ELFIN

ELFIN (Electron Losses and Fields Investigation)

Spacecraft Launch Sensor Complement References

ELFIN is a 3U CubeSat mission under development by the Earth, Planetary, and Space Sciences department at UCLA (University of California Los Angeles). The objective of the mission is to study space weather, specifically to explore the mechanisms responsible for the loss of relativistic electrons in the radiation belts. ELFIN will complete this goal by measuring for the first time the full energy distribution and pitch angle resolution of precipitating electrons using a UCLA built Energetic Particle Detector. Additionally, ELFIN will fly a 3-axis Fluxgate Magnetometer to take sensitive measurements of Earth's magnetic field, allowing for the detection EMIC (Electromagnetic Ion Cyclotron) waves, thought to be the primary contributor to particle losses. [1] [2] [3] [4]

ELFIN got its start in 2012 as a participant in the UNP (University Nanosatellite Program), funded by the AFRL(Air Force Research Laboratory). The mission was then picked up by CSLI/ELaNa (CubeSat Launch Initiative/Education Launch of Nanosatellite) and awarded joint funding from NASA/NSF in 2014, helping in providing the means to prepare ELFIN for development and launch.

The satellite is largely being developed by a student team with student leadership. It is currently in position to be UCLA's first fully built satellite. While UCLA staff have provided instruments on other satellites in the past, this is the first project to combine UCLA instruments and a UCLA bus on the same spacecraft. - The ELFIN mission is a collaboration of UCLA with the Aerospace Corporation.

The mission requirements call for:

• A mission duration of at least 3 months to have a high probability of seeing a geomagnetic storm

• An orbit is needed with an inclination of ≥ 65º with a perigee of > 400 km and an apogee of < 2500 km.

Figure 1: Artist's rendition of the ELFIN nanosatellite in orbit (image credit: UCLA) [5]

Spacecraft:

ELFIN is a spin-stabilized 3U+ CubeSat at 20 rpm. The nanosatellite spins like a hammer spinning head over handle to be able to resolve the full range of pitch angles. [6] The spacecraft is largely being developed by a student team with student leadership. It is currently in position to be UCLA's first fully built satellite. While UCLA staff have provided instruments on other satellites in the past, this is the first project to combine UCLA instruments and a UCLA bus on the same spacecraft.

UCLA students are working on all subsystems, including ADCS (Attitude Determination and Control Subsystem), Communication, C&DH (Command and Data Handling), Flight Software, Payload, Power, and Structures. The majority of the final spacecraft will be constructed in-house by UCLA students, with avionics and bus programming by UCLA students and structure fabrication in an in-house machine shop.

Structures: ELFIN's chassis is a modified C2B customized to use the stacer can and torquer coils as structural elements. Vibration simulations are conducted in SolidWorks. The spacecraft antennas are stowed, coiled in the P-

POD 3U+ Plus "tuna can" volume. All aluminum and plastic components of ELFIN are fabricated in-house, including the spacecraft chassis and the EPD (Energetic Particle Detector) shells. ELFIN uses a Haas TM-1 CNC mill, and directly export SolidWorks CAD files using the CAMWorks plugin. [7)]

V, W, X, Y, Z
Airborne Sensors
Observation of the Earth

ADCS (Attitude Determination and Control Subsystem): Two torquer coils, comprised of aluminum wire on plastic spools, provide spin and precession capability to ELFIN. Periodic (daily/weekly) scheduled maneuvers are executed with these coils using onboard control laws and a magnetoresistive magnetometer. Coarse sun sensors and a fine sun sensor, as well as the fluxgate magnetometer, provide supplementary data for ground based attitude determination.

Power: The magnetically clean solar panels contain 20 total UTJ (Ultra Triple Junction) 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, 2.2 Ah each) and provide +5 V for the spacecraft bus.

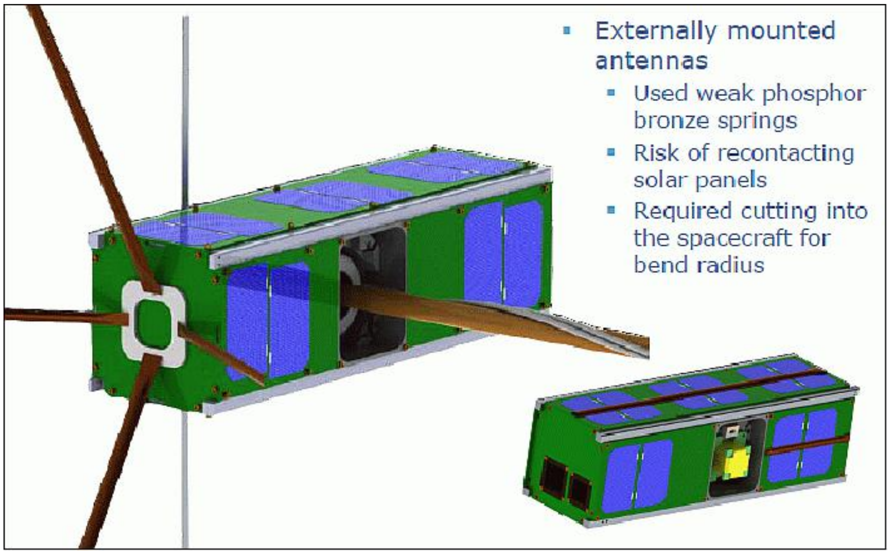

Figure 2: Antenna mounting scheme of ELFIN (image credit: UCLA)

