# The Low Energy Electrostatic Analyzer (LEESA) for DSX


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## Abstract

The Low Energy Electrostatic Analyzer (LEESA) is a 90° quadraspherical ESA designed for the Demonstration and Science Experiments (DSX) satellite. LEESA measures electron and ion fluxes from 30 eV to 50 keV. LEESA has two input apertures with the same fields of view (FOV), one for ion and one for electron measurement. LEESA measures the directionality of the particles by offering 5 angular zones within a 110° FOV. LEESA is designed to operate at two different data rate levels, sampling once per 0.0125 sec or once per 0.125 sec. Here we discuss the design characteristics, performance, and operation of the LEESA instrument.


## Instrument Description

LEESA determines the arrival energy of charged particles by allowing incoming particles to traverse a 90° spherical electrostatic analyzer (ESA) also referred to as a quadrasphere. The ESA consists of two oppositely biased quadraspherical electrode shells. As a charged particle passes through the plates its path is deflected toward the inner sphere by the potential difference between the shells. A cutaway view of the instrument showing the arrangement of the hemispheres, apertures and micro-channel plate (MCP) detectors is shown in **Figure 1**.

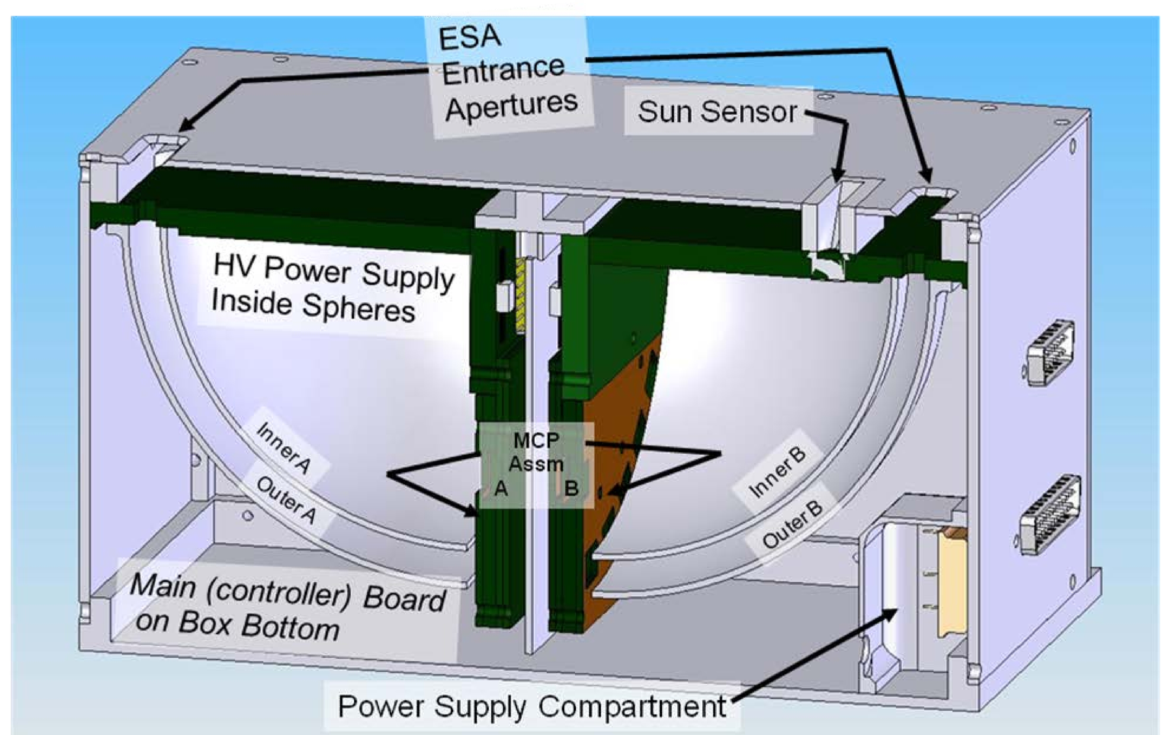


**Figure 1.** This cutaway view of LEESA shows the general arrangement of its major components. The 90° ion and electron analyzers are mirrored on either side of the instrument. The MCP detector assemblies are located in the center of the box.

The degree to which the path is deflected is determined by the magnitude of the potential difference between the deflector plates. The particles that successfully traverse the ESA plates pass through a grid and are post-accelerated onto an array of MCPs. The MCPs are charge multipliers and produce an electron cascade that is collected on an array of anodes. The MCPs and anodes are arranged in such a way as to give the instrument coarse angular resolution along the unfocused angle. Both the electron and ion ESAs have collectors divided into five zones of varying angular size.

