

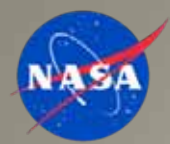
A photograph taken from the International Space Station (ISS) showing the Earth's surface and a vibrant green aurora (Northern Lights) in the upper atmosphere. The ISS structure, including solar panel arrays, is visible in the foreground on the left side of the frame.

Space Weather Monitoring for ISS Geomagnetic Storm Studies

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Space Weather Workshop
Boulder, CO, 16-19 April 2013

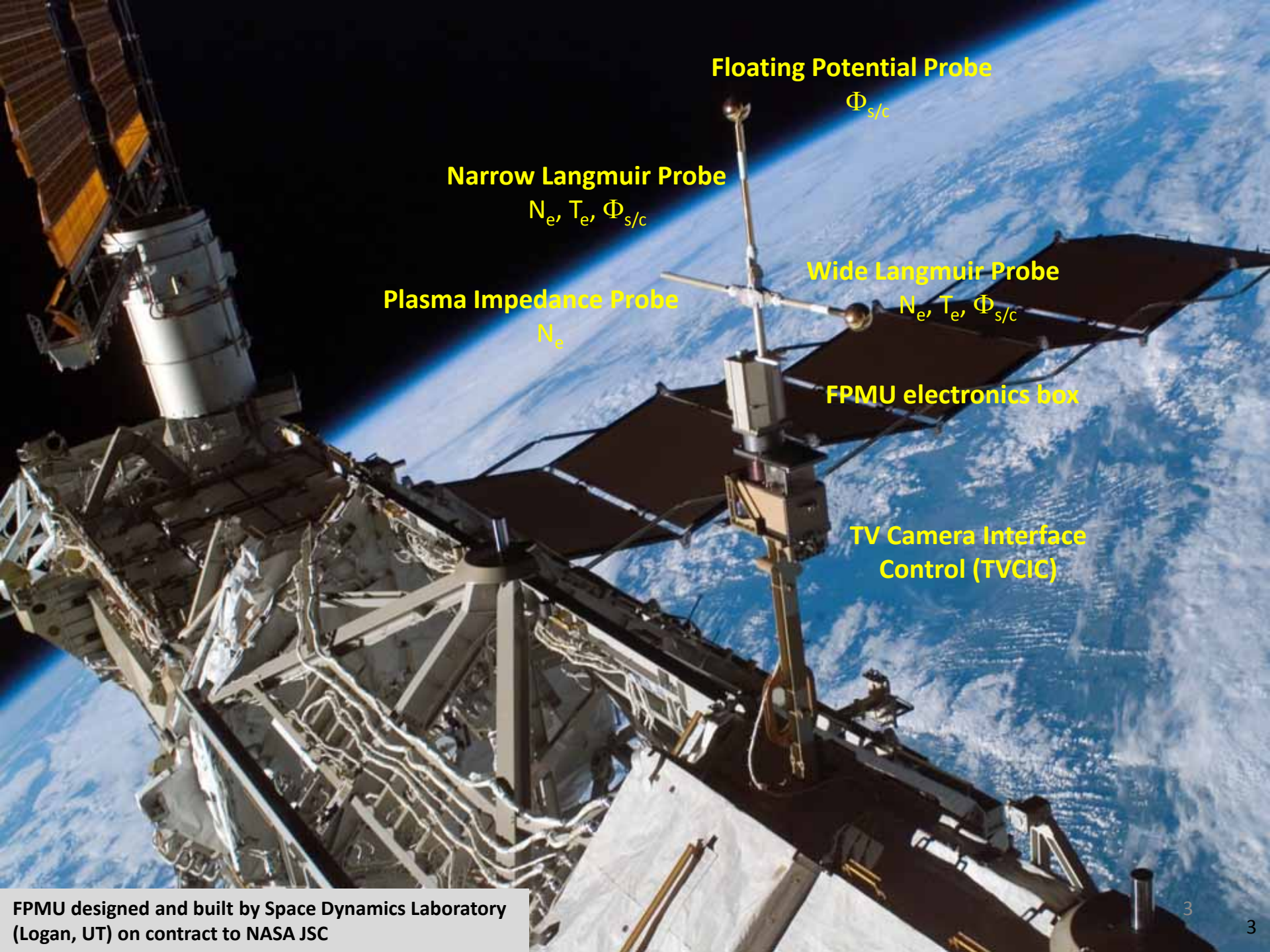


Introduction

Today's presentation describes how the International Space Station (ISS) space environments team utilizes space weather forecast and monitoring resources for an ongoing investigation of ISS auroral charging

Outline

- Floating Potential Measurement Unit (FPMU)
- Auroral charging of ISS
- Real-time space weather monitoring resources
 - NOAA Space Weather Prediction Center (SWPC)
 - GSFC Space Weather Research Center (SWRC)
 - Solar Influences Data Center (SIDC)
 - UAHuntsville/Center for Space Plasma and Aeronomic Research (CSPAR)
 - NASA/STEREO and ESA/SOHO chronograph images
- Examples of ISS auroral charging captured during space weather events
- Summary



Floating Potential Probe

$$\Phi_{s/c}$$

Narrow Langmuir Probe

$$N_e, T_e, \Phi_{s/c}$$

Wide Langmuir Probe

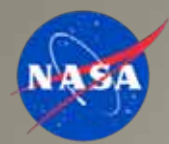
$$N_e, T_e, \Phi_{s/c}$$

Plasma Impedance Probe

$$N_e$$

FPMU electronics box

**TV Camera Interface
Control (TVCIC)**



ISS FPMU Operations

- **FPMU data encoded into a video signal is downlinked in the ISS Ku band telemetry stream**
 - Ku band telemetry is a shared resource, used for both ISS operations and science activities
 - Amount of time the TVCIC video box can be operated is restricted due to hardware issues

FPMU operated for up to ~30% of a year for periods from a few days to weeks at a time
- **Scheduled FPMU operations support ISS engineering and science activities:**
 - Characterizing ISS 160 volt solar array interactions with ionosphere plasma
 - ISS charging due to visiting vehicles
 - US and Russian extravehicular activity (EVA) plasma hazard support
 - ISS science payload support
 - Anomaly investigations
 - Collaborative ionospheric research with other spacecraft and ground based facilities
 - Incoherent scatter radar World Day periods