C&DH (Command and Data Handling) subsystem: The flight computer monitors the satellite, collects housekeeping data, executes scheduled tasks, and commands the Watchdog, ADCS Main PIC, two Power PICs (Peripheral Interface Controllers), and the radio. The Watchdog provides a layer of redundancy by heartbeating the flight computer and conducting scheduled resets of the entire spacecraft.

Communications: ELFIN has applied for an allocation as amateur experimental:

- 19.2 kbit GFSK (Gaussian Frequency Shift Keying) UHF downlink and international beacons

- 9.6 kbit VHF uplink.

An Astrodev He-82 (modified form factor of the He-100) transmits and receives data 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).

Figure 3: The VHF and UHF antenna elements are stowed in the 3U+ bonus volume ("tuna can"), image credit: UCLA

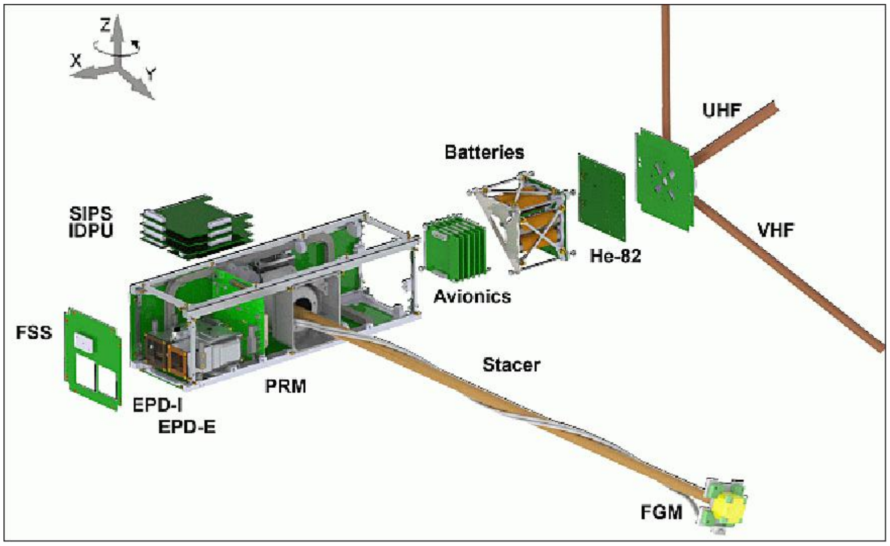

Figure 4: Exploded view of the ELFIN nanosatellite (image credit: UCLA)

TCS (Thermal Control Subsystem): Passive thermal stabilization is particularly important for the EPDs (Energetic Particle Detectors), the FGM (Fluxgate Magnetometer) sensor, and the Li-ion batteries. The FGM sensor is thermally stabilized with MLI (Multi-Layered Insulation) 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.

Launch: A launch of ELFIN as a secondary payload is scheduled for September 2018. ELFIN was selected for NASA's CLSI (CubeSat Launch Initiative) No 5. The primary payload on this mission is the ICESat-2 spacecraft of NASA. The launch service is provided by ULA's Delta-2 vehicle from VAFB, CA. [8)]

Orbit: Near polar circular orbit, altitude of ~496 km, inclination = 92º.

The secondary payloads on IceSat-2 are:

• **ELFIN** (Electron Losses and Fields Investigation), a pair of 3U CubeSats of UCLA (University of California Los Angeles). [9)]

• **SurSat** (Surface charging Satellite), a 2U CubeSat mission developed at the UCF (University of Central Florida), Orlando, FL.

• **CP-7** (CalPoly-7) or **DAVE** (Damping And Vibrations Experiment), a 1U CubeSat, a collaboration of Northrop Grumman Aerospace Systems and CalPoly.

Sensor complement: (EPD, FGM)

The science mission of ELFIN is complementary to larger NASA missions (THEMIS, MMS, DSX, etc). The conjunctions with equatorial spacecraft will reveal the full significance of wave-particle dynamics in the magnetosphere.

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 phenomenon 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.

