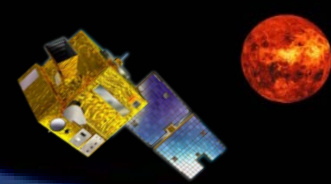
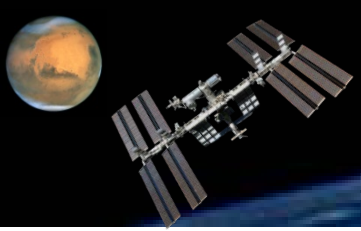


 Space Weather @ B.USOC

13th European Space Weather Week
November 14-18, Oostende, Belgium

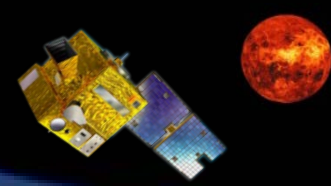
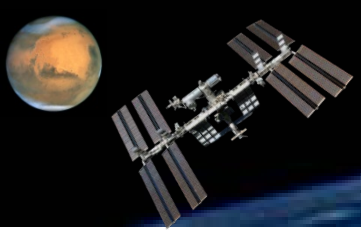


Belgian User Support & Operations Centre

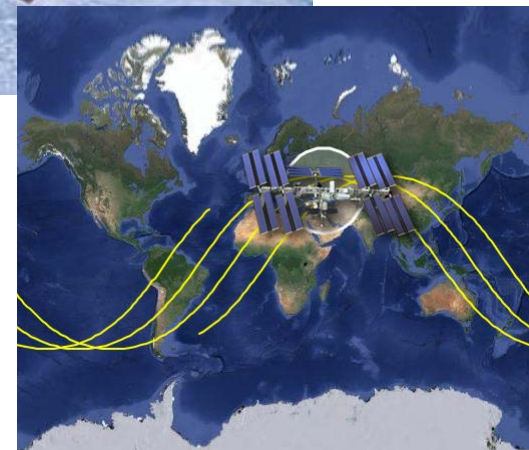


- European experiments in and outside Columbus, the European Module of the International Space Station, are operated from USOCs
- Link between the scientists and the ISS “world”
- Prepare and perform payload operations.
- Monitor, control and troubleshoot.
- Provide data access to user in R/T or near R/T.
- Archive/Process data received.

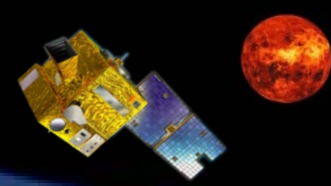
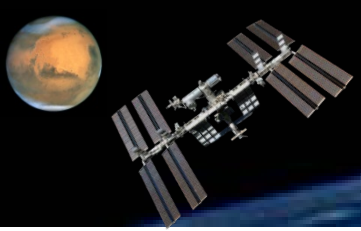
- Located in Brussels
- **2016:** team of
 - 11 Operation Engineers,
 - 6 Ground Controllers



International Space Station



- Altitude: ~400km
- Orbital inclination: 51.6°
- Orbital period: 92.65 minutes
- Typically 6 crew members

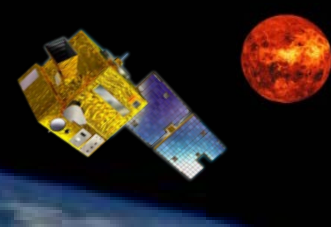
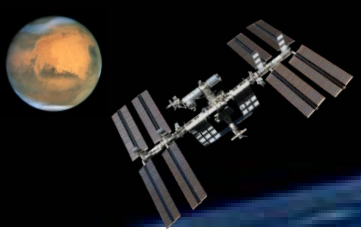


