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Early Results from the Floating Potential Probe on the International Space Station

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Background of FPP

Space Station Power System

160 Volts Solar Array

Mostly non-conducting Station body grounded to negative end of Power system

Station body floats 100-120 Volts negative of Plasma ground

Plasma Contactor added to design in 1991

Enhances electrical contact between Station body and ambient plasma, by emitting electrons

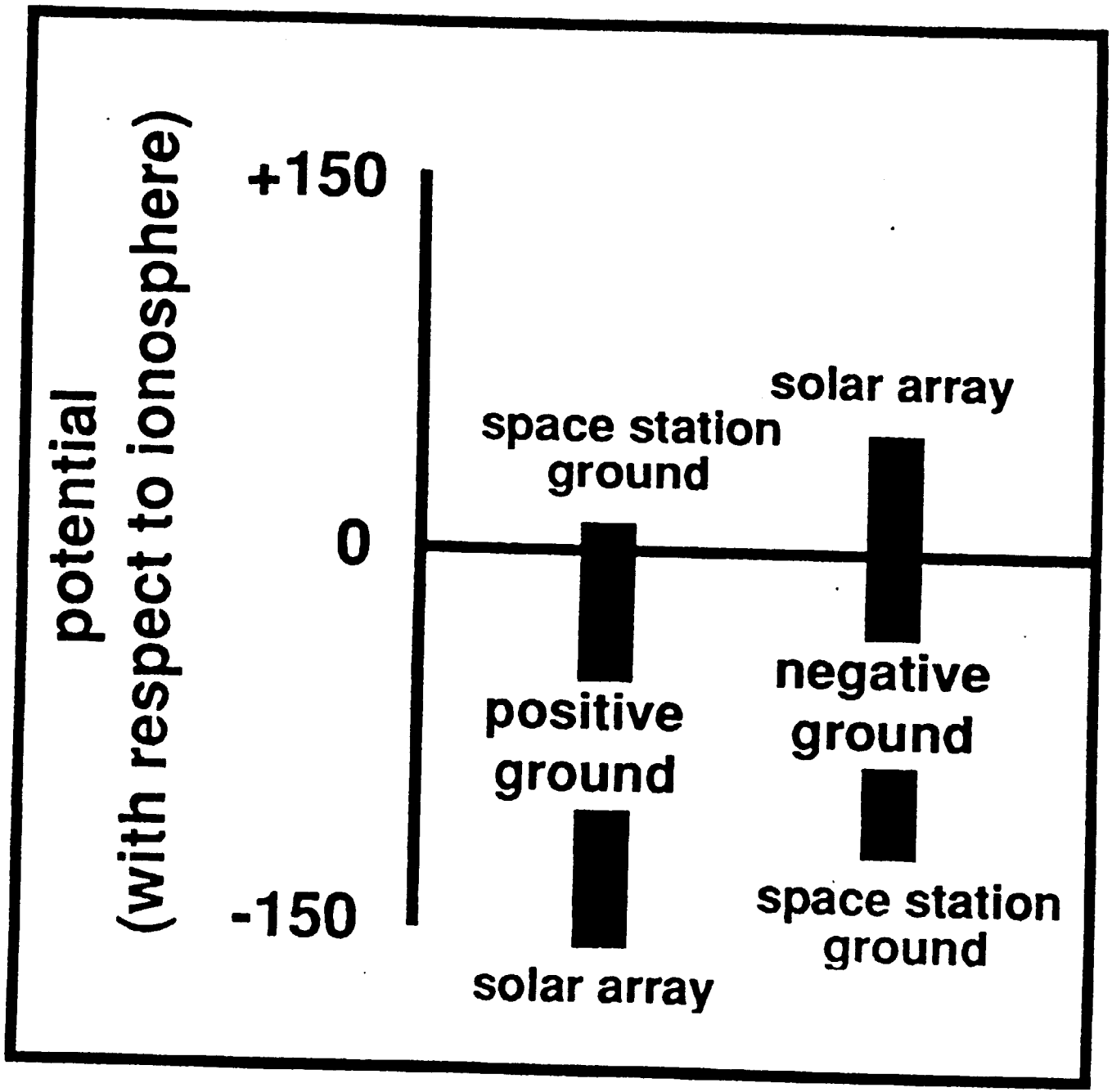
However, some failure modes were discovered in pre-flight testing

Didn't clamp voltage

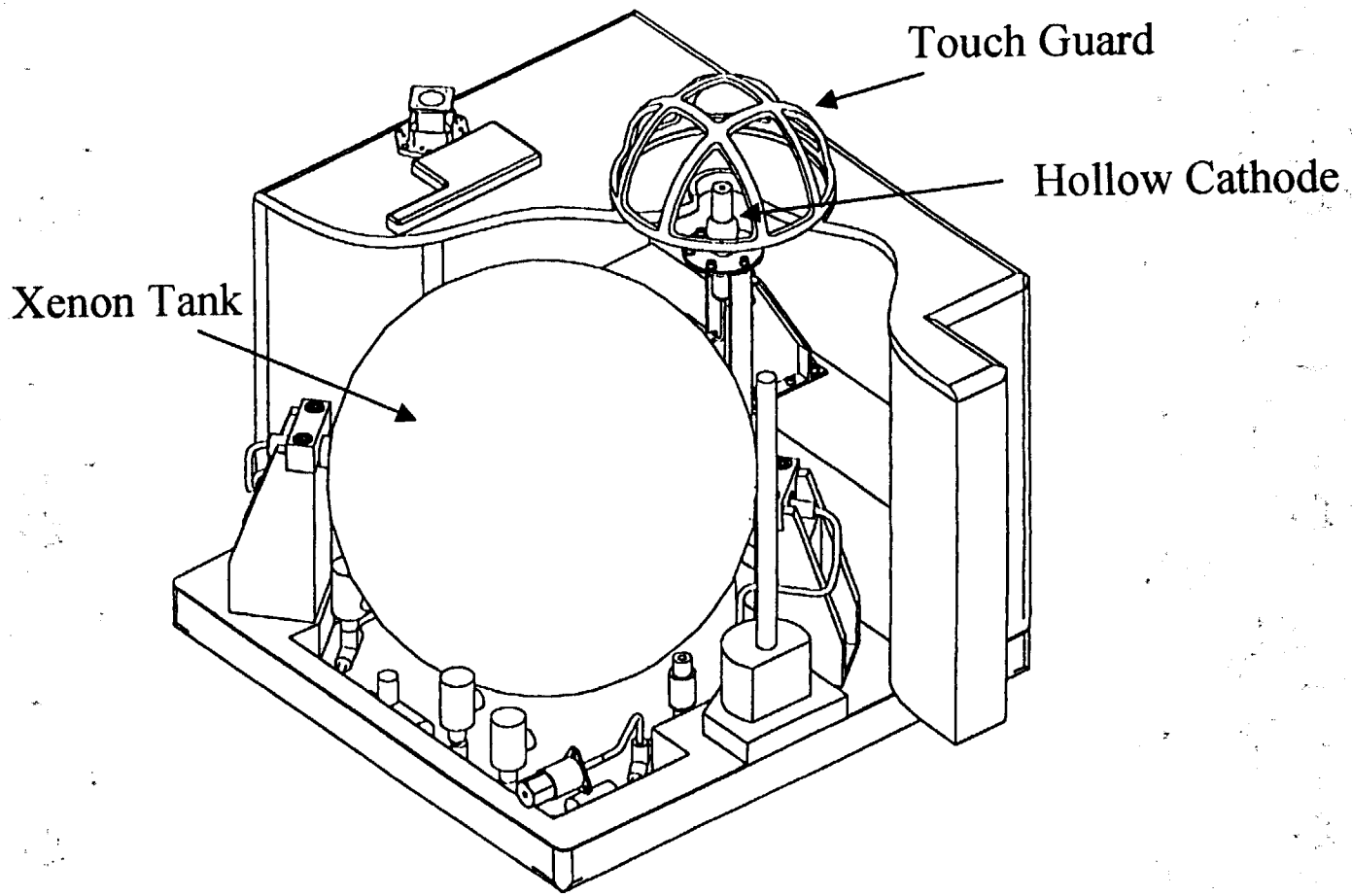
All telemetry was fine

Indicated that we couldn't rely on telemetry to monitor the effectiveness of the PC

Punctuate and space


potential
(with respect to ionosphere)
+150
0
-150
space station
ground
solar array
positive
ground
solar array
negative
ground
space station
ground

ISS PCU Cutaway Drawing



Decided to add Floating Potential Probe to Space Station in June, 2000

- Measures body voltage (electrical potential) of Space Station
- To speed construction and validation, used electronics that had been used for SAMPIE, on STS-62
- Includes a Langmuir Probe

