



# Quo Vadis Space Weather Modeling?

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# Origin of “Quo Vadis”

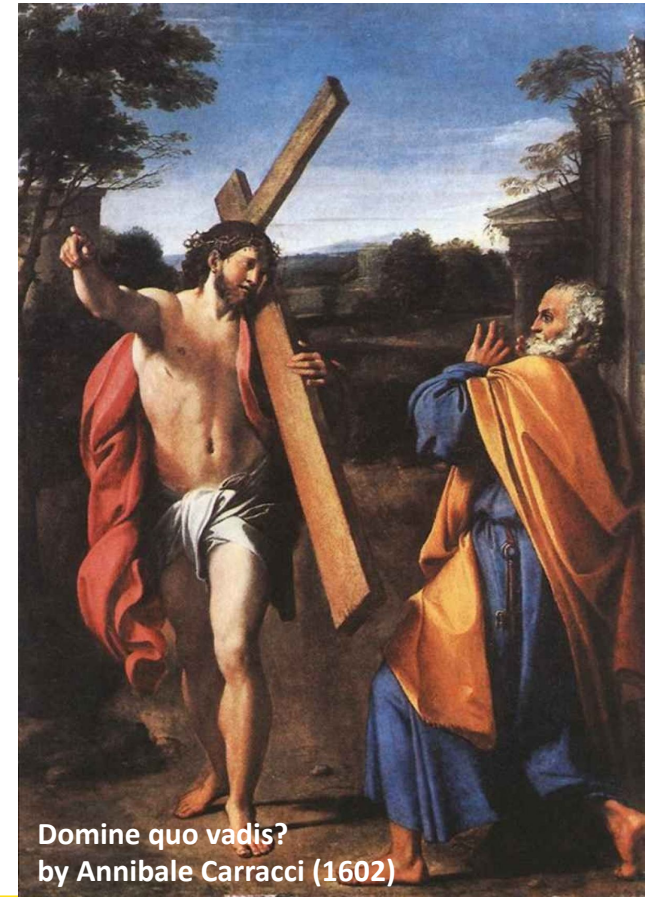
When the Neronian persecution of Christians begins, St Peter leaves the city rather than face crucifixion with other Christians in the Hippodrome. As he flees south along the Appian Way, he encounters the risen Jesus walking toward the city.

“*Quo vadis, Domine?*” Peter asks. (“Where are you going, Lord?”)

Jesus replies:

“*Romam eo iterum crucifigi*” (“To Rome, to be crucified again.”)

Peter, humiliated, thinks further, turns, and goes back to the city where, at his own request, he is crucified upside down, feeling himself unworthy of being crucified in the same way as his master.




## National Space Weather Strategy Goal #5

### Improve Space-Weather Services through Advancing Understanding and Forecasting

- Improve understanding of user needs for space-weather forecasting to establish lead-time and accuracy goals
- Ensure space-weather products are intelligible and actionable to inform decision-making
- Establish and sustain a **baseline observational capability** for space-weather operations:
  - To ensure adequate and sustained real-time observations for space-weather analysis, forecasting, and decision-support services, a baseline, or minimally adequate, operational observation capability should be defined
  - The observation baseline should also specify the optimal mix of ground-based and satellite observations to enable continuous and timely space-weather watch, warning, and alert products and services
- Improve forecasting lead-time and accuracy
- Enhance **fundamental understanding** of space weather and its drivers to develop and continually improve predictive models
  - Forecasting space weather depends on a fundamental understanding of the space-environment processes that give rise to hazardous events
  - It is particularly important to understand the processes that link the Sun to Earth
  - An improved understanding of space weather and access to better data will help drive the necessary advances in modeling capabilities and validation to support user needs.
- Improve effectiveness and timeliness of the process that **transitions research to operations**. Until better research models targeted to operational needs are developed and ultimately incorporated into operational forecasts, the Nation will not fully realize the benefits of its research investments.

# National Space Weather Action Plan (SWAP) 5.5



## 5.5.1

 **NSF and NASA**, in collaboration with DOC and DOD, will lead an annual effort to prioritize and identify opportunities for research and development (R&D) to enhance the understanding of space weather and its sources. These activities will be coordinated with existing National-level and scientific studies. This effort will include modeling, **developing, and testing models of the coupled Sun-Earth system** and quantifying the long- and short-term variability of space weather.

 Deliverable: Document R&D priorities

 Timeline: Within 1 year of the release of this Action Plan and every year thereafter, as necessary

## 5.5.2

  NASA, NSF, and DOD will identify and support basic research opportunities that seek to advance understanding of solar processes and how the sun's activity connects to and drives changes on Earth and its near-space environment.

 Deliverable: Announce and provide financial awards that enhance basic research in this area

 Timeline: Within 1 year and sustained thereafter

## 5.5.3


  NASA, DOC, and DOD will identify and support research opportunities that seek to address targeted operational space-weather needs.

 Deliverable: Announce and provide awards that enhance research in focused areas

 Timeline: Within 1 year and sustained thereafter

# National Space Weather Action Plan 5.6


## 5.6.1

 **NASA and NSF**, in collaboration with DOC and DOD, will develop a formal process to enhance coordination between research modeling centers and forecasting centers. This process will seek to identify roles and responsibilities in testing, verification, and validation for transitioning space-weather research models to space-weather-forecasting centers and for **sustaining and improving models that transition into operations**.

