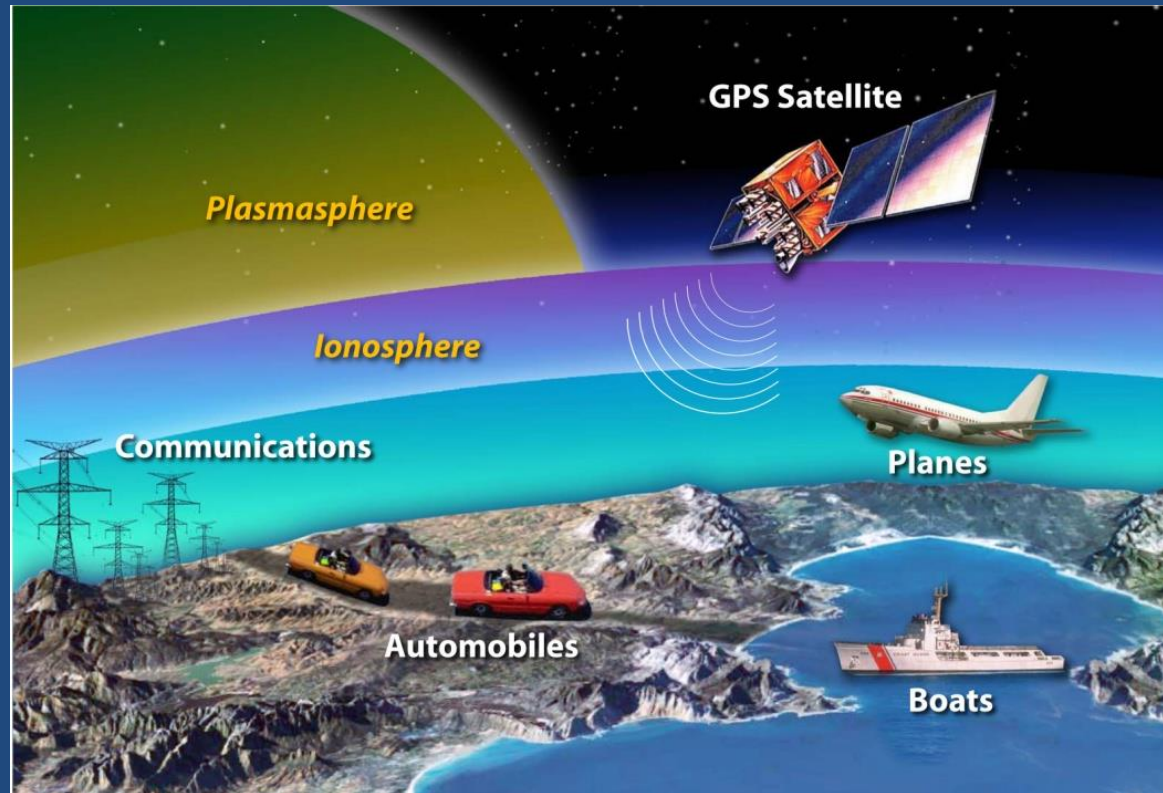


GPS & Space Weather:

Understanding the Vulnerabilities & Building Resilience



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Space Weather Workshop 2011

GPS/GNSS - a Component of the Global Critical Information Infrastructure



Satellite Operations



Precision Agriculture



Surveying & Mapping



Aviation



Communications



Trucking & Shipping



Disease Control



Power Grids



Oil Exploration

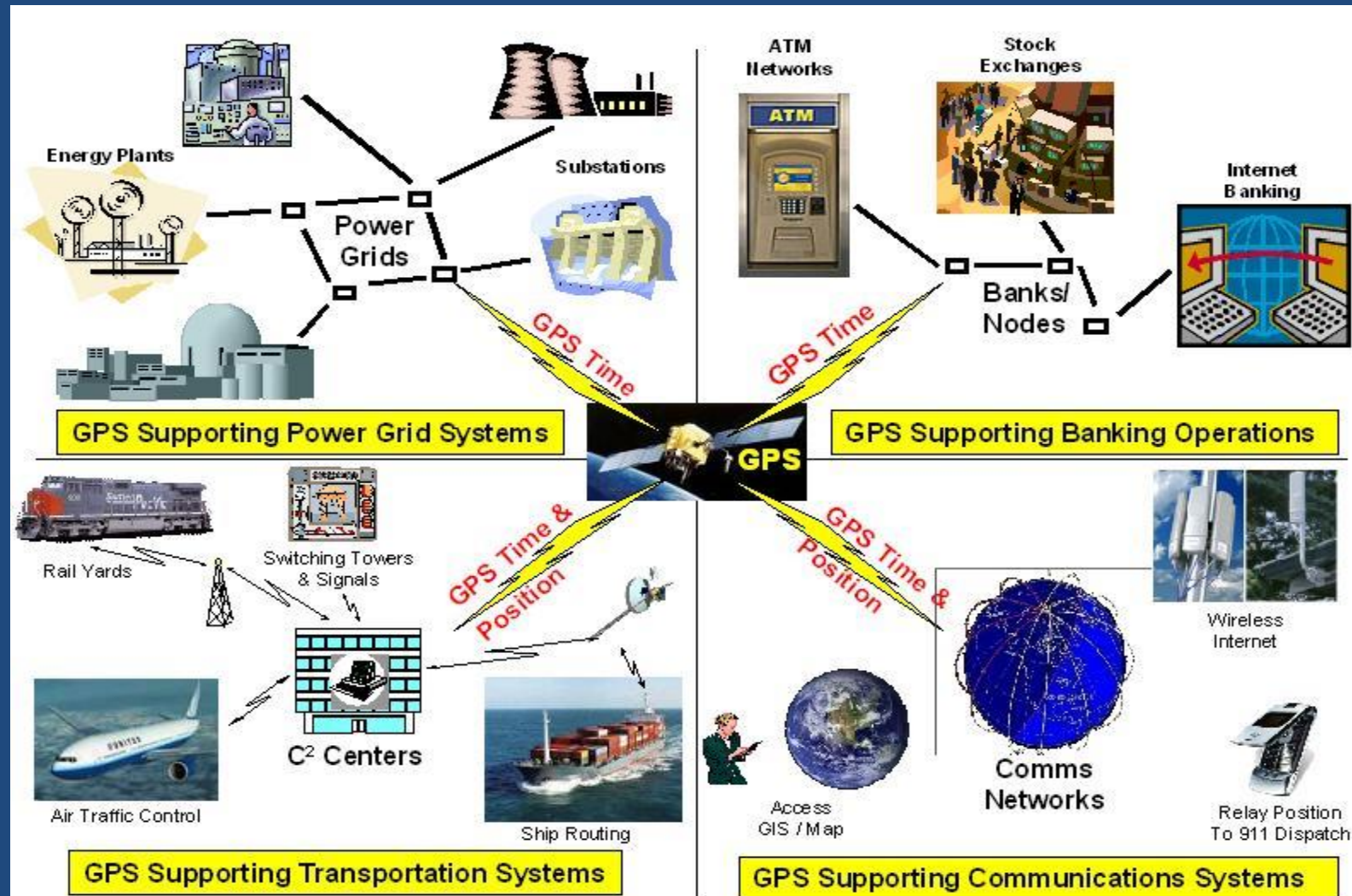


Fishing & Boating



Personal Navigation

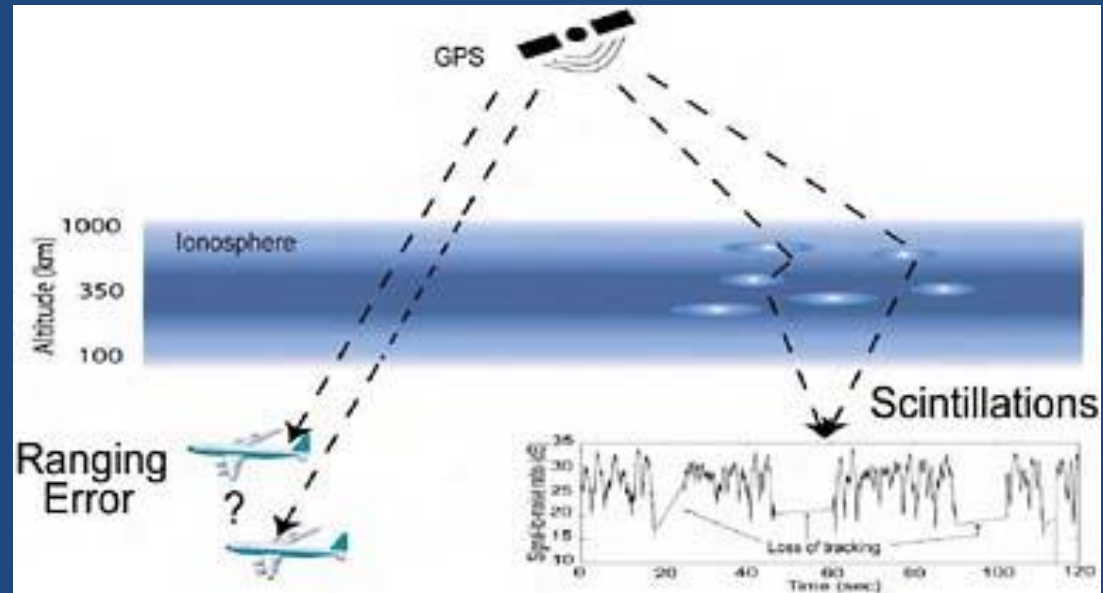
Extent of GPS Dependencies



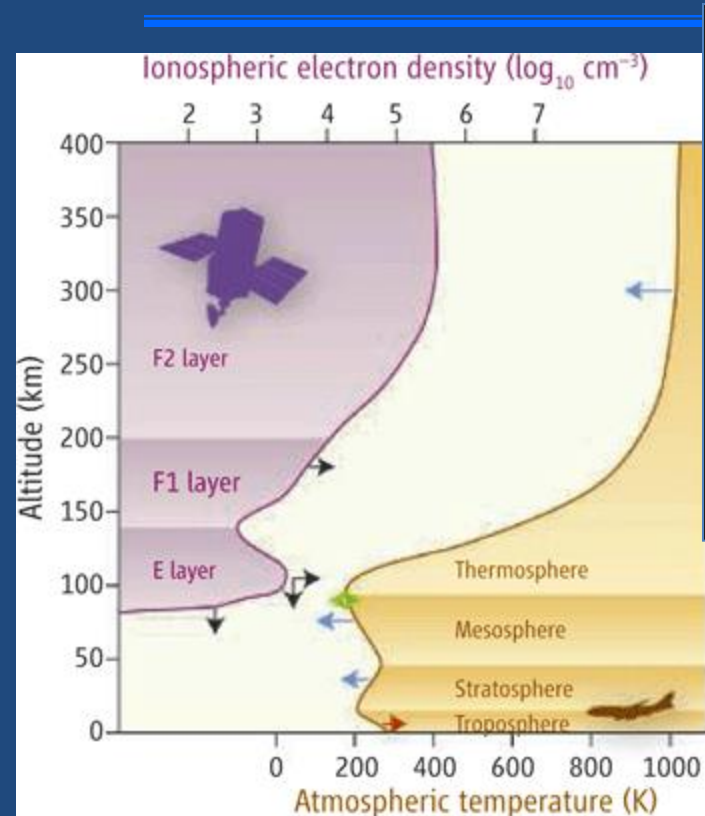
So what's the connection between GPS & SWx?

- SWx is the largest contributor to single-frequency GPS errors & a significant factor for differential GPS

