

Space Weather Benchmarks (2)

- Solar Radio Bursts
 - Emitted routinely average 3.5 days solar max and 18.5 days solar minimum
 - Disrupts GPS, comms & nav systems (coherent generally)
 - Coherent & incoherent emissions distinction needed
 - Lack of polarization data
- Upper Atmospheric Expansion
 - Characterize ability to determine increased neutral mass density in upper atmosphere
 - Enhances drag on satellites & space debris
 - Interfere with monitoring debris trajectories and reduce^s sat lifetime
 - Need more observational data to improve models



*IDA Science & Technology Policy Institute; Next Step Space Weather Benchmarks



American Commercial Space Weather Association

Leveraging the Commercial Sector

--

Space Weather Operations and Research Infrastructure: A Workshop in Two Parts

The National Academies
Space Studies Board
September 10, 2020

Conrad C Lautenbacher, Jr
CEO, GeoOptics, Inc



American Commercial Space Weather Association

Agenda

- Background (Last 20 yr Summary)
 - Space Weather development
 - Space Weather Bill
- Space Weather Enterprise
 - Commercial Space Weather Role
 - ACSWA
- Space Weather Bench Marks
- Commercial Contributions
 - Capabilities



U.S. National Space Weather Strategy*

In Place

- “The Strategy and Action Plan 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.” *
- “The Nation must continue to **leverage existing public and private network of expertise and capabilities** ... to improve the ability to manage risks associated with space weather.” *

Official Recognition of the Commercial Sector

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



American Commercial Space Weather Association

The Space Weather Enterprise

Products and Services

Maximizing Value



Analogy:
“Weather
Enterprise”

Government

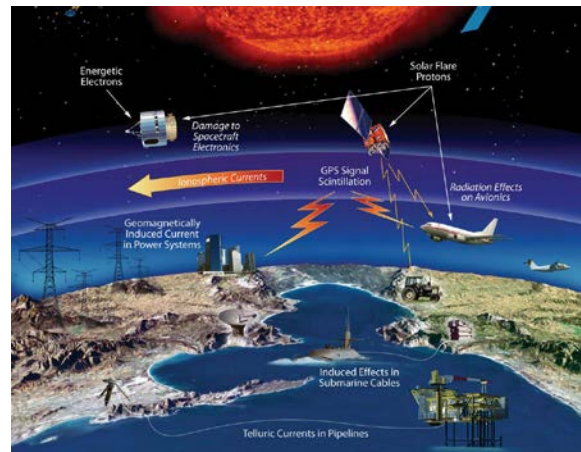
- **Public Safety**
- Economic Health
- National Defense
- **Regulation**

Academia

- Science
- **Research**

Commercial

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



American Commercial Space Weather Association

Commercial Space Weather Industry

Products and Services

Value Chain

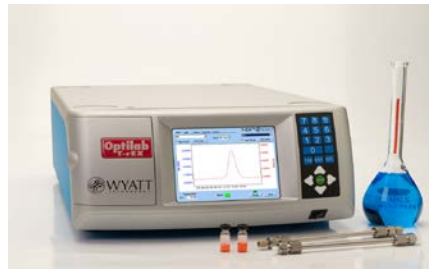
Upstream

- Research
- Observations
- Instrumentation
- Data



Mid-Stream

- Data Processing
- Computation
- Algorithms
- Models



American
Commercial Space
Weather Association

Downstream

- Forecasts
- Warnings
- Services
- Emergency Mgt



American Commercial Space Weather Association

American Commercial Space Weather Assn (ACSWA) (1)

Which system architecture is the most efficient?

Swim Lanes?

Making full use of
Academia, Government
and Commercial Sectors



Or an inefficient

Free for All?



