Workshops on the impacts of space weather on economic vitality and national security

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How did we start on this road?

- Through discussions with NOAA/SWPC and AF Weather
  - National needs in the area of space weather informational and predictive tools are growing rapidly.
  - At present, only a small fraction of the latest research and development results emanating from NASA, NOAA, NSF and DoD investments are being used to improve space weather forecasting and to develop operational tools.
  - The mere production of space weather information is not sufficient to address the needs of those who are affected by space weather.
  - This has led to frustration in the research community who consider the path between research and operations to be the “Valley of Death” – at least up until now!

How can we better bridge the "valley of death"?

- Coordinated efforts – such as the recent SWORM strategy and action plan – are critical to leverage from basic research to support research-to-applications transition efforts and to develop the tools required by those who rely on this information.
  - However while these reports have done an excellent job of raising the profile of space weather, they have not yet raised the necessary budget
- The community needs to help stakeholders demonstrate the need for systems to warn/mitigate space weather events
- A great way to do this is to provide agencies with information to form inputs to their responses to the SWORM strategy report and SWAP.

Goals of the Umbrella Study

- Series of workshops to examine the impacts of space weather, develop a straw man plan for analyzing these impacts, and determine the best plan for execution. Over the course of the next year we intend to continue to study a wide range of important topics
  - Space Weather: Normal and Extreme disturbances
  - Framework for assessment of economic impact – day to day operations and severe events
  - Framework for assessment of national security impact
  - Infrastructure impacts – “design to”, “operate optimally with”, “operate through”, and “survive and preserve to operate after”

Purpose of Workshops

- We aim to provide agencies with information to form inputs to their response to the SWAP and DoD classified annex – but our study has been broader in scope, covering everyday space weather through Carrington type events.
- We aim to help stakeholders in government, industry and academia to develop broader understanding of the economic issues surrounding on-going space weather events so that they can disseminate this information to policy makers in the Executive and Legislative Branches of government with an eye to developing a National program to address this issue

Workshop foci

- The first workshop was held October 2015 at the University of Maryland, College Park, and examined the impacts of space weather on economic vitality.
- The second workshop, in February 2016, focused on the National Space Security with an emphasis on Research-to-Operations for the DoD
- The third workshop in the series, on April 25, 2016, was a summary and wrap up of the previous workshops, and a planning session for the next steps

The workshops are not about finding specific funding opportunities

- Define the current state of the art:
  - what work needs to be done;
  - determine critical gaps in the current plans and suggest areas that would benefit from increased funding and/or interagency coordination;
  - determine work areas which cut across traditional organizational boundaries

Workshop Format

- The workshops are not like a typical science meeting but rather a chance for experts in many aspects of the field to come together to get work done.

- There are a few lead off talks designed to trigger thoughts with much of the agenda being devoted to open discussion time.

- During the last discussion session of the meeting we plan future workshop topics and formats