How Space Weather affects International Space Station

- **Communication**
 - S-Band (2-4GHz) and Ku-Band (12-18GHz) using TDRSS



TDRSS: Tracking and Data Relay Satellite System

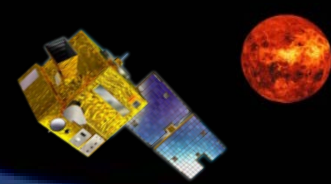
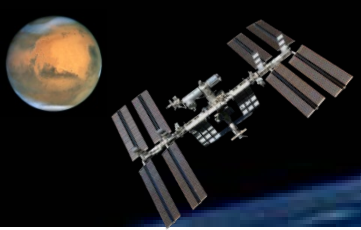


How Space Weather affects International Space Station

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How Space Weather affects International Space Station

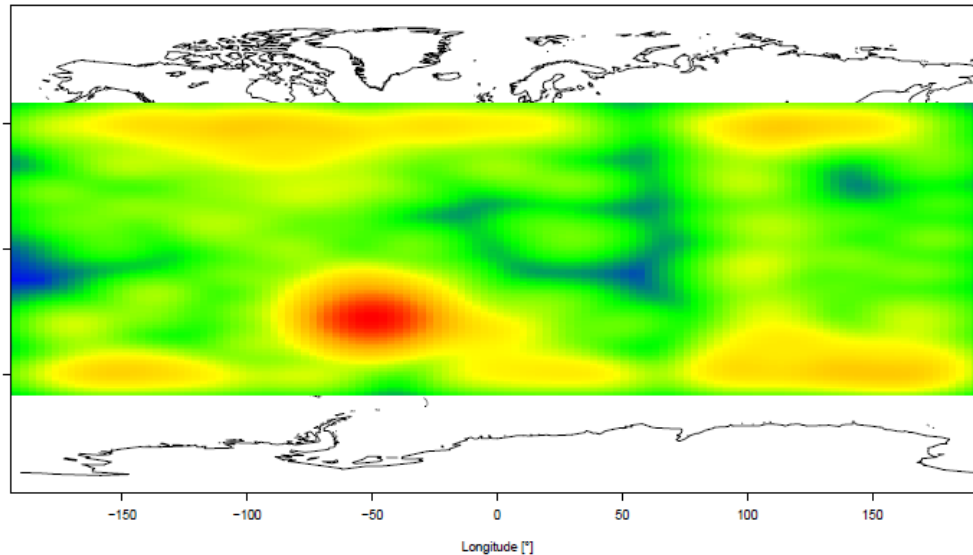
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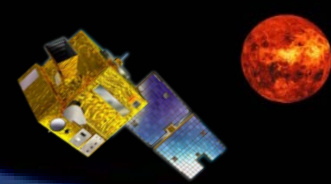
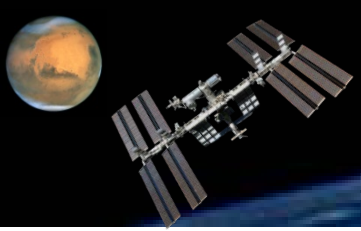
Distribution of single event upsets in 2012

(Verzola, Lagny, & Biswas, AIAA 2014-1722)



TDRSS:





How Space Weather affects International Space Station

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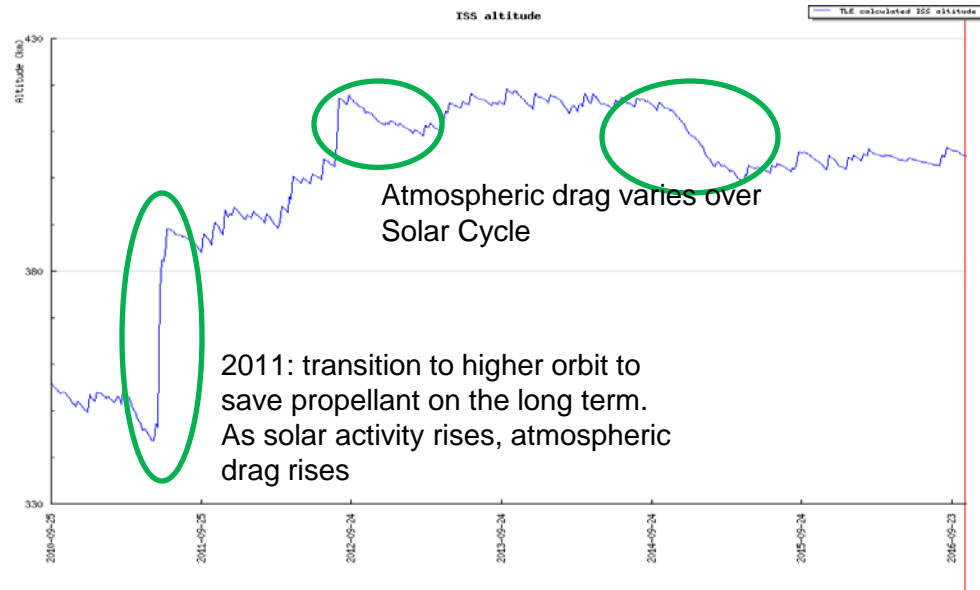
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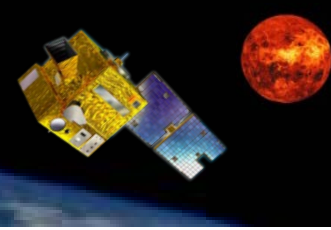
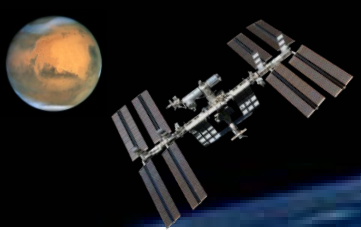
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- **Trajectory Predictions**

- Need for reboosts



TDRSS: Tracking and Data Relay Satellite System



How Space Weather affects International Space Station

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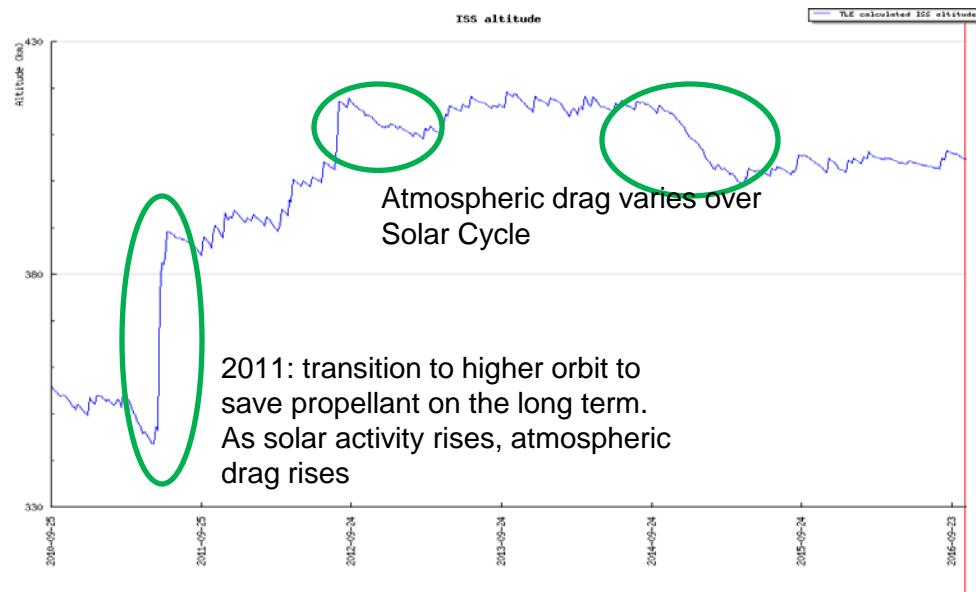
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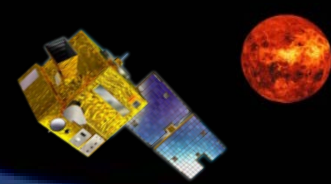
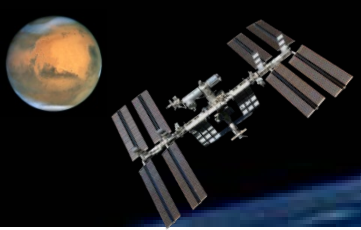
- Need for reboosts