American Commercial Space Weather Assn (ACSWA) (1)

- Atmospheric and Environmental Research (AER)
 - Product Highlight STK-SEET
- Atmospheric & Space Technology Research Acct (ASTRA)
 - Real-time Ionospheric Scintillation Monitors & data collection
 - Ionosphere & Thermosphere Specification & Forecast Models
 - Smallsats for in-situ and remote sensing
- Computational Physics, Inc (CPI)
 - Real-time magnetometers and optical sensors
- Carmel Research Center (CRC) Inc.
 - Quantitative 3D modeling Sun to Local Interstellar Medium of the solar wind, magnetic field, and energetic particles.
- GeoOptics, Inc (GO)
 - GNSS-Radio Occultation for ionospheric measurement



American Commercial Space Weather Assn (ACSWA) (2)

- NextGen Federal System (NGFS)
 - Solar flare & energetic particle forecasting
 - Enterprise IT, mission plan, architecture, C2 aids
- PlanetiQ (PiQ)
 - GNSS-Radio Occultation for ionospheric measurement
- Propagation Research Associates (PRA)
 - Characterize Tropospheric refraction & turbulence
- Predictive Science, Inc (PSI)
 - Quantitative modeling of solar corona and solar wind
- Q-up now (Q-up)
 - Real-time and Forecast HF Radio Propagation



American Commercial Space Weather Assn (ACSWA) (3)

- Storm Analysis Consultants (SAC)
 - Modeling the space weather threat environment
- Space Environment Corporation (SEC)
 - Ionospheric Forecast and Specification
- Space Environment Technologies (SET)
 - Dst Forecasts
- Space Hazards Applications (SHA)
 - impact on satellites from high-energy radiation
- Space Services Holdings, Inc (SHI)
 - Space Weather and remote telecommunication
- Science Prime, LLC (SP)
 - Space Weather Tech Consulting Services



Space Weather Benchmarks (1)*

- Induced Geo-Electric Fields
 - Interfere with high voltage transmission & critical infrastructure
- Ionizing Radiation
 - Satellites, Airline Comms, Crews, & Astronauts
 - 3 Types
 - Solar Energetic Particles (SEP)
 - Galactic Cosmic Rays (GRC)
 - Radiation belt particles
- Ionospheric Disturbance
 - Propagation of comms, navigation, & timing signals
 - Driven by 3 phenomena: Solar flares, solar energetic particle events, & geomagnetic storms



*IDA Science & Technology Policy Institute; Next Step Space Weather Benchmarks

ACSWA vs Space WxBenchmarks

ACSWA	Induced Geo-Electric Fields	Ionizing Radiation	Ionospheric Disturbance	Solar Radio Bursts	Upper Atmos. Expansion
AER		X	X		
ASTRA	X		X		X
CPI	X				
CRC	X	X	X	X	X
GO		X	X	X	X
NGFS		X			
PiQ		X	X	X	X
PRA					
PSI	X	X	X	X	
Q-up			X		
SAC					
SEC			X		
SET		X	X		X
SHA		X			
SHI					
SP	X		X		X

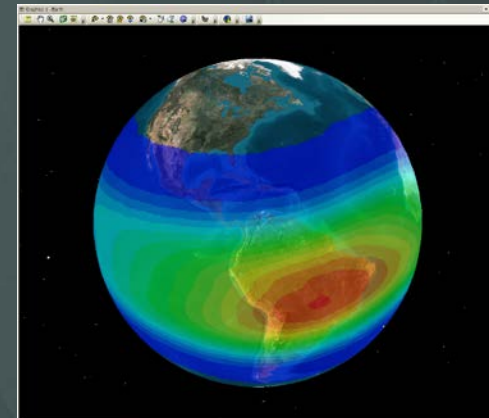
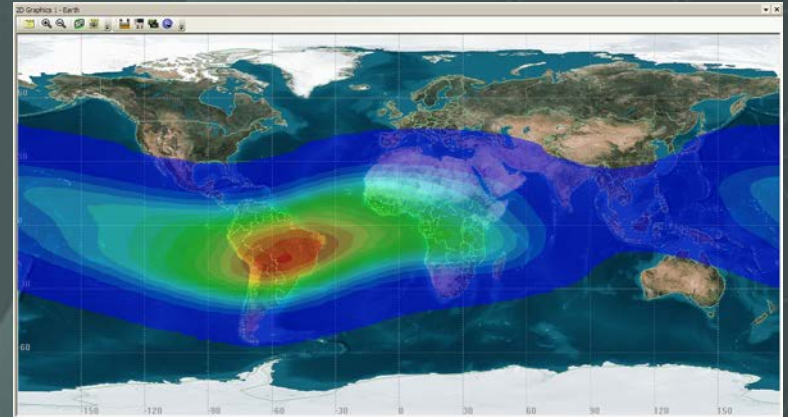