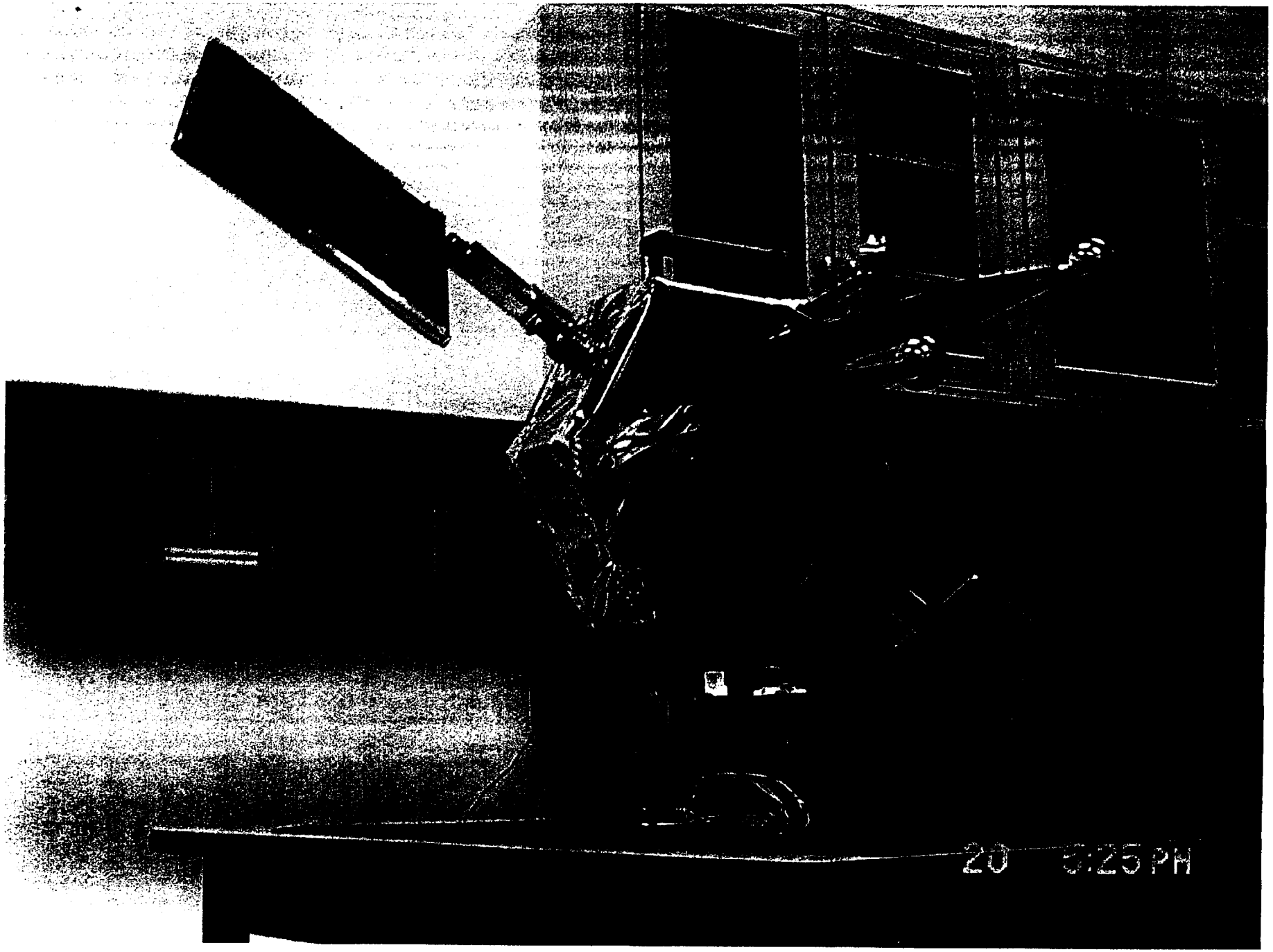
V-body probe reports electrical potential every 0.1 seconds

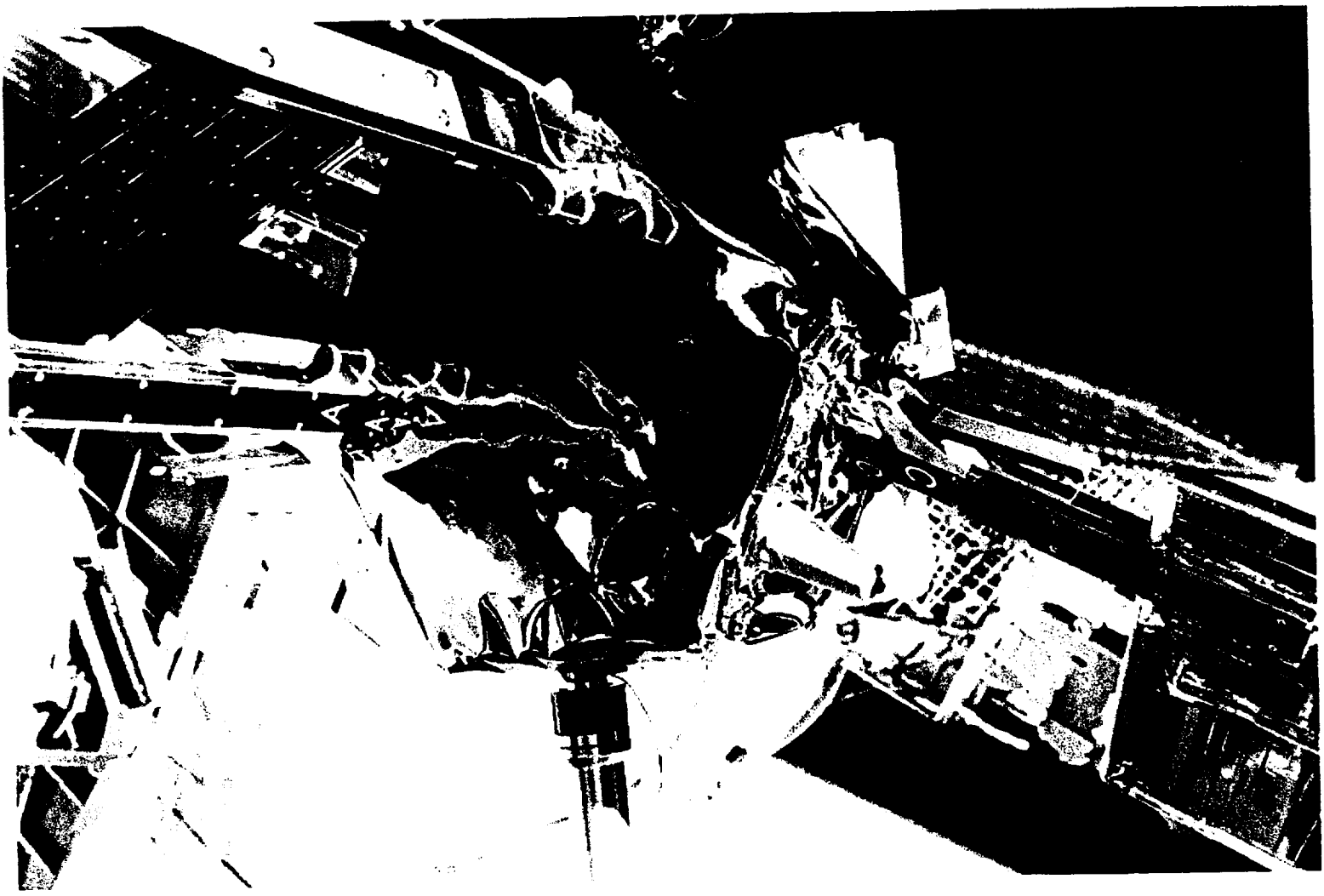
Langmuir Probe trace takes 20 seconds

- Sample Trace
- Electron current only!
- Used a model of current collection in a flowing plasma reported by Medicus

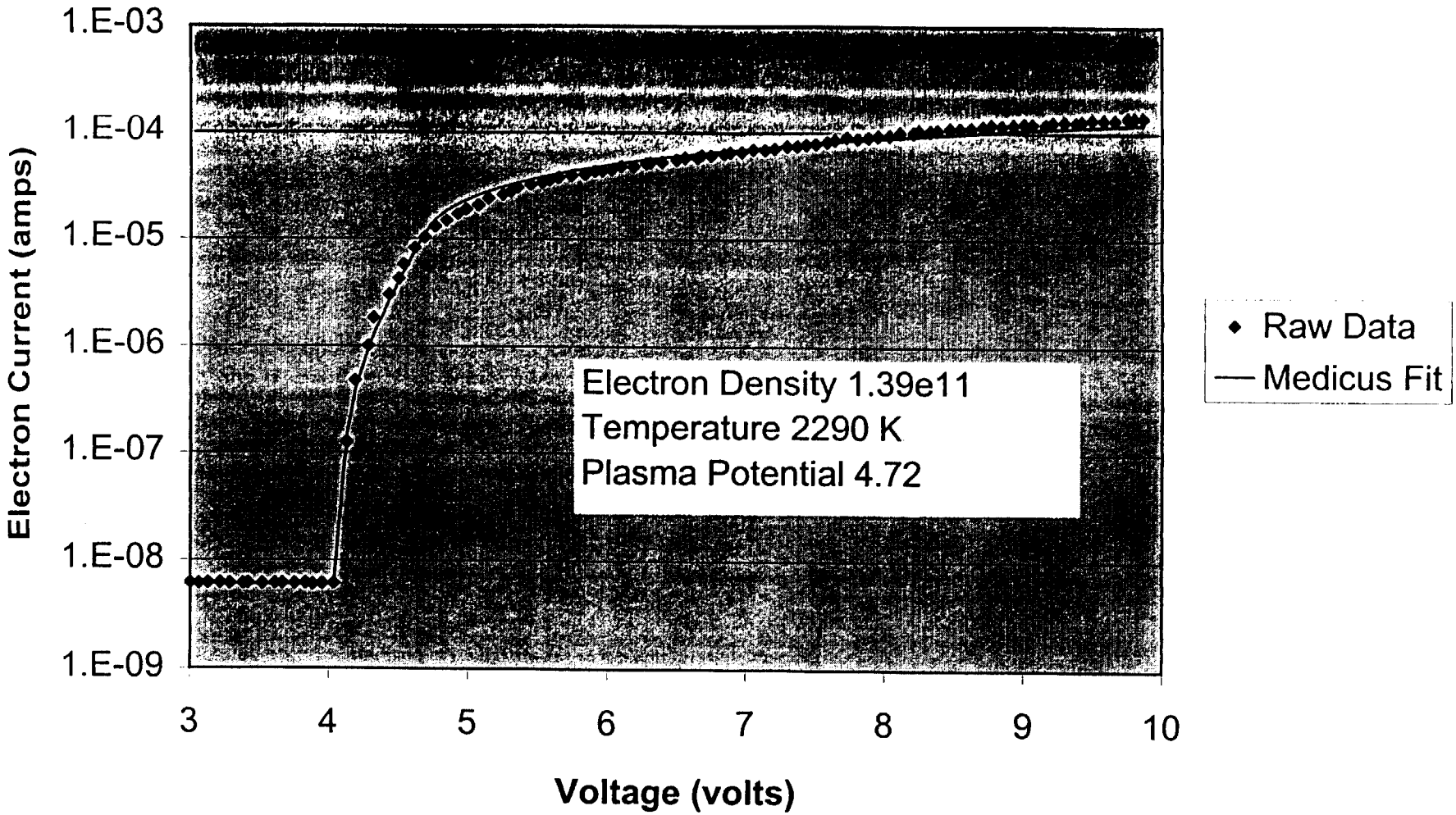
Data downloaded from Space Station every 8 hours in science data stream