Primary SWx impacts on GPS include range errors and loss of signal reception

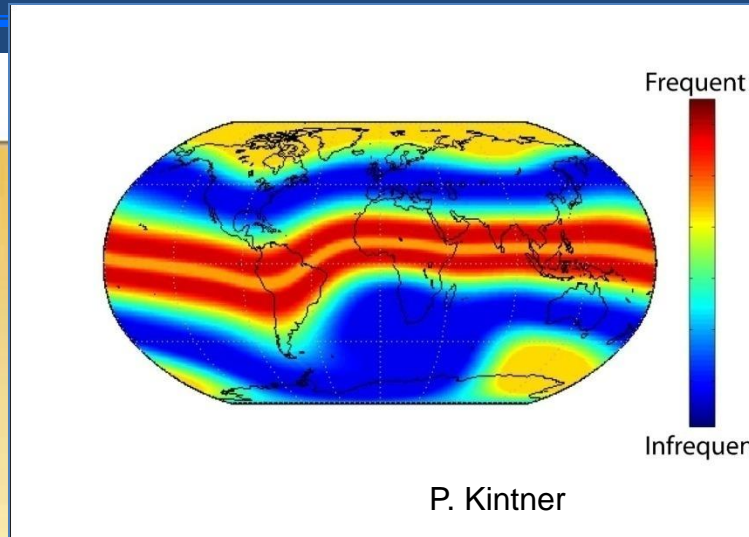


Space Weather Effects on GPS



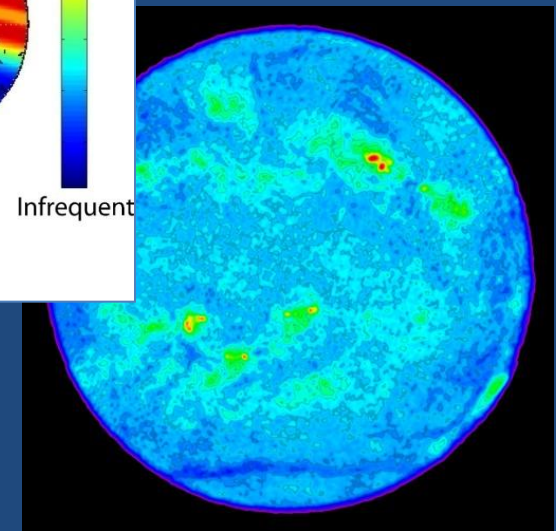
1. TEC-Induced Signal Delays

Results in changes in speed & direction of GPS signal



2. Scintillation

Results in GPS signal scattering and possible loss of signal



3. Solar Radio Noise

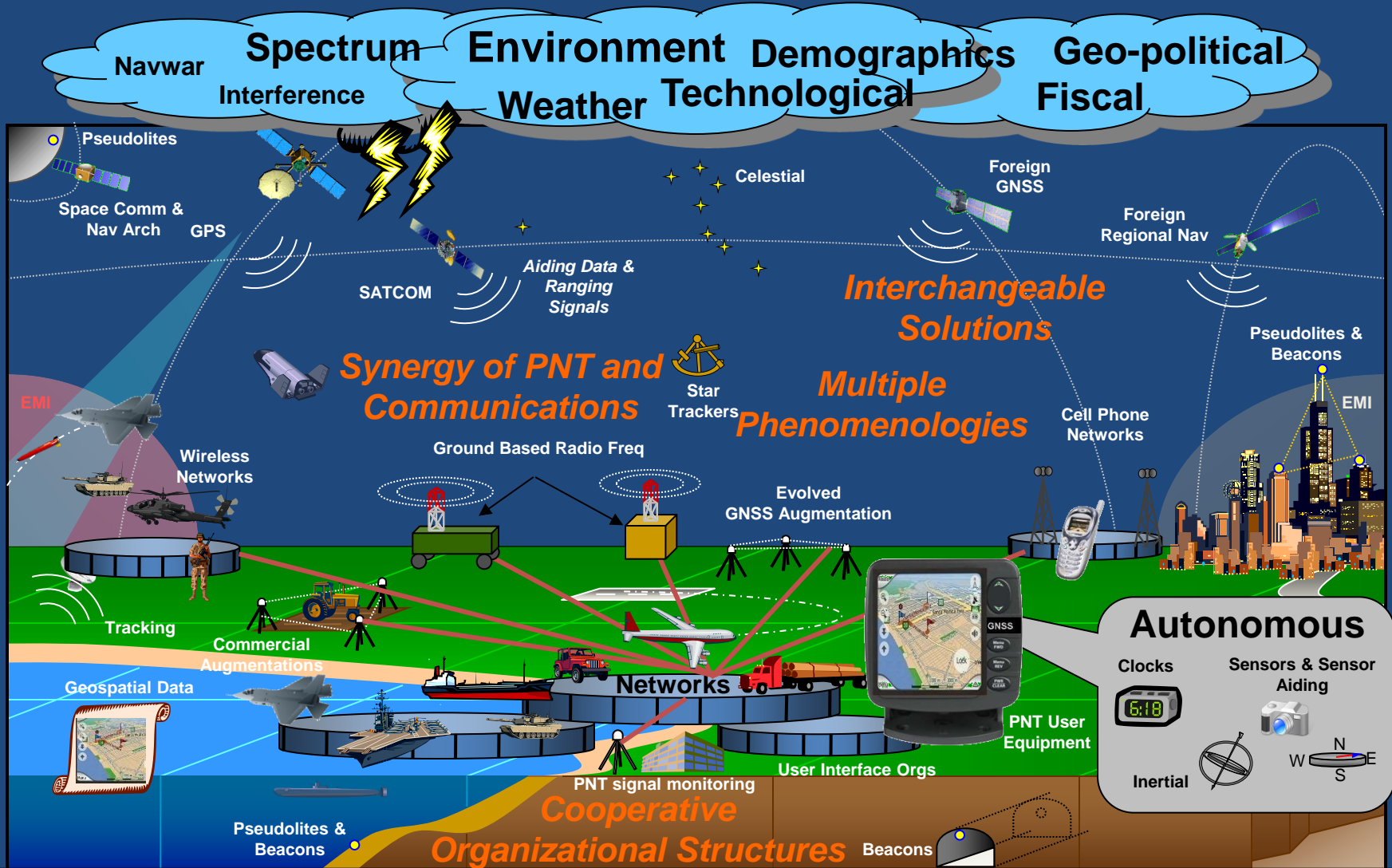
Results in background noise over GPS frequencies and degrades signal