LEESA is equipped with a sun sensor that can be used to safely reduce multiplier voltages in the event that solar illumination saturates the instrument. This helps reduce risk of damage to the multipliers and simplifies operations. The sun sensor can be disabled if necessary.

## Orientation on DSX

LEESA is mounted on the DSX science instrumentation module with a field of view overlapping a number of other particle instruments. One zone of LEESA is nominally in the loss cone while the other 4 angular zones are outside of it. **Figure 2** illustrates the orientation of LEESA and its fields of view on the DSX satellite.

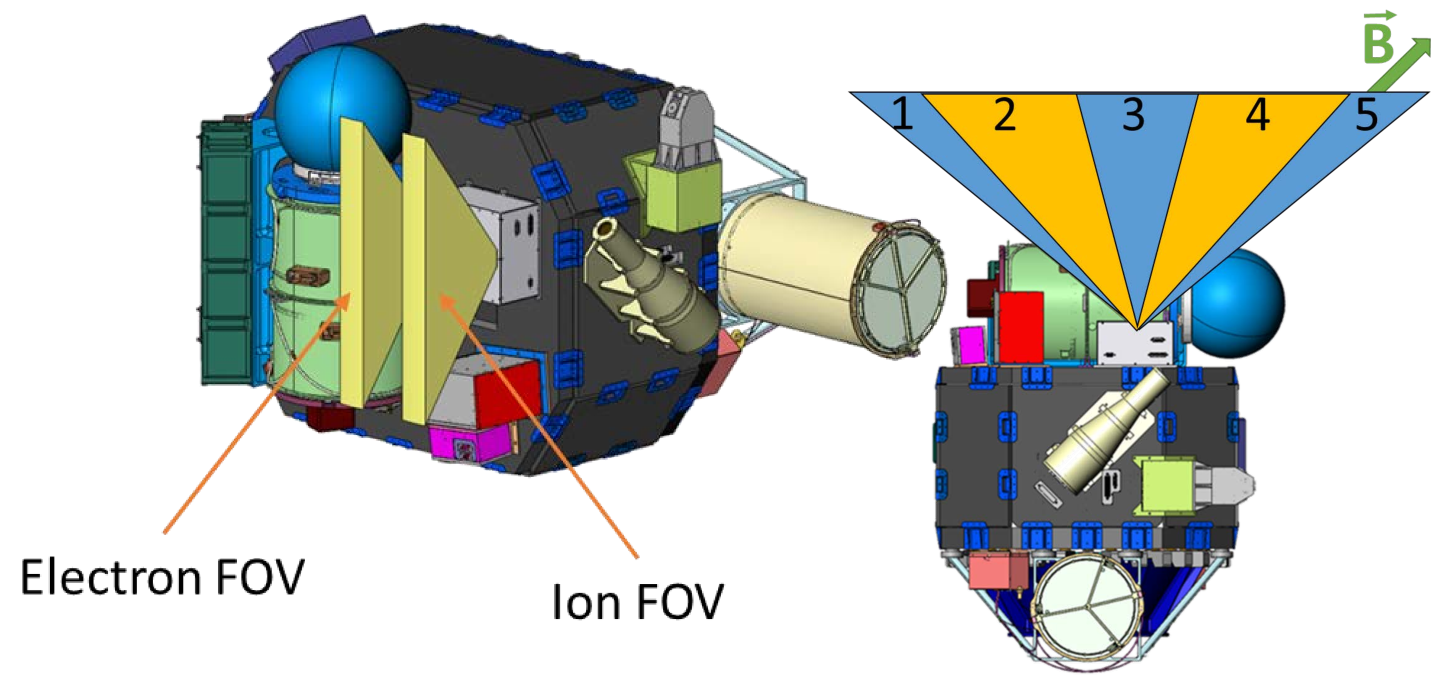


**Figure 2.** These views of the DSX instrument module show the placement of LEESA relative to the other experiments and illustrate the 5 field-of-view zones.

## Mode of Operation

LEESA is capable of storing a number of fully flight programmable energy scan patterns. That is, LEESA is not limited to slewing through all 256 energy bands sequentially; it can be repeatedly reprogrammed to execute complex energy scans that fit the needs of individual experiments. For example, LEESA could dwell at a particular energy for some time and then scan a broader energy range. The goal is for LEESA to be able to support a number of experimental modes and adapt to changing mission requirements.

