STEIN (SupraThermal Electrons, Ions and Neutrals), A New Particle Detection Instrument for Space Weather Research with CubeSats

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ABSTRACT

The Space Sciences Laboratory at UC Berkeley is proposing a 3U CubeSat mission, the CubeSat for Ions, Neutrals, Electrons, and MAgnetic fields (CINEMA), to be funded by the NSF Space Weather CubeSat program and Kyung Hee University, S. Korea. CINEMA will have a particle detector called STEIN (SupraThermal Electrons, Ions, and Neutrals), part of a new breed of highly capable, low mass, and low power consumption silicon semiconductor detectors (SSDs). STEIN will measure particles in the ~2-100 keV range and distinguish between electrons, ions and neutrals up to ~20 keV. It will perform fundamental research on magnetic storms and the storm-time ring current, charged particle precipitation, and electron microbursts. STEIN separates electrons, ions, and neutral atoms with an electrostatic deflection system. It has analog electronics with a very low energy threshold and a mechanical attenuator that lowers the particle count by 10^2. Using a data decimation scheme and the attenuator, STEIN can measure particle fluxes as high as 10^8 (cm^2 s sr keV)$^{-1}$. Preliminary tests of a prototype indicate that the electrostatic deflection system works as expected. After a complete set of tests, a flight version of the instrument will be assembled, in anticipation of a possible launch in 2011.

1 INTRODUCTION

The CubeSat platform was originally developed in part to serve as an inexpensive and convenient vehicle for scientific research, and for testing new technologies in space. During its decade of existence, the capabilities of the platform have gradually improved to the point where CubeSat science missions are now becoming a reality. As part of this trend, the National Science Foundation (NSF) is, for the second consecutive year, funding 3U CubeSat missions for space weather research.

The Space Sciences Laboratory at the University of California, Berkeley (UCB/SSL) has proposed a mission for the NSF CubeSat program (which will also have a second identical satellite funded by Kyung Hee University of South Korea) called the CubeSat for Ions, Neutrals, Electrons and MAgnetic fields (CINEMA). The principal science instrument on the CINEMA mission is a particle detector called SupraThermal Electrons, Ions, and Neutrals (STEIN). STEIN will be used both to conduct significant space weather science and to test a vital technology for future space weather missions.

STEIN is designed to measure ~2-100 keV particles and to distinguish between electrons, ions and neutrals up to ~20 keV. The two CINEMA satellites will be placed in a high inclination LEO, spinning at 2 RPM, with an ecliptic-normal attitude. In this orbit STEIN will map energetic neutral atoms (ENAs) from the ring current, measure precipitated charged particles in the auroral zones, and measure electron microbursts.

Energetic particle and plasma measurements are fundamental for space plasma physics and space weather research, and they are needed for a wide variety of space missions, including planetary missions. In particular, to separate spatial and temporal effects for magnetospheric and space physics, multi-point measurements are required – e.g., the currently operating 4-spacecraft Cluster and 5-spacecraft THEMIS missions. In general, resources for scientific payloads are tightly constrained and will be even more so for multi-spacecraft missions, such as magnetospheric constellations that depend on tens (or more) satellites of CubeSat scale. Consequently, the development of miniature, lightweight, low-power instruments such as STEIN is essential.

The previous state-of-the-art detectors for suprathermal particles (below ~20-30 keV), electrostatic analyzers, which have been used on space missions for the past four decades, are difficult to miniaturize and still retain the required sensitivity. STEIN is the second generation of instruments with a new type of silicon semiconductor detector (SSD) that was developed at UC Berkeley and Lawrence Berkeley National Laboratory[1]. The first was the STE (SupraThermal Electrons) instrument, flown on both of NASA's STEREO (Solar TERrestrial RElations Observatory) spacecraft[2]. The small size of the SSD is what allows STEIN to be used in a 3U CubeSat. Unlike STE, STEIN is able to distinguish between ions, electrons, and neutrals due to the addition of an electrostatic deflection (ED) system. STEIN will weigh <0.5 kg and use <550 mW of power, compared to ~3 kg and ~3 W for a typical electrostatic analyzer used for the same purpose[2].