- **Astronaut health**

- Radiation effects
- Max. radiation dose over entire career: 1Sv



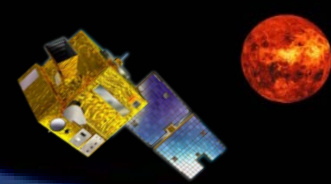
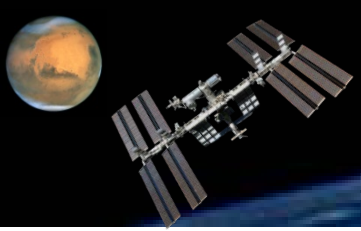
TDRSS: Tracking and Data Relay Satellite System



Crew Radiation Exposure

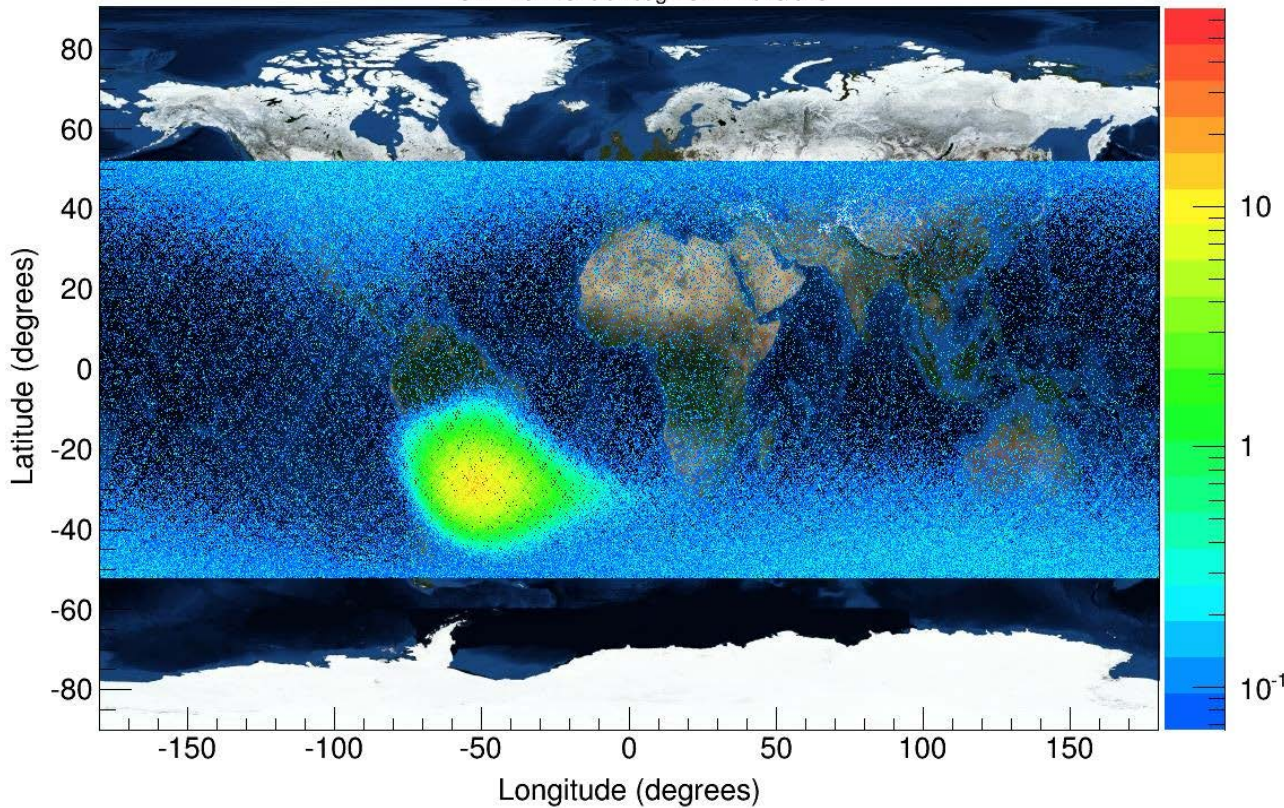
The Space Radiation Analysis Group (SRAG) at the Johnson Space Center is responsible for ensuring that the radiation exposure received by astronauts remains below established safety limits. SARG provides:

- Radiological support during missions.
- Pre-flight and extra-vehicular activity (EVA) crew exposure projections.
- Evaluation of radiological safety with respect to exposure to isotopes and radiation producing equipment carried on the spacecraft.
- Comprehensive crew exposure modelling capability.
- Radiation instruments to characterize and quantify the radiation environment inside and outside the spacecraft.



Crew radiation exposure

REM Orbital Dose Rate Map (uGy/min)
D03-W0094 (S/N 1007)
GMT 2012/320 through GMT 2013/045



Radiation Environment Monitor Data (Timepix instrument onboard the ISS)



Radiation Event Definition and Warning

- Natural sources of space radiation: trapped particles, Galactic Cosmic Rays, Solar Particle Events
- Solar Particle Event (SPE)
 - Exceed of 10 pfu (>10 MeV) at geosynchronous altitude → **alert**
 - Previously, alarm levels were based on X-ray flux level $>M5$
 - Mostly a concern for EVA astronauts
- Energetic SPE
 - Exceed of 1 pfu (>100 MeV) at geosynchronous altitude → **contingency**
 - particles with sufficient energy to penetrate the ISS modules
- Geomagnetic Storm
 - Major: $K_p=6$
 - Severe: $K_p \geq 7$ → **alert**
- Warning generated by NOAA/SWPC and predicted time window provided

pfu: Particle Flux Unit (particles/sr.cm².s)

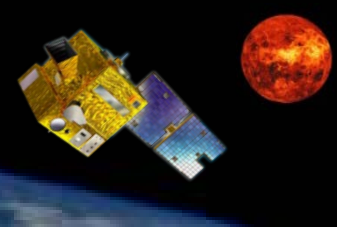
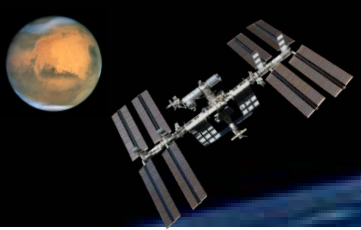
EVA: Extra Vehicle Activity

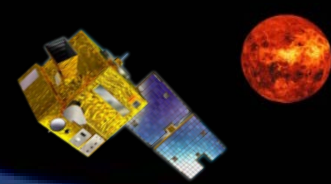
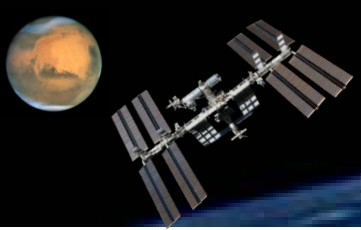
NOAA: National Oceanic and Atmospheric Administration

SWPC: Space Weather Prediction Centre

14-Nov-2016

ESWW13





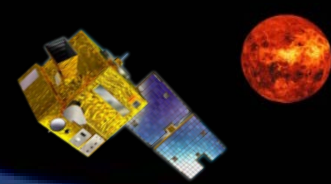
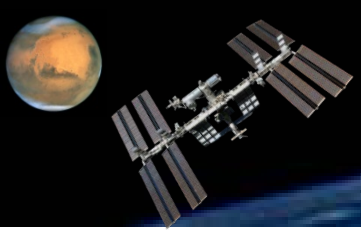
Crew radiation exposure