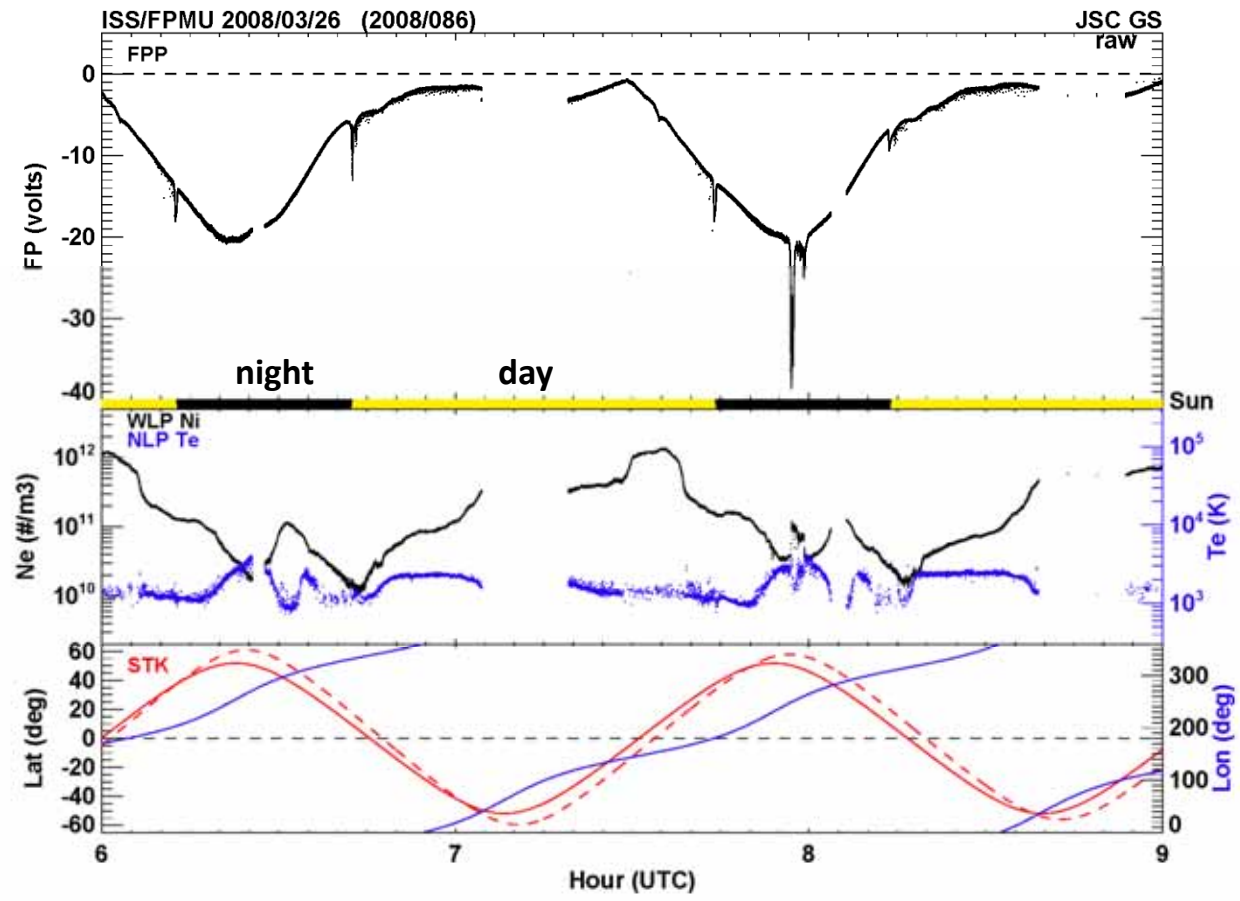
Space weather is not an issue for scheduled events, but sometimes we fortuitously capture geomagnetic storm data during regular operations...
- **Collecting ISS charging data during geomagnetic storm periods is more of a challenge due to the limitations on total FPMU operation time and pre-scheduling requirements for FPMU operations**

Require a strategy to improve odds of operating FPMU during geomagnetic storm periods...



First FPMU Record of ISS Auroral Charging

26 March 208: FPMU captures auroral charging data during operations in support of STS-123 ISS and ATV docking

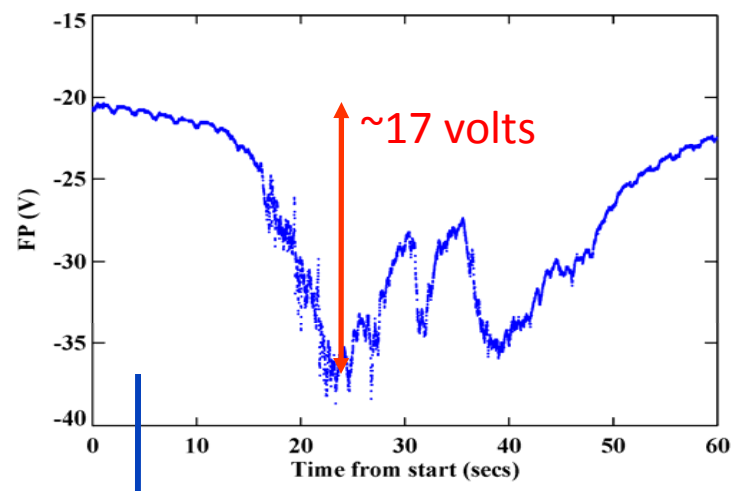


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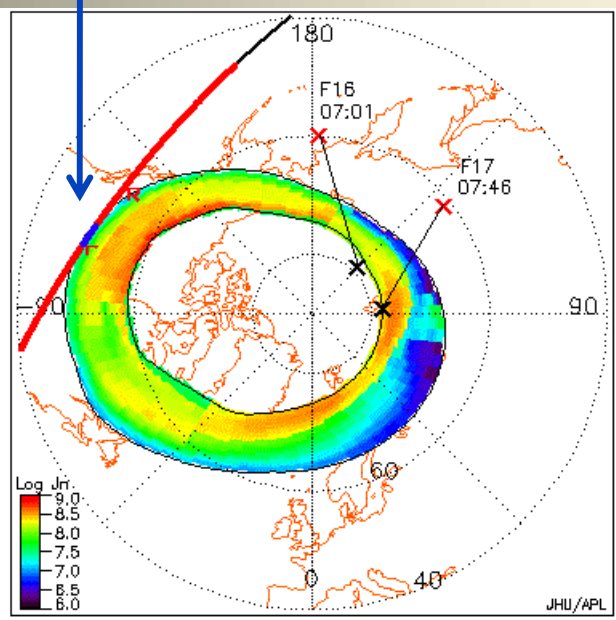