Atmospheric and Environmental Research (AER)

STK SEET™

STK Space Environment and Effects Tool

- Robust custom handling of the modeled radiation environment – using IRENE starting in March 2020
- Compute SAA transit times and probable fluxes for custom orbits
- Compute magnetic fields, trace fieldlines and magnetic conjunctions
- Compute Solar and Galactic Cosmic Ray fluences
- Estimate mean temperature due to solar and reflected Earth radiation



Developing tools for understanding space weather impacts to satellites.

Space Radiation Models:

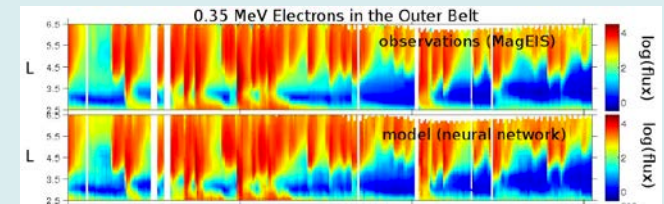
SHELLS: A neural network map of electron radiation belts that includes retrospective, real time, and forecast outputs.

SPAM: A real time map of solar energetic particle fluxes, SAA fluxes, and Single Event Upset Rates

User Applications/Tools

SatCAT: Online configurable tool to generate and view internal charging levels tailored for user defined satellites, shielding thickness, materials and mission duration. Will be updated to include SPAM model outputs.

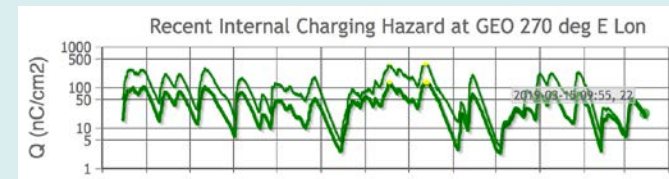
SHELLS



SPAM



SatCAT

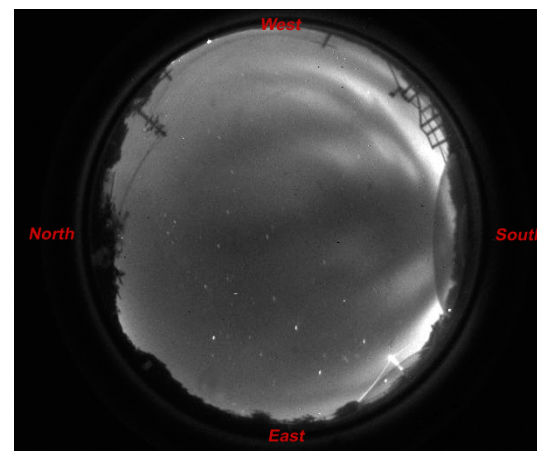


Sensor Technologies

CPI develops **sensor technology** for monitoring the near-earth space environment from the ground and space.

