The Space Weather Enterprise
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The Time is Now

Space Weather Workshop
Westminster, CO
April 17, 2018

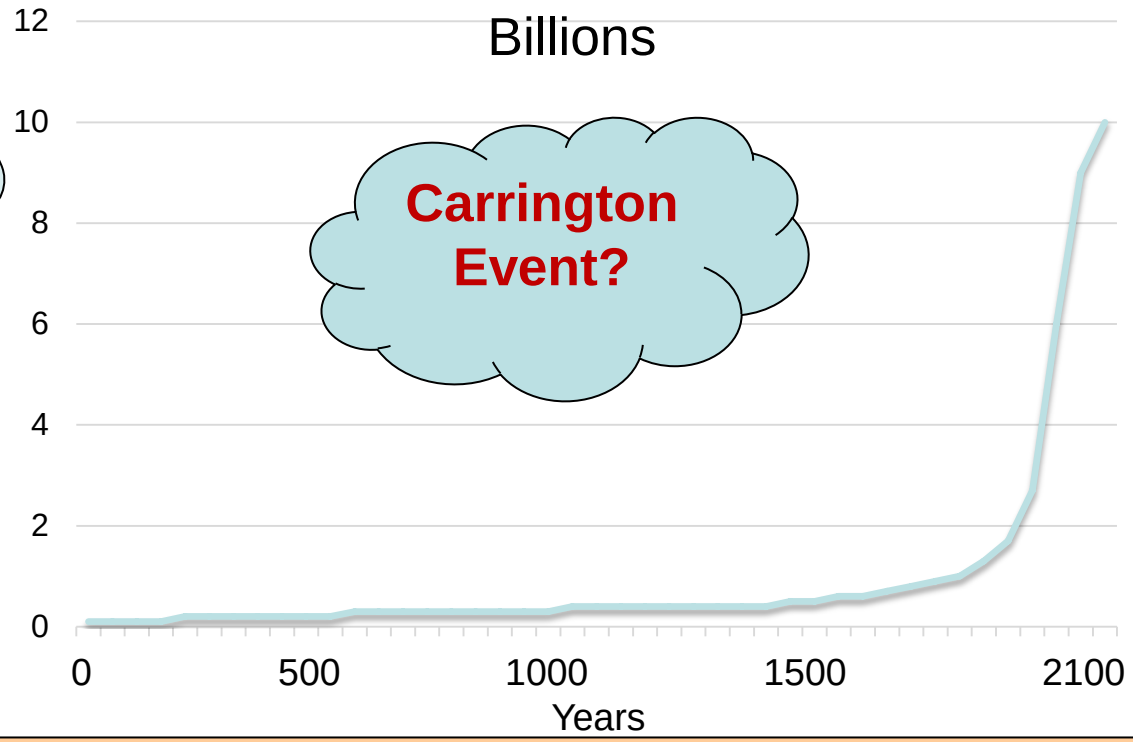
Conrad C Lautenbacher, Jr
CEO, GeoOptics, Inc

Agenda

- Space Weather in the Future
- International Situation
- National Organization
  - Government
  - Commercial
  - Academic
- Commercial Contributions
  - ACSWA
  - Specific capabilities

Long Term Sustainability?

World Population Growth (UN)*



Space Weather Role?

Carrington Event?

- **Earth (& Atmosphere & Sun) -- a system of systems**
- **Current actions inadequate to achieve sustainability**
- **Collaborative International action essential**

*http://www.census.gov/prod/cen2010/briefs/c2010br-09.pdf

International Level

- Space Weather **Enterprise? (**Academic, Government, Commercial)

- Committee on the Peaceful Uses of Outer Space (COPUOS)
- Committee on Space Research (COSPAR)
- International Committee on Global Navigation Satellite Systems (ICG)
- United Nations Office for Outer Space Affairs (UNOOSA)
- Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)

- Handful of Bilateral Agreements
- Fair Weather Report (US only)
- Commercial Contributions ?

Many pieces – How can/will they work together?