 Deliverable: Signed memorandum of understanding between modeling and forecasting centers

 Timeline: Within 6 months of the publication of this Action Plan

## 5.6.2

 DOC and DOD, in collaboration with NASA and NSF, will develop a plan (which may include a center) that will ensure the improvement, testing, and maintenance of operational forecasting models. This action will leverage existing capabilities in academia and the private sector and enable feedback from operations to research to improve operational space weather forecasting.

 Deliverable: Complete plan for improving, testing, and maintaining operational forecasting models and enabling operations-to-research feedback

 Timeline: Within 6 months of the publication of this Action Plan

# However.....

- Raimondo, Count of Montecúccoli (1609 – 1680)
- Italian military commander who also served as general for the Habsburg Monarchy
  - Defeated the Rákoczi uprising in Hungary
- He was also influential as a military theorist
- “For war you need three things:
  1. Money,
  2. Money, and
  3. Money”



# NASA Space Weather Increase

- The President's FY17 budget request includes \$25M “**mandatory spending**” increase for heliophysics
  - \$10M for cubesats
  - **\$10M for space weather research in support of the SWAP**
  - \$5M for R&A
- Is “**mandatory spending**” highest priority (mandatory)?
- **Hell, NO!**
- The President describes his NASA budget request as **\$19B**, but it actually is **\$18.3B** for funds that are within the jurisdiction of the appropriations committees. The remainder is what the President is calling “**mandatory**” funding that is outside their purview.
- “**Mandatory**” spending can only be appropriated if Congress finds offsetting cuts in “real” mandatory programs, such as Social Security, Medicare, interest on the national debt, etc.



# 2016 NASA ROSES

- Heliophysics Supporting Research
- **Heliophysics Technology and Instrument Development for Science**
  - We need a similar incubator program for model development!
- Heliophysics Guest Investigators
- Heliophysics Data Environment Enhancements
- Magnetospheric Multiscale Guest Investigators
- **Heliophysics Living With a Star Science**
  - Strategic Capabilities: joint with NSF GEO/ATM/Geospace
- **Heliophysics Grand Challenges: Theory, Modeling, and Simulations**
- **Heliophysics Grand Challenges: Heliophysics Science Centers**
  - ...numerical simulations and modeling become tools that can and have been used synergistically with data analyses and rigorous theory development to solve the fundamental problems of Heliophysics. They lead the way to new understanding and drive science concepts for future strategic missions. The ultimate goal of such investigations is to provide a complete chain of reasoning extending from the basic laws of nature to comparison with observation to the identification of future quantitative tests of the behavior of the environment.
  - Joint with NSF GEO/ATM/Geospace?
  - New program, still poorly defined
- Heliophysics U.S. Principal Investigator



# NSF Space Weather Funding

- No significant increase in AGS/Geospace funding
- GEO-wide **PREEVENTS** (Prediction of and Resilience against Extreme Events) initiative is funded at \$17.75M in FY16 and FY17
  - Deepen fundamental **scientific understanding** of natural processes underlying geohazards **and extreme events**.
  - Enable **improved quantitative models** and qualitative research that can enhance societal preparedness and resilience to natural disasters and extreme natural events.
  - Reduce the impact of extreme events on our life, society, and economy.
  - **Improve prediction** and warning systems that will support mission agencies such as **NOAA**, OHS, and USGS.
- Specific response to SWAP is not clear yet

# Scientific Trends (Personal Opinion)

- Standard models are increasingly coupled
  - Corona + Inner Heliosphere
  - Global Magnetosphere + Ionospheric Electrodynamics + Ionospheric Outflow + Ring Current
  - Coupled height-resolved thermosphere/ionosphere
- More coupling in the works
  - Corona + Inner Heliosphere + Magnetic Connectivity + SEP
  - Include Geomagnetically Induced Currents
- Sun-to-Mud simulations become more realistic
  - Increased computing power
  - Improved codes

# New Directions

- Data Assimilation/Ingestion
  - For ionosphere/thermosphere the first generation of models work
  - Data assimilation beyond the ionosphere/thermosphere is in its infancy
    - **M** Some proof of concept initiative were published
  - Synoptic data driven corona/solar wind models are standard now
    - **M** Synchronic models are coming operational
- High-order moment closures
  - Several groups are working on including kinetic effects in moment closure approaches
    - **M** Initial effort focuses on the full electron pressure tensor in the generalized Ohm's law
- Embedded PiC/Hybrid
  - One-way and two-way coupled efforts show initial results
  - Two-way coupling has only been applied to weakly magnetized objects so far (Ganymede, Mercury)

# Take Away Message (Do not Crucify the Messenger)

- National Space Weather Strategy/Action Plan
  - Nice beginning
  - Unfunded mandate
  - Pits NOAA against NASA
- Funding opportunities
  - \$10M “mandatory” increase for Space Weather is a gimmick
  - There are new opportunities in the 2016 NASA ROSES
  - We need a modeling incubator program
  - NSF/GEO PREEVENTS is a new opportunity
- Science trends
  - Code coupling
  - Data assimilation
  - Incorporating kinetic effects in continuum codes