MREFC thoughts

Larry J. Paxton
What are the major gaps in scientific understanding or engineering capability that limits our ability to describe Sun-Earth connections?

Where is discovery science likely to occur?

How can we predict the occurrence of and reaction to space weather?
Now is the time to stop fiddling around

- NSF GS portfolio review
- White House Space Weather Action Plan
- White House Space Weather Strategy
- Bipartisan support in Congress
- The Decadal Survey and NASA Heliophysics Roadmap
Science is a human endeavor and must appeal to some aspect of our humanity.

Science is a human endeavor and must appeal to some aspect of our humanity.

- The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed" Albert Einstein ["The World As I See It," 1930]
Unde venimus et quo vademus?

- How is our home planet connected to the Sun and space?
  - Why is the Earth different from Mars and Venus?
  - With the thousands of exoplanets discovered how many Earth-like worlds might there be?
  - What is the role of the Earth’s magnetic field is shaping the evolution of our home?
  - How does the Sun’s magnetic field and solar wind shape the evolution of our planet’s atmosphere? (T Tauri stage and beyond)
  - Does it matter what the relative orientation is of the magnetic fields?
  - Does it matter what the relative strengths are?
The Drake equation is:

\[ N = R_* \cdot f_p \cdot n_e \cdot f_i \cdot f_i \cdot f_c \cdot L \]

- \( N \) = the number of civilizations in our galaxy with which radio-communication might be possible (i.e. which are on our current past light cone); and
- \( R_* \) = the average rate of star formation in our galaxy
- \( f_p \) = the fraction of those stars that have planets
- \( n_e \) = the average number of planets that can potentially support life per star that has planets
- \( f_i \) = the fraction of planets that could support life that actually develop life at some point
- \( f_c \) = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
- \( L \) = the length of time for which such civilizations release detectable signals into space

\[ N' = N \cdot f_m \]

How many planets could have life?
Is there a term missing in the Drake Equation?

How important is a magnetic field to the evolution of the atmosphere?
What can we learn about the role of a planetary magnetic field by studying our own atmosphere?
To do that we have to understand the system as a whole and the differences between the hemispheres because that determines the nature of the interaction of the “Earth” – Sun system.
How many planets could have life? Is there a term missing in the Drake Equation?

- The Drake equation is:
  \[ N = R_* f_p n_e f_l f_i f_c L \]

- The number of civilizations that one might be able to detect is limited by the lifetime of a technical civilization.
- What if there was inherent limitation in the star-homeworld span of possibilities that limited the lifetime of a technological civilization?

Paxton (2012)
Space Weather applications

- Anomaly resolution
  - Satellite or system anomalies are mission-degrading or mission-terminating events
- Key activity is assignment of cause to human or natural
  - Must be timely
  - Must be accurate
- Need for nowcast and forecast - Examples include
  - s/c failure
  - System performance degradation
    - Lifetime (radiation, drag, propulsion)
    - Comms
    - Geolocation error above acceptable SEP
    - Aircraft routes
    - Power grid
    - Farming
    - GPS

GOAL: find efficiencies

Science needed

Engineering solution
Within the Vision there are Themes Driven by the Need to “Use” and “Know”

- We tend to think of scientific programs as a linear “requirements flowdown” or “traceability matrix”
- The MREFC goals can be thought of as a “matrixed approach”

VISION

- Theme: Humanity as a driver
- Theme: Turbulence
- Theme: Instabilities
- Theme: Coupling
- Theme: Variability
- Theme: ....
If we determine that there is fundamental information in the cusp the MREFC can be our vehicle for studying it.

- Long duration UAVs **could** host instruments at 75,000 feet for days
- Small satellites could be used to provide continuous coverage
- An aircraft can keep pace with MLT
Movie by Rob Barnes
AMPERE, SuperDARN, SuperMag and SSUSI
New platforms for exploring our world
- UAVs and Stratospheric platforms
- Commercial suborbital and rideshares
- Buoys
- Aircraft (like Rivet Joint?)

Virtual reality environments for exploring our data and model results

Integrated HSC environment that enables
- Particle filters
- Interaction with the solution trajectories
- Quantification of impact of uncertainties
- Development of OSSE
- Ensemble modeling
- Realtime assimilative modeling
- Small satellites can image the cusp in the UV – day and night
Enabling exploration and discovery

- We use techniques that are over 200 years old to share our results
- Challenges include
  - Data analytics
  - Computer-assisted “vision”
  - VR interactions
- Bring in other communities
- Lead other communities
  - Anomaly resolution requires timely results
  - Exploitation requires speed and accuracy
Quo vadis? Where are you going?

- Easter Island
  - Isolated island with a peak population of 15,000
  - By 1722 it had dropped to 2,000
- Jared Diamond, *Collapse: How Societies Choose to Succeed or Fail*, 2011
- Terry Hunt and Carl Lipo, *The Statues that Walked*, 2012
- J.B. McKinnon, *The Once and Future World*, 2013
Quo vadis? Where are you going?

- J.B. McKinnon, *The Once and Future World*, 2013
  - The soil on Easter Island is poor
  - The islanders took rocks broke them up so that wind erosion would release minerals into the soil so that they could grow crops
  - Garbage dumps show 60% of the bones were rats – their major source of protein.
- The Easter Islanders survived with their rock gardens and rats with no lumber to build a canoe to get off the island.
- They made do with what they had.
What do we do?

- We can continue as we have
- Or we can chart a new path
  - The community has to come up with a plan that communicates the value of the program to
    - the members of the community
    - the NSF
    - the NSF stakeholders
  - There must be a readily articulated theme that can be internalized and accepted within GEO
  - That theme should be something we can articulate internally and externally.
- Find commonality within NSF
  - Mathematical and Physical Sciences (MPS)
  - Computers and Information Science and Engineering (CISE)
  - Engineering (ENG)
  - Education and Human Resources (EHR)
  - Biological Sciences (BIO)
- Inspire the NSB
“WHETHER I shall turn out to be the hero of my own life, or whether that station will be held by anybody else, these pages must show.” Charles Dickens, *David Copperfield*