- Crew ionization radiation exposure limits

<u>EXPOSURE PERIOD</u>	<u>blood forming organ (BFO)</u>	<u>Eye</u>	<u>Skin</u>
30 DAYS	0.25 Sv	1.00 Sv	1.50 Sv
ANNUAL	0.50 Sv	2.00 Sv	3.00 Sv

- Passive and Active dosimeters all around the station
- In case of **alert**:
 - Regular monitoring by Crew and Ground
- In case of **contingency** crew could be advised to avoid lower shielded areas
- If energetic SPE reached 100 pfu (>100 MeV) level, crew should remain in the higher shielded areas:
 - Service Module Aft of Treadmill
 - Node 2 Crew Quarters
 - US Lab





Crew radiation exposure

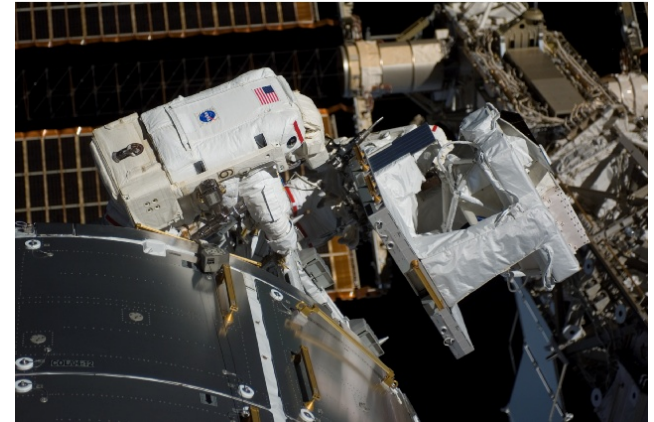
Actions required for radiation exposure conditions

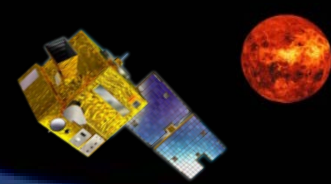
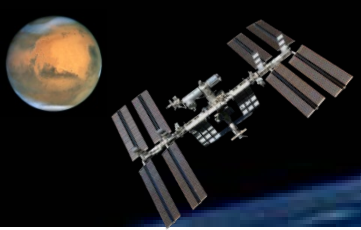
EXPOSURE STATUS	ACTIONS REQUIRED
non-restricted (below the action levels)	<ul style="list-style-type: none"> • Provide routine crew exposure monitoring. • Perform EVA exposure management (go/no-go criteria for EVA based on radiation exposure).
restricted (EXCEEDED action levels)	<p>non-restricted PLUS:</p> <ul style="list-style-type: none"> • review EVA schedules and update end of mission exposure projections. • consider positive actions to reduce the risk of exceeding the joint exposure limits, such as <ol style="list-style-type: none"> 1. restricting crew location within ISS 2. limiting EVAs
VIOLATION or projected violation of Joint Exposure Limits	<p>restricted PLUS:</p> <ul style="list-style-type: none"> • consider positive actions to reduce the risk of exceeding the joint exposure limits, such as <ol style="list-style-type: none"> 1. terminating an EVA in progress 2. changing ISS altitude/attitude 3. DEFERRING reboost 4. accelerating crew rotation



B.USOC Operations – recent missions

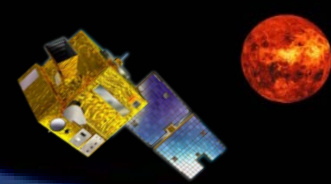
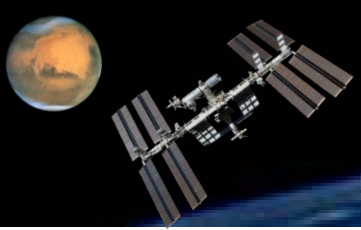
- SOLAR
Spectral Solar Irradiance Measurements
- METERON
Robotic operations
- Fluid Science Lab
- THOR
Observation of thunderstorms and Transient Luminous Events
- ASIM (expected Sep 2017)
Atmosphere Space Interaction Monitor
 - Detection of Terrestrial Gamma Ray Flashes and Transient Luminous Events
 - Science campaigns for Aurora, Polar Mesospheric Clouds, Aerosols,...