2 SCIENTIFIC OBJECTIVES

The STEIN instrument is the first step in developing miniaturized instrumentation that can measure electrons, ions, and neutrals for a wide variety of space and planetary physics missions. For CINEMA, STEIN will make measurements relevant to magnetic storms, substorms, and particle precipitation, all important space weather research goals. In particular, STEIN will demonstrate a powerful new capability for imaging energetic neutral atoms (ENAs) from LEO with high sensitivity and energy resolution in the ~4-100 keV range and separating ENAs from electrons from ions up to ~20 keV; also noteworthy will be its high energy resolution in-situ measurements of precipitating ions and electrons.

Magnetic Storms and Storm-Time Ring Current

Understanding magnetic storms is important for space physics research and also has practical applications in telecommunications. Magnetic storms are driven by changes in the solar wind, causing the ring current to become intensified in the inner Van Allen radiation belt. Ring current ions may collide with low energy neutral atoms in the upper atmosphere; when this happens, the ions, which would otherwise stay bound to the magnetic field lines, gain an electron, causing them to become ENAs that follow straight-line trajectories from the site of the collision. Imaging ring-current particles by means of charge-exchanged ENAs[3] can therefore provide a quantitative global view of the ring current evolution in space and time. Images from the LEO vantage point are particularly advantageous for extracting the local time dependence of the ring current pressure.

Recent measurements of ENAs from STEREO STE[4] indicate that STEIN will easily detect ~4-100 keV ENAs even at quiet times and in small substorms, as well as during storm times. CINEMA's STEIN instrument will image ENAs from the ring current and substorm injected particles in local time at a cadence as fast as 30 s (the satellite spin period), for energies of ~4-20 keV (the energy range of most ring current ions). The spin axis and imaging plane of STEIN have been specifically chosen to rapidly image the storm-time asymmetric ring-current pressure distribution.

Charge Particle Precipitation

Charged-particle precipitation, the raining down of energetic particles from space into the high latitude atmosphere, occurs in many forms and is intimately tied to injection of particles during magnetic storms and magnetospheric substorms. CINEMA imaging of ENAs in an inclined orbit can thus map ring current precipitation losses while imaging the trapped ring current as well, in the energy range covering the bulk of the ring current ions. In addition, CINEMA will also make direct in situ measurements of the precipitating ions (utilizing its charged particle measurement capability) while traversing the footpoints of ring-current field lines. This combination enables quantitative evaluation of ring-current precipitation losses, and measurement of the scale size of the wave-particle interaction regions. Auroral ion and electron precipitation has previously been studied in detail by FAST electrostatic analyzers from plasma energies to ~30 keV[5]. STEIN extends the energy range of in situ electron and ion measurements to ~100 keV with a single detector.

Electron Microbursts

Electron microbursts are short (~0.25 s) bursts of precipitating electrons that have been detected from tens of keV to >MeV. They are thought to occur due to rapid pitch angle diffusion by wave particle interactions, but the rapid filling of the loss cone has yet to be explained[6]. Accurate measurement of the cutoff energy in microburst energy spectra is important for determining the physics that precipitates these electrons. CINEMA will measure precipitated microburst electrons with a single detector that covers the energy range across the electron energy cutoff (around tens of keV), with energy resolution of ~1keV, and sufficient time resolution to observe microburst shape and any dispersive effects.

3 INSTRUMENT OVERVIEW

STEIN is a new instrument designed to enhance the capabilities of STE and to have a form factor, mass and power consumption suitable for use in a 3U CubeSat.

At UCB/SSL, an engineering test unit (ETU) has been assembled and partially tested. The instrument consists of a housing that includes a collimator, an electrostatic deflector, an attenuator mechanism, the detector (and signal processing electronics), and structures for mounting the instrument to the CubeSat chassis (See Figure 5). Separate from the instrument housing are also high voltage (HVPS) and low voltage (LVPS) power supplies.

The STEIN SSD, shown in Figure 1, is identical to that used in STE, and described in detail previously[1, 2]. The detector consists of a row of four 0.09 cm^2 pixels on a 3.5 cm square ceramic PCB. The range of particles detected is ~2-100 keV for electrons, and ~4-100 keV for ions and neutrals. The energy resolution varies from ~1 keV (low range) to 0.2 keV (high range). In addition to energetic particles, the SSD is also sensitive to visible and UV light and X-rays. To reduce the amount of incident and scattered light striking the detector, the aperture of STEIN has a collimator with a set of five blackened optical baffles (See Figure 2). The baffles will primarily be of use when the instrument FOV is near the Sun or the Earth. The entrance aperture is 60° along the spacecraft axis of rotation and ~40° in the plane of rotation.