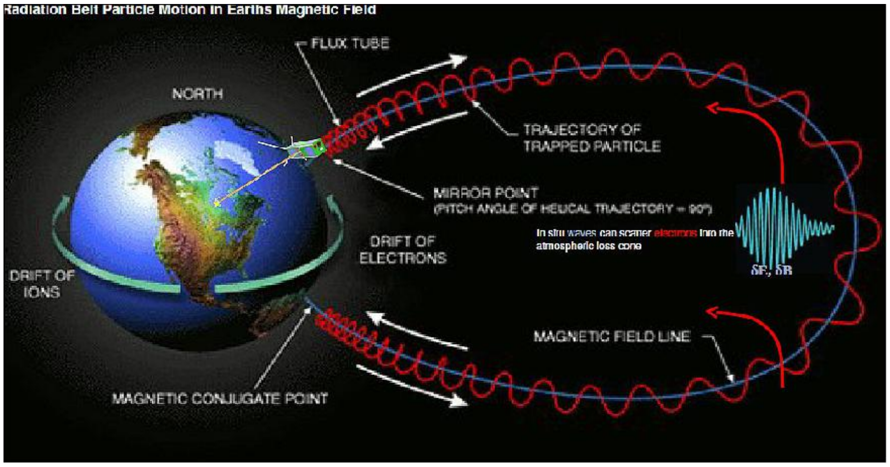

Figure 5: Schematic overview of the ELFIN science mission (image credit: UCLA)

EPD (Energetic Particle Detector)

Two 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.

ELFIN will measure, for the first time, if the angle and energy distribution of precipitating electrons bear the characteristic signature of scattering by EMIC (Electromagnetic Ion Cyclotron) waves.

• EPD- E (Energetic Particle Detector – Electrons): 50 keV – 4 MeV

•EPD-I (Energetic Particle Detector – Ions): 50 keV – 300 keV

• Capable of 10,000 to 50,000 counts/s

• Field of View < 28°

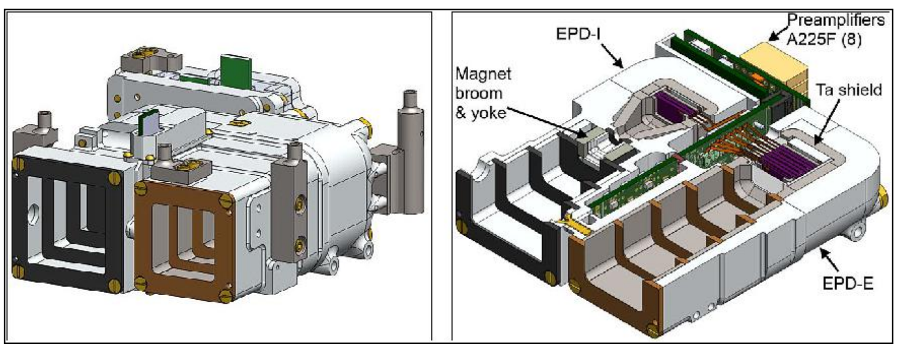

Figure 6: Left: The EPD instrument; Right: Cross-section of the EPD instrument with annotations (image credit: UCLA)

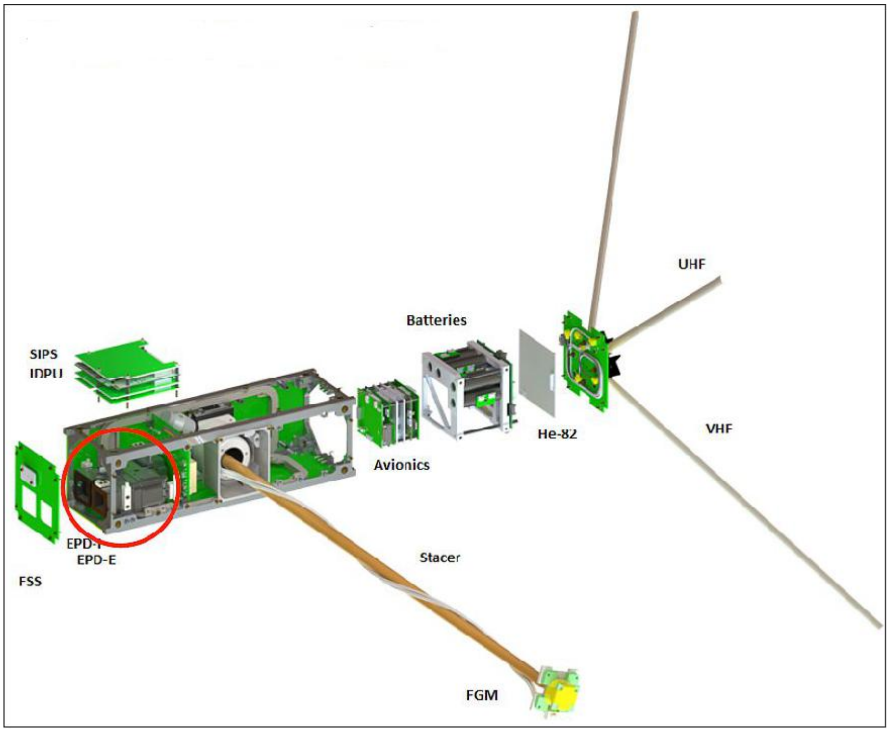

Figure 7: Illustration of the EPD component accommodation within the ELFIN nanosatellite (image credit: UCLA)

