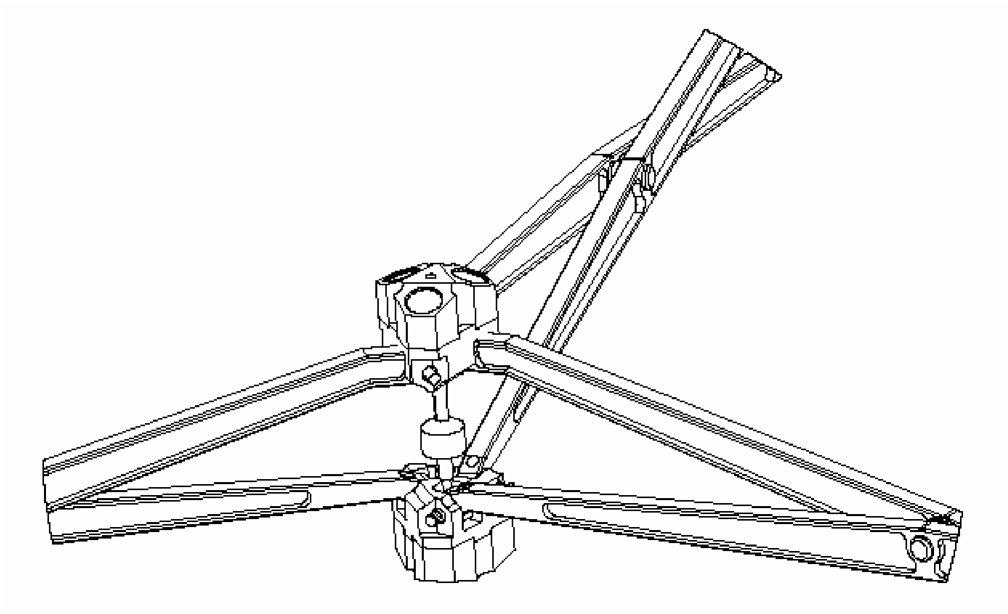

Figure 2. Retro-reflector holders for 1-cm corner-cubes on each PERCS vertex.

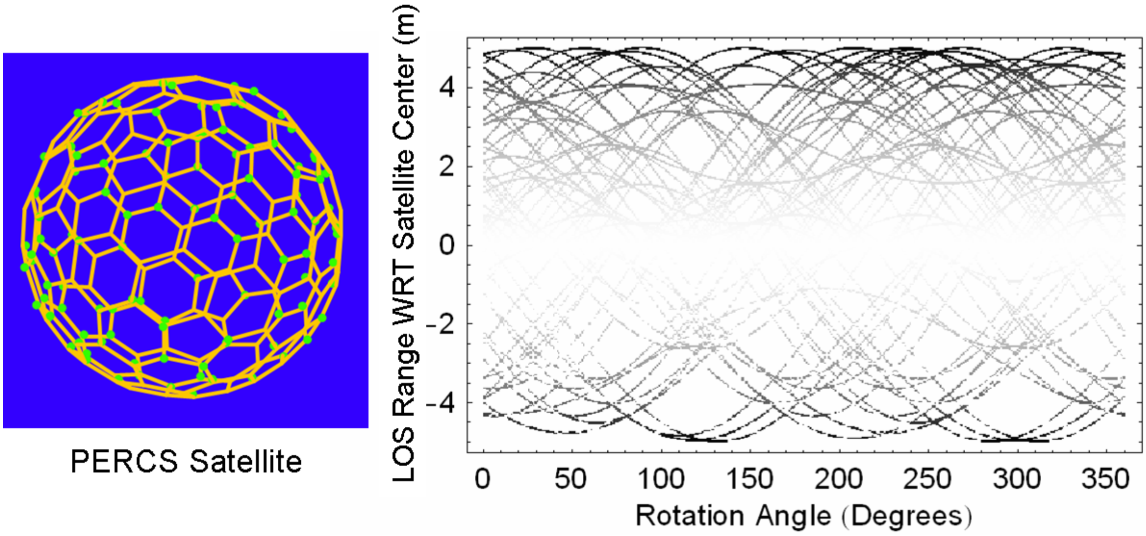

Figure 3. Coding of the PERCS retro-reflector locations to yield the orientation of the sphere in sphere. The line-of-sight (LOS) returns for a ground laser pulse provide unique time sequence depending on which side of the sphere is facing the viewer.

Each vertex of the deployed sphere has retro-reflector holders that are illustrated in Figure 2. The PERCS structure opens up into a locked configuration that has a precise distance between each vertex as well as a precise distance across a sphere diameter. The retro-reflector holders are populated with a fixed pattern that does not fill every position on a vertex. This allows measurement of the orientation of the sphere with a coded laser pulse response. Figure 3 shows a simulated pulse return from PERCS using a fixed coding of the retro-reflector locations. The sphere reflects laser pulses from both the inside and outside of the sphere. The line-of-sight (LOS) pulse return plot uses the zero as the reference distance at the center of the satellite in Figure 6, left frame. The strongest echoes are either from the front closest to the observer (negative distance offset) or from the inside back of the satellite at the farthest (positive distance) from the observer.

The PERCS satellite is currently in the design phase and funding has been allocated for construction of one pentagon section (Figure 4). It is hoped that that the fully constructed satellite is finished by 2011 and that PERCS will be in orbit by 2012. Investigators interested in joining the PERCS science team could contact the authors at the e-mail address given above.

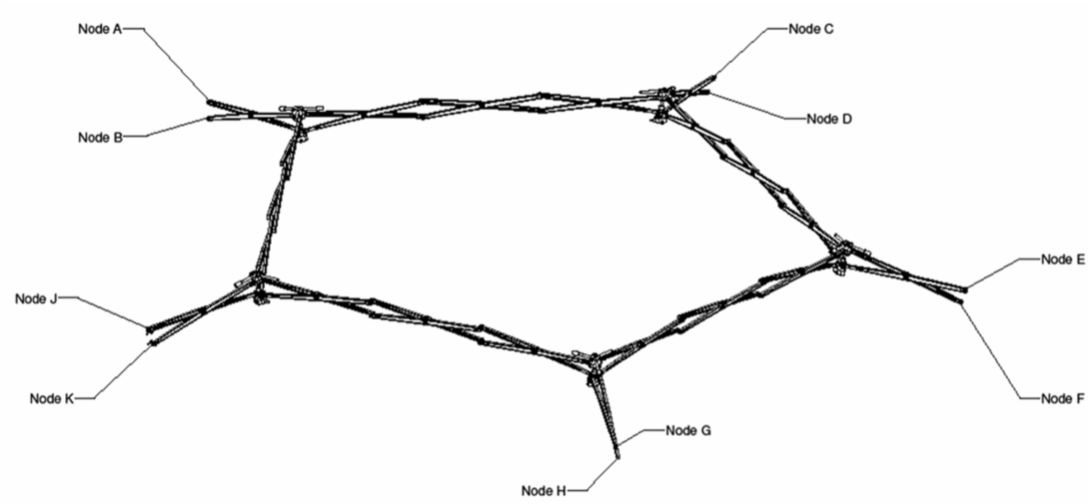

Figure 4. Pentagon section of the PRERCS satellite under construction by Hoberman Associates.

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