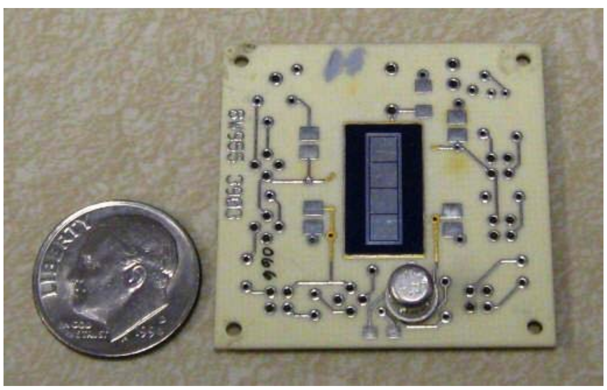

Figure 1 Silicon Semiconductor Detector, Showing the 1 x 4 Pixel Array

Interior to the collimator is a parallel plate electrostatic deflection (ED) system that can be charged up to ±2000 V. Electrons and ions are swept to opposite sides, where they are measured by the two edge pixels on the detector, while neutrals (un-deflected) and higher energy (less deflected) ions and electrons strike the center pixels (See Figure 2).

In the space between the ED plates and the detector is a mechanical attenuator that, when closed, reduces the number of particles striking the detector by a factor of one hundred. The attenuator mechanism is mounted on one side of the housing exterior. The SSD, and two larger PCBs, that mount at the rear of the instrument, are surrounded by a light-tight aluminum cover.

The estimated totals for mass and volume for STEIN are shown in Table 1. The power consumption is expected to be 290 mW for the signal processing electronics and 250 mW for the HVPS.

Table 1 Mass and Volume of STEIN Components

Component	Mass	Volume Envelope
Housing & Cover	150 g	380 cc
Detector Electronics	90 g*	Included w/ Housing
Attenuator Mechanism	70 g	140 cc
HV Power Supply	75 g*	75 cc*
Total	385 g*	670 cc

* Estimated Value

4 ELECTROSTATIC DEFLECTOR

Space physics particle detectors must meet a variety of competing requirements. Generally, an instrument must measure charged and/or neutral particles over a wide range of energies and angles, with high sensitivity, energy resolution, and angular resolution, while still fitting within the often tight requirements on mass, power, and volume.

A number of compromises have been developed to accomplish this task. One standard instrument for measuring charged particles, the electrostatic analyzer, uses two hemispherical sections with a deflection voltage between them to select charged particles of a given energy and species; these particles enter the analyzer and follow curved trajectories through the deflection region between the two plates to reach an anode assembly. These instruments have very good energy and angular resolution, and select a single charged species very well, but have lower sensitivity, unless very massive, and cannot measure neutrals.

On the other hand, another standard instrument, the solid state detector, can have very high sensitivity and low mass, but generally has a lower energy resolution and a higher energy threshold. A solid state detector also has no way to select between charged particles (or neutrals) without some separation mechanism. The STEREO STE instrument took a step towards solving one of these problems by using detectors with very thin dead layers, and state-of-the-art electronics, to reduce the energy threshold from the usual ~20-30 keV for a solid state detector to ~1-2 keV[2].

In concert with some mechanism for separating different species of charged particles and neutrals, this type of detector therefore could provide a very capable instrument. Unfortunately, a standard scheme for separating ions and electrons using foils and magnets will not work for these particle energies. The stopping power for electrons and ions in a foil is nearly identical at ~1 keV, so one cannot use a foil to stop ions while allowing electrons to pass, as is generally done for higher energy particles.

For STEIN, therefore, an ED system was chosen, thereby combining some features of electrostatic analyzers and solid state detectors. Unlike the curved deflectors of electrostatic analyzers, STEIN has a linear deflection area with a sweeping voltage between two deflector plates. This symmetric arrangement allows measurements of both electrons and ions with one instrument. The detector consists of a 1 x 4 pixel array, behind the deflection plates, oriented with the long axis of the array perpendicular to the plane of the deflectors (See Figure 2).

The ED system has been designed such that, for a given deflection voltage, charged particles of one sign are deflected one direction and measured in one edge pixel, while charged particles of the other sign are deflected to the other edge pixel. Higher energy charged particles are not deflected as significantly, and are measured in the two center pixels.