- Optics and imagers
- Magnetometers
- Real-time infrastructure
- Data processing and analytics

Optics and imagers



CONTACT INFORMATION

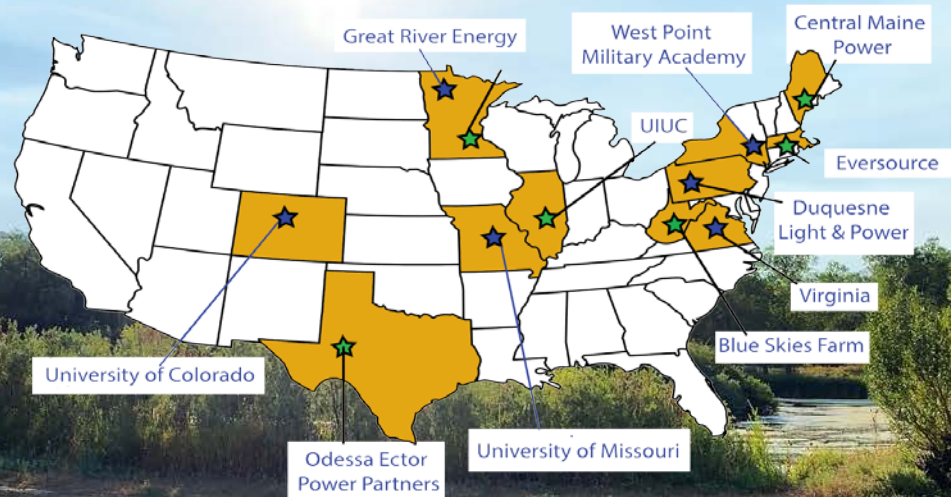
John Noto
978-251-4554
noto@cpi.com

ESF plume over the Arecibo Observatory. Image taken 20 Nov 2014 at 10:30 PM local time, with a 4 minute exposure at 630.0 nm. ESF plumes started at about 8:20 PM. Top image is the corresponding 6300 FPI wind data

Commercial GLC products

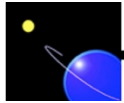
- Scientific and industry-ready magnetometer installations
- **Real-time geoelectric field** using CPI's AVERT model