International

UN/US Workshop International Space Weather Initiative: The Decade after the International Heliophysical Year 2007

BOSTON COLLEGE, CHESTNUT HILL, MA 31 JULY - 4 AUGUST, 2017

Marks tenth anniversary International Heliophysical Year, which led to International Space Weather Initiative (ISWI).

Focus on recent scientific research advances by:

- Using ISWI instrument data
- With space mission data
- Adding significant new knowledge on Space weather phenomena
- In near Earth and interplanetary space.

International Weather

WMO Efforts to Create a World Weather **Enterprise**

- Special Executive Committee Meeting Session June 2016
  - Academic, Government, Commercial Speakers invited
- World Bank/WMO Workshop Nov 2017
- World Bank/WMO Workshop at AMS Jan 2018
- Critical need: location and organization to serve as host and “honest broker”

Can WMO perform that role?

Fair Weather Report*

Effective Partnership in Weather and Climate Services

- In 2002 Friction among the Three Sectors
  - New technologies and emerging user communities affect role definition
  - Different philosophies of sharing data and models
  - NRC was requested to study the issues and develop a solution
- Recognizes the Three Sectors
  - NWS (Government) -- protecting life and property and enhancing the national economy
  - Academia -- advancing science and educating future generations
  - Private Sector – production of products and services tailored to client needs
- System is productive but with built-in frictions
  - All contribute to same activities – Differentiating roles difficult
  - Different philosophies of sharing data and models
  - New technologies and user communities emerge affecting role definition

*Fair Weather: Effective Partnerships in Weather and Climate Services (2003) NRC Report

Fair Weather Report*

- Eleven Recommendations
  1. NWS defines processes for making decisions not products
  2. NWS Establish independent advisory body
  3. All three parties seek neutral host to discuss issues periodically
  4. NWS maintain activities essential to mission
  5. NWS Make data and products available in internet accessible formats
  6. NWS Improve process for developing new products that meet new needs
  7. NWS develop process to balance local new product creation with public-private partnership
  8. NWS Adopt/improve processes for communicating information in probabilistic formats
  9. NWS retain role as official source of instrumentation, data, and data collection standards
  10. Private sector work with other sectors to develop processes to minimize friction
  11. Academia use transparent processes to transfer technologies and avoid conflicts of interest

*Fair Weather: Effective Partnerships in Weather and Climate Services (2003) NRC Report

National Space Weather Strategy*

Introduction

"The Strategy and Action Plan build on recent efforts to **reduce risks** associated with natural hazards and reduce risks associated with natural hazards and **improve resilience** of essential facilities and systems, aiming to foster a **collaborative environment** in which **government, industry,** and the **American people** can better understand and prepare for the effects of space weather."

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"The Nation must continue to **leverage existing public and private network of expertise and capabilities** and pursue targeted enhancements to improve the ability to manage risks associated with space weather."