The charged and neutral particle optics of the STEIN instrument were designed by first using a simple approximation of a constant electric field between the deflector plates and simulating particle trajectories in order to perform a basic optimization of the instrument geometry. Given the 1 x 4 pixel layout, an optimal balance was created between two tradeoffs: total deflection and sensitivity. Longer deflection plates and a narrower gap between them produce greater total deflection, but with a corresponding loss in sensitivity and angular acceptance.

After this initial design phase was complete, a full Laplace solver was used to determine the actual electric field distribution for arbitrary deflection voltage, and then the particle tracing simulations were repeated. A Runge-Kutta integration (with adaptive time step) was used to solve the Lorentz equations for charged particle motion, in order to accurately determine the response of the STEIN instrument to electrons and ions. Traces for Neutral particle trajectories were simulated as straight lines constrained by the geometry of the ED plates.

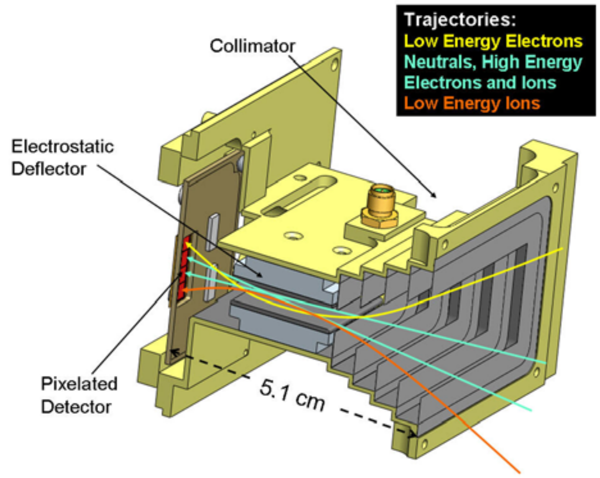

Figure 2 Cutaway View of STEIN Showing Electrostatic Deflection (Attenuator Not Shown)

Figure 3 (top) shows the simulated response for one species of charged particles in one edge pixel, for the maximum deflection voltage, and Figure 3 (bottom) shows the corresponding simulation for a center pixel. For a smaller deflection voltage, the energy response is simply shifted proportionally to lower energies. Thus, by sweeping the deflection voltage over the full range of ±4 kV (±2 kV on each plate), a range of energies and angles for both electrons and ions can be measured. Since the energy of each particle is measured in the detector, the resulting measurements can then be deconvolved to determine the angular distribution as well as the energy spectrum of the charged particles.

Meanwhile, neutral particles pass through the entrance aperture unaffected by the deflection voltage, and are also measured in the center pixels. For the highest deflection voltage (Figure 3, bottom), charged particles up to ~20 keV are completely excluded from the center pixels (instead swept away to the sides), and clean measurements of neutral particles can be obtained from ~4-20 keV in the center pixels. STEIN therefore allows measurements of electrons, ions, and neutrals all in one miniaturized package with very low mass and power requirements.

5 ELECTRONICS

Power Supplies

STEIN is fed by two different power supplies. An LVPS on the CINEMA bus uses COTS converters and switching regulators to convert the unregulated spacecraft bus voltage (~8V) into voltages used by the various instruments, as well as magnetic torque coils (+/-12V, ±5V, 3.3V, 1.5V).

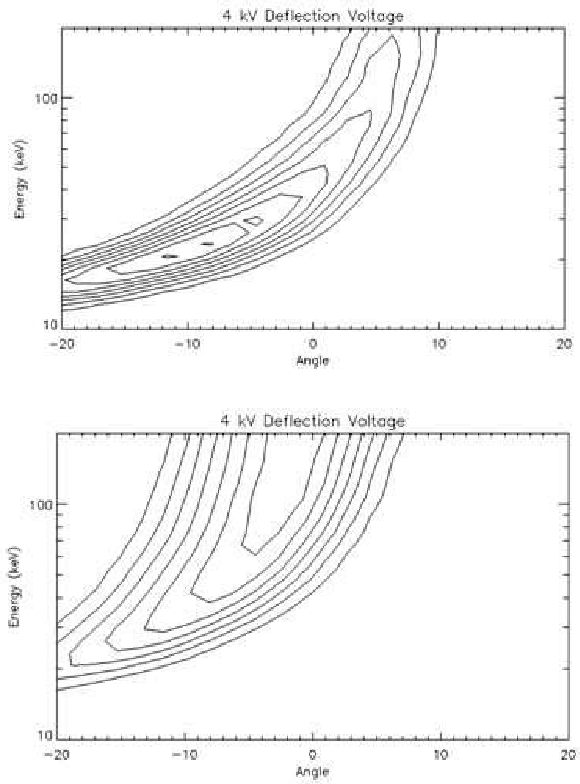

Figure 3 Simulated Response to Charged Particles at the Maximum Deflection Voltage for an Edge Pixel (Top) and a Center Pixel (Bottom).