28 March 2008 -- Auroral Charging Details

2008/086/07:56:50

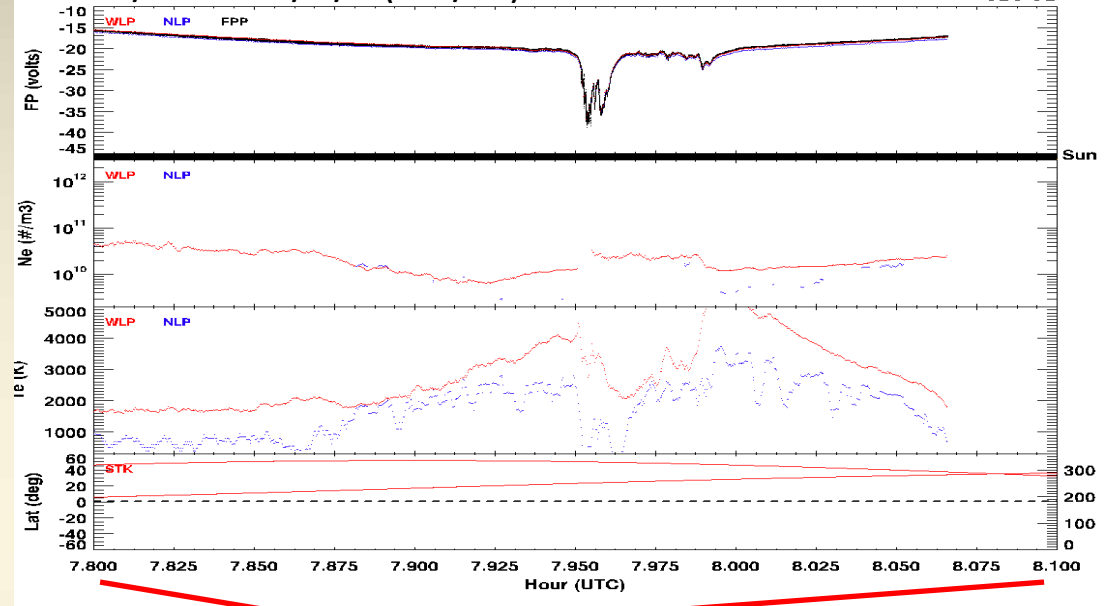


26 Mar 2008 07:30 – 08:00 UT

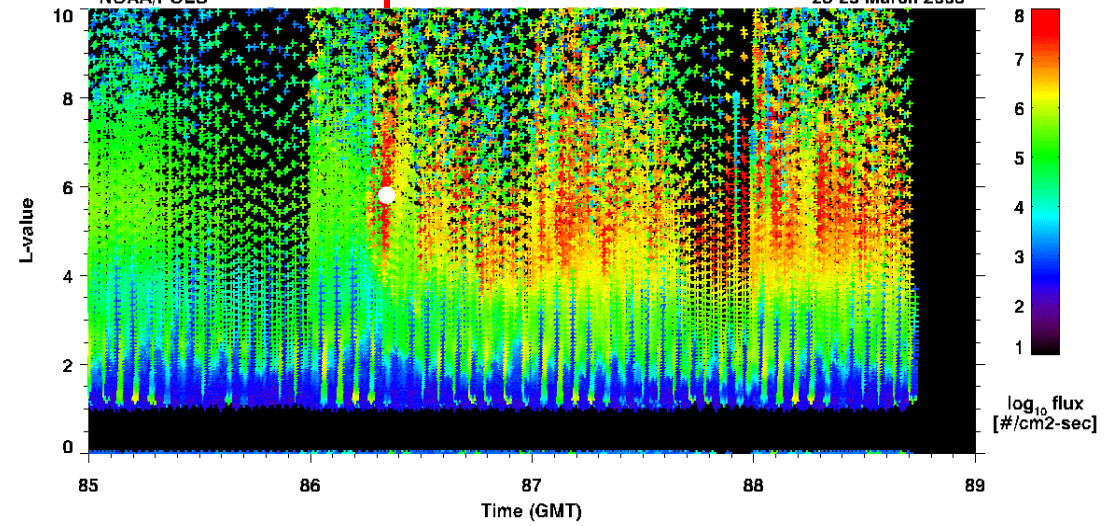


Normalized B_{2i} = 62 Flux = 726 MWb
 Equivalent K_p = 3.0 Global e^- E-Flux = 23.0 MW

ISS/FPMU 2008/03/26 (2008/086)



NOAA/POES >30 keV electrons, 0 deg 25-29 March 2008

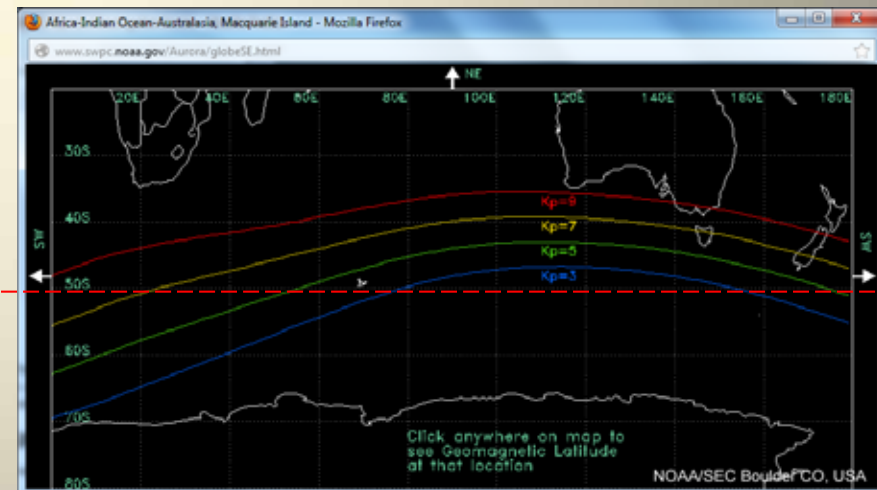
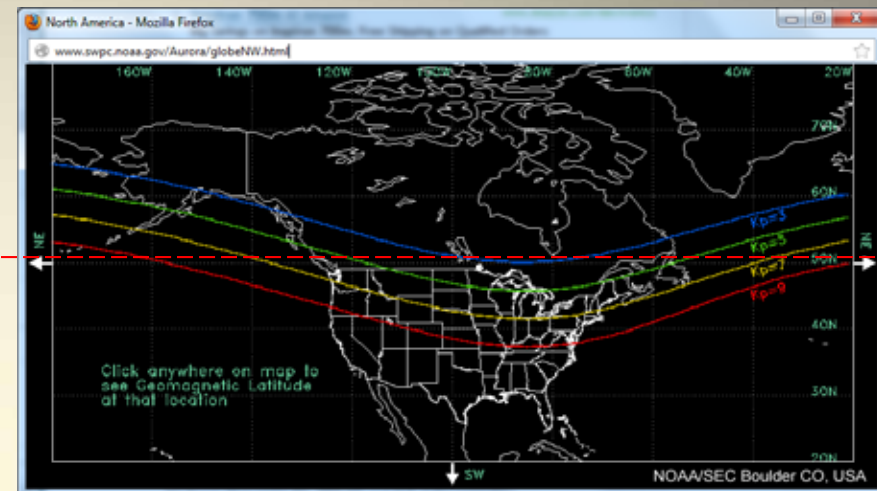


[adapted from Craven et al., 2009]



FPMU Geomagnetic Storm Operations

- **Space weather monitoring using real time space weather data provides a method for targeting FPMU operations during geomagnetic storm periods:**
 - Investigate ISS high voltage solar array charging during geomagnetic storm periods
 - Improve the odds of capturing ISS auroral charging
- **Strategy is to operate FPMU for periods immediately before and a few days after predicted time of geomagnetic storm onset:**
 - Space weather alerts for earthward directed CME's give advanced warning for potentially geoeffective solar events
 - Fast (≥ 1000 km/s) CME's provide the best chance for driving the auroral oval equatorward of the 51.6° inclination ISS orbit for extended periods of time
 - Activate FPMU in advance of CME arrival if not already in operation