*https://www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf

The Space Weather Enterprise

Products and Services

Maximizing Value

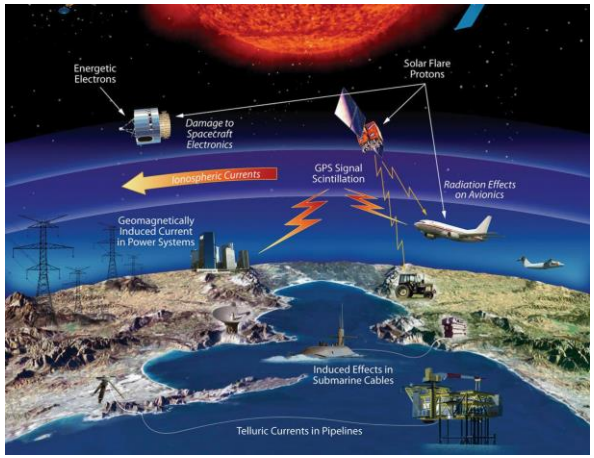
Analogy: **"Weather Enterprise"**

Government

- **Public Safety**
- Economic Health
- National Defense
- **Regulation**

Academia

- Science
- **Research**



Commercial

- Services
- **Efficiency**
- Competition
- **Robust Economy**
- Communication

Enterprise Efficiency

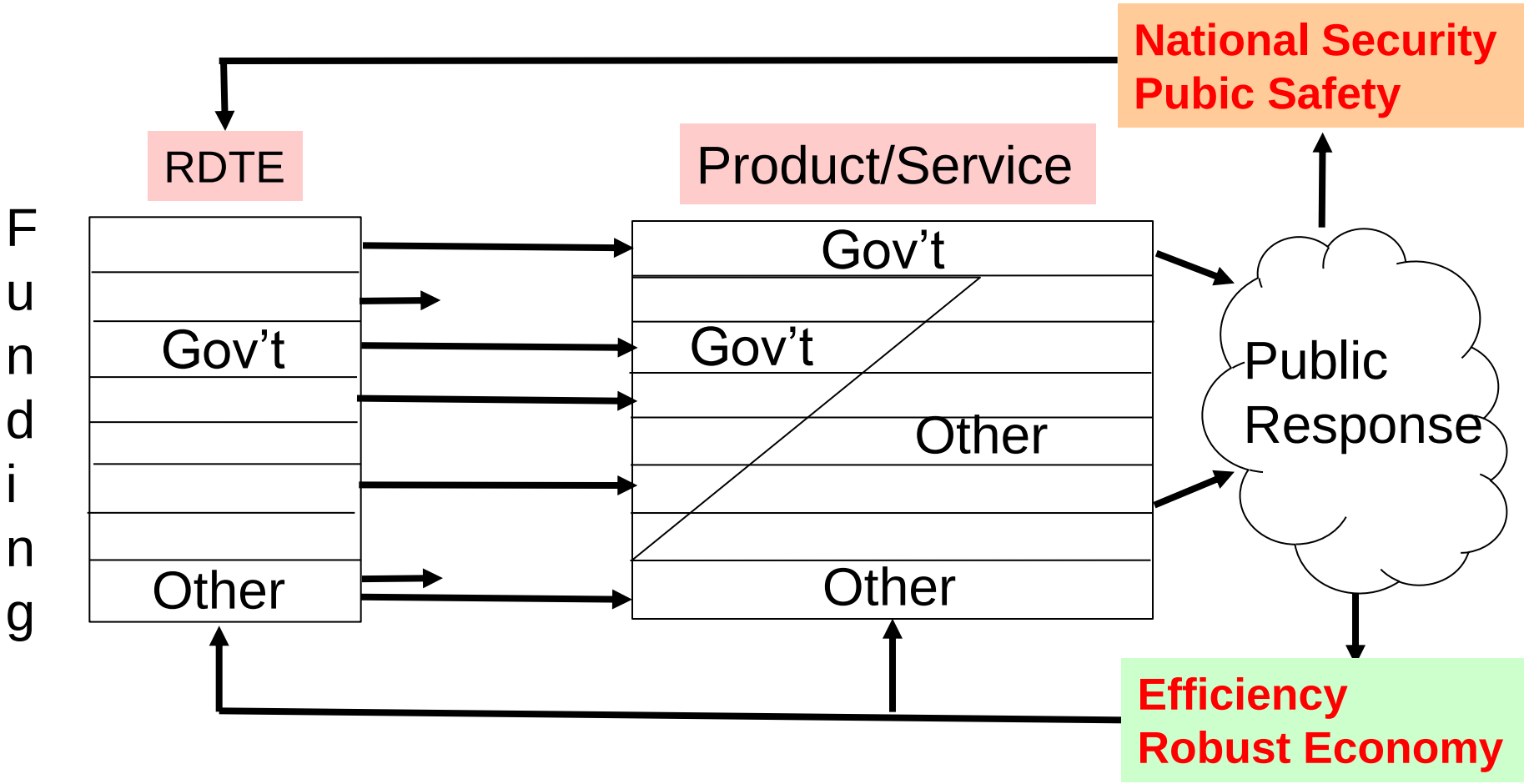
Which system architecture is the most efficient?

Swim Lanes?

Free for All?