A separate HVPS, controlled by the Instrument Digital Electronics (IDE, see below), converts spacecraft bus voltage into a pair of programmable high voltages to bias the STEIN electrostatic deflectors. The HVPS first generates fixed +2 kV and -2 kV supplies using a standard voltage multiplier scheme. A pair of high voltage optocouplers connects each output to the ±2 kV supplies. A feedback loop sets the output voltage to the desired level by modulating the current provided from the ±2 kV supplies via the optocouplers. The HVPS also contains the bias circuit for the STEIN detectors, (also controlled by the IDE), which can be programmed from zero to 150V.

Instrument Digital Electronics

The STEIN, as well as other instruments aboard CINEMA, is integrated to the Command and Data Handling System (C&DHS) via the Instrument Digital Electronics (IDE). This is an FPGA-based system that controls instrument operations and collects instrument telemetry under the control of the C&DHS. The IDE also provides the stream of science data to the C&DHS.

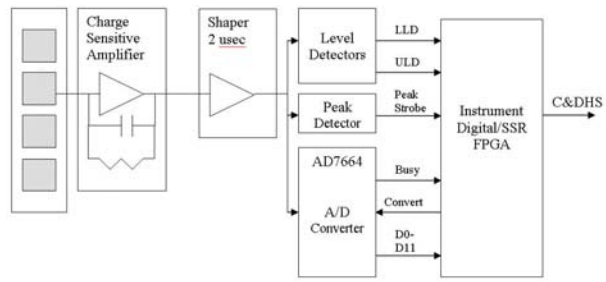

Figure 4 Schematic of STEIN Signal Processing Chain for Each of the Four Detector Pixels.

Signal Processing

The STEIN signal processing electronics, diagramed in Figure 4, are based on those for STEREO STE but, to minimize mass and power, are simplified by the elimination of pulse-reset circuitry and the use of smaller, surface mount components. The signal from each SSD pixel goes to a conventional charge sensitive amplifier with dual gate input FETs, to achieve low noise performance (a background of ~1 c/s, compared to ~20 c/s for an electrostatic analyzer[2]). The output goes to a 5-pole unipolar shaping amplifier with a 2 μsec shaping time - the same low power design as STE. This circuit includes comparators to provide low level and upper level discriminators and a peak detector to indicate when the A/D conversion should take place. The outputs of the peak detector and discriminators go to an ACTEL FPGA that controls the A/D converters, acquires the data and then passes it to the C&DHS. This is essentially the same design used in STEREO STE, and it will use the same components, which are already known to function successfully in the space environment. This exact design has been prototyped for another instrument that uses the STE detectors.

6 MECHANICAL DESIGN

Instrument Housing

The STEIN ETU housing is a single piece of machined aluminum. The housing can be divided into five functional and physical areas: the collimator, the ED, the attenuator mechanism, the detector and signal processing electronics, and structures for mounting the instrument to the CubeSat chassis (See Figure 5). The inner surfaces of the collimator and ED sections are painted flat black with Aeroglaze® Z307 paint.