U.S. Policies relevant to GPS

- In 2000, Selective Availability (intentional degradation of accuracy of single-freq GPS position) turned off
- DOT Volpe Center's report on the Vulnerability of GPS identified ionosphere as largest error source
- U.S. PNT policy requires providing uninterrupted access to space-based PNT services
- National Space Policy: invest in activities to detect, mitigate, & increase resiliency to harmful interference to GPS

"Should-Be" PNT Architecture Graphic (2025)



Autonomous

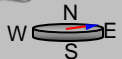
Clocks



Sensors & Sensor Aiding



Inertial



Standards

Reference Frames

Cryptography

Science & Technology

USNO

NIST

NGA

NGS

Star Catalogs

Launch

ENABLERS & INFRASTRUCTURE

NSA

Industrial Base

Electro Optical Info.

Modeling

Mapping/Charting/Geodesy

Laser Ranging Network

Policies Testing

Policy Issues



Given it is well understood that space weather can have a major impact on the GPS system...

- What are the vulnerabilities of GPS applications & services to space weather?
- How can models and forecasting be improved for the GPS industry & users?
- How can the application of the use of space weather information be improved?
- How can we build resiliency of the GPS system to space weather?

AMS Policy Workshop

- Oct 2010, 2 days, Washington DC
- Policy makers, scientists, GPS industry
- Discussion Sessions
 - » Vulnerability of GPS technologies & services to SWx
 - » How this vulnerability affects users of GPS
 - » Policies to build resilience and mitigate risk
- Discussion of overarching findings & recommendations
- Actions & next steps

Satellite Navigation & Space Weather:
Understanding the Vulnerability &
Building Resilience



American Meteorological Society
Policy Workshop Report
March 2011



Some interesting points by DHS A/S Arif Alikhan

- How do you manage risk of disruption on a key system like GPS?
- We can't rely on our experience since society continues to develop more and more complex technology
- Need stories/anecdotes to move forward
- Constraints are what we know—need to figure out and predict what we don't know