MagStar



NSF-funded MagStar array

Radiation Monitoring

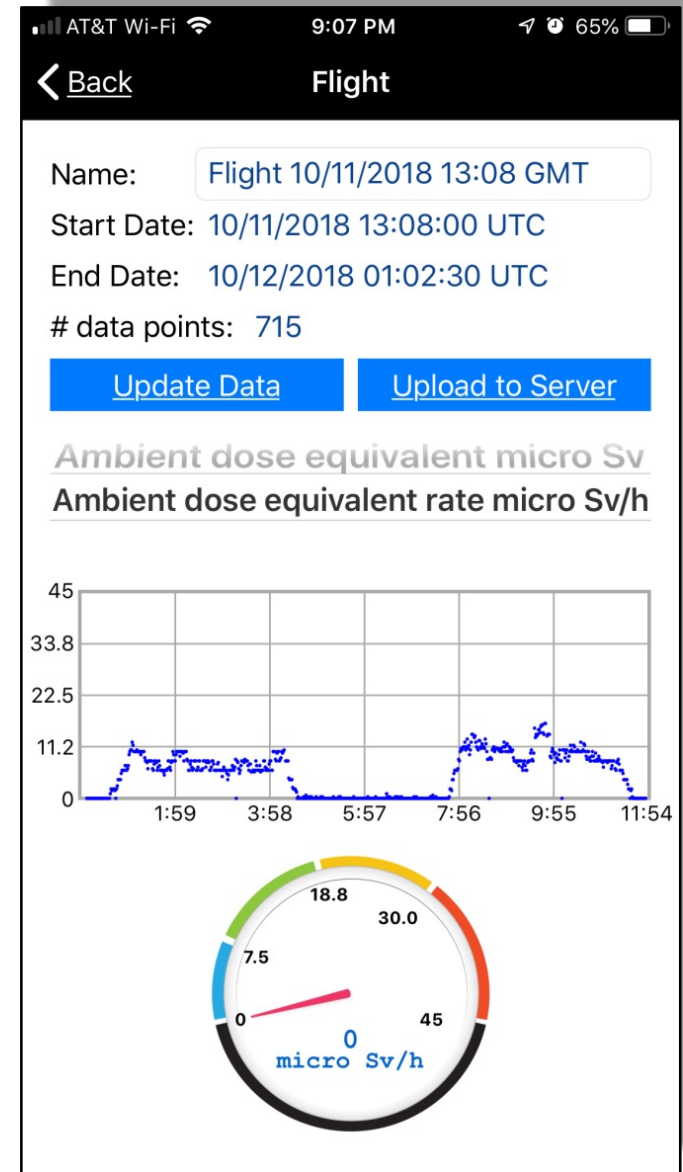


SPACE ENVIRONMENT TECHNOLOGIES

Space Weather Division

Compact Radiation Monitor plus app

State-of-the-art ARMAS Flight Module 7 (FM7) with Bluetooth



American Commercial Space Weather Association

Radiation Monitoring (2)



SPACE ENVIRONMENT TECHNOLOGIES

Space Weather Division

Compact Radiation Monitor plus app

Features:

- Measurement of absorbed dose in silicon
- Small size and mass
- Data retrieval via Bluetooth paired with smartphone or tablet app
 - Display current status on app
 - Use plane's WiFi to transmit to ground as needed
- Levels 2–3 real-time dose rates provided (absorbed, equivalent dose, & ambient dose equivalent rates)

Status:

- 4 units delivered 2018
- First production run for business jets complete in Q1 2019