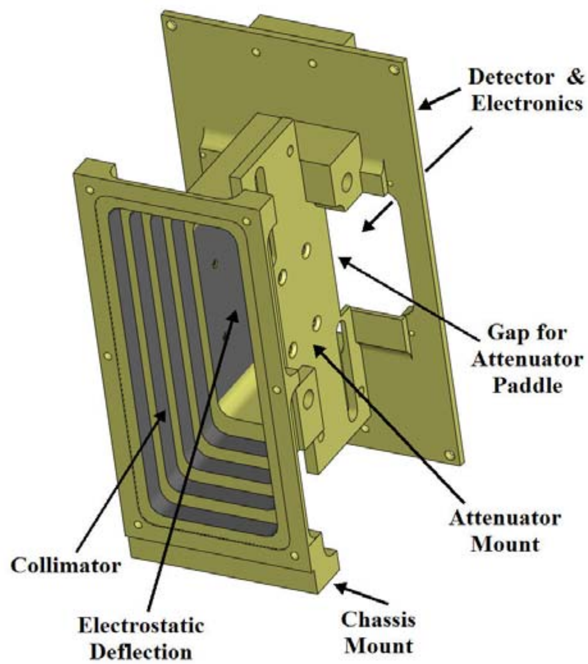

Figure 5 STEIN Housing, Showing the Five Functional Areas

Collimator

A set of five baffles of decreasing size creates a 60° x 40° entrance aperture. The baffles themselves are made of 0.002 inch (0.05 mm) thick copper plated BeCu that are surface treated with Ebanol C to give them a flat black finish. Each baffle is fastened to the housing with epoxy. The geometry of the baffles is such that stray light will reflect against the baffles multiple times, decreasing significantly the amount of light reaching the detector. Any particles striking the baffles are also absorbed.

Electrostatic Deflector

Interior to the baffles the ED plates lie inside a chamber of rectangular cross section, separated by a distance of 4 mm. Each plate is made of 0.032 inch (0.81 mm) thick copper, with dimensions of 1.1 x 0.80 inches (2.8 x 2.0 cm). All exposed copper surfaces are blackened with Ebanol C. Each plate is epoxied to a G10 fiberglass isolator; the isolator in turn is fastened to the housing wall with screws. The high voltage wire from each ED plate terminates in an external high voltage connector.

Attenuator

The attenuator mechanism mounts as a single module onto one side of the ED area and the shutter paddle passes through a rectangular opening in the housing on that side (See Figure 5 and Figure 8). The attenuator itself is a rectangular piece of photo etched BeCu foil (0.002 inches (0.05 mm) thick, inlayed in an aluminum frame paddle (See Figure 6). The foil has four sets of nine holes. Each hole is 0.0047 inches (0.12 mm) in diameter, and each set of nine holes is centered over a pixel. The total area of the holes equals one percent of the detector area.

The mechanism for pivoting the paddle is an adaptation of a design used on the five-satellite THEMIS mission, which was in turn adapted from a sensor cover door mechanism used on the STEREO STE instrument[2]. It uses two opposing linear actuators to toggle the paddle through an angle of 35°, between its open and closed states. In either of these two states a detent on one of two cams on the pivot shaft engages with a roller follower. A spring plunger acts on the roller to create a force that prevents the shaft from turning, except if the shaft is rotated by one of the opposing linear actuators. The linear motion of each actuator is converted to rotary motion via a flexible Kapton® yoke acting on a shaft-mounted pulley (See Figure 6).

The linear actuators, called *NanoMuscles*, are powered by shape memory alloy (SMA) wires. SMA materials are capable of contracting a repeatable amount when heated by a current passing through them, and expanding to their original length when the current is shut off and they cool. A NanoMuscle actuates by means of a stack of seven laminations that are pulled together by six SMA wires. In a method analogous to how biological muscles work, each layer contracts a small amount (4 percent of its length) and the sum of these contractions makes for a usable stroke length[7], in this case 3 mm. In order to increase its robustness agains launch vibrations, the Nanomuscles are mounted to a fixture made of Vespel® SP3 plastic, shown in Figure 7.

The Nanomuscle is very advantageous for the STEIN attenuator application because of its small size, low mass (2.9 g with the base) and low power consumption. It also has the advantage of producing much less of a magnetic field than electromagnetic actuators, eliminating the requirement for magnetic shielding for magnetically-sensitive missions (CINEMA will have two sensitive magnetometers on board).