FGM (Fluxgate Magnetometer)

The FGM enables correlation of pitch angle information with energetic particle spectra by making 3-axis magnetic field measurements. UCLA has a long history with magnetometer design, and the FGM is based on a previously delivered magnetometer. The following parameters apply to the FPM:

• Dynamic range: ±55,000 nT

• Resolution: 6.5 pT

• Noise resolution: 0.2 nT/√Hz

• Digitization: 24 bits

• Sample rate: 80 samples/s.

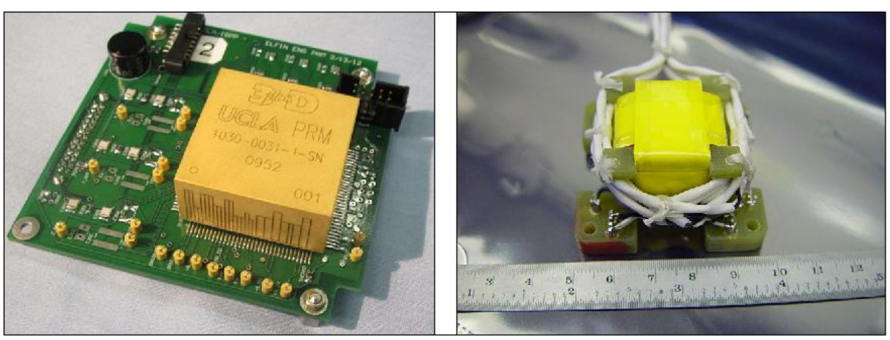

Figure 8: Left: FGM electronics of size 90 x 90 x 25 mm and a mass of 100 g; Right: FGM sensor of size 48 x 48 x 25 mm and a mass of 58 g (image credit: UCLA)

Figure 9: Illustration of the FGM component accommodation within the ELFIN nanosatellite (image credit: UCLA)

1) Chris Shaffer, "ELFIN - An Update on UCLA's Electron Losses and Fields Investigation," Proceedings of the 11th Annual CubeSat Developers' Workshop - The Edge of Exploration," San Luis Obispo, CA, USA, April 23-25, 2014, URL: http://mstl.atl.calpoly.edu/~bklofas/Presentations/DevelopersWorkshop2014/Schaffer_ELFIN.pdf
2) Daniel Lee, "Tuna Can Antenna Design for CubeSat Missions," URL: http://elfin.igpp.ucla.edu/wp-content/uploads/2014/04/TUNA-CAN-ANTENNA-DESIGN-FOR-CUBESAT-MISSIONS.pdf

3) Christopher Shaffer, "A Study on the Usage of TASC and UTJ Solar Cells in the Design of a Magnetically Clean CubeSat," Proceedings of the 27th AIAA/USU Conference, Small Satellite Constellations, Logan, Utah, USA, Aug. 10-15, 2013, URL: http://elfin.igpp.ucla.edu/wp-content/uploads/2013/08/TASCandUTJSolarCellsInAMagneticallyCleanCubeSat.pdf

4) Lydia Bingley, Vassilis Angelopoulos, Ryan Caron, "ELFIN - Electron Losses and Fields Investigation," Proceedings of the 30th Annual AIAA/USU SmallSat Conference, Logan UT, USA, August 6-11, 2016, paper: SSC16-VIII-5, URL: http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=3489&context=smallsat

5) http://elfin.igpp.ucla.edu/

6) http://elfin.igpp.ucla.edu/mission/

7) "ELFIN Overview and Update," 2014, URL: http://elfin.igpp.ucla.edu/wp-content/uploads/2013/08/002-ELFINOverview2014-00-Q.pdf

8) "2018: A Big Year for NASA's Launch Services Program," NASA, 1 Feb. 2018, URL: https://www.nasa.gov/feature/2018-a-big-year-for-nasas-launch-services-program

9) "ELFIN," UCLA, 9 March 2018, URL: http://elfin.igpp.ucla.edu/

The information compiled and edited in this article was provided by Herbert J. Kramer from his documentation of: "Observation of the Earth and Its Environment: Survey of Missions and Sensors" (Springer Verlag) as well as many other sources after the publication of the 4th edition in 2002. - Comments and corrections to this article are always welcome for further updates (herb.kramer@gmx.net).

Spacecraft **Launch** **Sensor Complement** **References** **Back to top**