*NOAA's Policy on Partnership; Edward Johnson, Dir Strategic Planning & Policy NWS 1/22/ 2015

“Swim Lanes” for National Needs



Other = NGO, Free Enterprise

Commercial Space Contributions

Examples

- Power Grid Outages*
  - Storm Severity Index “Dst”
    - Commercially developed for USAF
    - Now publically available and in use
- Radiation in Air Travel*
  - ARMAS Program
    - Started by commercial company
    - Measures radiation dose
- Ionospheric Scintillation*
  - Event during Katrina wiped out HF radio
    - Companies w/Utah State -- free 24 hr global forecasts

*Courtesy of W. Kent Tobiska

Commercial Space Contributions

Examples

- Upper Atmosphere Storm Density Increases*
  - 1990 NORAD lost 200 satellites
    - Companies working with Space Command
    - HASDM system and new density model created
- Power Utility Local Situation Awareness
  - Geomagnetically Induced Current (CIG)
    - Magnetometer installations for monitoring GIC hazard
    - Hazard Analysis for planning & operations
- Monitoring the near earth space environment
  - Sensors, Models, Data Products
    - Small form factor high luminosity optics for space sensing.
    - Remote, autonomous ground based sensing stations

*Courtesy of W. Kent Tobiska

The Environmental Data Services Company

The End

ARMAS FM6

Features:

- Measurement of absorbed dose in silicon
- Small size and mass
- Data retrieval via Bluetooth pairing with smartphone or tablet app
  - Display current status on app
  - use plane's WiFi to transmit to ground as needed
- Level 4 real-time dose rates provided (effective dose rate)

Status:

- First 6 units in production for specific customers
- FM6A delivered Jan 2018
- FM6B-F deliveries in June 2018

American Commercial Space Weather Association

Capabilities*

- Algorithm development
  - Automatic event detections (flares, solar energetic particles, geoeffective CMEs)
- Calibration/validation
- Data assimilation
- GPS modeling and services
- HF propagation
- Numerical modeling and simulation
  - Sun, interplanetary medium
  - magnetosphere, ionosphere
  - thermosphere, lower atmosphere
- Operational implementations / Research to Operations (R2O)
- Risk and threat analyses for infrastructure and space resources
- Satellite data analysis & data product development
- Sensor hardware & modeling
- Software tools
  - Application development (web-based and smart phone)
  - Data hosting / data product delivery
  - Data / model visualization
- Space Situational Awareness (SSA)
- Spacecraft anomaly prediction and assessment
- Space weather data product and service distribution
- Space weather now-casting/forecasting

*http://www.acswa.us/capabilities.html

American Commercial Space Weather Association

- **Formed in 2010, 5 Members;**
- **2017, 19 Members:**

AER, ASTRA, CPI, CRC, FF, GO, IS, PiQ, PRA,PSI, Q-up, SAC, SEC, SET, SSI, SSH, SA, SWFTT, NGF

www.acswa.us

Executive Committee:

G. Crowley (ASTRA)
A. Engell (NGF)
D. Intriligator (CRC)
C. Lautenbacher (GO)
R. Robinson (IS)
R. Schunk (SEC)
K. Tobiska (SET)