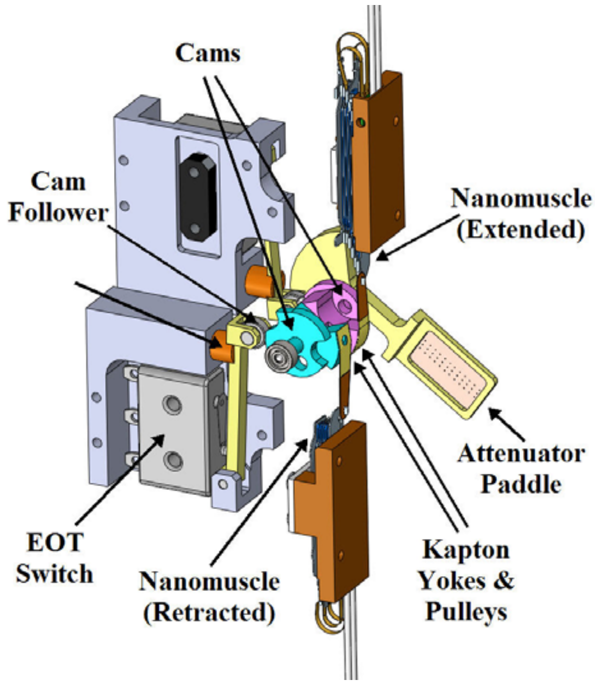

Figure 6 STEIN Attenuator Mechanism in the Open Paddle Position

When transitioning from one paddle state to the other, the appropriate NanoMuscle contracts, causing the shaft to turn, overcoming the spring plunger force on the cam follower, and bringing the roller up and out of the detent. Just before the roller reaches the cam OD, an end-of-travel (EOT) switch, connected in series to the NanoMuscle, is opened, cutting off the electrical power. At the same moment that this roller is exiting its detent, the opposite cam turns such that its roller enters its respective detent, propelled by the force of its spring plunger, causing the mechanism to snap smartly into the opposing state. In doing so, a second EOT switch closes, priming the second NanoMuscle to reverse the paddle state whenever it next receives electrical power.

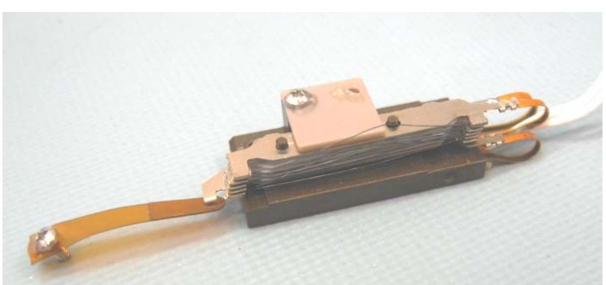

Figure 7 Nanomuscle (Retracted) on Vespel® Base with Kapton® Yoke

Detector Electronics Mounting

The SSD board screws into an aluminum standoff frame that in turn screws into a pocket in the back of the instrument housing. A larger PCB, with the analog amplifier circuitry, screws into the other side of the standoff, and a third PCB, the A/D converter, attaches to the second board via two other standoffs along the edge. The rear of the SSD is also sensitive to light, so all three PCBs are covered with a light-tight aluminum cover (See Figure 8).

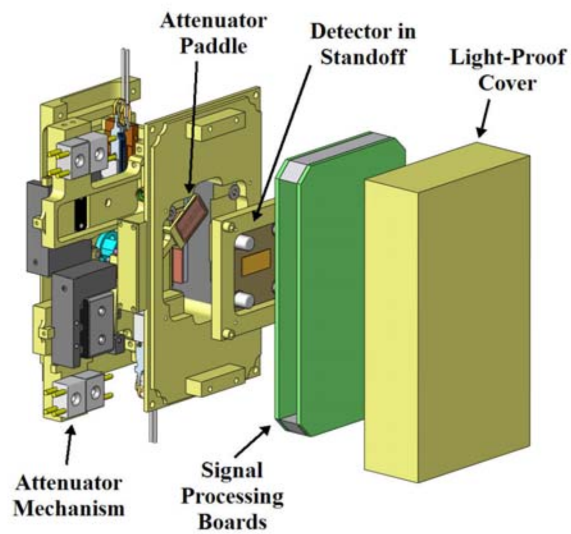

Figure 8 STEIN Exploded View, Showing Arrangement of Detector and Signal Processing Boards

7 MODES OF OPERATION & DATA FORMAT

STEIN has two electronic modes of operation (Normal and Decimation) and two mechanical modes (Attenuator Closed and Open), for a total of four possible operational modes. In Normal electronics mode, every particle event detected by STEIN is stored in the C&DHS memory and downlinked. The data storage format is 8 bits for particle energy (~0.4 keV resolution), 2 bits for pixel ID and 6 bits for time stamping (~15ms resolution). Whenever the predicted telemetry bandwidth will not be sufficient to downlink the science data stored in the C&DHS memory, Decimation mode reduces and downlinks the amount of data by a factor of ~1/N (where N = 4, 16, 64, etc.). This scheme is used very successfully with sensors on the RHESSI spacecraft, operated by UCB/SSL, to deal with intense solar flares.[8]

The SSD saturates above 30,000 counts per second. During times when the count rate approaches this level, the attenuator will automatically close, reducing the detector counts by a factor of one hundred. Table 2 gives the predicted particle fluxes and instrument count rates. Except during intense auroral precipitation, information on every particle detection will be downlinked to the ground, providing complete flexibility in the data analysis.

