The Role of New and Evolving Technology in Aeronomy - The Space Segment

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This Talk Will Focus on Transitioning New Technologies to Space

- There is no current technology development line that addresses the unique requirements of the aeronomy community.
- We must take a hand in focusing technology development to meet our community's needs.
  - First we need to define what we want to do then decide how to do it.

“I have seen the future and it works”

Lincoln Steffens, reporting on Russia in 1919

- Aeronomy will follow two paths:
  - Upper atmosphere space weather support
  - Upper atmosphere research
- Technology supports each of these paths
  - Technology enables “better, faster, *cheaper*” approaches
    - And “cheaper” will become increasingly important!
  - We need to work together to shape the vision that holds the future for aeronomy.

What is the time frame for this talk?

- Space physics is a “Space Age” field
  - Our ideas about what aeronomy is and what we can do may be tied to a paradigm developed along with the Space Age and may ultimately limit the field.
- Technologies for the currently roadmapped missions are already in the pipeline.
  - Geospace Electrodynamics Connections (GEC) has been studied and a strawman implementation has been developed.
  - Where will we be at the end of the next generation?
    - Let’s consider what we might do for the next generation of aeronomy missions.

What are the “Frontiers” of Aeronomy?

- There are different kinds of frontiers
  - Exploring the interactions at the boundaries
    - Inputs from above and below
  - Spatial and temporal resolution
    - “better” measurements and/or more measurements
  - Exploring new places
    - “to boldly go where no one has gone before”
    - Testing our understanding of what will happen in the future – “the undiscovered country”
      - E.g. an improved predictive capability

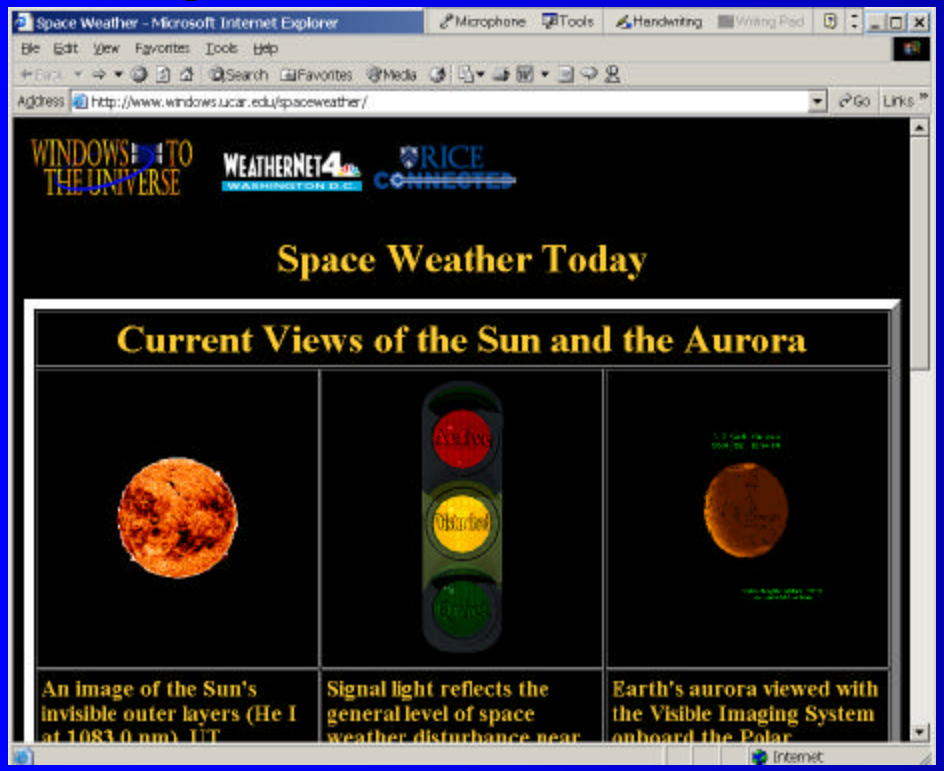
New Technology Development is Supported by NASA Programs