- Can be accelerated if needed
- Sometimes delayed for days


20 5:25PM



Sample Langmuir Probe Trace



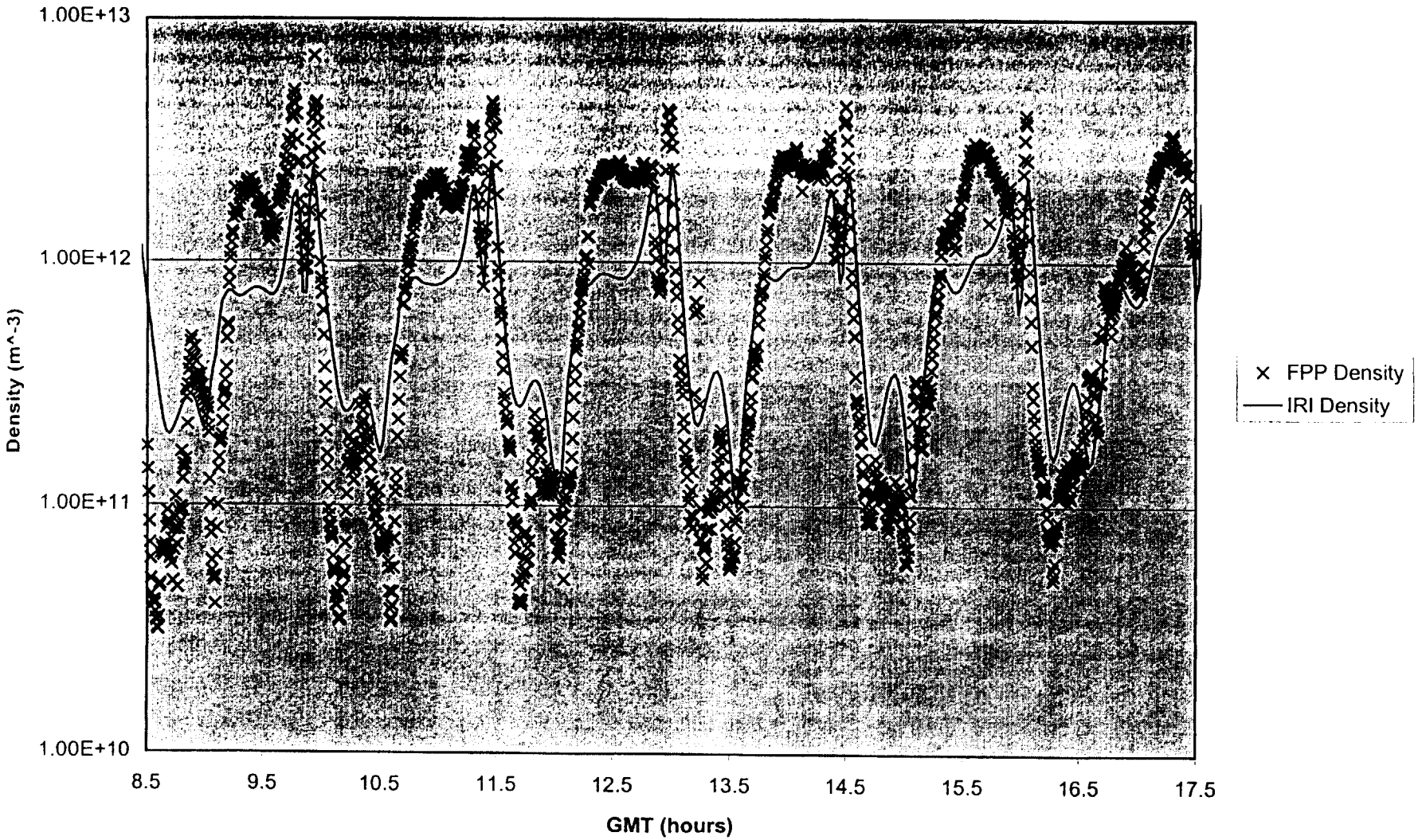
Low Resolution Results

We show FPP plasma densities and temperatures for several dates, as a function of time. In general, the FPP densities show a greater range than the IRI densities, but show the same structure. The temperatures also show a similar structure, but are uniformly higher than the IRI temperatures. We also saw this in the SAMPIE mission, and attributed it to the limitations of the Langmuir Probe. However, in this case, we were able to obtain plasma measurements from Millstone Hill, which indicate that the plasma densities could get as high as 3100 K (.3 eV).

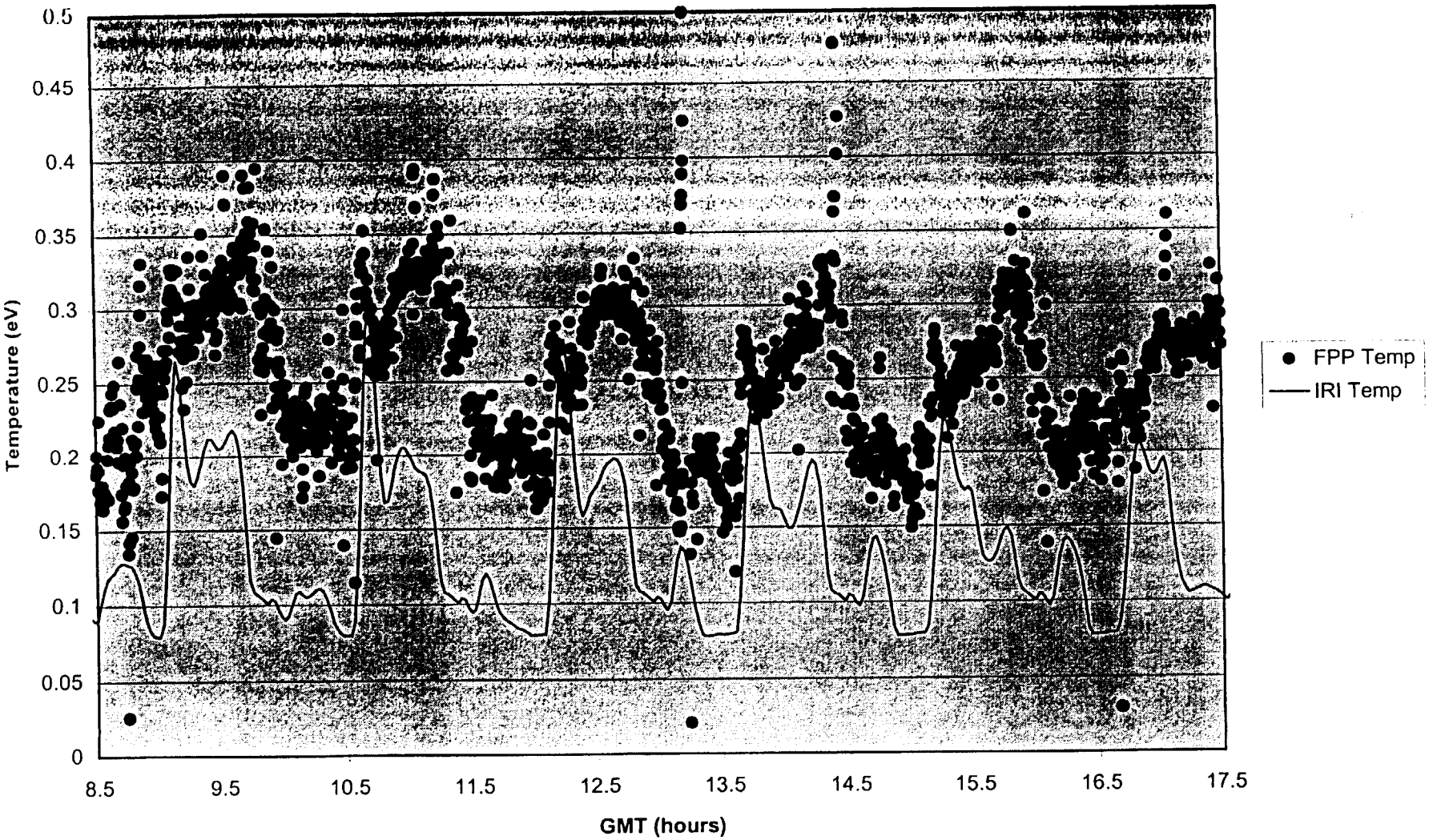
We also show FPP measurements of the Space Station potential (Vbody) for several dates. Much of the variation through an orbit can be explained by the variation in $\vec{v} \times B$ potential along the Space Station truss.

On February 5, the solar arrays were pointed at different angles away from the velocity vector, for a full orbit each, with the plasma contactor off. We see little variation in the behavior of Vbody. In order to correctly model this behavior, we found that we needed to include more conductors on Space Station than had been described. Subsequent discussions revealed exposed wires used to support the arrays. Including this conductive area allowed us to accurately model the variation in Vbody during an orbit.

