Description of the Vector Electric Field Instrument (VEFI) on the C/NOFS Satellite

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The vector electric field instrument (VEFI) on C/NOFS consists of one central electronics box that receives inputs from electric field double probes, a fixed-bias Langmuir probe, a flux-gate magnetometer, and a lightning detector. All of the instruments were designed, built, and tested at the Goddard Space Flight Center with the exception of the lightning detector that was designed at the Univ. of Washington (R. Holzworth and M. McCarthy, lead Co-I's), although fabricated and tested at Goddard. The VEFI instrument is thus one experiment with many sensors. The main data features of the VEFI instrument and the principal data products are described below and summarized in the attached table.

Electric Field Booms and Sensors. The central VEFI instrument is the 3-axis electric field detector that gathers DC and AC (or wave) electric fields using the double probe technique. The instrument includes six 9.5m booms with 12 cm diameter spherical sensors with embedded pre-amps. The booms are similar to those flown on the Dynamics Explorer-2 (DE-2) satellite [Maynard et al., 1981], except that the spherical sensors are placed on the ends and are connected with wires down the center of the booms. Shadow equalizers extend past the spheres to minimize photoelectron current imbalances. The booms are oriented to provide 3 orthogonal 20 meter tip-to-tip double probes that are used to detect the vector DC and AC electric field. Two of the boom pairs are in the orbit plane and hence are primarily near the plane perpendicular to the magnetic field. Inner cylindrical electric field sensors comprised of 25 cm bare aluminum are situated 2 m in-board of the outer spheres. These sensors, similar to those used on DE-2, provide a second, independent electric field solution.

DC Electric fields**.** Vector DC electric fields are gathered by digitizing with 16 bits the potential differences between opposing sensors at 16 s/sec. Offsets and $\mathbf{V} \times \mathbf{B}$ electric fields are subtracted using either the measured or the model magnetic field, and the solution is then rotated from the spacecraft frame into geomagnetic and other meaningful coordinate systems. Advanced processing techniques to subtract contact potentials and assure high quantitative accuracy are in development. The DC-coupled electric field data can also be sampled at higher rates (up to 32 ks/sec) in the VEFI burst memory described below.

AC Electric fields. Broadband AC or wave electric field measurements are gathered continuously at 512 s/sec in the nominal mode or at 2048, 4096, or 8192 s/sec in the fast or "campaign" mode. A 12 channel filter bank gathers continuous data in logarithmically spaced frequency bands from 3 - 8000 Hz at 0.75 spectra/sec. On-board FFT computations provide VLF power spectra. Higher frequency components are also available.

DC Magnetic fields. Vector DC magnetic field data are gathered with a flux-gate magnetometer extended on a 0.6 m boom with active thermal compensation at the sensor location. The three magnetometer components are digitized at 1 s/sec with the same 16 bit A/D that sample the DC electric field data and are gathered with ±45,000 nT dynamic range.

AC Magnetic fields. AC or wave magnetic field components are gathered by passing the same DC magnetic field components through a bandpass filter with gain. The resulting three AC magnetic field components are digitized with 16 bits at 16 s/sec with ±900 nT dynamic range.

Relative Plasma Density. Relative plasma density data are gathered in a fixed-biased mode to collect ion current. The VEFI plasma density sensor is a 2.5 cm diameter sphere extended on a 0.5 m boom below the spacecraft. The data are nominally sampled at 16 s/sec, but can also be sampled in a broadband mode at 512 s/sec and 2048, 4096, and 8192 s/sec (fast mode) by the same A/D converter that samples the wave electric field data. The plasma density also serves as the main trigger for the burst memory, identifying plasma depletions for high resolution irregularity studies. Note that C/NOFS satellite also includes a planar Langmuir probe in the ram direction provided by AFRL that gathers absolute plasma density and electron temperature data.