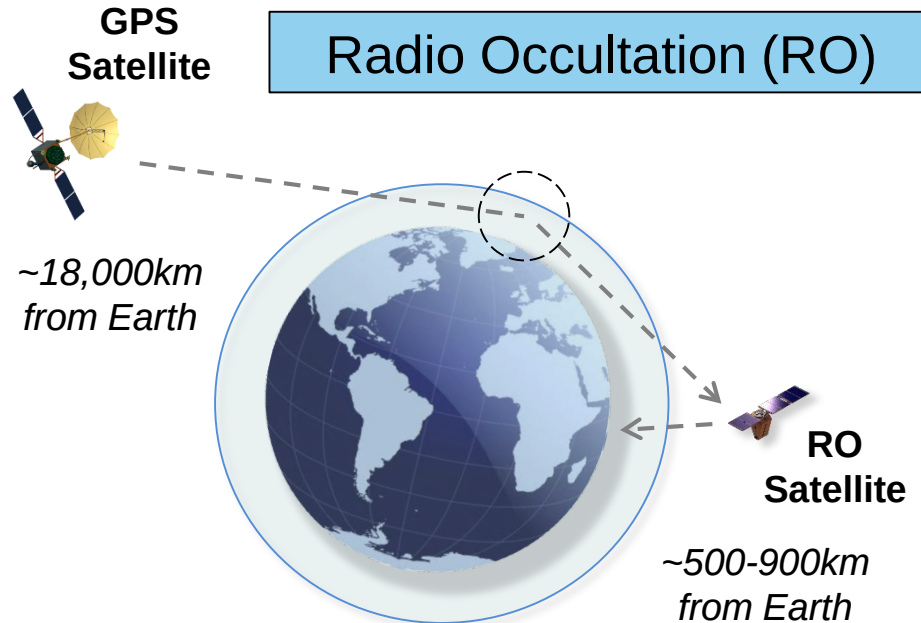
Ionospheric Data



“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
- Now at End of Life





American Commercial Space Weather Association