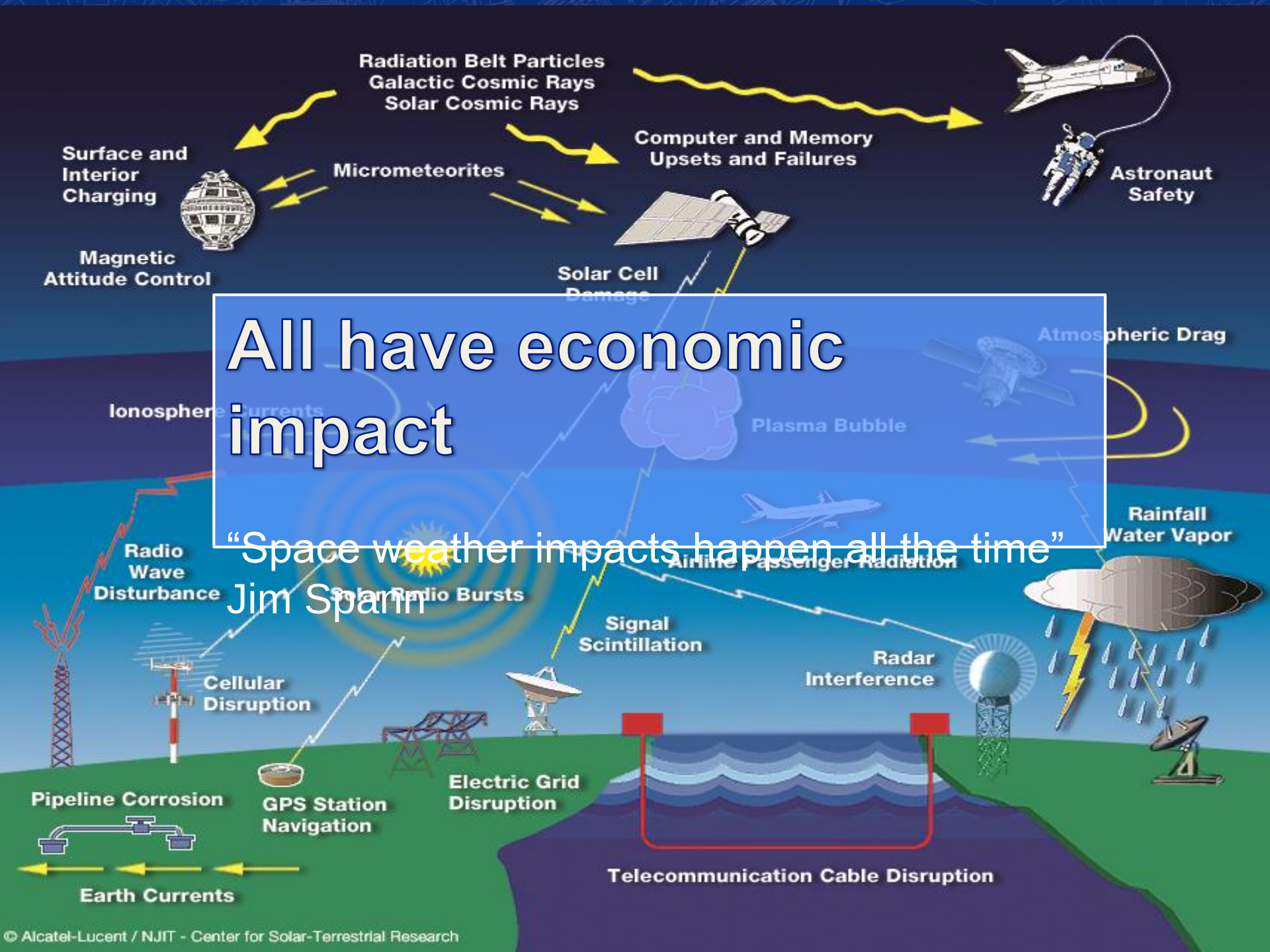
Workshop on the impacts of space weather on economic vitality

- This was the first in a series of workshops to examine the impacts of space weather, develop a straw man plan for analyzing these impacts, and determine the best plan for execution.
- Discuss how to conduct a comprehensive analysis of economic and infrastructural of space weather, ranging from typical space weather conditions, to the best estimate of possible extreme cases.
- Connect individuals and research from across academia, industry and government to foster collaboration and promote the goal of developing strategies for effective space weather forecasting to meet the economic and defense/security requirements.
- Promote an active forum among science, technology, economic, policy and security communities, raise awareness and inform decision makers on the current needs, capabilities and future outlook.

Workshop on the impacts of space weather on economic vitality

- **"…aim to help stakeholders in government, industry, and academia to develop broader understanding of the economic issues surrounding on-going space weather events…."**

- **Overview of Space Weather Impacts and Current Forecasting Capabilities**
- **Economic Impacts – General**
- **Major infrastructure Impacts**
- **Space Weather: Normal and Extreme Disturbances**
- **Priorities to Meet Critical Requirements**