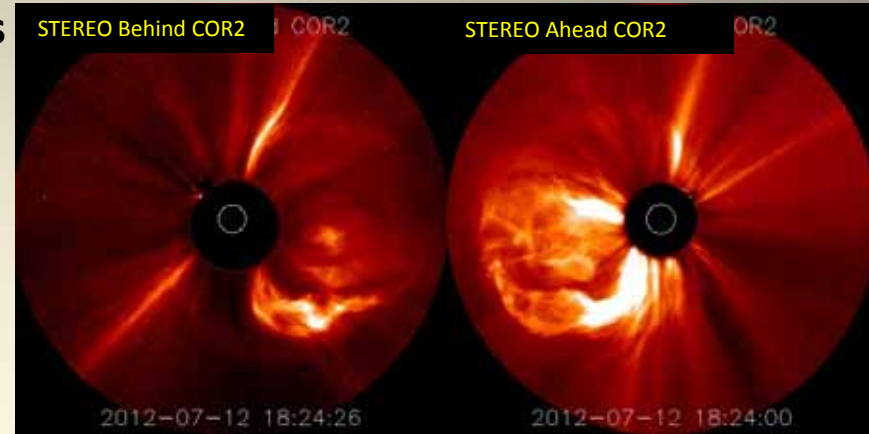




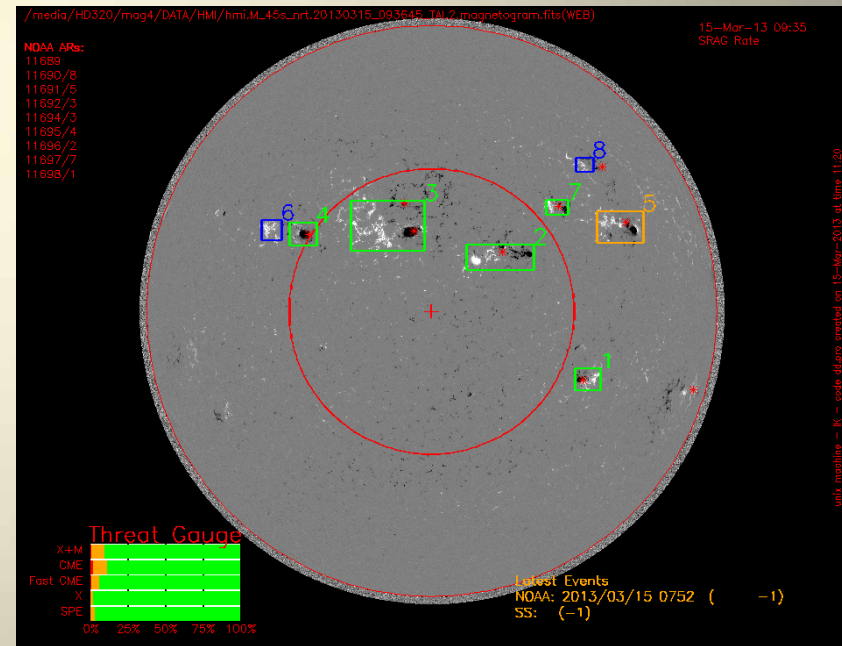
SWx Situational Awareness

Monitor SWx products looking for potential drivers of terrestrial space weather events:

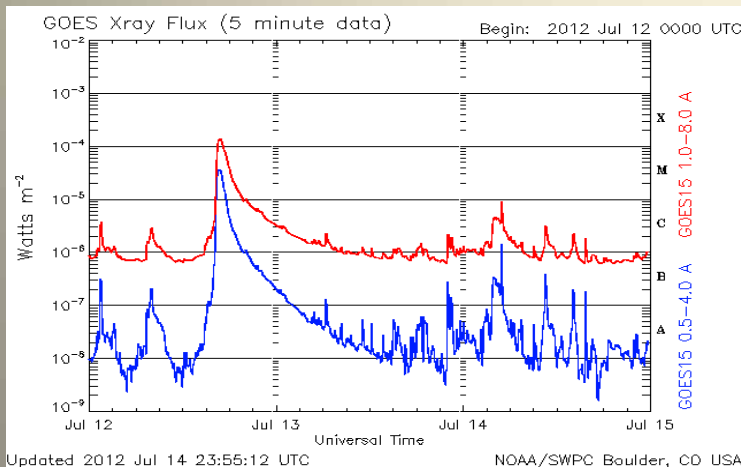
- STEREO and SOHO coronagraph images for solar active regions, CME's
- UAHuntsville/CSPAR Near Real Time forecast tool provides situational awareness to solar activity and probabilities of M- and X-class flares, CME events
- GOES x-ray flux real time products for x-ray flares
- Subscriptions to e-mail alerts from NOAA SWPC, GSFC SWRC, and SIDC for x-ray flare and CME alerts give advanced warning of potentially geoeffective solar disturbances



<http://stereo-ssc.nascom.nasa.gov/browse/2012/07/12/index.shtml>



<http://www.uah.edu/cspar/research/mag4-page>



only available in R - code ddparm enabled on 15-Mar-2013 at time 11:20



Space Weather Alerts and Forecasts

Decision on when to activate FPMU is based on earliest arrival time and NOAA SWPC, GSFC SWRC, and SIDC predictions of shock arrival:

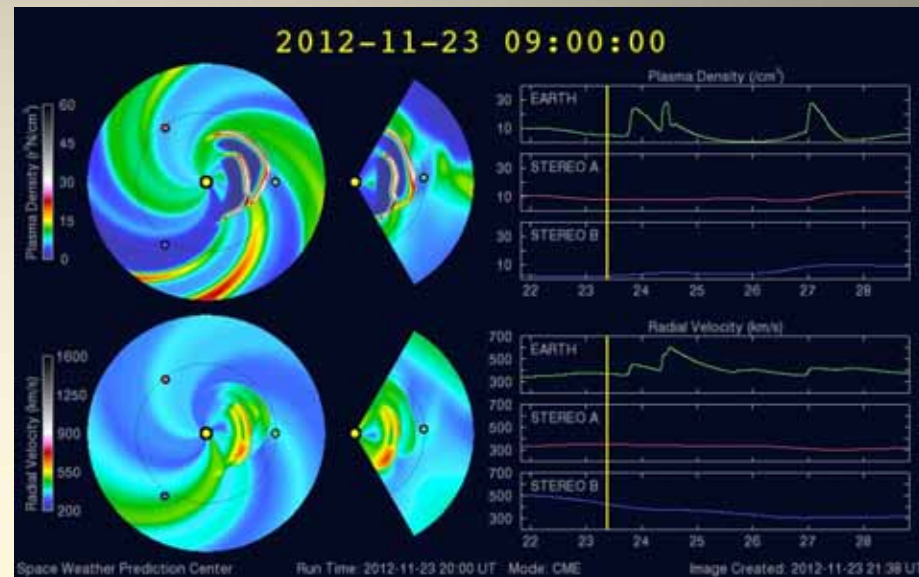
- Subscription alert services from NOAA, GSFC, and SIDC provide CME speeds, arrival times at Earth, and potential levels of geomagnetic activity
- A *conservative* earliest arrival time (EAT):