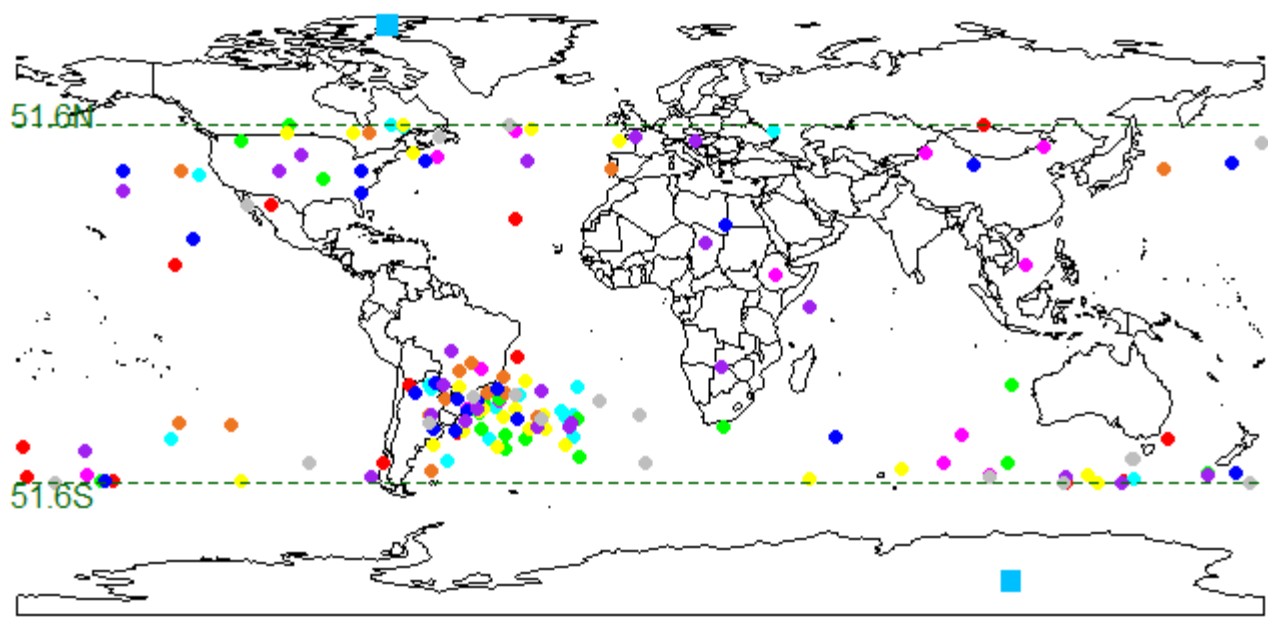
Space Weather and B.USOC operations

- SOLAR
 - Operational since 2008
 - Measure long-term evolution of Total Solar Irradiance (TSI) and Spectral Solar Irradiance (SSI)
 - important for climate models
 - EUV data are input to Total Electron Content models
 - One of the instruments is sensitive to the South Atlantic Anomaly
 - impact on science data; avoid measurements during SAA passage
 - Radiation sensitive component causes the anomalous deactivation of the “Analog Input Board” → recovery requires reboot