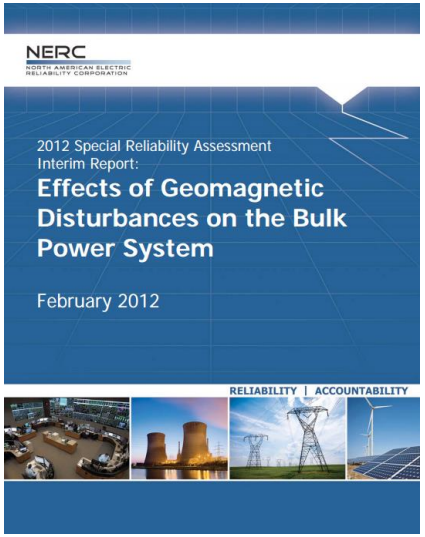


All have economic impact

"Space weather impacts happen all the time"
Jim Spann

Major infrastructure impacts

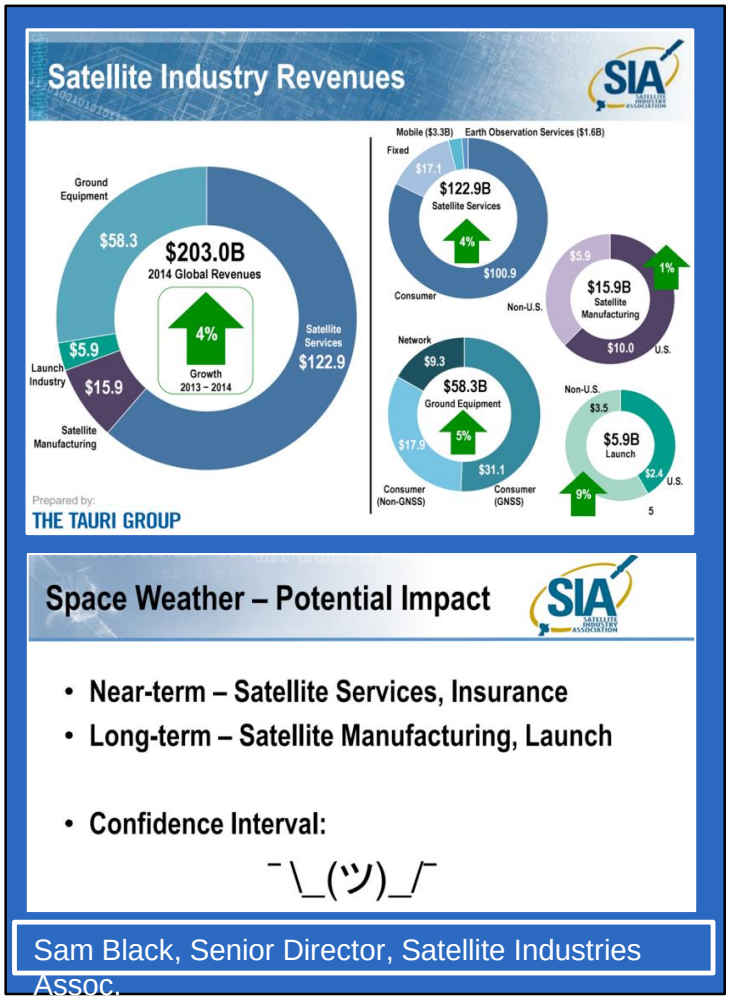
- ***GIC effects***



PJM Perspectives

- Reduce west-east transfers if GIC > 10 amps at detection station
- Raise voltages and anticipate reactive asset loss during storms
- Not concerned with transmission congestion by geomagnetic activity
- (Congestion loss ~$918M 1st 6 months 2015; PJM billings ~$50B/year)
- Not clear what fraction is due to SpWx

- ***Satellite systems***



Sam Black, Senior Director, Satellite Industries Assoc.

Space APL

Major infrastructure impacts

- ***Railway & Air navigation impacts***

Risk posed to rail systems/technology not clear
Secondary impact of power grid and GNSS loss or SEU
Costs remain unknown

Met Office

Federal Aviation Administration

US Controlled Airspace

- Approx. 77 million sq. km of total airspace
- Largest area of all ANSPs (Australia 2nd at 47 million sq. km)
- 15.15% of earth's surface