Table 2 Expected Count Rates and Operational Modes for the STEIN Instrument

Scientific Observation	Expected Flux @ ~10 keV (cm^2 s sr keV)$^{-1}$	Mode (Electronic Mechanical)	Avg. Counts/Sec
Ring Current ENAs	~10^3 *	Normal Open	300
Low Altitude ENAs	~10^4 *	Normal Open	3×10^3
Auroral Protons	~10^5 **	Normal Closed	30
Microburst Electrons	~$10^{6\dagger}$	Normal Closed	300
Auroral Electrons	~10^8**	Decimation Closed	~3×10^4 (before decimation)

Instrument Geometric Factors (cm^2 sr): *0.02; ** 3 x 10^{-5}; †0.003

8 TESTING PROCEDURE

The attenuator mechanism was assembled and calibrated and it performs nominally. The assembled STEIN ETU (Figure 9) was integrated with a computer controlled three-axis manipulator that was in turn integrated into a vacuum chamber equipped with an electron gun and an ion source. A set of initial tests has been performed with 15 keV electrons and the ED voltage swept from 0-2000 V. During the tests, a vacuum pressure of less than 10^{-5} Torr was maintained. In future tests, a range of electron energies, and also ions, will be tested and the three-axis manipulator will be used to vary the detector angle throughout the range of the instrument. Tests will also be performed with the attenuator in its closed position.

9 PRELIMINARY TEST RESULTS

Table 3 shows the results for one of the preliminary tests with a 15 keV electron beam. At lower voltages all of the incoming electrons struck the two center pixels (except a few percent scattering). As the voltage was increased counts shifted away from the center toward the edge pixel on the positive voltage side, while the opposite edge pixel never measured high counts. Other tests showed that above ±400 V the electron trajectories were bent so much that they missed the detector completely, i.e., the upper energy limit of STEIN will be significantly higher than 15 keV. These initial tests indicate that the ED system works nominally with electrons. Ion rejection by STEIN is expected to be even better since ion scattering is less efficient.

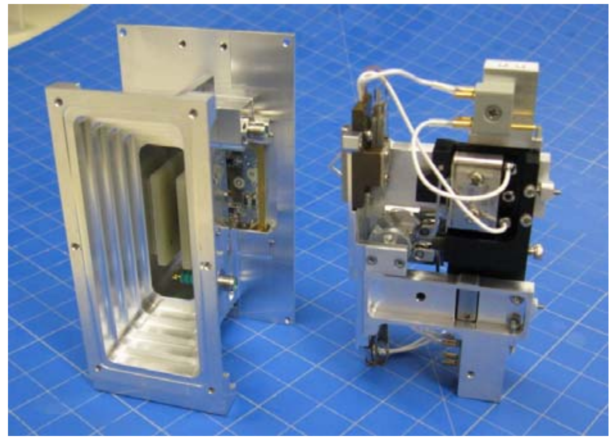

Figure 9 Housing and Detector (Left), Attenuator Mechanism (Right)

Table 3 Preliminary Test Results with 15 keV Electrons (Counts Per 2 s Integration)

ED Voltage	Pixel 1 (+ V)	Pixel 2	Pixel 3	Pixel 4 (- V)
±400	100-120	10-20	10-20	≤ 20
±300	100-120	10-20	10-20	≤ 20
±250	80-100	300	10-20	≤ 20
±200	20-40	400-500	10-20	≤ 20
±150	0-2	500-600	10-20	≤ 20
±50	0-2	500-600	100-200	≤ 10
0	0-3	300-400	200-300	0-3

10 CONCLUSION

The success of the STEIN instrument in the CINEMA mission would provide important new space weather data and would represent a significant technological improvement in suprathermal particle detectors for space missions. In particular, it would help pave the way for an important goal of space weather science: the placement in orbit of constellations of small satellites with similar particle detectors to obtain multi-point observations of important space weather phenomena.

A STEIN ETU has been assembled and partially tested, and initial test results indicate that the instrument works as expected. A complete battery of tests using electrons, ions, and the attenuator, will be performed in the summer of 2009. Vibration and Thermal Vacuum Chamber tests will also be performed. Flight versions of the instrument will then be designed and assembled in preparation for a possible launch on the CINEMA CubeSat mission in 2011.

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