$$\Delta t = (1 \text{ AU}) / (\text{CME initial shock speed})$$

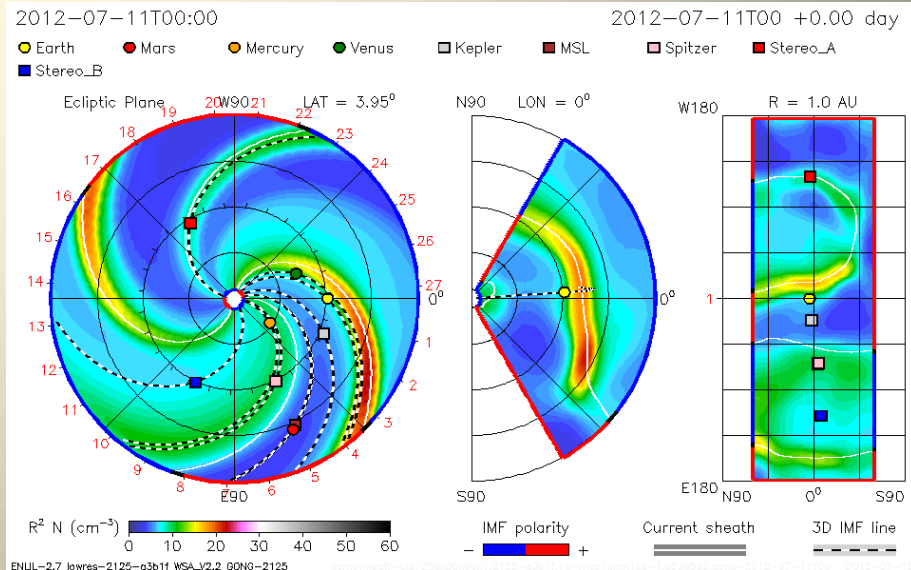
indicates earliest time FPMU needs to be activated assuming no CME deceleration

- NOAA SWPC and GSFC SWRC implementations of the WSA-Enlil CME propagation models provide independent estimates of CME arrival times at Earth that include solar wind drag on CME speed
- The independent EAT, GSFC, NOAA, and SIDC predictions provide an *“ensemble forecast”* for CME arrival time at Earth

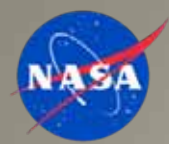
Strategy is to activate FPMU in advance of the CME arrival and initial geomagnetic activity!