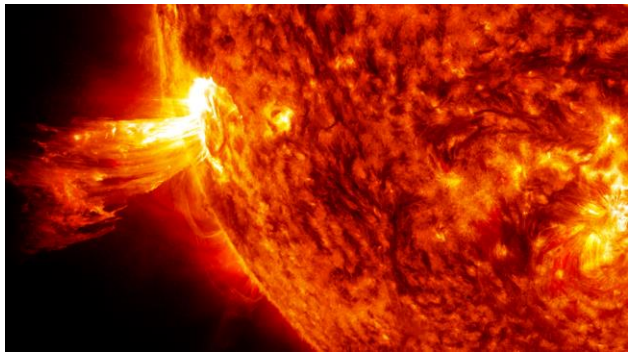
Commercial Space Weather Industry

Products and Services

Value Chain

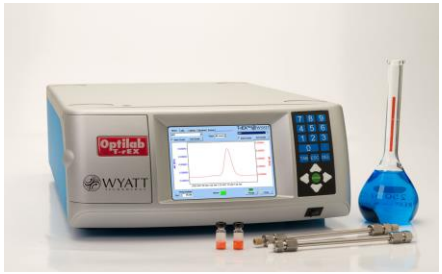
Upstream

- Research
- Observations
- Instrumentation
- Data



Mid-Stream

- Data Processing
- Computation
- Algorithms
- Models



Downstream

- Forecasts
- Warnings
- Services
- Emergency Mgt

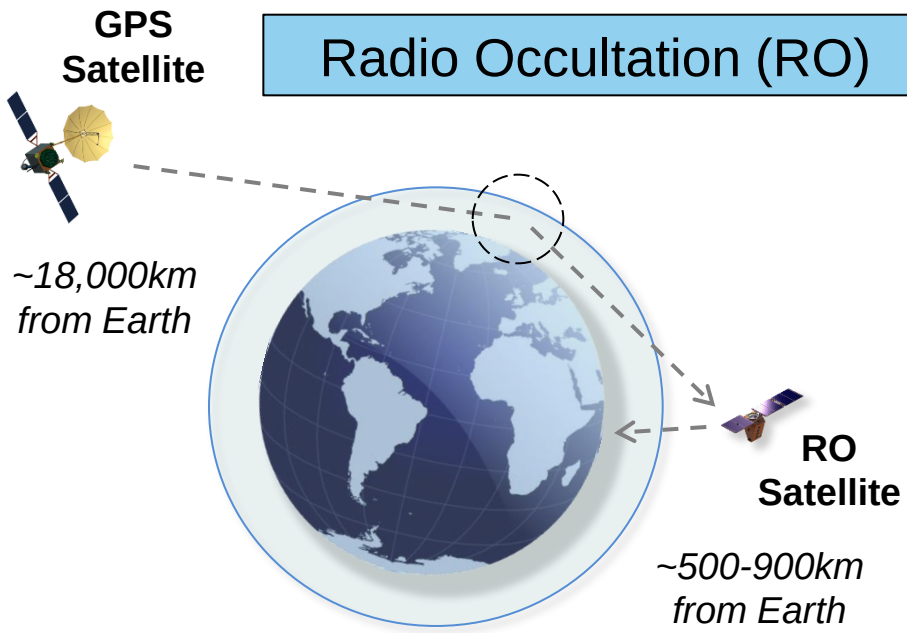
ACSWA
American Commercial Space Weather Association
2010

American Commercial Space Weather Association

"Community Initiative for Continuing Earth Radio Occultation"

CICERO

- Nano Satellites
- 6 ⟶ 24 ⟶ 48 ⟶ ?
- Cion Receiver
- Ground Command & Control
- Data Processing
- Products
  - High Resolution Atmospheric Profiles
    - Bending Angle
    - Refractivity
    - Density
    - Pressure
    - Temperature/Moisture
    - Absolute Measurement Heights
  - Ionospheric Electron Density
  - Global Temporal & Spatial avgs
  - Global pressure contours, gradients & geostrophic winds
- Replenishment & Updating



COSMIC

- Fully Successful RO Test
- Rapidly Reaching End of Life

COMPUTATIONAL PHYSICS, INC.

Local situational awareness of GIC - "Geomagnetically Induced Current"- for power utility planning and ops

AVERT real-time induced electric field hazard map: GIC hazard analysis for power utility research, planning and operations

Above: AVERT with SHM sites (existing ; planned 2017)

Space Hazard Monitors (SHM)

Magnetometer installations for monitoring GIC hazard

Designed to meet power industry standards

Remotely deployable and fully autonomous

CONTACT INFORMATION
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COMPUTATIONAL PHYSICS, INC.

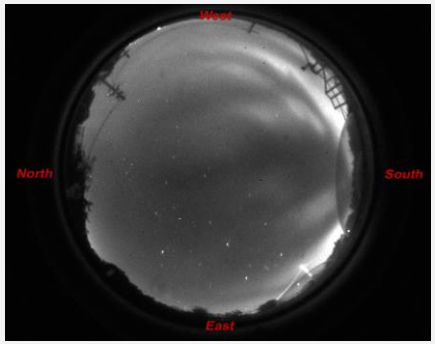
Modeling and monitoring the near earth space environment from the ground and space.