Lightning Detector. VEFI includes an optical Lightning Detector (developed by the Univ. of Wash.) to record lightning count rates within 7 intensity levels looking north and south. The raw lightning detector signal can also be digitized in the burst memory and can be used to trigger the burst memory wave capture.

Burst Memory. VEFI includes a programmable burst memory to capture high resolution (up to 32 ks/sec) data with 16 bits of 1, 2, 4, or 8 data channels triggered when spread-F plasma depletions, electric field wave activity, lightning events, or a pre-assigned time event is encountered. The trigger continuously scores events that are encountered and the bursts with the highest scores are subsequently telemetered to the earth. The data channels may be from any of the VEFI sensors. All of the selected channels are digitized at the same rate, selectable from 2, 4, 8, 16, or 32 kHz. The length and number of the bursts are restricted by the ~8 Mbyte memory. For example, four 1 minute bursts consisting of four data channels sampled at 4 ks/sec each would fill the memory on one pass. The burst memory is designed to operate during half of the orbit (normally night), and to download the data to the s/c memory during the second half (normally day). When the burst memory is downloaded, the 512 s/sec ELF waveforms are not gathered.

VEFI Measurement List

Measurement Output	Units	Estimated Accuracy	Sample Frequency	Output range	Initial Focus for Data
DC Electric Field (High Precision, 1 s/sec)*	mV/m	<0.3 mV/m (absolute)	1 sample/sec (3 components)	± 450 mV/m prior to **V×B** removal	• Large scale ESF drivers • Global scale electrodynamics • Gravity waves • Integrated potential along orbit
DC Electric Field (Standard Precision, 16 s/sec)	mV/m	<1 mV/m‡ (absolute) 0.02 mV/m (relative)	16 sample/sec (3 components)	± 450 mV/m prior to **V×B** removal	• High spatial resolution (0.5 km) electrodynamics • ESF depletion physics, km scale instabilities
AC Electric Field ELF Waveforms	mV/m	0.001 mV/m (relative)	512 s/sec (nominal) 2048, 4096, 8192 s/sec (Fast mode)	± 45 mV/m	• Ionospheric Instabilities • ESF irregularities, spectra
AC Electric Field VLF Spectrograms	$\frac{(mV/m)^2}{Hz}$	-80 dB	1 spectrum every 4 sec (nominal)	100 dB	• Irregularity ΔE spectra • Instability Physics • Other wave modes
AC Electric Field Filter Bank (3Hz-8 kHz)	$\frac{(mV/m)^2}{Hz}$	-80 dB	1 spectrum every 0.75 sec	100 dB	• Irregularity and hiss "background" measurements
Relative Plasma Density	cm^{-3}	± 5%	16 samples/sec	10^2 - 10^7 cm^{-3}	• Physics of plasma depletions and km-scale instabilities
Plasma Density Fluctuation ELF Waveform	cm^{-3}	± 0.005% (relative)	512 s/sec (nominal), 2048, 4096, 8192 s/sec (Fast mode)	10^2 - 10^7 cm^{-3}	• Irregularity ΔN Spectra • ΔE/ΔN comparison
DC Magnetic Fields (1 s/sec) *	nT	20 nT (fn. of s/c noise)	1 sample/sec (3 component vector)	± 45,000 nT	• Geomagnetic currents • **V×B** determination
AC Magnetic Fields (0.05 - 8Hz)	nT	0.1 nT	16 s/sec (3 component vector)	± 900 nT	• ESF Magnetic perturbations • Poynting flux, Alfven waves
Optical Lightning Detector Levels	Counts		Count rates in 7 bins twice per sec in North, South directions		• Correlate storms with ESF • Storm related electric fields • Causal link for explosive ESF
Burst Memory (all VEFI data)	Varied		1, 2, 4, or 8 channels up to 32 k s/sec per channel.		• Full ESF instability spectra • Spaced receiver analysis • Lightning generated E fields

* High accuracy absolute fields utilize advanced processing techniques.
‡ Accuracy improves to 0.3 mV/m when high precision offsets and matrices incorporated.