*Linking Scientific Understanding
with Operational Priorities*

The End



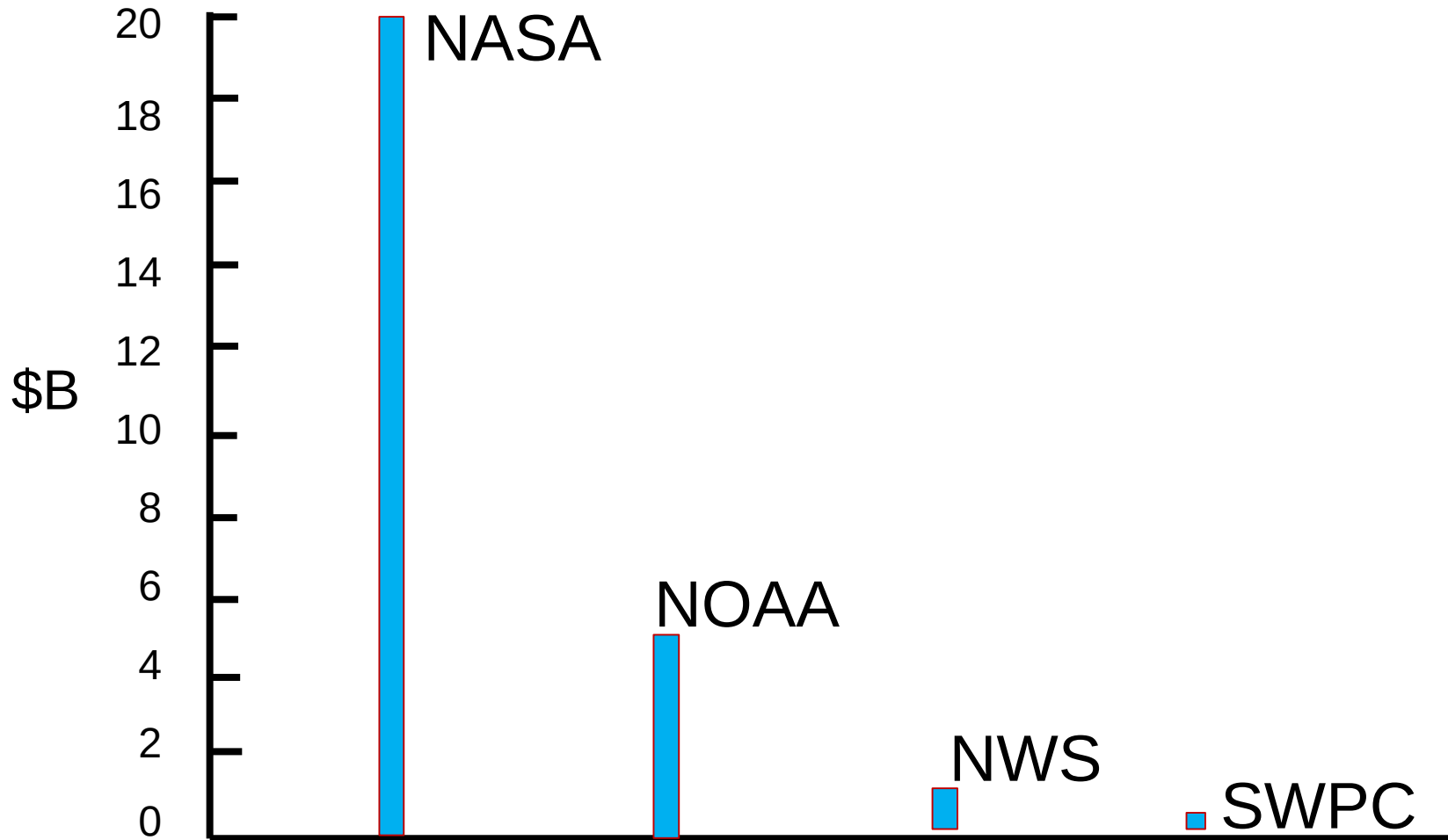
Leveraging the Commercial Sector

Back-up Charts