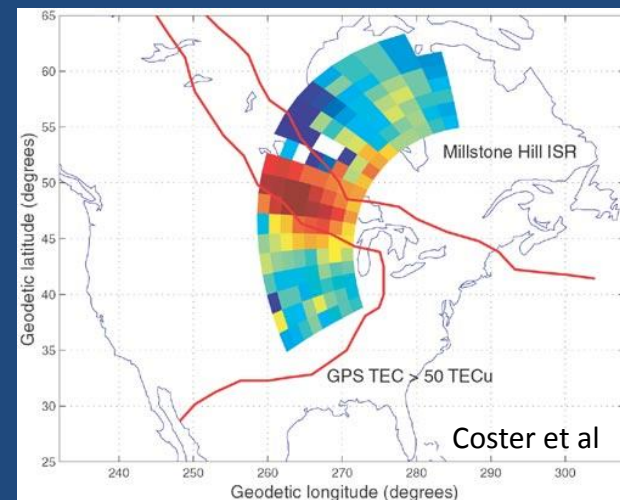
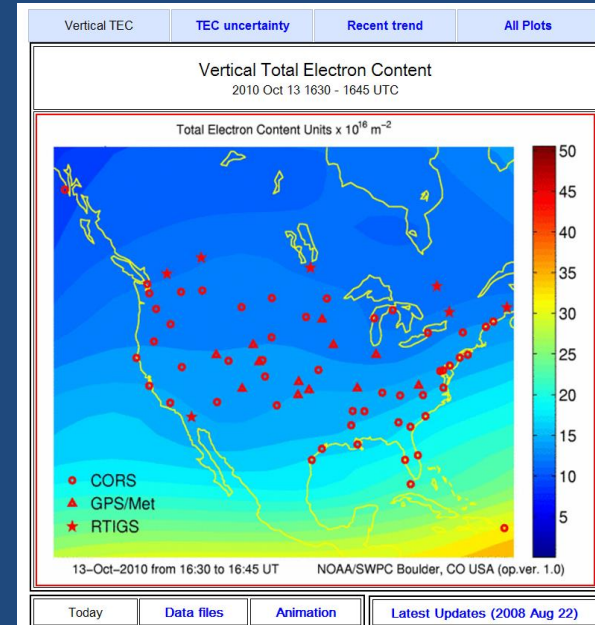
Recommendations: Understand Vulnerability

- Develop a threat assessment
- Define & quantify user vulnerability for different user segments & systems



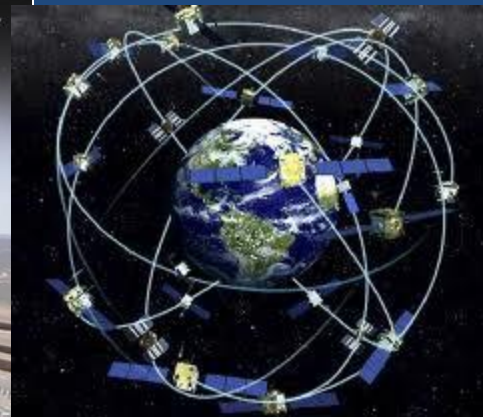
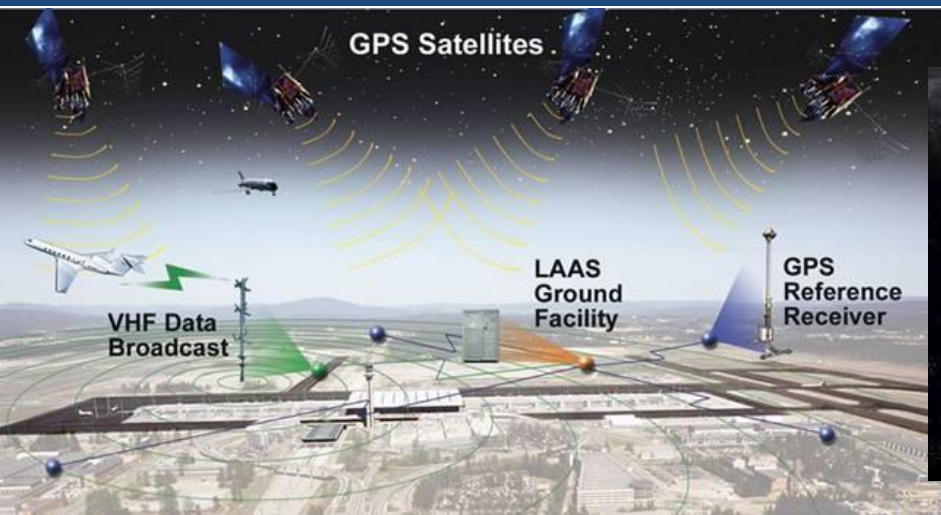
Recommendations: Science & Engineering