- NASA Institute for Advanced Concepts (NIAC)
  - Looks 10 to 40 years out (or further)
- New Millenium
  - Provides broader-based support for new technologies
- Cross-cutting technology programs
  - Sun Earth Connections R&A Technology
- Dedicated technology development
  - E.g. Next Generation Space Telescope (NGST)
- SBIR
  - Opens technology flow to small businesses
  - May become more important as “space weather” becomes a business
    - e.g. Space Environment Technologies SpaceWx

Space Weather May Support Aeronomy

- Much as meteorology provides baseline support for atmospheric sciences, space weather make provide the “market” for aeronomy.
  - This provides a “political” base to advocate technology development funds.
- Will there be space weather majors as undergrads?
  - The pool of undergraduates (potential researchers) needs to be broadened.

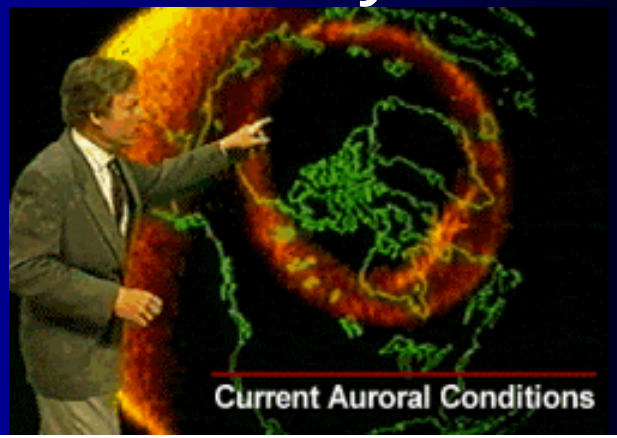
Space Weather as “Business”



- Can cost sharing be used to advantage to reduce mission cost while still doing aeronomy?

Space weather can be infotainment as well as an engineering design driver.

Can we imagine how the infotainment “requirement” for real-time auroral imagery could be used to meet “aeronomy: needs?



New Technologies Should Take Us to the New Frontiers

- Requirements flow down
  - Science question
    - What you want to do
  - Observations required
    - What you think you can measure
  - Measurement required
    - Data Products
    - Validation
  - Instrument required
  - Implementation requirements
    - What you think you can do

We shouldn't define the science we do by what we think we can get by with – our vision should include those things that are currently beyond our grasp.

Aeronomy Missions Face Competition From Others for the Same Resources

- Missions to places we've never been "sell" better than missions to refine our understanding.
- TRLs for proposed missions have to be high to reduce risk.
  - This is the "tyranny of the TRL".
  - Without dedicated tailored technology development TRLs stay high in the areas you need to do new missions in new ways.

TRL: Technology Readiness Level – used to assess risk estimates in mission design studies

How Can the Best Qualities of the Ground-based Programs be Preserved?