DATA PRODUCTS:

Thermospheric neutral temperatures and Doppler winds at the Arecibo and Millstone Hill Observatories.

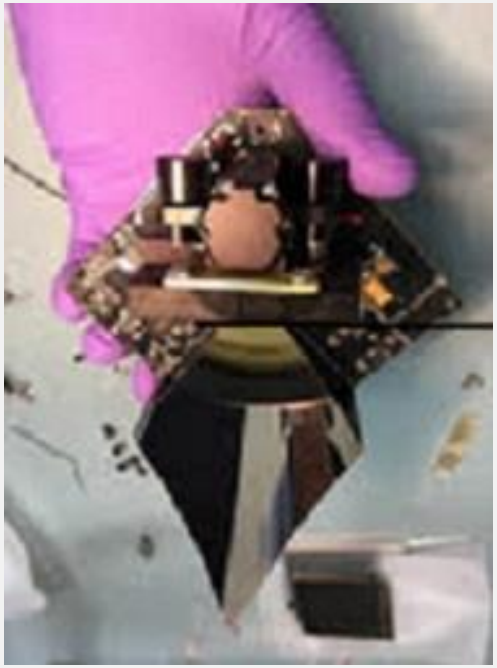
MODELS:

AURIC atmospheric radiance model; **B3C** auroral model.



ESF plume imaged at 630 nm over the Arecibo Observatory. Image taken 20 Nov 2014 at 10:30 PM local time. ESF plumes started at about 8:20 PM.

SENSORS &



Small form factor high luminosity optics for space based remote sensing.

Ground based neutral atmosphere sensors, including imagers, spectrographs and Doppler imagers.

Remote, autonomous ground based sensing stations for monitoring TEC and the neutral thermosphere.

CONTACT INFORMATION

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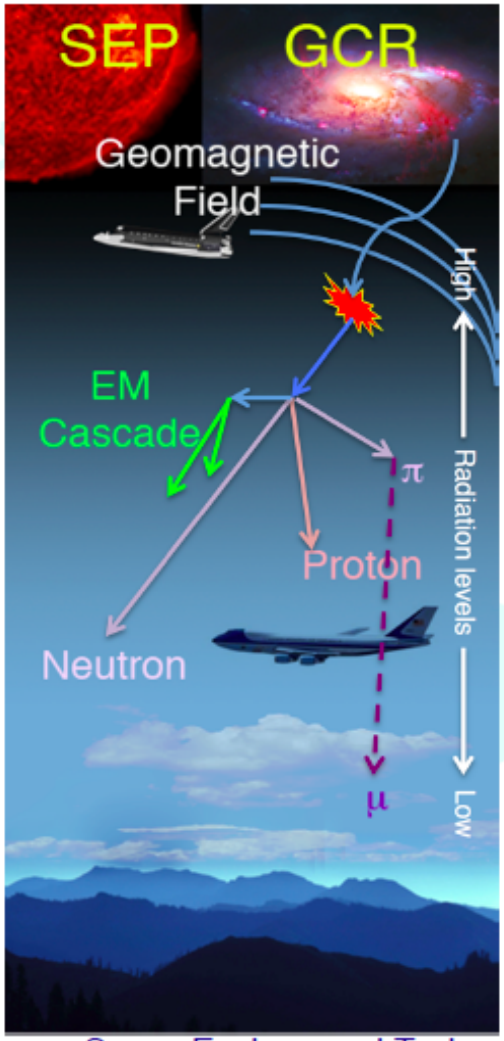
noto@cpi.com
http://www.cpi.com
http://www.neutralwinds.com

ACSWA
American Commercial Space Weather Association
2010

SPACE ENVIRONMENT TECHNOLOGIES
Space Weather Division

ARMAS



Space weather creates a dynamic radiation environment at aviation altitudes

Aviation radiation exposure can come from

- ✓ **global phenomenon** GCRs (career health issue)
- ✓ **high latitude phenomenon**
  - ✓ **Extended major events** SEPs (fleet operations and aircrew/passenger safety issue)
  - ○ **Possible short-term minor events** precipitating outer radiation belt energetic electrons (career health issue)?