- Conduct further research on SW and effects
- Develop and maintain observational capabilities
- Understand user requirements & develop better products



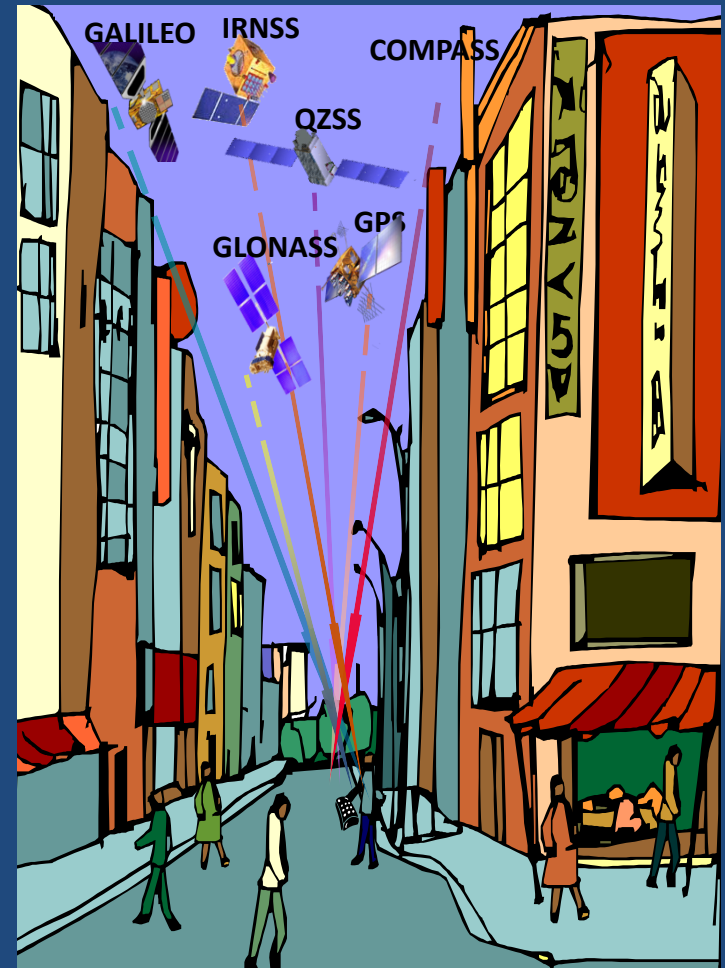
Recommendations: Policy (1)

- Strengthen integrity and robustness of system
 - Complete GPS modernization
 - Ensure back up systems
 - Develop better SWx predictions
 - Setting standards for satellites & receivers
 - Examine through all-hazards lens

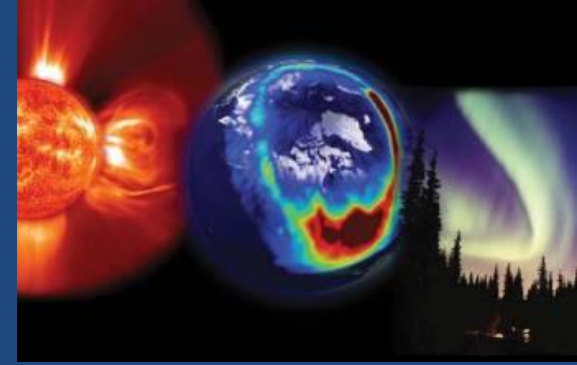


Recommendations: Policy (2)

- Investment in research
- Attention to research to operations
- Public-private partnerships
- International collaboration
- Education/outreach



Future Actions



- AMS distributing report to appropriate stakeholders & decision makers in science, GPS, & policy communities
- Capitol Hill Briefing
- Follow-on community meetings
 - ION session September 2011, Portland OR
 - Future meetings on space weather user needs