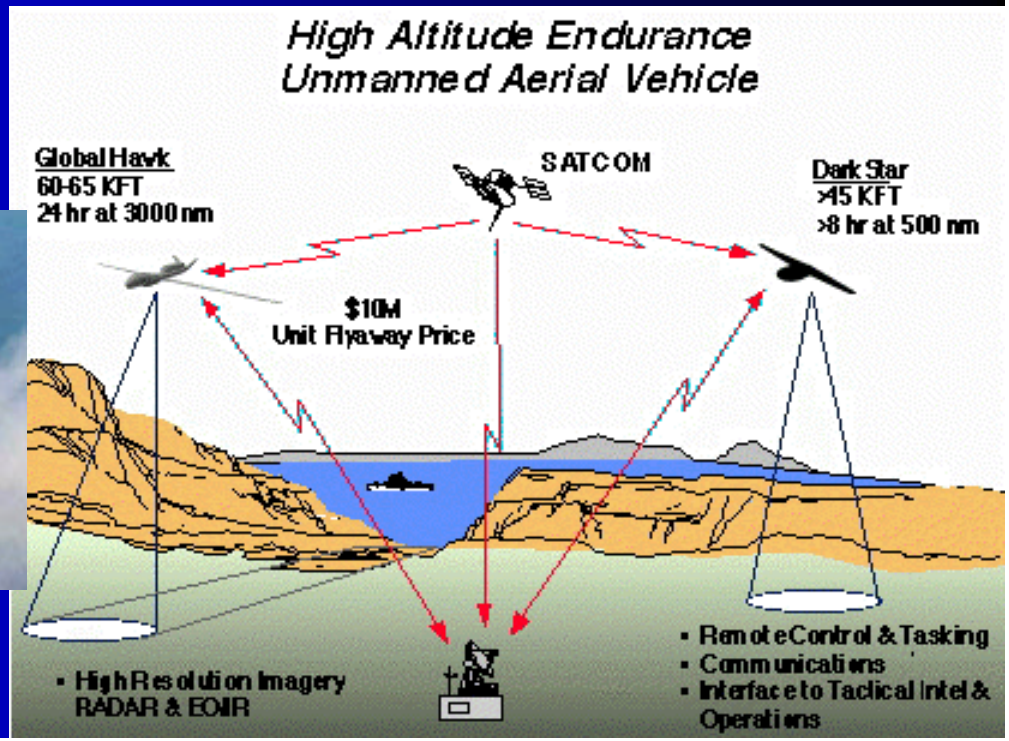
- Ground-based programs offer
  - faster cadence for innovation
  - greater opportunities for students because program lifetimes are shorter
  - more readily sustainable funding and schedules
    - Better, faster, and *CHEAPER!*
- *But how do we make the transition from ground to space?*

Let's Consider A Few Examples to Show How Technology Might Reshape Our Approach to Aeronomical Problems

- To identify a technology that needs focused investment we need to identify a research problem that we are currently addressing at the limits of our abilities.
  - In the following slides, a few technologies are considered that hold considerable strategic programmatic promise.

What is the next step for ground-based measurements?

- Long duration aircraft may offer the opportunity for sustained observations from a range of locations.



UAV/RPVs Have Advantages

- You can go to new locations and stay there for focused campaigns.
  - Code Y (Earth Science Enterprise already does this)
- Low cost, high payload capability that raises TRLs and provides enhanced science.
  - Hypersonic vehicles can reach the edge of space.
- Current UAVs can fly fast enough that they enable multiple tomographic passes in coordination with a satellite overpass.
  - Let’s take the next step to multidimensional imaging

UAV/RPVs Have Advantages

- UAVs can enable daylight observations of airglow and aurora by flying above the peak in the Rayleigh scattering source function.
  - This means that the instruments can be simpler and still provide required information under sunlit conditions.
  - Ground sites are also affected by weather.
    - Current UAVs can fly above the weather
    - The availability of assets for coordinated campaigns can be assured.

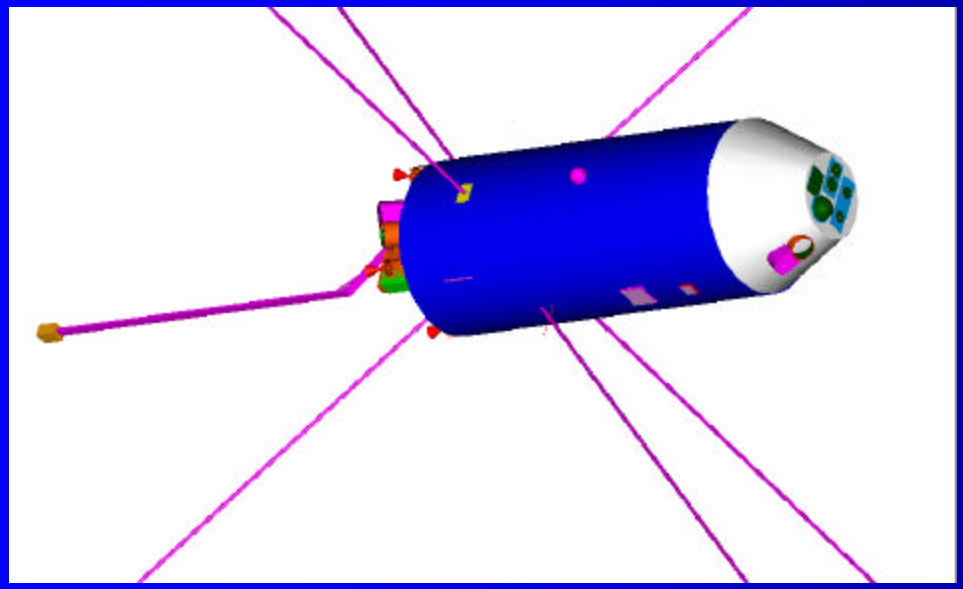
Where do we go beyond GEC?

