ELFIN
Electron Losses and Fields Investigation

Mission Overview
ELFIN’s mission is to study the losses of relativistic electrons in Earth’s ion–Allen radiation belts. It is a 3U+ CubeSat spin stabilized to approximately orbit normal. The science payload is comprised of two Energetic Particle Detectors and a Fluxgate Magnetometer on a 75 cm stacer boom. ELFIN requires a high inclination (∼70°) orbit to observe electron behavior about Earth’s poles.

ELFIN is a participant in the NS-8 round of the AFRF’s University Nanosatellite Program and is funded by grants from NSF and NASA LCAS. Delivery is planned for Q3 2016. With a nominal mission life of six months, the spacecraft should be able to observe two electromagnetic storm events. ELFIN’s avionics are developed in collaboration with The Aerospace Corporation.

Science Overview
Charged particles from the Sun interact with Earth’s magnetic field and travel along field lines in a spiral or helical fashion, and the angle between a particle’s velocity vector and the direction of the field line is known as a pitch angle. Those that travel within a characteristic range of pitch angles, known as a loss cone, can collide with atmospheric particles and get lost in the atmosphere to create phenomena such as auroras.

Particles sometimes come close enough to Earth such that the stronger magnetic field causes them to reverse direction, and particles that continuously oscillate due to these mirror points are said to be trapped and become highly energetic. When these trapped particles precipitate into the loss cone, damage towards critical assets can occur, ranging from single event upsets, losses of satellites, and even terrestrial blackouts.

Modeling suggests that equatorial electromagnetic ion cyclotron (EMIC) waves may be the primary cause of trapped electron losses, but the contribution from other effects have not been determined observationally. The ELFIN mission will address this contentious issue by determining whether electron losses bear the characteristic signatures of EMIC wave scattering.

Energetic Particle Detectors
Two Energetic Particle Detectors (EPDs) will resolve pitch angle distributions of charged particles in the loss cone of Earth’s radiation belts. One detector is dedicated to detecting electrons (EPD-E) and the other for ions (EPD-I). They are made of aluminum and tantalum, and their design was driven by Geant4 simulations.

Fluxgate Magnetometer
ELFIN’s Fluxgate Magnetometer (FGM) enables correlation of pitch angle information with energetic particle spectra by making 3-axis magnetic field measurements. Requirements for the FGM are shown in the tables below. UCLA has a long history making 3-axis magnetic field measurements. Requirements for the FGM are shown in the tables below. UCLA has a long history making 3-axis magnetic field measurements.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Energy Range</th>
<th>Energy Resolution</th>
<th>Field of View</th>
<th>Geometric Factor</th>
<th>Time Resolution</th>
<th>Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPD-E</td>
<td>0.50 – 0.00 MeV</td>
<td>ΔE/ΔE ≤ 50%</td>
<td>&lt; 28°</td>
<td>0.100 cm/s•sr</td>
<td>24 sectors/spin</td>
<td>10–100 counts/(cm2•s•sr)</td>
</tr>
<tr>
<td>EPD-I</td>
<td>0.05 – 0.30 MeV</td>
<td>ΔE/ΔE ≤ 50%</td>
<td>&lt; 28°</td>
<td>0.005 cm/s•sr</td>
<td>24 sectors/spin</td>
<td>10–100 counts/(cm2•s•sr)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Magnetic Field Range</th>
<th>Relative Stability</th>
<th>Noise @ 0.1 Hz</th>
<th>Noise @ 1.0 Hz</th>
<th>Digitization</th>
<th>Orthogonality</th>
<th>Frequency Range (DC)</th>
<th>Sampling Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>50,000 nT</td>
<td>0.5 nT/hr</td>
<td>0.2 nT/√Hz</td>
<td>0.1 nT/√Hz</td>
<td>80 bits</td>
<td>&lt; 1°</td>
<td>10 Hz</td>
<td>≥ 1 Vectors/s</td>
</tr>
</tbody>
</table>

Power
The magnetically clean solar panels contain 20 total UTI cells that are arranged in opposing pairs and distributed along the 3U faces. The body mounted panels mean only some cells will be illuminated at a time for a given attitude. Two power boards, equipped with PIC microcontrollers, manage the four Lithium-ion batteries (18650 2.2Ah each) and provide +5V for all electronics. The Flight Computer monitors the satellite, collects housekeeping data, executes scheduled tasks, and communicates with the Watchdog, ADCS Main PIC, two Power PICs, and radio. The Watchdog provides a layer of redundancy by heartbeat communications.

Thermal
Passive thermal stabilization is particularly important for the Energetic Particle Detectors, the Fluxgate Magnetometer sensor, and Li-ion batteries. The FGM sensor is thermally stabilized with MLI blankets, and overall heat input into the spacecraft will be reduced with aluminized Kapton. In addition to an in-house MATLAB simulation, ELFIN is beginning to use Thermal Desktop for validation and improved fidelity.

Command and Data Handling
The Flight Computer monitors the spacecraft, collects housekeeping data, executes scheduled tasks, and commands the Watchdog, ADCS Main PIC, two Power PICs, and radio. The Watchdog provides a layer of redundancy by heartbeat communications.

Communications
ELFIN has applied for allocation as amateur experimental:
- 1962 Q5SK UHF downlink and international beacon
- 966 VHF uplink
An Astrodove He-82 (modified form factor of the He-100) transmits and receives using two bent dipoles antennas deployed out of the 3U+ “tuna can” volume. These elements are made from magnetically clean fiberglass tape springs (with Beryllium copper Inlays).

Earth Station
UCLA’s primary Earth Station uses:
- Quad array 43CPPLUS/UGS cross polarized UHF Yagis
- Dual array 2MP22 cross polarized VHF yagis
- RAS-1 2m/70cm dual band HAM radio
- Icom IC-900H, soundmodem
An additional high gain OSCAR station at Worcester Polytechnic Institute (MA) completes ELFIN’s data volume and provides geographic diversity.