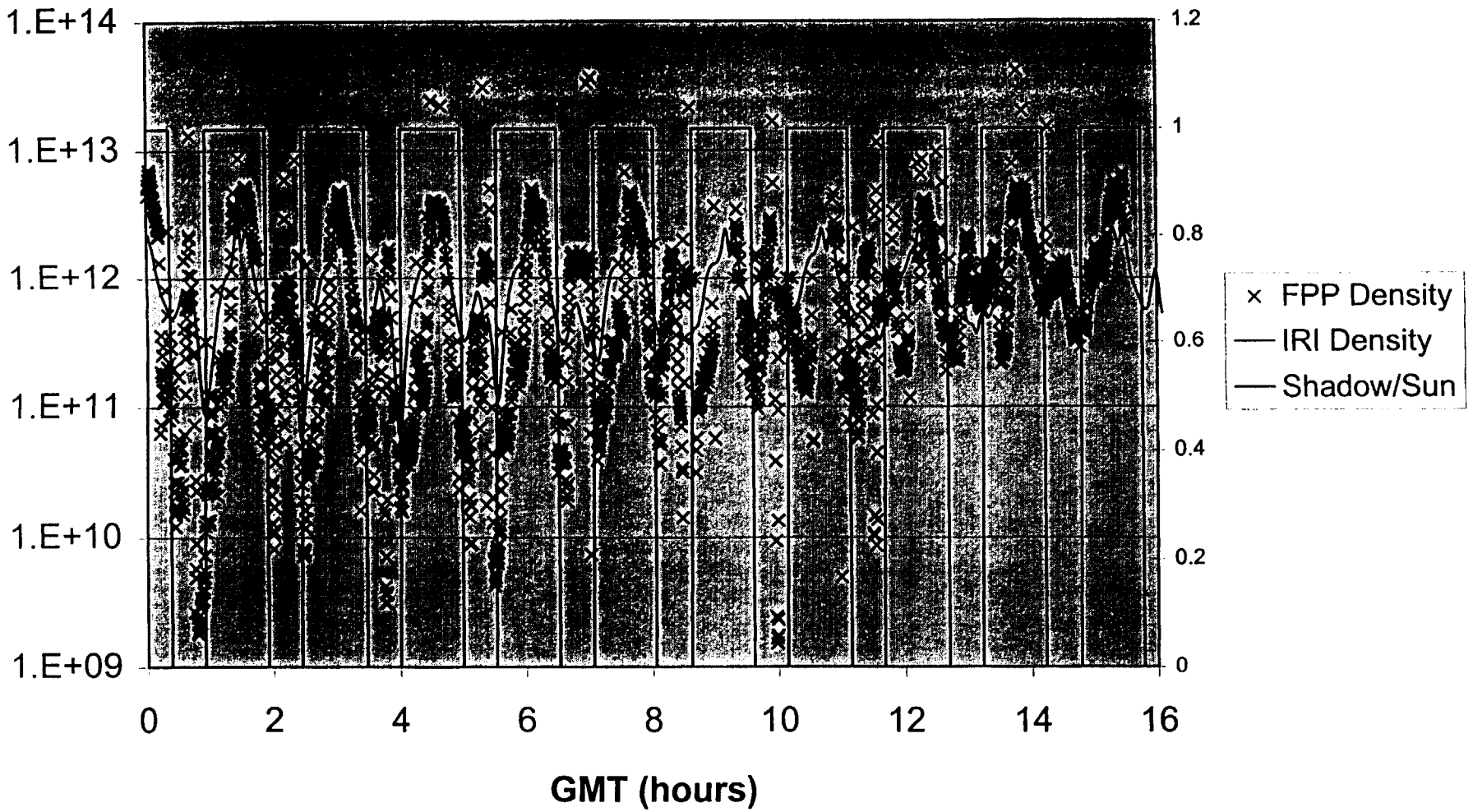
On April 11 and 12, the plasma contactor was again disabled, and the solar array angles were varied. We note that on April 11, the solar arrays were aligned to track the sun, while on April 12, the solar arrays were aligned to face constantly into the ram velocity vector. In the latter case, there is an increase in Vbody at local noon, which is because at that point, the solar arrays are illuminated edge-on, and therefore do not generate any power. This causes all the arrays to become unshunted, and they therefore collect much more current than usual.


February 5, 2001
1.00E+13
1.00E+12
1.00E+11
1.00E+10
Density (m^-3)
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
17.5
GMT (hours)
FPP Density
IRI Density