LEESA stores the programmed scans as a series of lines, pages, and books. A line consists of 40 energy values, a page consists of 32 lines, and a book contains 4 pages. LEESA can store 32 unique line sets, 32 pages sets, and 4 book sets (2 for each data rate). In flight, LEESA will run through books, pages, and lines sequentially allowing for a tremendous number of allowable scan patterns.

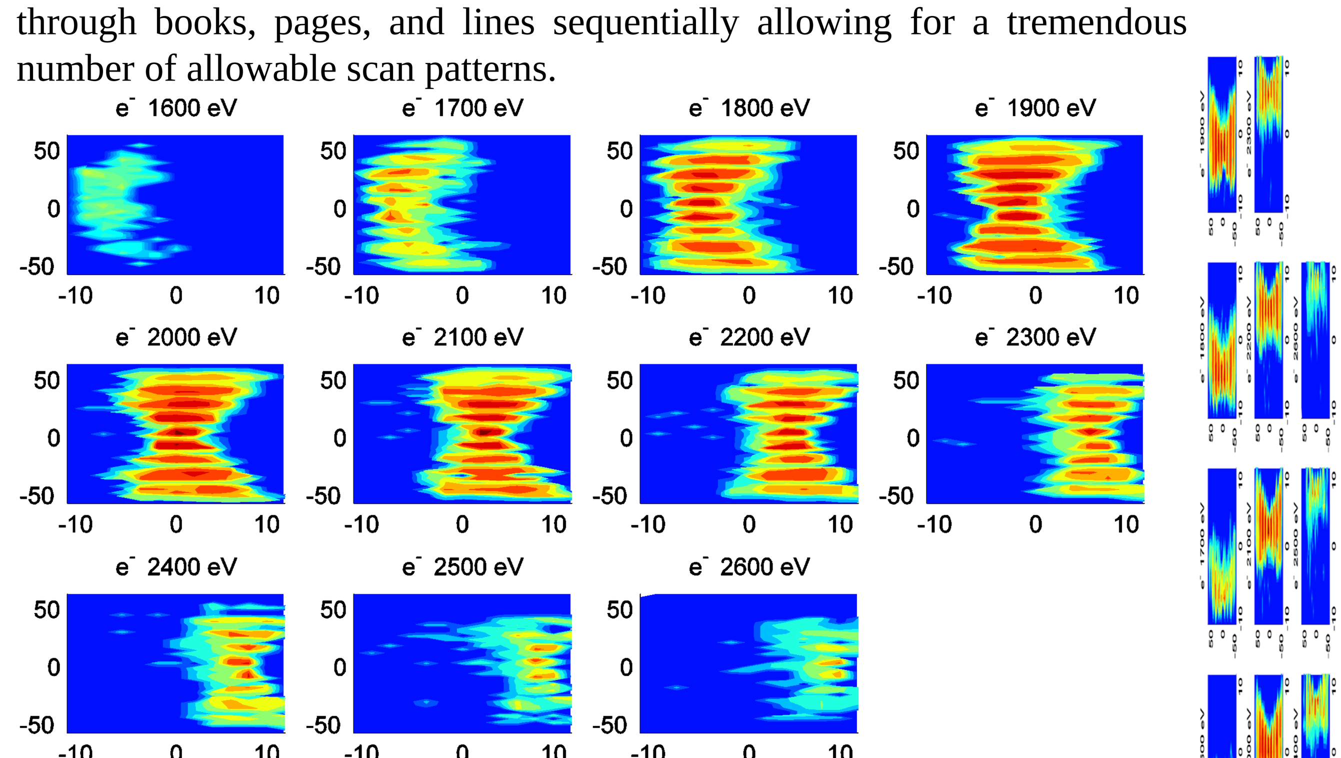


**Figure 3.** Counts observed by LEESA during calibration run 908e001. The vertical axis corresponds to unfocused angle, the horizontal axis to focused angle, and intensity corresponds to log(counts/sec).

## Calibration

A set of raw electron counts for one electron calibration run performed on 8 September 2010 (file identifier 908e001) is shown in **Figure 3**. The instrument was scanned from -57° elevation (unfocused angle) to 63° in 40 steps of 3°. At each elevation angle, the instrument was scanned from ±12° in 12 steps of 2°. At each of the 533 angular orientations of the instrument, the electron beam was stepped over 11 discrete energies from -1600 eV to -2600 eV in -100 eV steps. LEESA was commanded to an ESA bias command of 178 for this run. The counts recorded by the instrument at each position and energy are shown as intensity plots in **Figure 3**.