Space Environment Technologies

http://spacewx.com

SEP – Solar Energetic Particles CME – Coronal Mass Ejection GCR – Galactic Cosmic Radiation

SPACE ENVIRONMENT TECHNOLOGIES
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ARMAS

SET manufactures the ARMAS FM6

- FM6 has a micro dosimeter, GPS, micro SD data logger, Bluetooth and external in a size similar to a smart phone; app link to phone or tablet
- Measures all altitude ranges and all sources of radiation
- **Personal dose exposure reported around the world** providing situational awareness with NAIRAS model data inclusion
- **Provides management options for rad flight events**
- FAA compliant (stand-alone – no attachment to plane)

SPACE ENVIRONMENT TECHNOLOGIES
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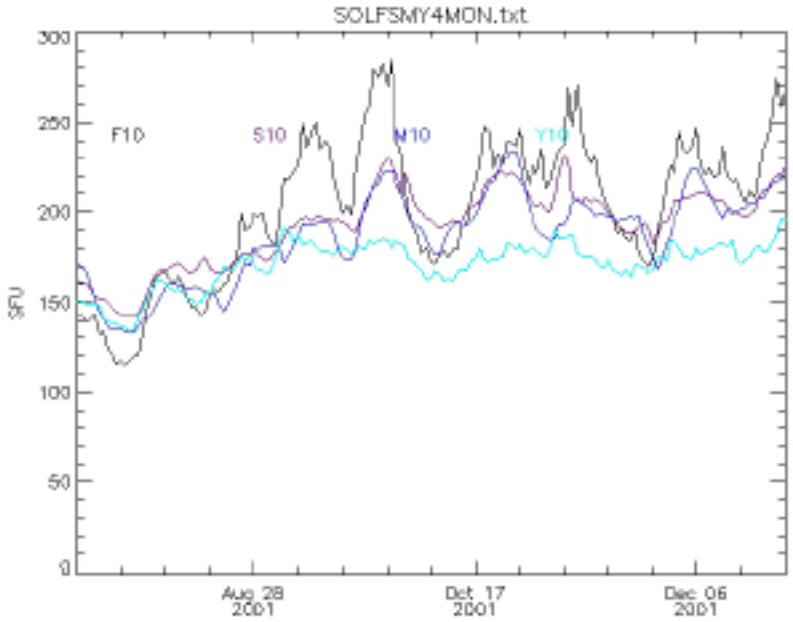
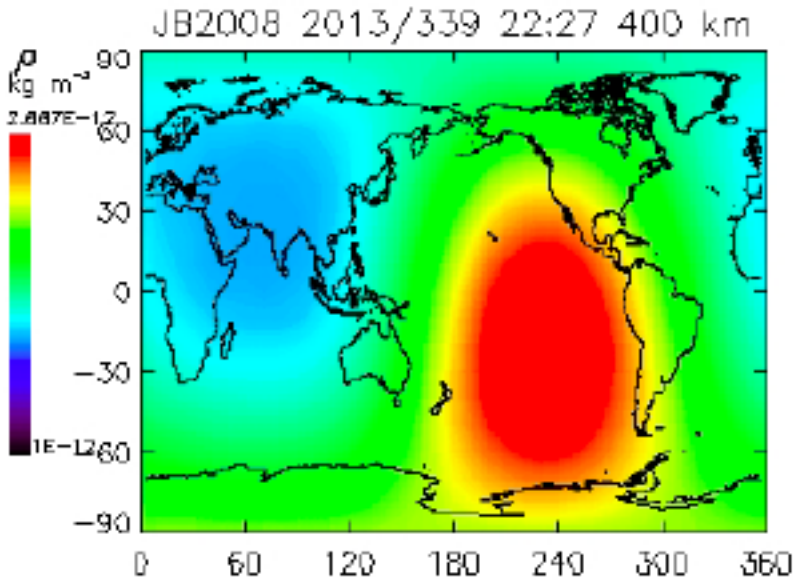
JB2008

JB2008 solar indices provide most accurate specification of Low Earth Orbit neutral densities





Space Environment Technologies

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Solar Activity