February 5, 2001

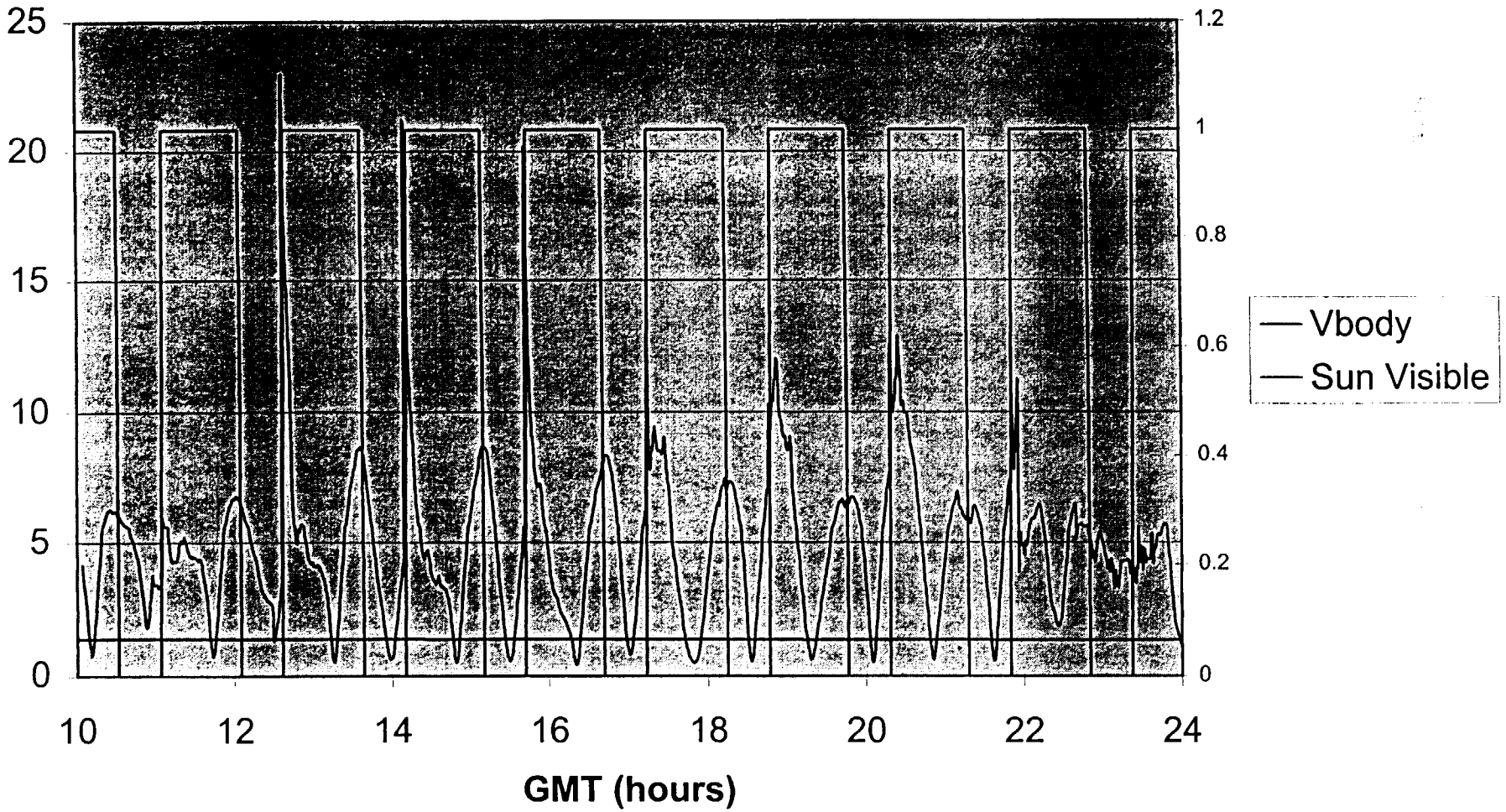


April 12, 2001



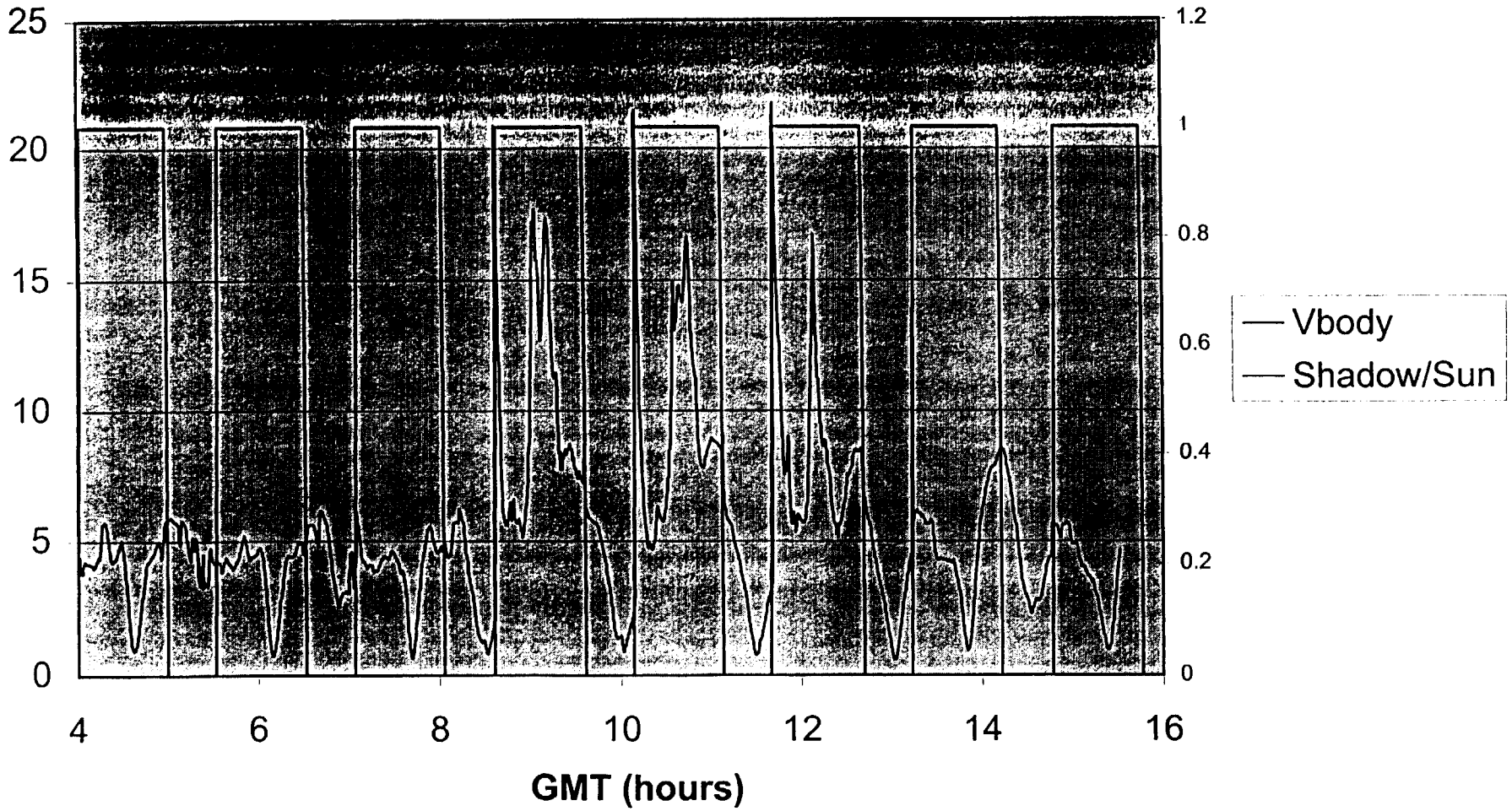
April 11, 2001

Arrays tracking sun

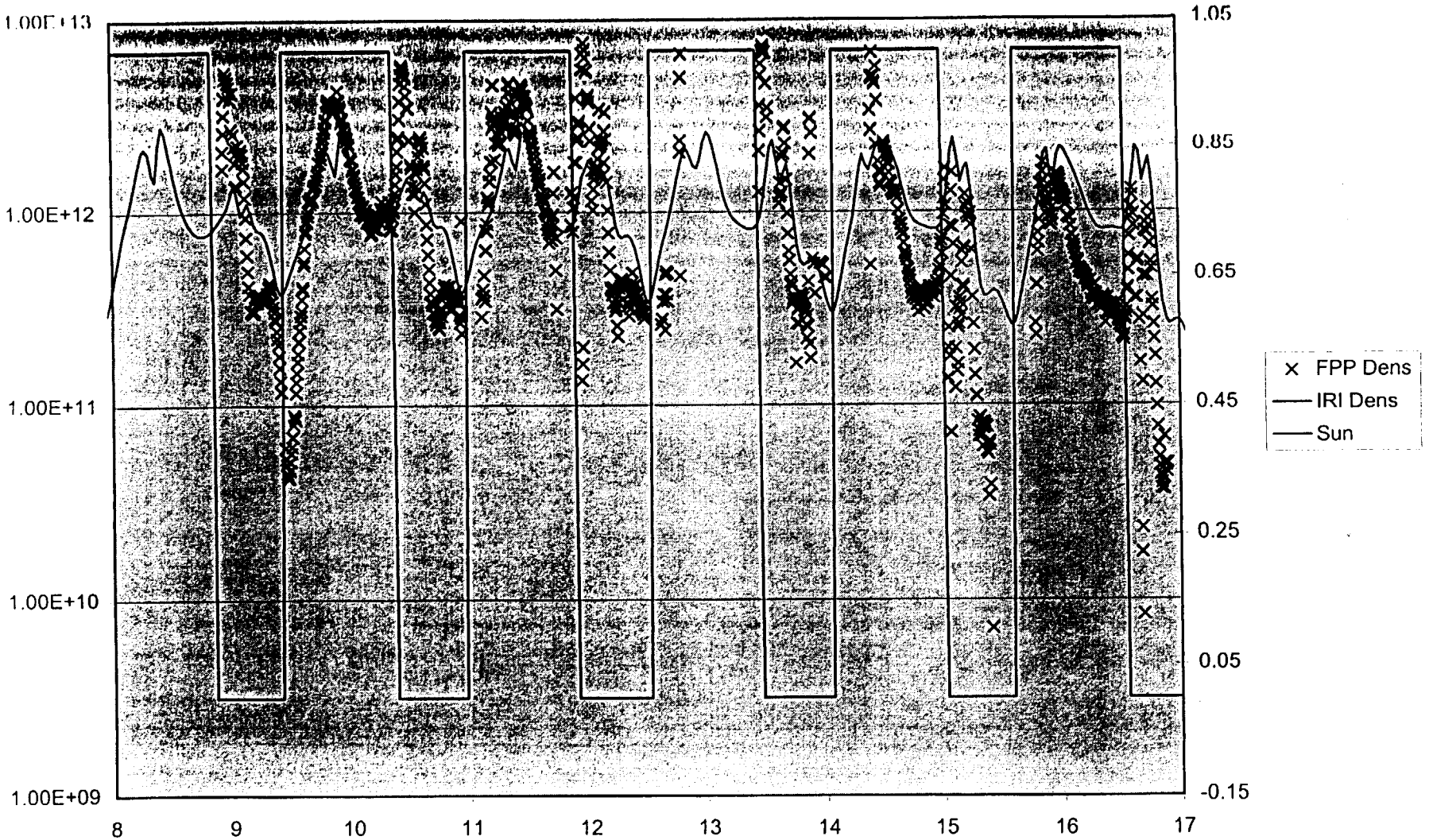


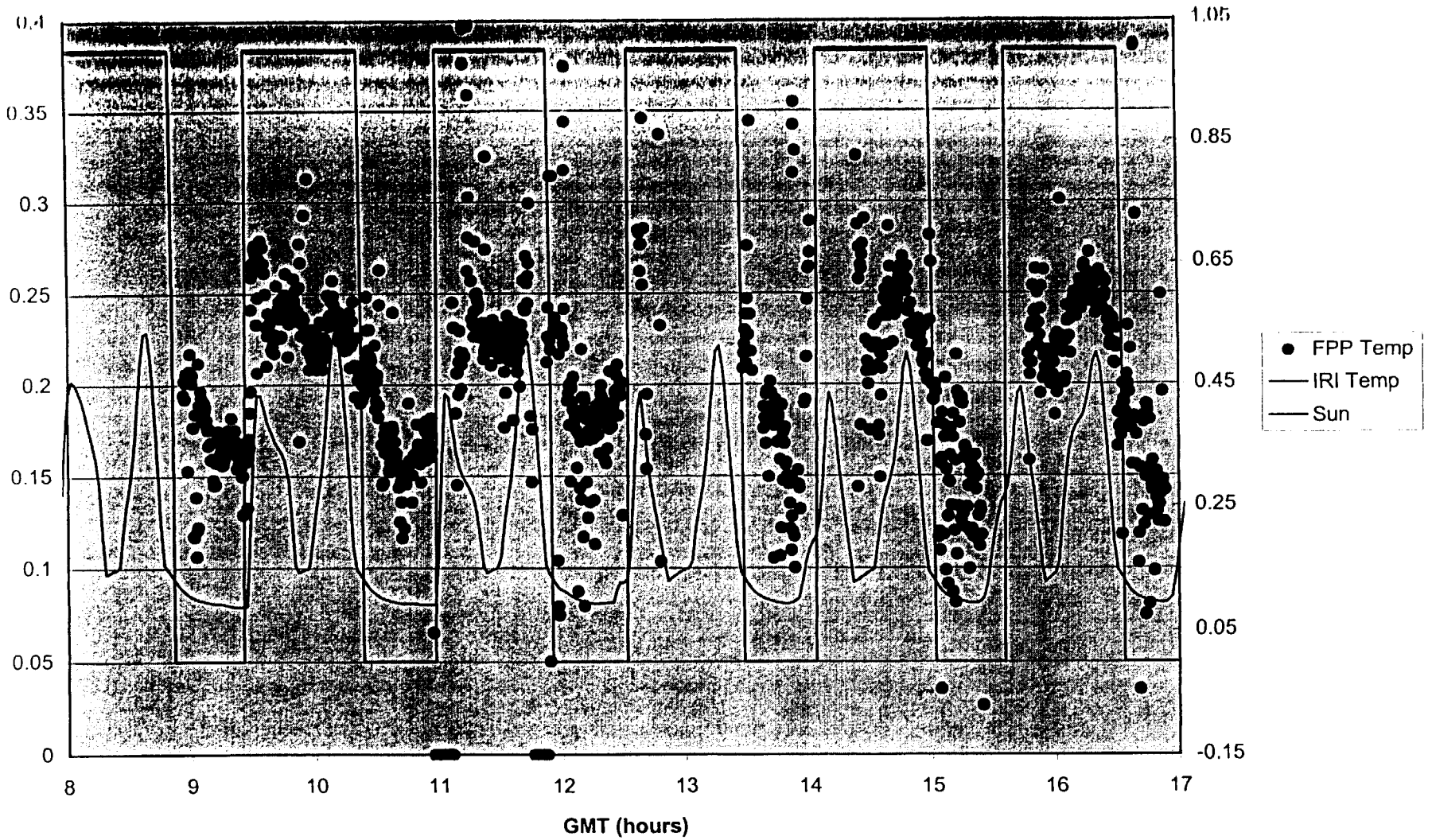
April 12, 2001

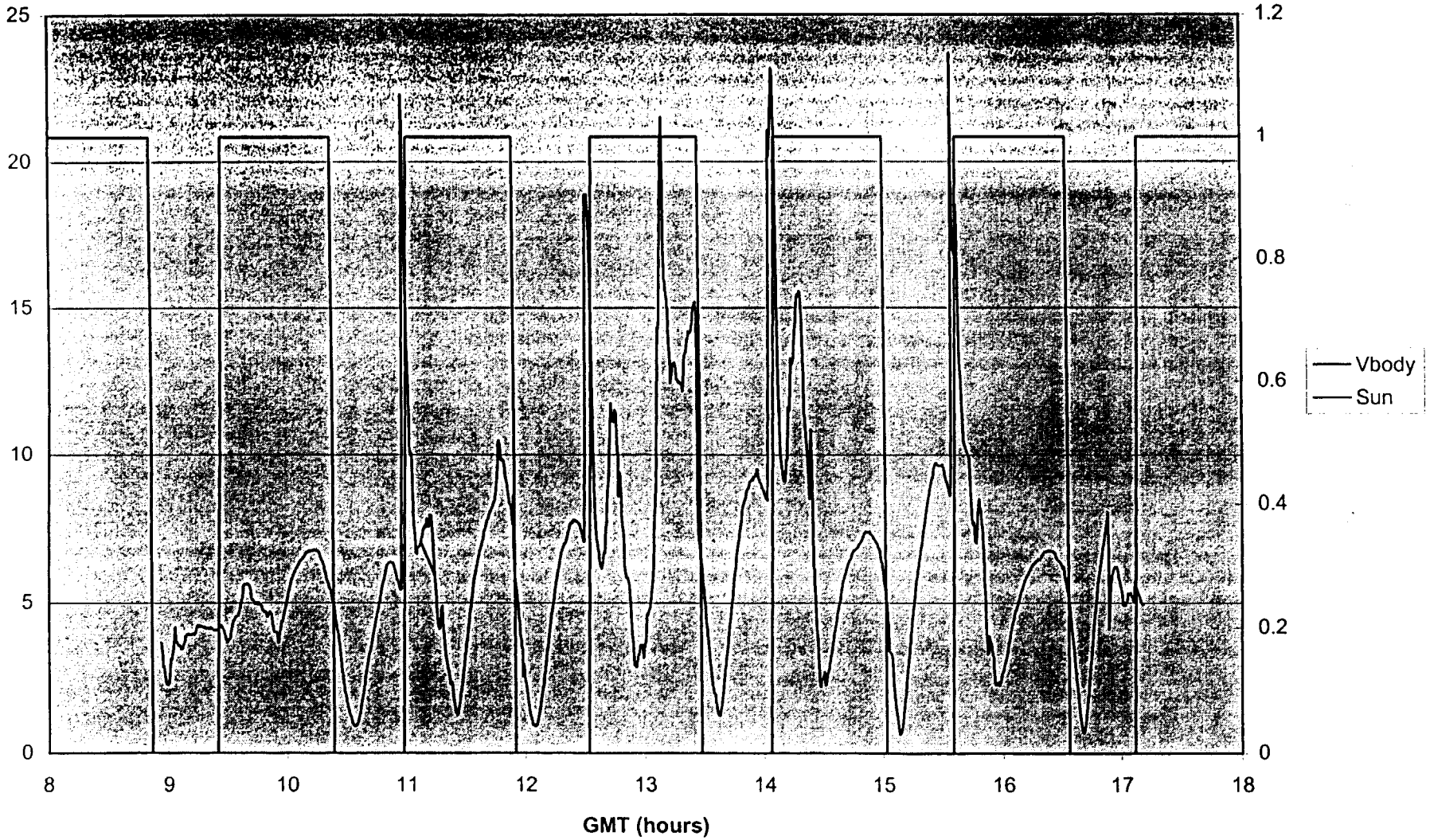
Arrays into ram



April 21, 2001




April 21, 2001
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1.05
0.85
0.65
0.45
0.25
0.05
-0.15
8
9
10
11
12
13
14
15
16
17
GMT (hours)
FPP Temp
IRI Temp
Sun


April 21, 2001
25
20
15
10
5
0
1.2
1
0.8
0.6
0.4
0.2
0
8
9
10
11
12
13
14
15
16
17
18
GMT (hours)
Vbody
Sun

High Resolution Results

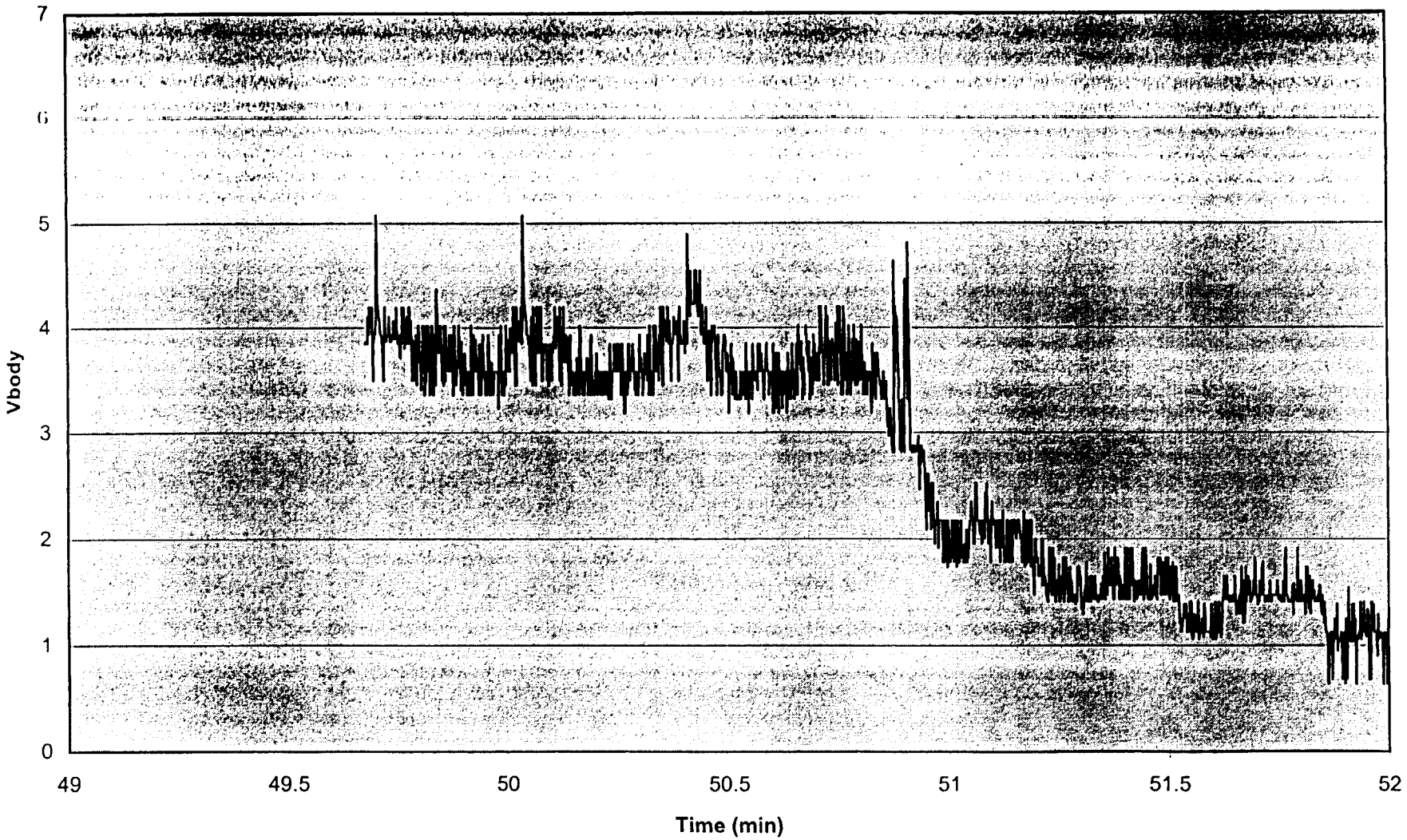