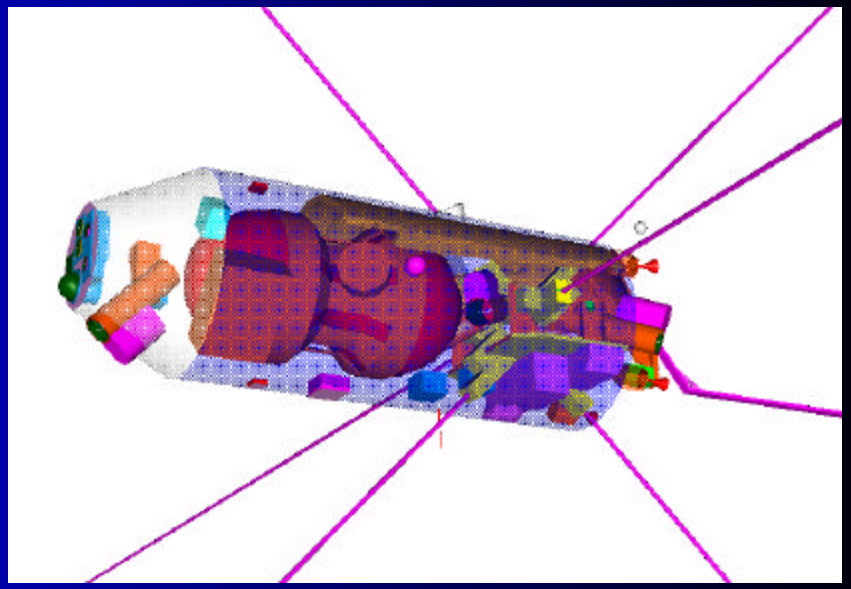
How Would New Technologies Reshape GEC II?

- The GEC mission consists of a series of dippers.
  - Dippers allow direct access to the lower thermosphere but you can only go to about 130 km.
  - Spacecraft design compromises are driven by the environment.
    - Dipping drives s/c control and power systems and instrument accomodation.
  - Space missions are relatively inflexible.

GEC is a Great Mission!

- Four spacecraft in 83deg 2000 km x 185 km orbit.
- Launch in 2008 in “pearls on a string” configuration.
- Designed for dipping campaigns to 130 km.