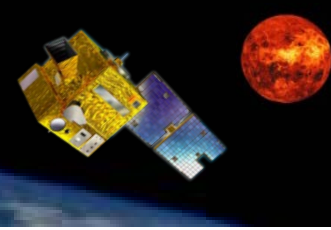
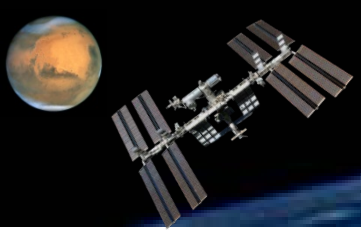
Space Weather and B.USOC operations

position of the ISS at time of AIB failure



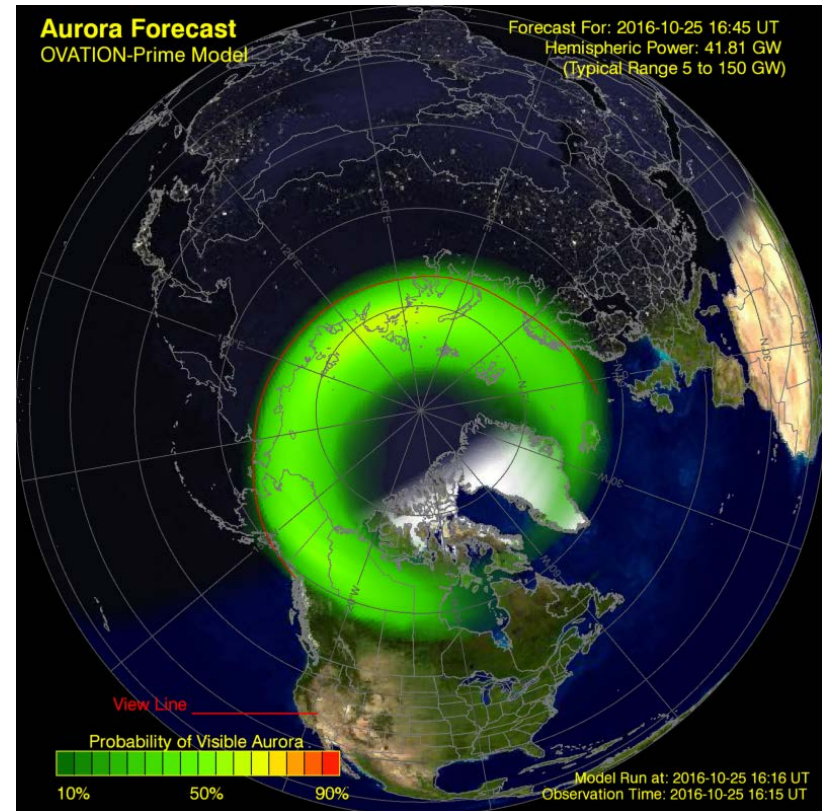
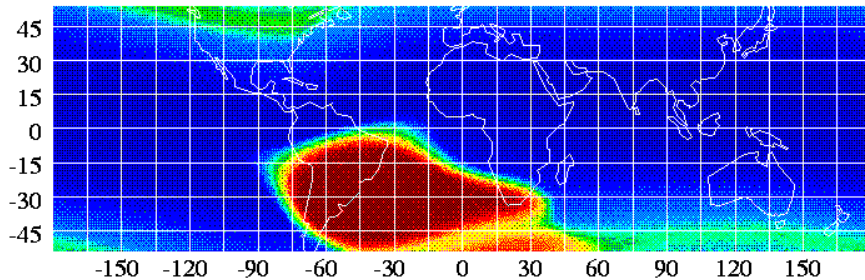
● 2008	● 2012	● 2016
● 2009	● 2013	■ geo-magnetic poles
● 2010	● 2014	
● 2011	● 2015	

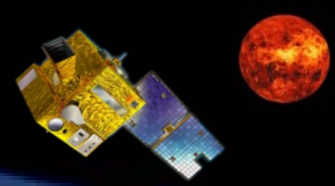
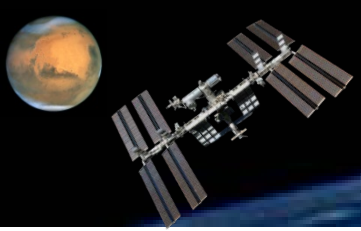




Space Weather and B.USOC Operations

- ASIM
 - One of the ASIM instruments should not be operated over SAA (early degradation of instrument)
 - ISS orbit and trajectory
 - Auroral Oval predictions





Questions?