Summary

- **Aeronautical Radionaviogation is both Robust and Resilient from interference**
  - Natural or Manmade
- **The vulnerabilities of satellite-based navigation are mitigated to a large etent by ground-based systems and air traffic management and control**
  - ***SAFETY IS ALWAYS MAINTAINED – at the expense of some capacity and efficiency***
- **Advanced Receiver Autonomous Integrity Monitoring will allow aircraft to model the ionosphere and develop corrections without the need of ground-based monitoring**
- **The FAA's WAAS and other SBAS systems are an excellent source of ionoshperic data, measured in real time and archived**

Major infrastructure impacts

- ***Economic impacts on GNSS systems***

Preliminary 2013 U.S. GPS Economic Benefit Estimates		
Application Category	Range of Benefits ($billions)	Mid-range Benefits ($billions)
Precision Agriculture – grain*	10.0-17.7	13.7
Construction – earthmoving with machine guidance*	2.2-7.7	5.0
Surveying	9.8-13.4	11.6
Air Transportation	.119 -.168	0.1
Rail Transportation – Positive Train Control	.010-.100	0.1
Marine Transportation – private sector use of nautical charts and related information*	.106-.263	0.2
Fleet Vehicle Connected Telematics*	7.6-16.3	11.9
Timing – average of eLoran and GEOs estimates	.025-.050	0.1
Consumer and Other Non-Fleet Vehicle – average of estimates based on willingness-to-pay and value of time*	7.3-18.9	13.1
TOTAL	37.1-74.5	55.8

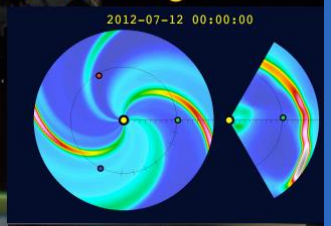
NIST: Anderson; Levenson

Ranges of estimates from peer reviewed literature – shows where there are large GPS impacts

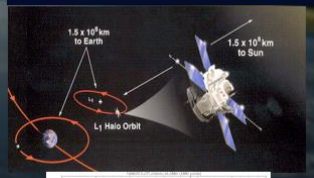
Space Weather Forecasting

Tom Berger, NOAA NWS SWPC

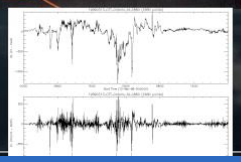
What is Space Weather Forecasting?



1. Geomagnetic Storm Watch
Issued upon coronagragraph detection of Earth-directed CME and WSA-Enlil model run
- 15 – 72 hour forecast



2. Geomagnetic Storm Warning
Issued upon detection at the ACE (soon DSCOVR) spacecraft at the L1 Lagrange point
- 15-60 minutes before impacting Earth

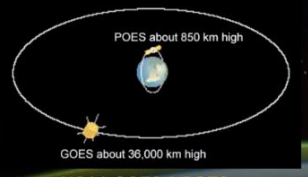


3. Geomagnetic Storm Alert
Issued when geomagnetic storm is detected on USGS magnetometers
- Current condition

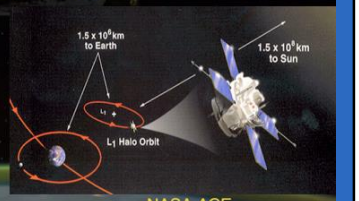
National Weather Service

Does not include prediction or forecast of solar x-ray or radio burst event

Operational SWx Observations



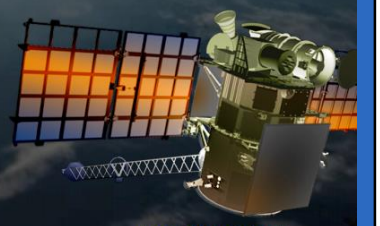
NOAA GOES & POES



NASA ACE

Air Force SEON Network

National Weather Service

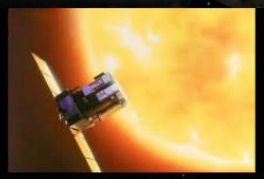


DSCOVR: Q4 2015

SWPC Operational Models

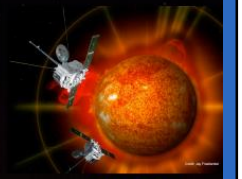
- **Current**
  - WSA/Enlil. Two hours to run on 2015 WCOSS (next slide).
  - Ovation auroral forecast
- **Near Future**
  - U.Mich "Geospace" FY16
  - Whole Atmosphere Model (WAM) FY15
- **Future**
  - E-field model of continental US FY17
  - Integrated Dynamics of Earth's Atmosphere (IDEA) FY17—19