We were also able to examine the body potential for time intervals of 0.1 seconds. On this scale, there is much more noise, but we can see some effects. When the Space Shuttle docks with the Space Station, the increase in conductive area (the bell nozzles on the Shuttle are conductive) changes the body potential by 2 volts, in a matter of seconds. Also, turning the plasma contactor on or off changed the body potential by 2-3 volts, in a matter of seconds.

Interesting Results

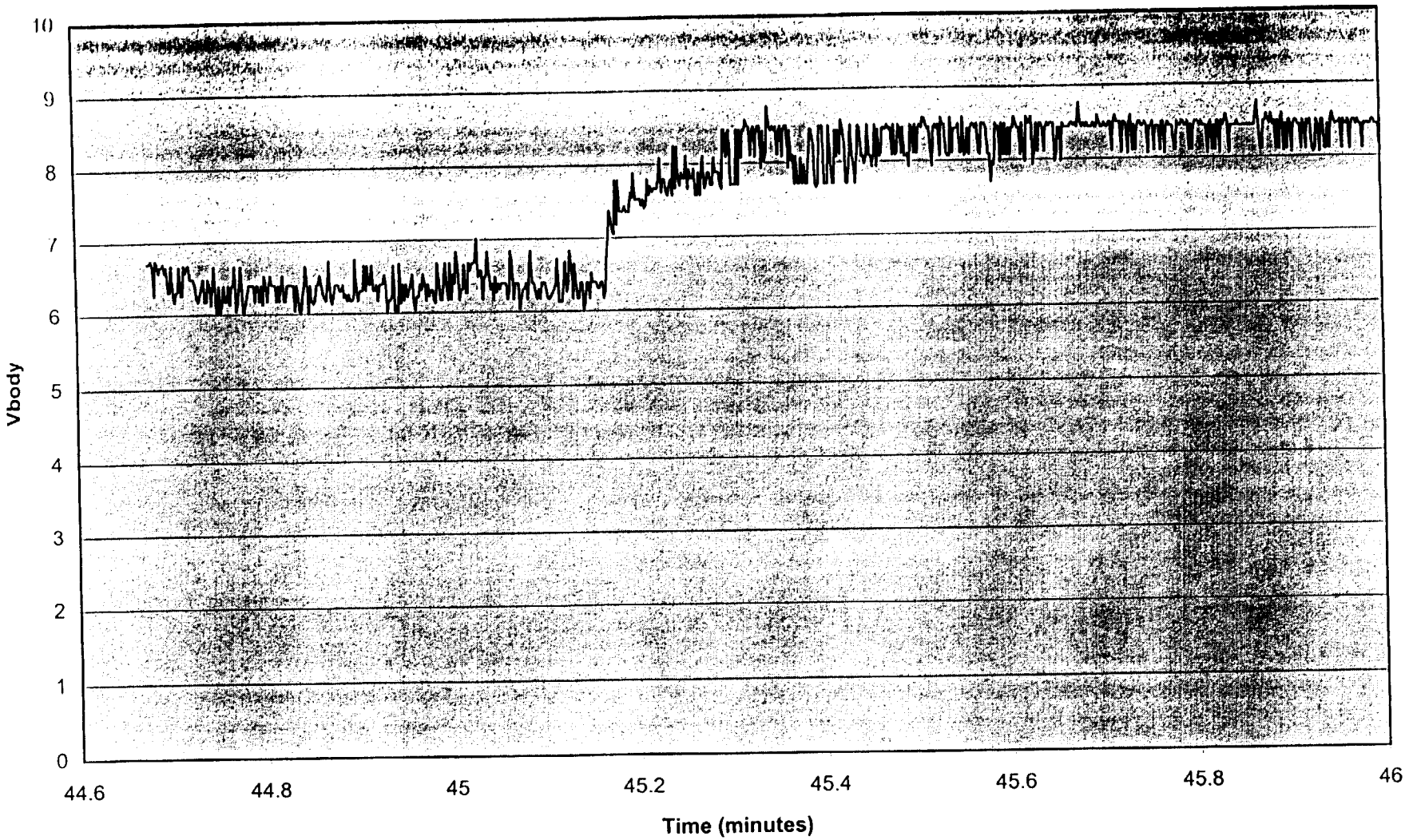
Even with the plasma contactor off, and the solar arrays aligned into the ram velocity vector, the potential at the FPP does not exceed 25 volts, and that is usually at local sunrise, or local noon. If we include a possible 15 volts of $\vec{v} \times B$ along the structure, the potential anywhere on Space Station does not exceed the 40 volts specified in the safety documents.