The ESA central band-pass energy was set to -2 keV for this sample run and as such the beam appears most centered for the -2 keV scan. The individual MCPs' active areas are clearly visible as horizontal stripes at each energy level. Another important feature that can be seen is that the acceptance of the focused angle grows larger as you move away from incidence normal to the LEESA aperture. The zones at the edges of the instrument are much broader in focused angle acceptance at a given energy than at the center. The 10th electron MCP associated with zone 5 is shadowed by the MUMBO calibration fixture and so does not appear at an elevation angel of -51°. An immediately obvious feature is that the angles at which the beam can be seen by the instrument clearly vary with beam energy. This behavior is expected and model results match the observed behavior.

The LEESA calibration was performed in the MUMBO calibration facility, then at Hanscom AFB, during September and October of 2010. A total of 11 electron and 9 ion energies make up the calibration. A fraction of the calibration scans were performed after environmental testing. LEESA was removed from the DSX satellite in 2014 for a calibration and multiplier health check, both of which were satisfactory.

## LEESA Science Objectives

LEESA supports the primary DSX experiment which is active VFL transmissions to observe wave-particle interactions in the medium Earth orbit (MEO) radiation belt region. Observed particle fluxes in the LEESA energy measurement range will allow diagnosis of electrostatic sheath dynamics and local plasma heating which is a potential sink of injected VLF. During high power transmissions, the LEESA survey mode will be high cadence sampling of energies selected for this diagnosis.

The secondary DSX experiment includes a suite of five particle instruments to characterize the energetic particle environment in MEO across energies from eV to 10-100 MeV. LEESA covers the lower portion of this energy range. The instrument will observe ring current and radiation belt seed populations. It is not designed to sample the low energies of the cold plasma that forms the bulk of the plasmasphere (though it may sample the energetic tail of this distribution). At energies observed by LEESA, there are significant longitudinal variations in plasma densities. The DSX orbit (2-3 $R_E$, 42° incl.) is well suited for sampling these variations. Such investigations will benefit from the flexibility of survey programming supported by LEESA, e.g., sampling of a subset of the instrument's energy measurement range at high time cadence.

In addition to science applications, LEESA data will be incorporated in a future version of the plasma component of the AE9/AP9/SPM radiation belt and space plasma model suite.

## Performance characteristics

LEESA was designed to have a large geometric factor and large ΔE/E to support the DSX active wave-particle interaction experiments. Calibration of the instrument indicates that LEESA has a ΔE/E of 21%. **Figures 5 and 6** show the LEESA energy-dependent geometric factor. The LEESA zones have an unfocused angle full width-half max (FWHM) FOV between 10° and 20° with the zones on the edge having the largest FOV. The individual MCPs have an unfocused angle FWHM FOV of 7°.