Non-operational SWx observations



SOHO/LASCO

SDO/AIA, MDI, EVE



STEREO

NSF GONG Network

USGS Magnetometers

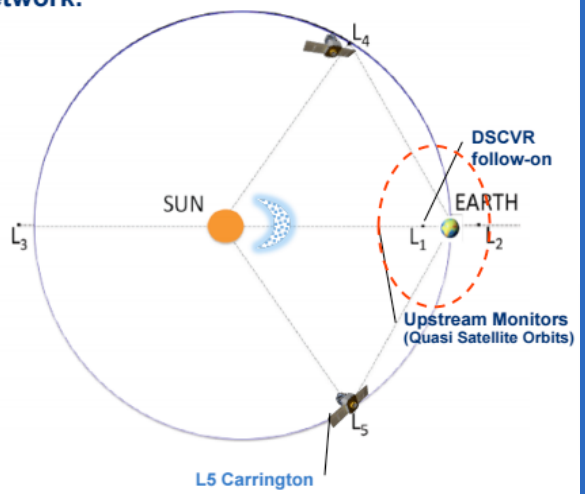
Neutron Monitor Network

Space APL

Space Weather Forecasting

- **a future?**
  - **importance of an L5 Carrington monitor**
  - **follow on the DSCOVR and ACE**
  - **large gaps in prediction capability**
  - **need modeling to gain understanding**
  - **need tools – continuous coverage; global coverage; continued model refinement, validation and transfer of model to ops**

- **Deploy a Space Weather Sentinel Network:**
  - **DSCVR Follow-On.**
  - **L5 Mission (UK Carrington Concept).**
  - L1 Upstream Monitor(s) at ~0.3AU (SpW Diamond Concept).
  - L4 Mission.
  - …
- **Balance Research and Operational Needs**
  - **Large gaps remain in the physics of transients and ITM response.**
  - **Optimize payloads for R2O.**



Angelos Vourlidas, JHUAPL

Considerations forward

- **Solar-terrestrial processes in the form of space weather have impacted technological systems since the deployment of the electrical telegraph**
- **Economic impacts clearer in some cases than others**
- **Solar and terrestrial impacts on technologies are technology dependent**
- **As technologies increase and change in type and use, more and different information will be required about the solar-terrestrial system**
- **Mitigating engineering solutions are often preferable to absolute scientific understanding**

Workshop on the impacts of the space environment on national security systems and processes

- The workshop focused on the impacts of the space environment on national security Security with an emphasis on Research-to-Ops for the DoD
- Included attendance by representatives from the UK
- Allowed for classified talks
- The goal of this workshop will was to collect information to help formulate a classified annex to the National Space Weather Strategy and Action Plan.
  - DoD involved in 35 of 99 actions within Space Weather (wx) Action Plan