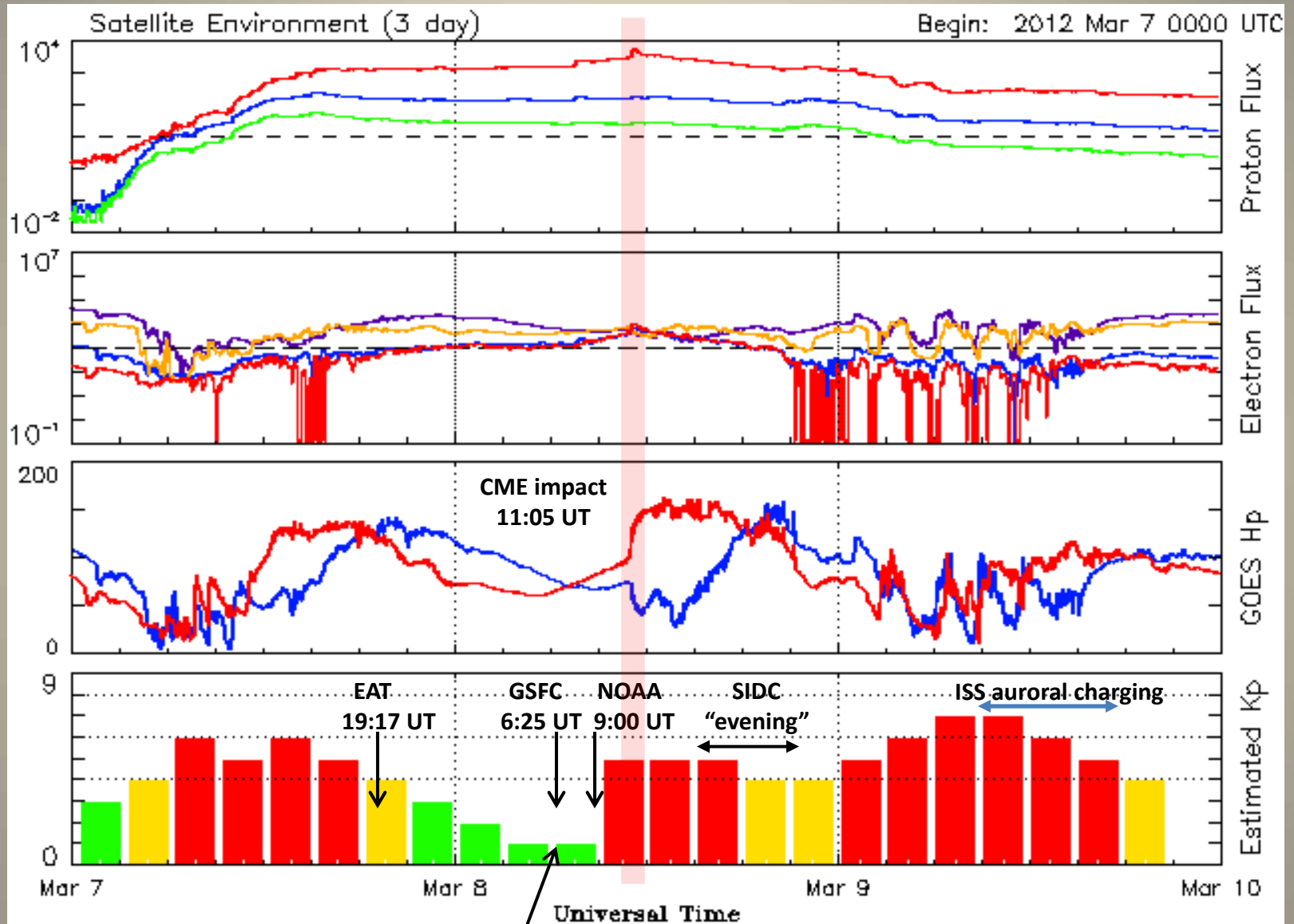
<http://www.swpc.noaa.gov/wsa-enlil/>



http://iswa.gsfc.nasa.gov/downloads/20120712_193100_anim.tim-den.gif

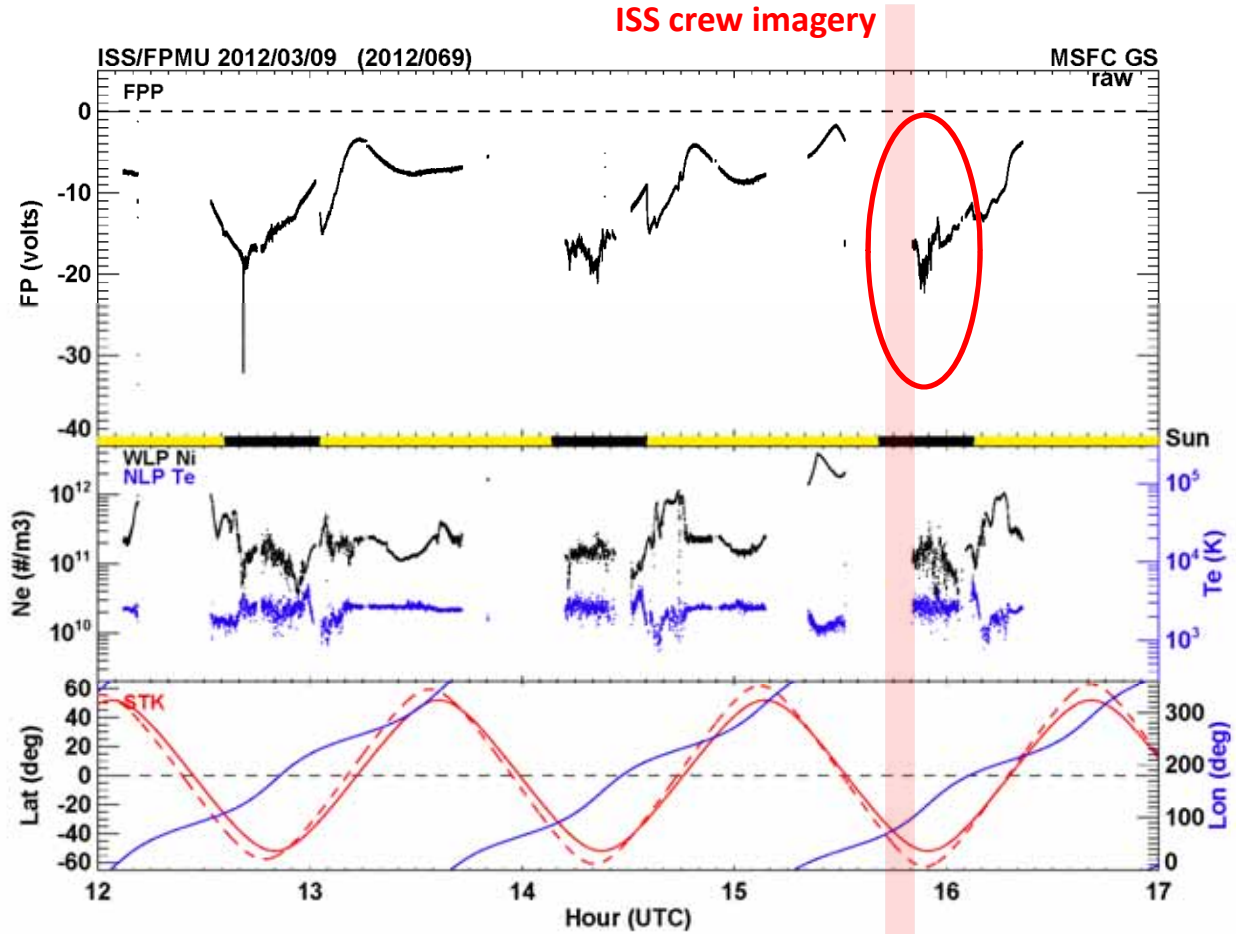


March 2012 Geomagnetic Storm





9 March 2012



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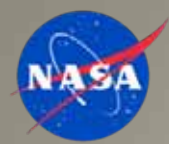
Auroral Images

time

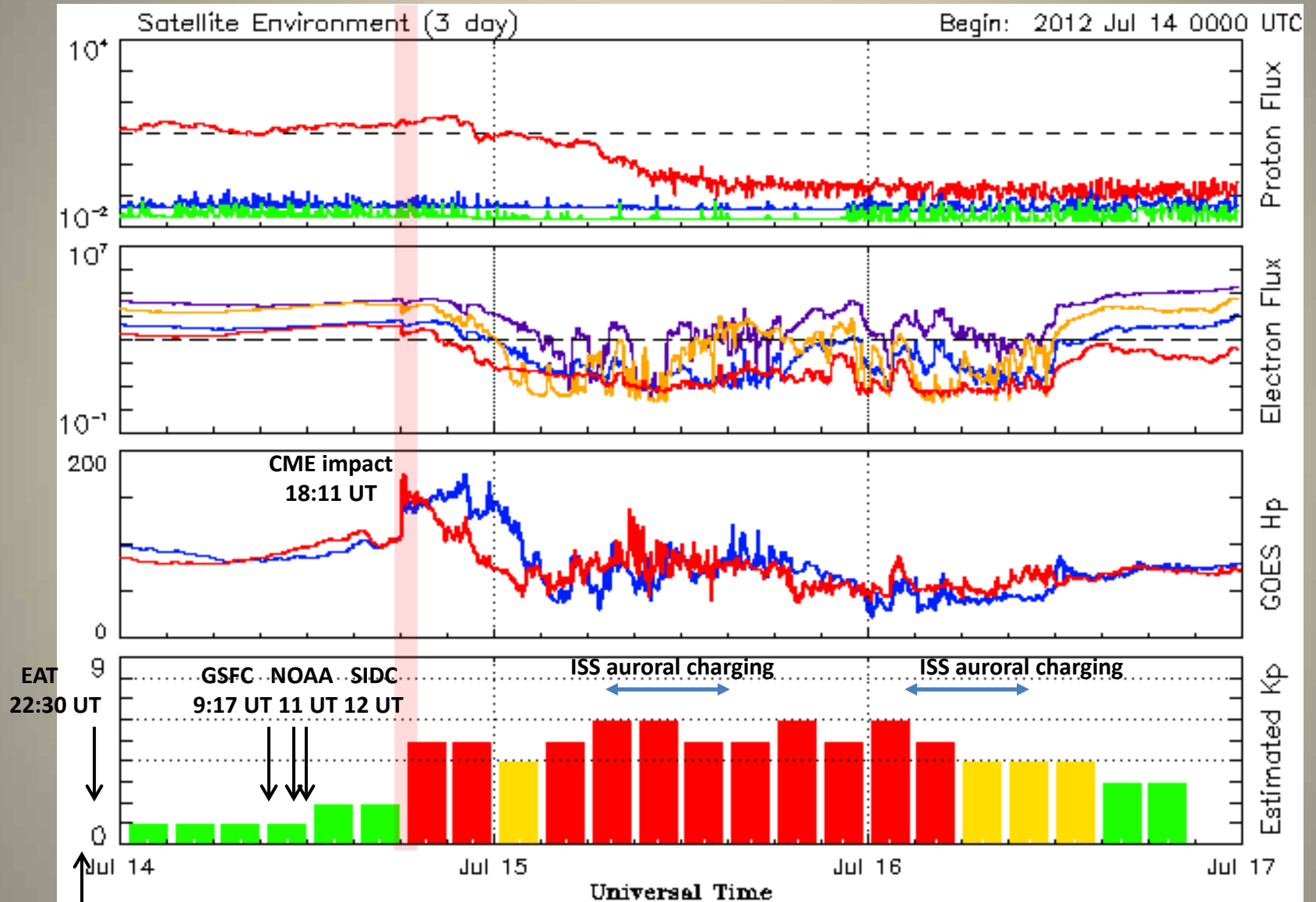
Auroral images from digital camera using wide angle lens through ISS Cupola (Don Pettit, Exp 30/31) show aurora in nadir and ahead of ISS immediately before FPMU records auroral charging

Documents ISS passing through auroral arc!