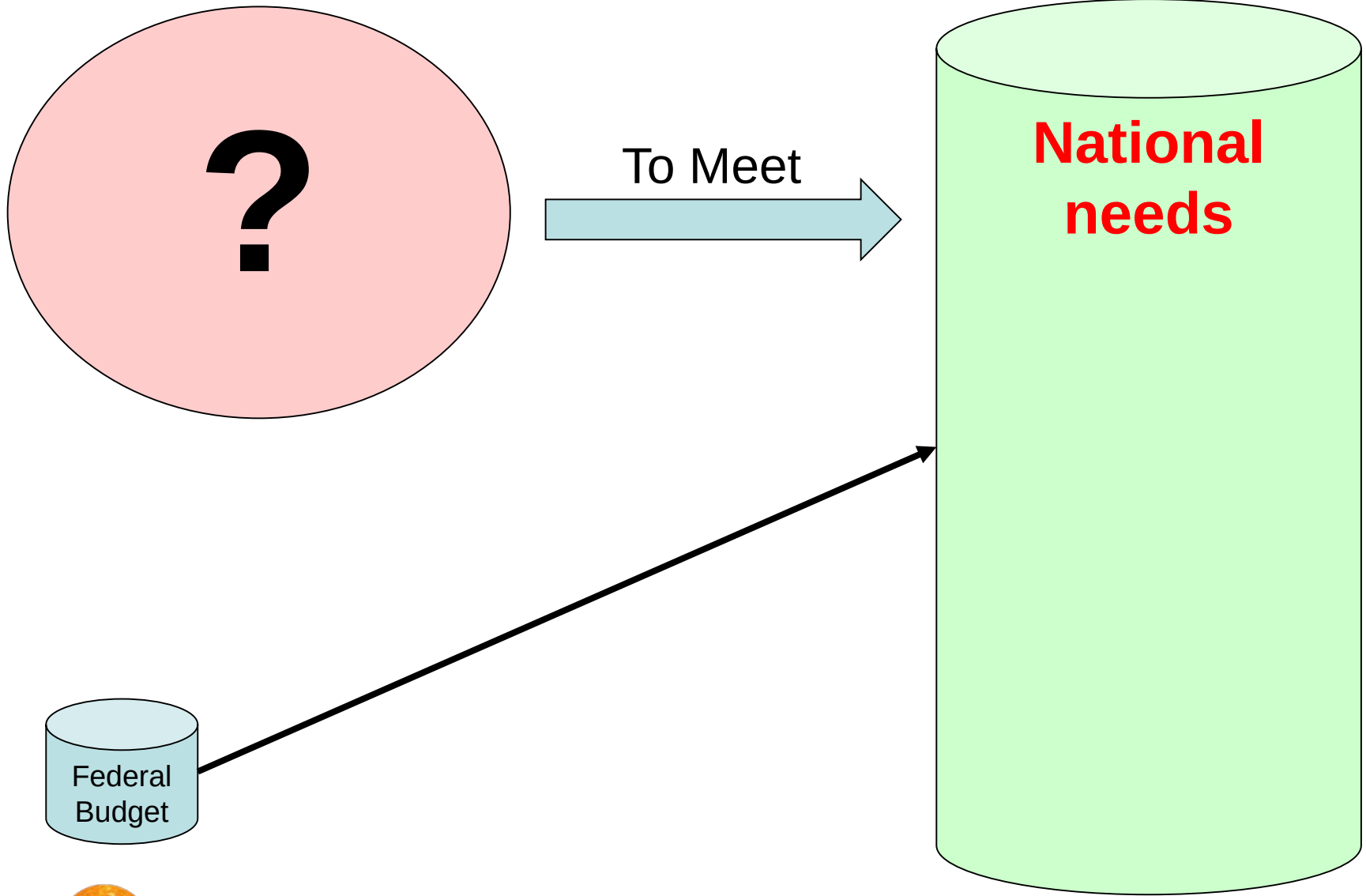


Importance of Working Together

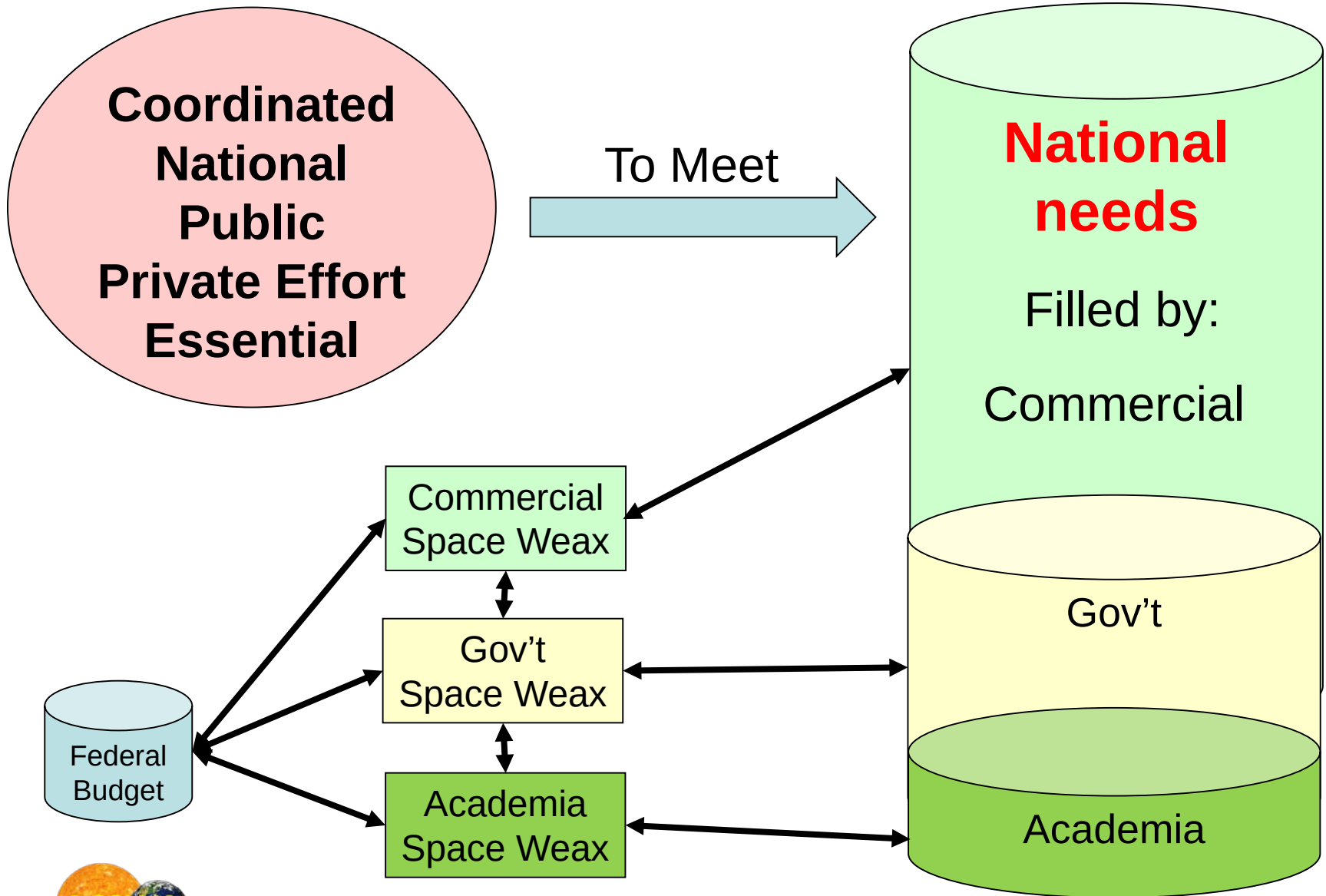
Budgets



Dilemma



Partnership



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>