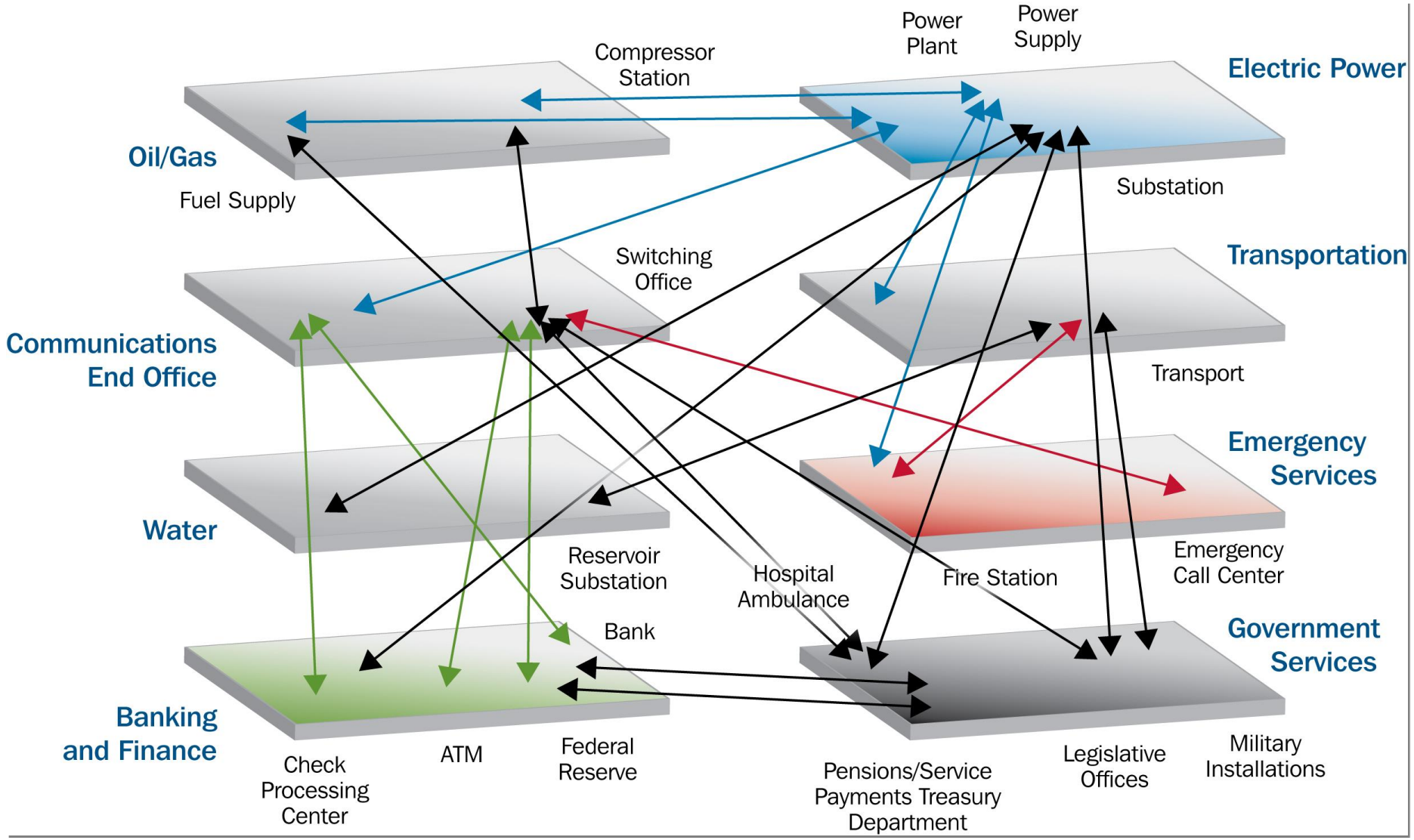
OSTP

- Introduced the National Space Weather Strategy and Action Plan to military stakeholders
- Identified 6 goals of the National Space Weather Strategy:
  - Establish benchmarks for space weather events
  - Enhance response and recovery capabilities
  - Improve prediction and mitigation efforts
  - Improve assessment, modeling, and prediction of impacts on critical infrastructure
  - Improve space weather services for advancing understanding and forecasting
  - Increase international cooperation
- National Space Weather Action Plan (NSWAP) establishes process to implement the strategy
  - Assigns DoD and DoC to collect ground- and space-based observations
  - Asks DoD and DoC to develop a plan to ensure the improvement, testing, and maintenance of operational forecasting models

Key Points

- Military operates a global network of space- and ground-based sensors for space weather monitoring and forecasts
- Important to generate decision assistance from space weather data and forecasts
  - e.g DMSP SSUSI radiances → electron density → geolocation impacts → GPS-guided munitions
  - accurate SpWx is very important but how do we develop visualizations and turn them into decision making tools. Young service personnel who have no idea what to do with Kp etc.
- Large geomagnetic storms can cause severe damage to power grid
  - → Impacts DoD because of dependency on civilian power grid and cascading effects
  - how do you call the National guard if you have no power
- DoD and SWPC dependent on large number of NASA missions (ACE/DSCOVR, SOHO, Stereo)
  - how do we develop a stable architecture?