We have plasma densities and temperature for more than 20 days in early 2001, along the Space Station orbit, 370-400 km, 51.5 degree inclination. The densities resemble the IRI model, but the temperatures are uniformly higher than the model. However, radar measurements suggest that the temperatures may be realistic, (perhaps due to increased solar activity?).

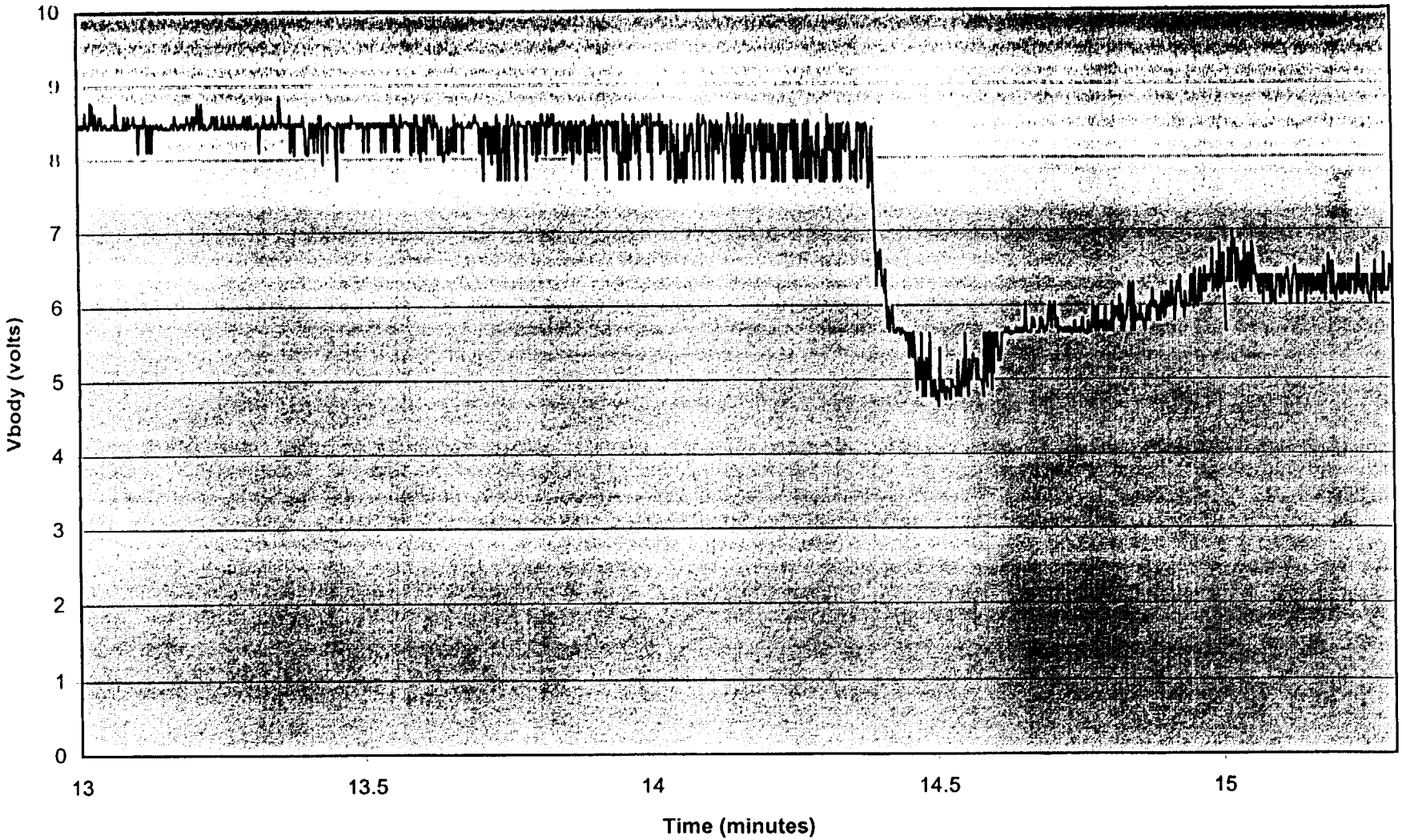
February 9 - Shuttle Docking

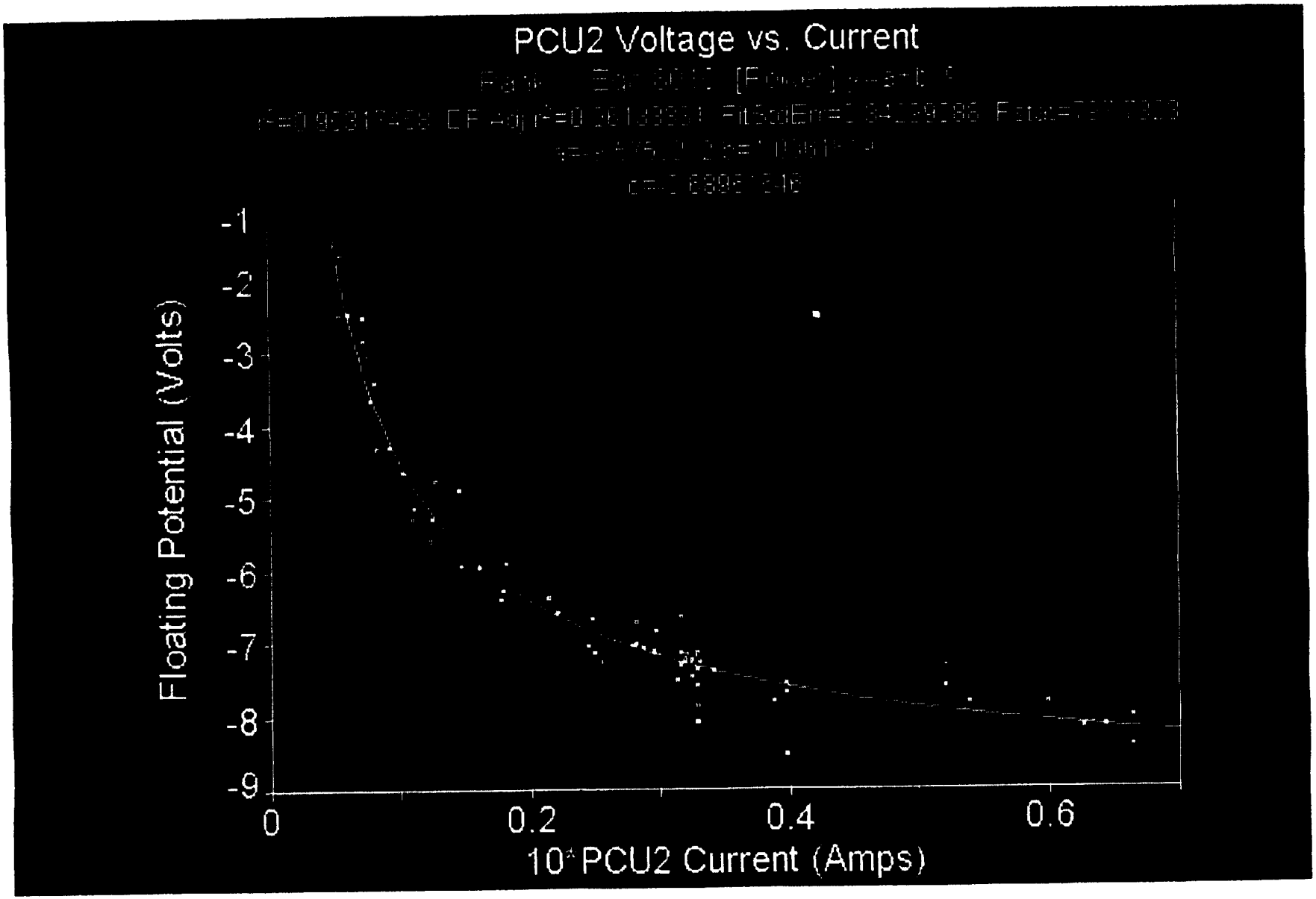


February 5 - PCU Turn off

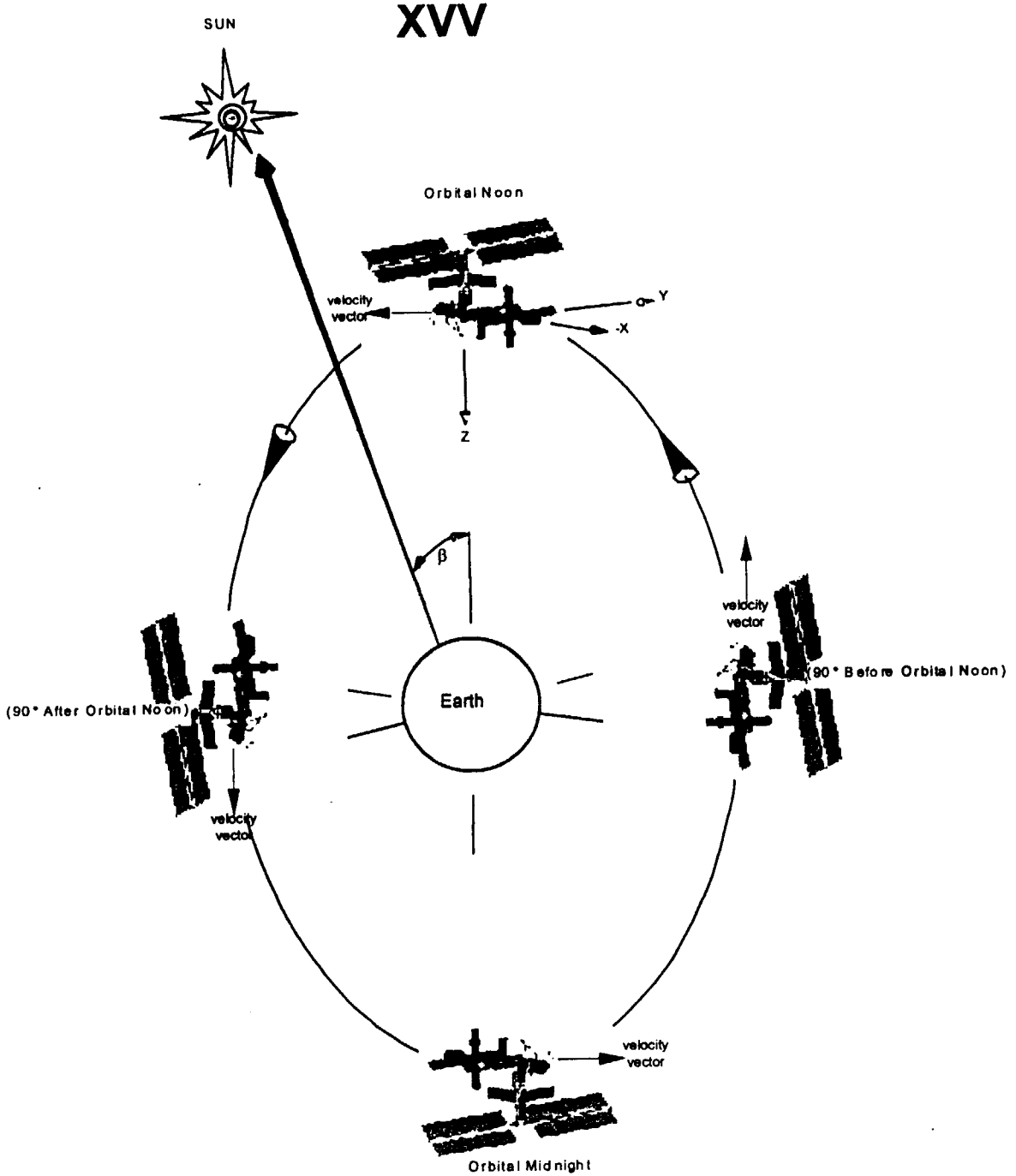


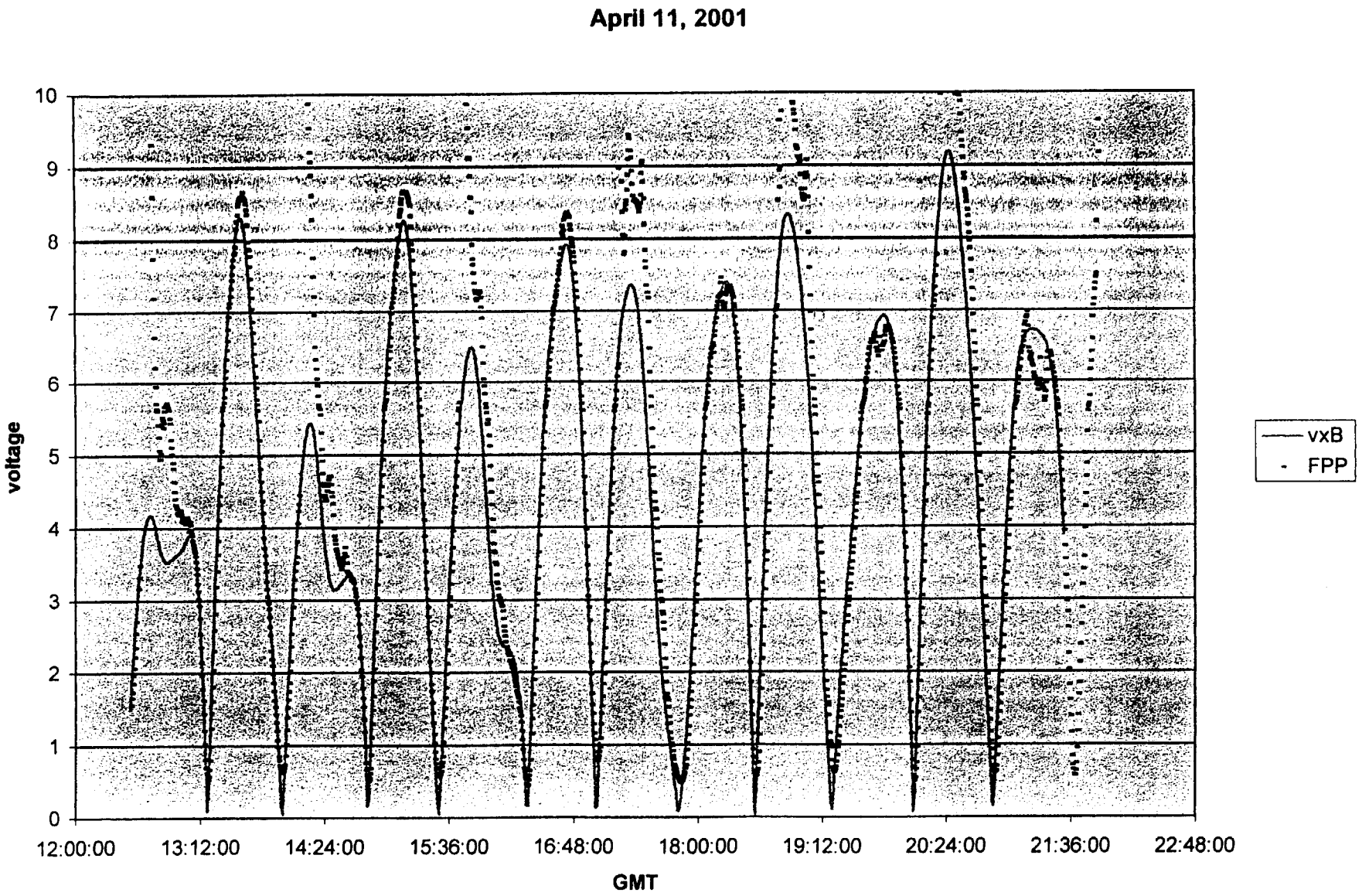
February 5, 2001 - PCU Activated



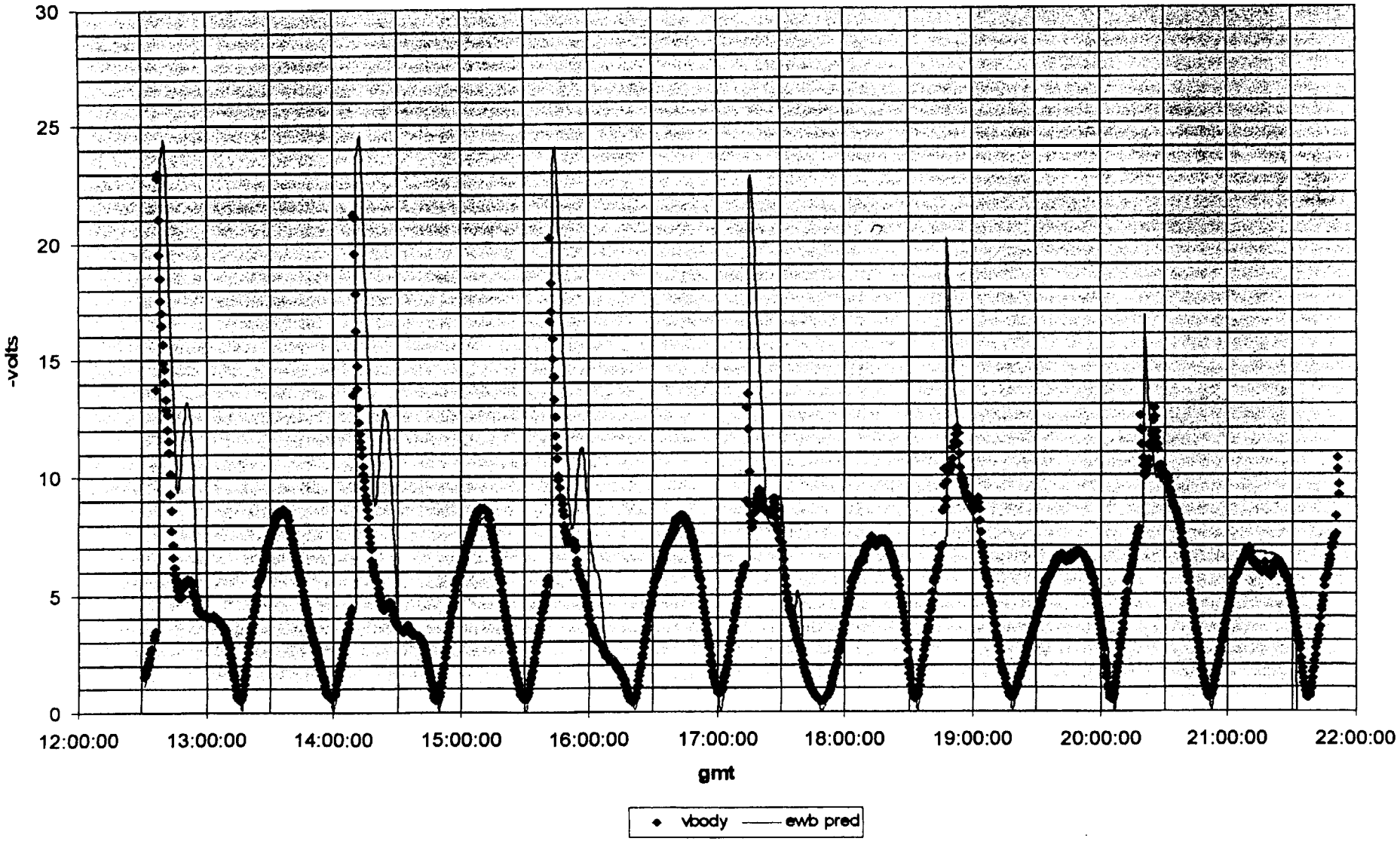

PCU2 Voltage vs. Current
Floating Potential (Volts)
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
0.2
0.4
0.6
10⁻⁴ PCU2 Current (Amps)

XVV


SUN
Orbital Noon
velocity vector
Y
-X
Z
β
Earth
(90° After Orbital Noon)
velocity vector
velocity vector
(90° Before Orbital Noon)
velocity vector
Orbital Midnight


April 11, 2001
voltage
10
9
8
7
6
5
4
3
2
1
0
12:00:00
13:12:00
14:24:00
15:36:00
16:48:00
18:00:00
19:12:00
20:24:00
21:36:00
22:48:00
GMT
vxB
FPP

4/11/01


vbody vs gmt
30
25
20
15
10
5
0
-volts
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
18:00:00
19:00:00
20:00:00
21:00:00
22:00:00
gmt
vbody
ewb pred