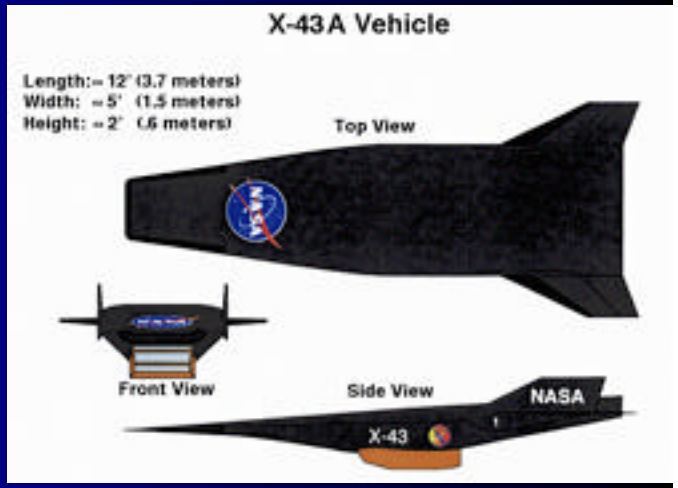


GEC Carries a Lot of Fuel to Make Up For Dipping Losses

- An evolutionary step is:
  - GEC-like spacecraft that refuel on-orbit
    - Space Technology 6 has an autonomous rendezvous demo that, if funded, would confirm technologies in 2003/2004 timeframe
  - Small satellites using lifting body technology to “skip” through the atmosphere
    - Use autonomous control to maneuver during dipping
    - Outgrowth of the DoD Skipper program
  - Use solar sails to enable orbit plane changes during the mission to enhance flexibility.
    - Conventional approaches cost too much (fuel=mass=dollars)

Can We Look at the GEC Problem in Another Way?

- Hypersonic vehicles are being studied and will probably be developed.
  - 40 years ago the X-15 reached 108 km
  - We could do good science if we had that capability today.
- A hypersonic vehicle could make repeated excursions along ballistic trajectories into the mesosphere and lower thermosphere (or D, E, and F1 region).
  - Could be reconfigured to address different focused objectives.
  - Would enable higher risk innovative payloads.



What is the Gen II RAO?

- Can we imagine a scenario in which the Relocatable Atmospheric Observatory (RAO) is in space?
- The technology for flying an ISR in space appears to be within reach.
- Could RAO Gen II be placed on a solar sail in a pole sitter configuration?
- To get there we have to build a technology infusion plan and timeline.

NGST Will Build and Fly Technologies Useful for RAO Gen II

- Solar sail observatories are planned for 2012-2014 timeframe.
- RF transmitter technology, high efficiency power sources (nuclear fission reactors), and large reflect-array antennas are being developed under NMP.
  - Key technologies include large deployable structures
    - Micropositioning actuators and control mechanisms with high stability
    - Developed for Next Generation Space Telescope (NGST)
- RAO Gen II in 2016?
  - We could do if we decided that this is a community goal.

New Aeronomy Missions to Other Planets Become Feasible

- Getting there
  - Nuclear electric or solar electric drive
    - High specific impulse means that you can reduce cost and increase payload
    - Great where aerocapture isn't an option.
- Staying there
  - Aerobraking
    - Enables new missions by reducing the fuel burden
      - Jupiter polar orbiter in a circular low radiation orbit (TIMED goes to Jupiter)

How do we deal with ITAR?

- ITAR regulations may limit the technologies used by US investigators in aeronomy missions with other partners or may limit the extent of partnerships
  - Technology transfer
- DoD and DoC has fostered significant growth in aeronomy and space weather
  - DoD data access policies have been evolving towards more restricted access as the value of the data are recognized.
    - Community advocacy is a key determinant of the future course of these policies

What is the Future Role of the US in Space Weather?

- The US is the technical and scientific leader in Space Weather.
- World-wide participation enhances our ability to do space weather.
- Do we manage this effort as a colonial power or as a partner?
  - ITAR dictates how we interact with other countries.
    - Does it address the control of critical technologies in cooperative space weather ventures, appropriately?

How Do We Publicize the Role of New Technologies in Aeronomy Missions?

- Focused meetings
  - World Space Congress joint IAA/COSPAR session on low-cost geospace missions
    - Fall 2002
      - Kent Tobiska
      - Larry Paxton
    - Papers published in *Acta Astronautica*
  - Chapman Conference on “Frontiers of Aeronomy”
    - This is a good time to have such a meeting.

Where do we go from here?

- We need to establish a technology roadmap for aeronomy.
- Identify the future directions of aeronomy.
  - What are the new questions?
- Decide what technologies are going to enable those missions.

  The aeronomy community has relied upon and benefited from the “low hanging fruit” developed by other programs.