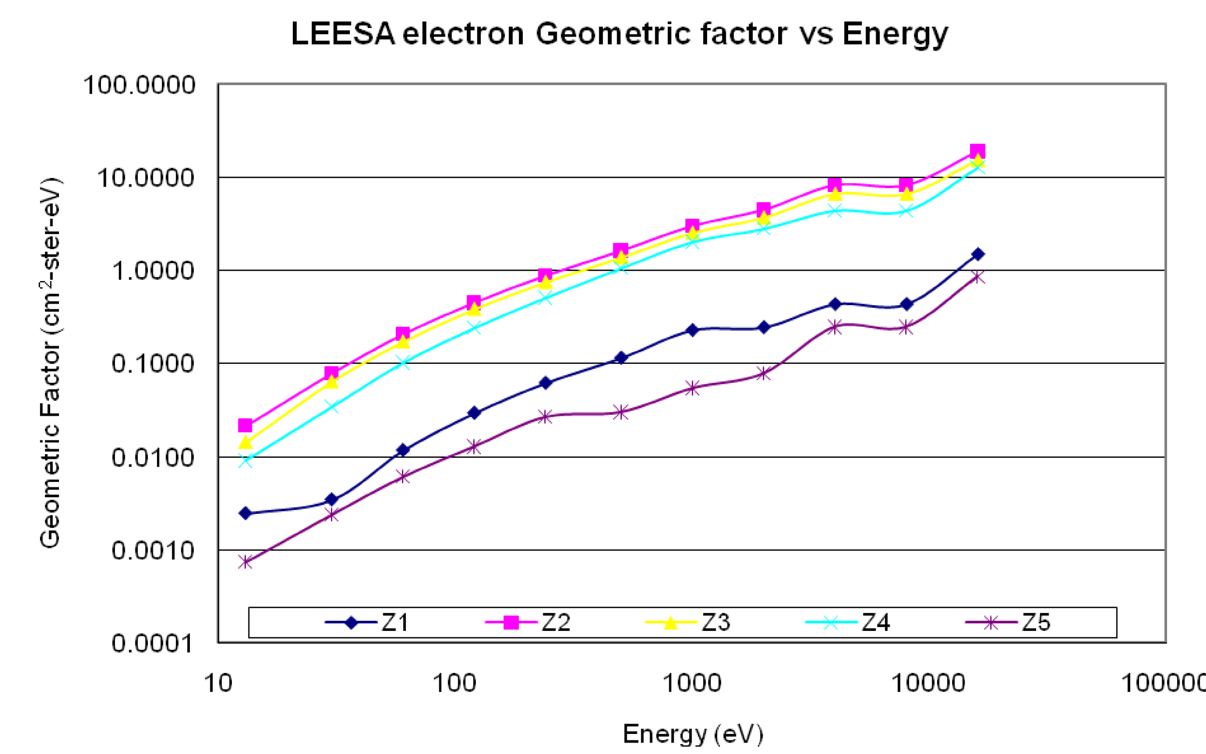


**Figure 5.** LEESA electron geometric factors

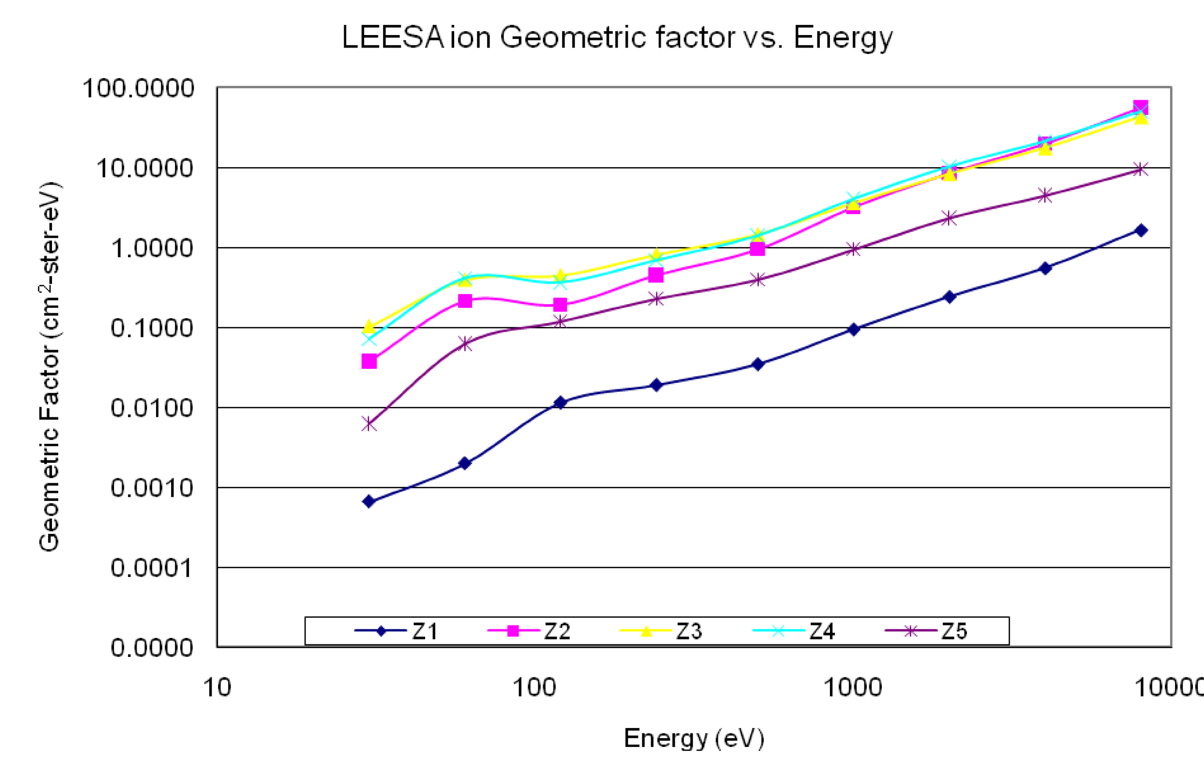


**Figure 6.** LEESA ion geometric factors


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