July 2012 Geomagnetic Storm



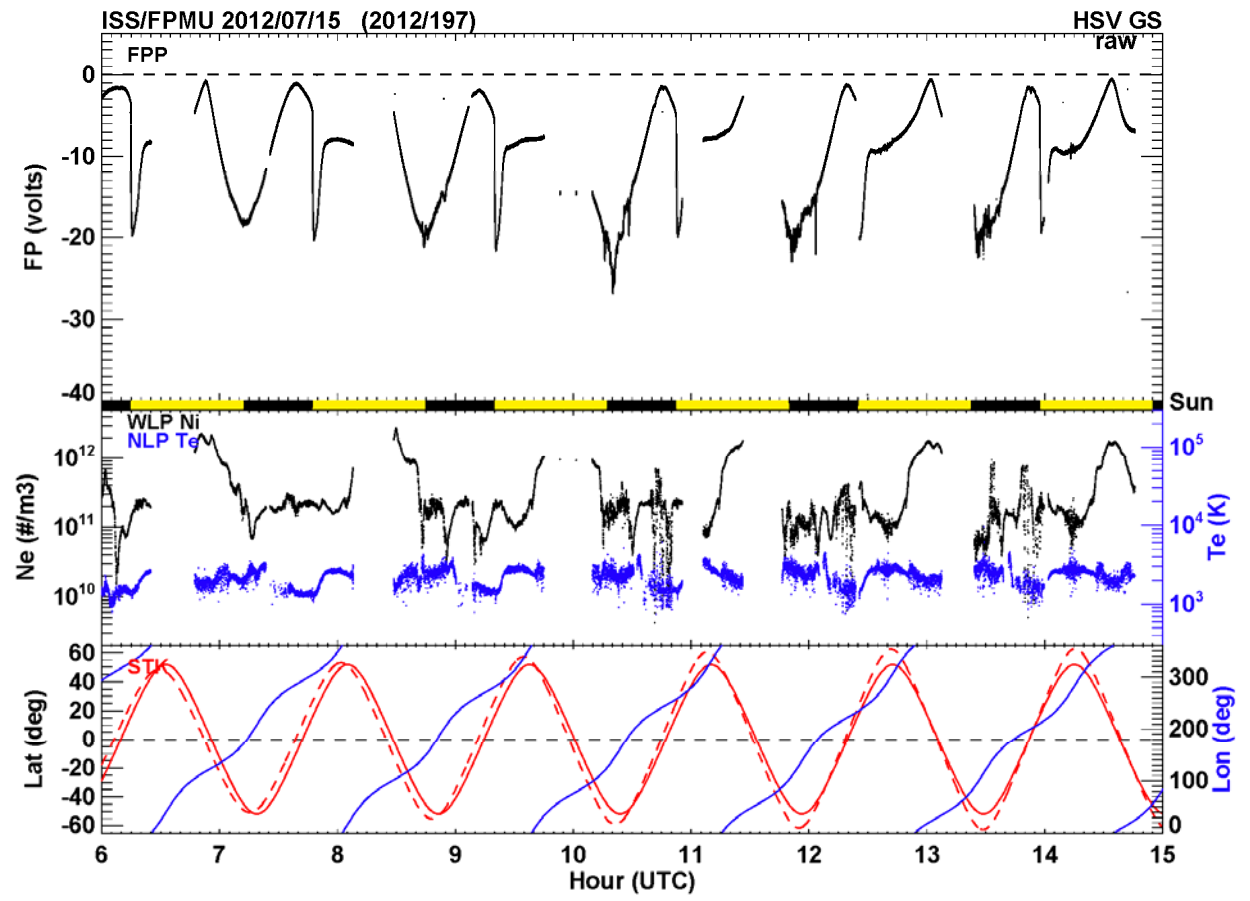
Updated 2012 Jul 16 23:56:05 UTC

NOAA/SWPC Boulder, CO USA

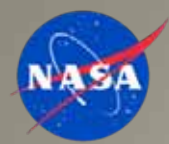
FPMU start 22:00 UT on 13 July



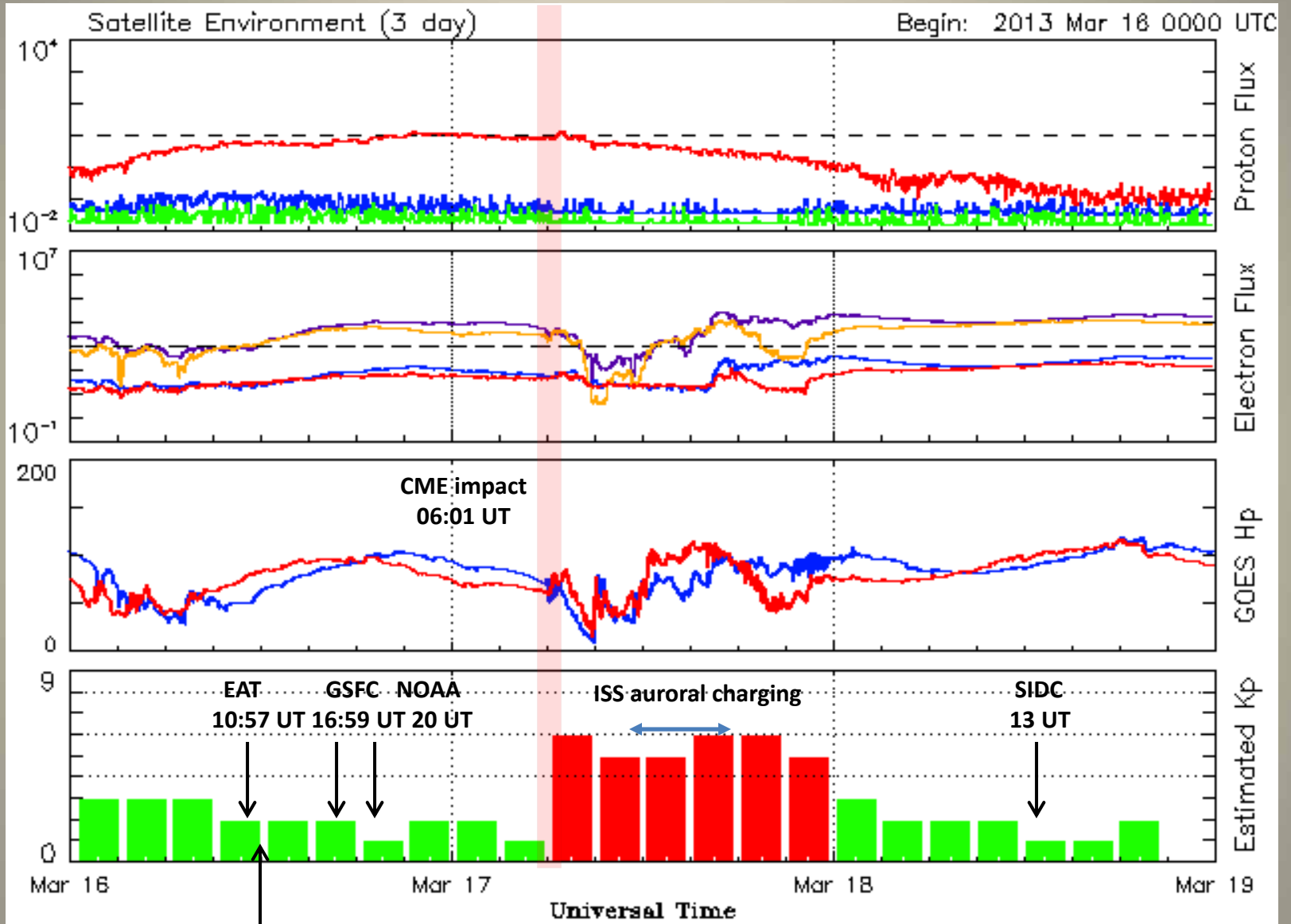
15 July 2012



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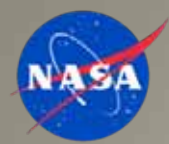
17 March 2013 Geomagnetic Storm



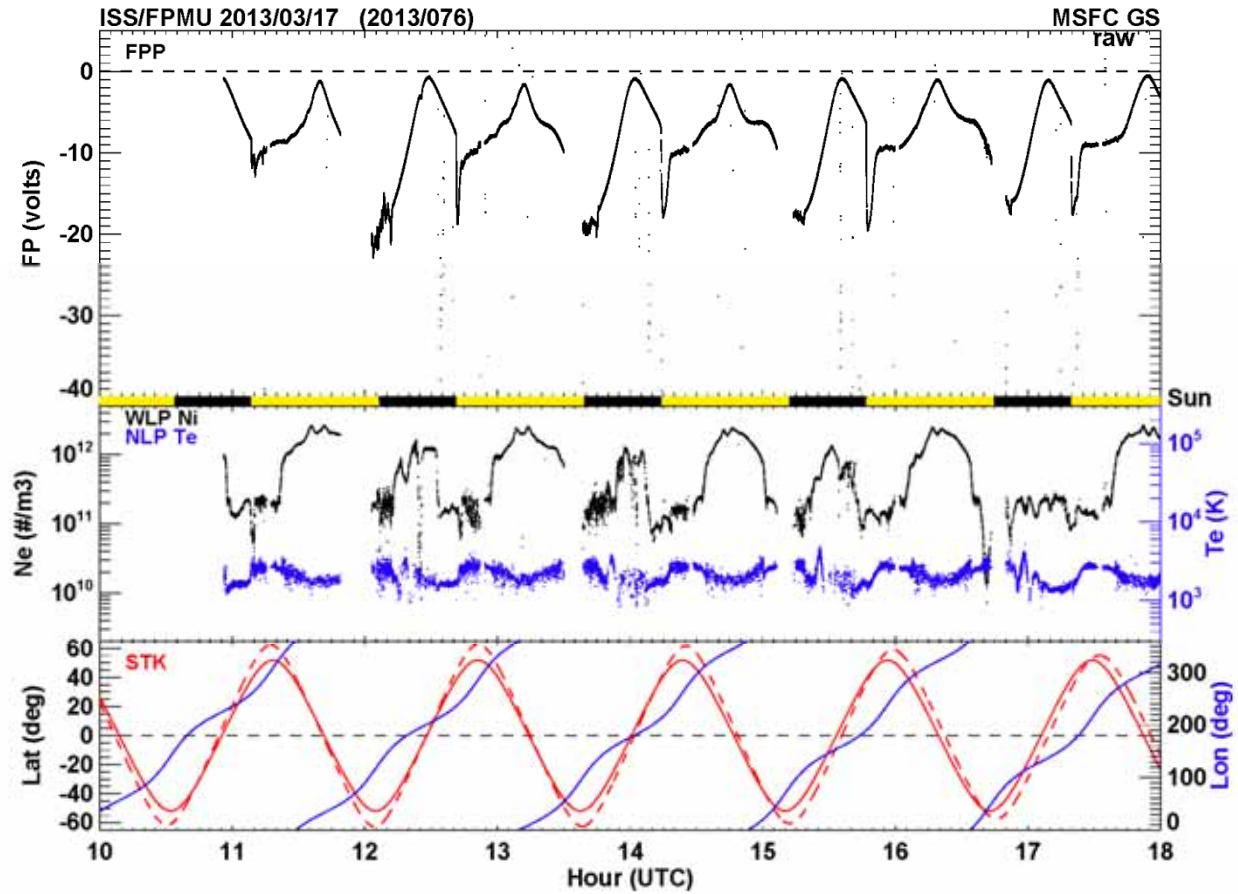
Updated 2013 Mar 18 23:56:08 UTC

NOAA/SWPC Boulder, CO USA

FPMU start 12:17 UT



17 March 2013



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Summary

- Space weather forecast, monitoring, and subscription alert resources provided by NOAA, GSFC, and SIDC aid in capturing periods of ISS auroral charging within the constraints on FPMU operations
- ISS environments team will continue using space weather resources to capture additional FPMU data during future geomagnetic storm periods through the remainder of peak and declining phase of Solar Cycle 24 and into Cycle 25

ISS Auroral Charging Observations

FPMU Operations

1)	26 March 2008 (GMT 086)	STS-123/ESA ATV-001 docking
2)	5-6 April 2010 (GMT 095-096)	STS-131/ISS 19A
3)	22,23,25 January 2012 (GMT 025)	SWx: M8.7 flare, CME ~2211 km/s
4)	9-11 March 2012 (GMT 069-071)	SWx: X5.4 flare, CME ~2200 km/s X1.3 flare, CME ~1800 km/s
5)	23 May 2012 (GMT 144)	SpaceX Dragon berth/unberth
6)	15-16 July 2012 (GMT 197-198)	SWx: X1.4 flare, CME ~1400 km/s
7)	3 September 2012 (GMT 247)	US EVA (contingency)
8)	20 January 2013 (GMT 020)	Solar Cycle 24 Solar Maximum
9)	17 March 2013 (GMT 076)	SWx: M1.1 flare, CME ~1400 km/s

Events obtained specifically due to space weather operations



Thank You