Interconnectivity of Society



Operations - What is the affect and what is my impact ?

- Direct Impacts - Affects many technologies and missions at many different levels
  - Satellite Anomalies (Assessment process)
  - RADAR
  - Army operations
  - Daily space weather
- Indirect Impacts
  - Cascading effects due to interconnections of society
    - what happens when you lose satellite capability? What if there is a big event and you lost a number of spacecraft?
  - Loss of power grid
  - Loss of satellite capability (e.g. communications, navigation)
- Operationalization of research missions
  - Concern about dependence on NASA research missions that have no planned replacements
  - Create stable observing programs based on prior NASA research mission
- If you lose key capabilities – we will be severely strapped!!

Research

- Integration of space weather to improve SSA
- Analysis to improve attribution
- Advance disruptive innovations
- Improved data fusion and correlation
- Sustained effort to improve space weather models
  - High visibility missions can make impact but we need the modeling to back this up
- Development of space weather effects models
  - key thing for helping us to understand the space weather effect related to a particular system. What can we do if we care about that?

APL National Security Forum Highlights

- Need assured access and persistent awareness to support National Security
- Sensors need to have clear mission set
- Need to be concerned about more than the extreme events (e.g. Carrington events)--space weather impacts daily operations
- DoD will start flying Energized Charge Particle (ECP) sensors on all future satellite launches
- Need to develop tailored decision-making models/tools/visualizations
- Pursue a classified annex for items not covered in initial Space Weather Strategy
- Improve R2O and civil/international partnerships

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Summary

- Provided a very good forum to discuss impacts and mutual cascading effects
- Discussed the need for space weather and space weather effects models
- Identified the need for many areas of new or expanded research
- Identified a strategy to focus on research to operations (R2O)

Collected outstanding inputs for military annex to the Space Weather Action Plan

Wrap up workshop and Plans forward

- We met on Monday (April 25th) to present summaries of the first two workshops and solicit feedback from the wider community
- Excellent and very wide ranging discussions – thanks to everyone who came
- Discussions included:
  - Workshop report content
  - Plans for future workshop topics
  - Advocacy
  - “Big” questions in the field – what are our future sound bites?
  - Innovation programs

Future challenges:

- Cascading impacts
- How can we improve that R2O and O2R feedback loop?
  - Forum where the research communities can engage with the operational community?
- Expand inclusion of international participants – different perspective with not the usual suspects.
- Think big – challenge user community as well as researchers to determine note only what we are ready to transition in the near term, but also where there could be a sea change
- Research challenge based on future capabilities.
- Knowledge and technology that can be combined to lead to more interesting things.

Summary

- These have been highly successful and very enjoyable meetings.
- Provided a forum for science, technology, economic, policy and security communities to come together to tackle hard problems together
- Raised awareness and inform decision makers on the current needs, capabilities, gaps and future outlook
- Provided inputs to the agencies responding to the SWAP and DoD classified annex
- Promoted advocacy within the community
  - We all need to get behind these recent giant leaps forward and show community support

- Next workshop: The Cascading Effect of SpWx to an Interconnected Society, Summer 2016

SEASONS Conference
November 15–17, 2016

- APL hosts SEASONS (Space Environment, Applications, Systems, and Operations for National Security) every two years
- SEASONS will continue discussions from this week's meeting and will focus on topics of interest to all agencies represented here today
- Topics include:
  - Space Weather Missions, Tools, & Decision Aids: Existing Products and Future Needs
  - Economic and Infrastructure Impacts
  - Allied Perspectives on Operational Space Weather
  - Operational Space Weather Support for the Warfighter
  - Space Environment Impacts / Energetic Charged Particles
  - Space Weather Intelligence Applications / HF Geolocation
- Day 1 Unclassified, Day 2 held at Secret level, Day 3 at TS/SCI level
- Solar Probe Tour – see hardware before 2018 launch
- For more information see our web site: https://secwww.jhuapl.edu/SEASONS/ or contact us at seasons@jhuapl.edu