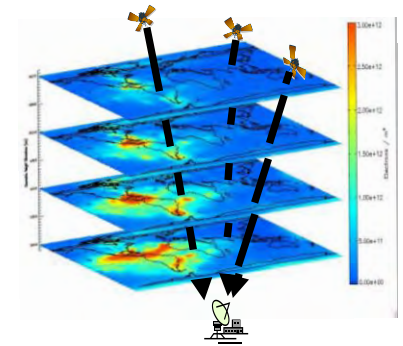
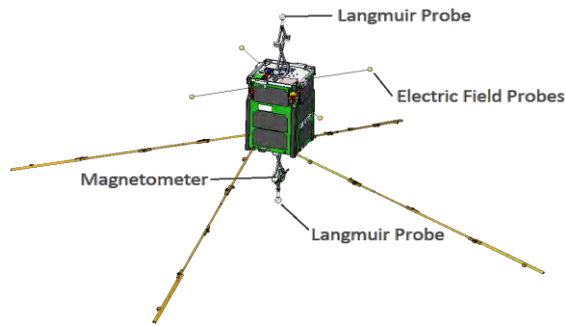


# National Space Weather Infrastructure (& Extreme Events)



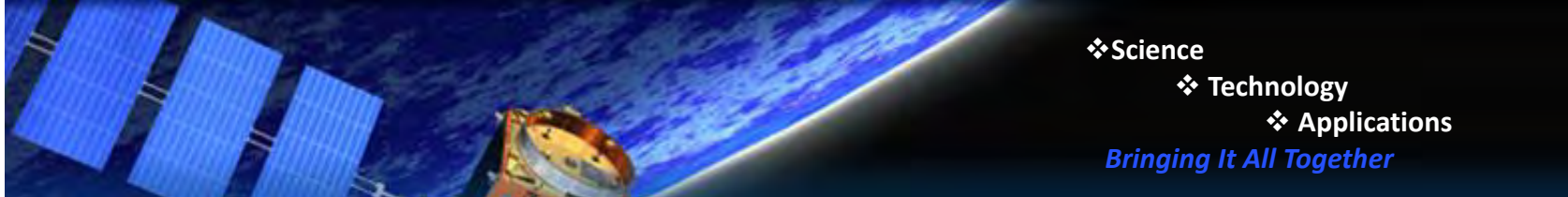
**Geoff Crowley, Ph.D.**

**Executive Committee Member  
American Commercial Space Weather Association (ACSWA)**

[www.acswa.us](http://www.acswa.us)

**President/Chief Scientist  
Atmospheric & Space Technology Research Associates (ASTRA) LLC**

[www.astraspace.net](http://www.astraspace.net)

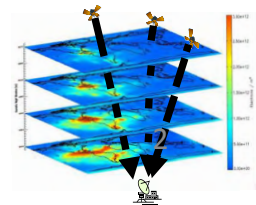
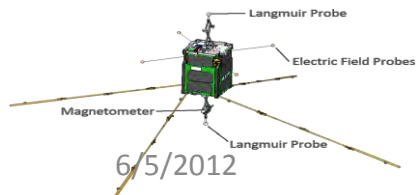



## ABSTRACT

Accurate knowledge of the ionospheric and thermospheric environment of the Earth’s upper atmosphere are required in order to understand and predict their impacts on operational systems. The ionosphere affects vital radio-based systems, including communications, navigation, and surveillance systems. The thermosphere affects satellite orbits and spacecraft maneuvers. Over the past decade, our understanding of space weather and our ability to produce simulations and measurements of space weather phenomena have both developed to a remarkable degree.

In concert with this growth of knowledge, a community of commercial space weather providers has sprung up. The commercial providers offer various space weather services that extend from the Sun to the earth’s atmosphere, including ionospheric and thermospheric effects that are of interest to operational systems. The commercial providers recently formed the American Commercial Space Weather Association (ACSWA) - [www.acswa.us](http://www.acswa.us).

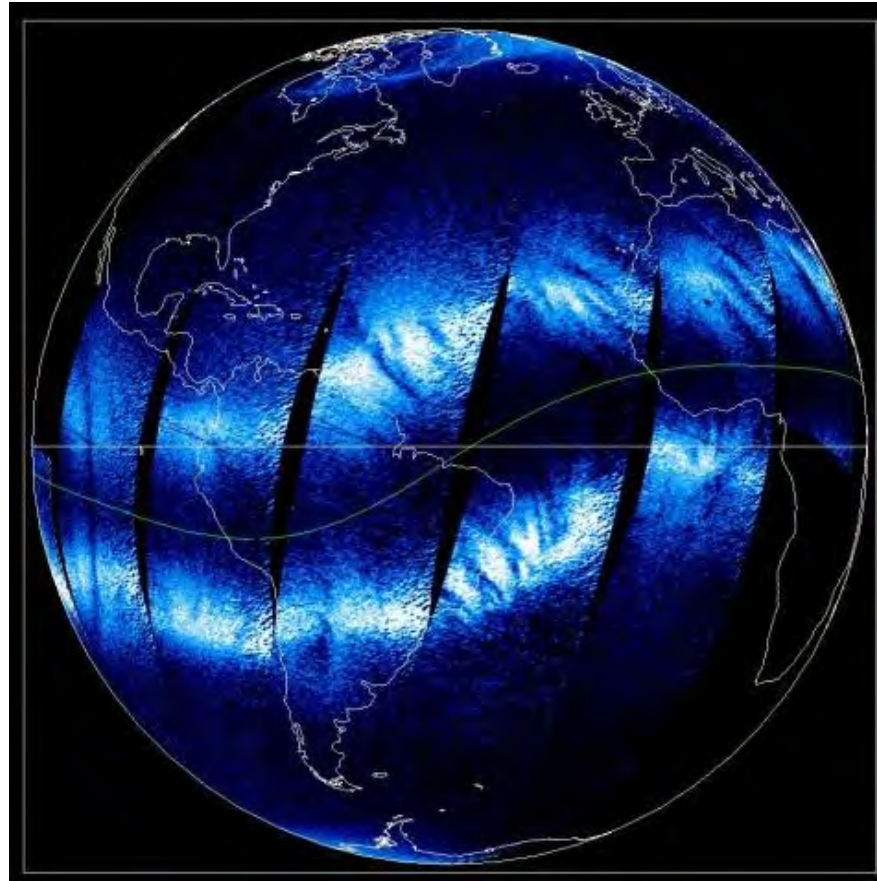
This presentation describes ACSWA, and some of the scientific and engineering capabilities of ACSWA members. The small companies that comprise ACSWA have world-class capabilities that can contribute to the national infrastructure, and our response to extreme events. This presentation will cover modeling and simulation, instrument development, smart-phone Apps and future directions of the US commercial space weather community.



- 
- Space Weather affects technology
    - Satellite drag
    - Satellite SEUs
    - Power grid GIC
    - Aviation radiation
    - GPS position accuracy
    - Communication outages
    - Satellite surface charging
    - Satellite internal charging

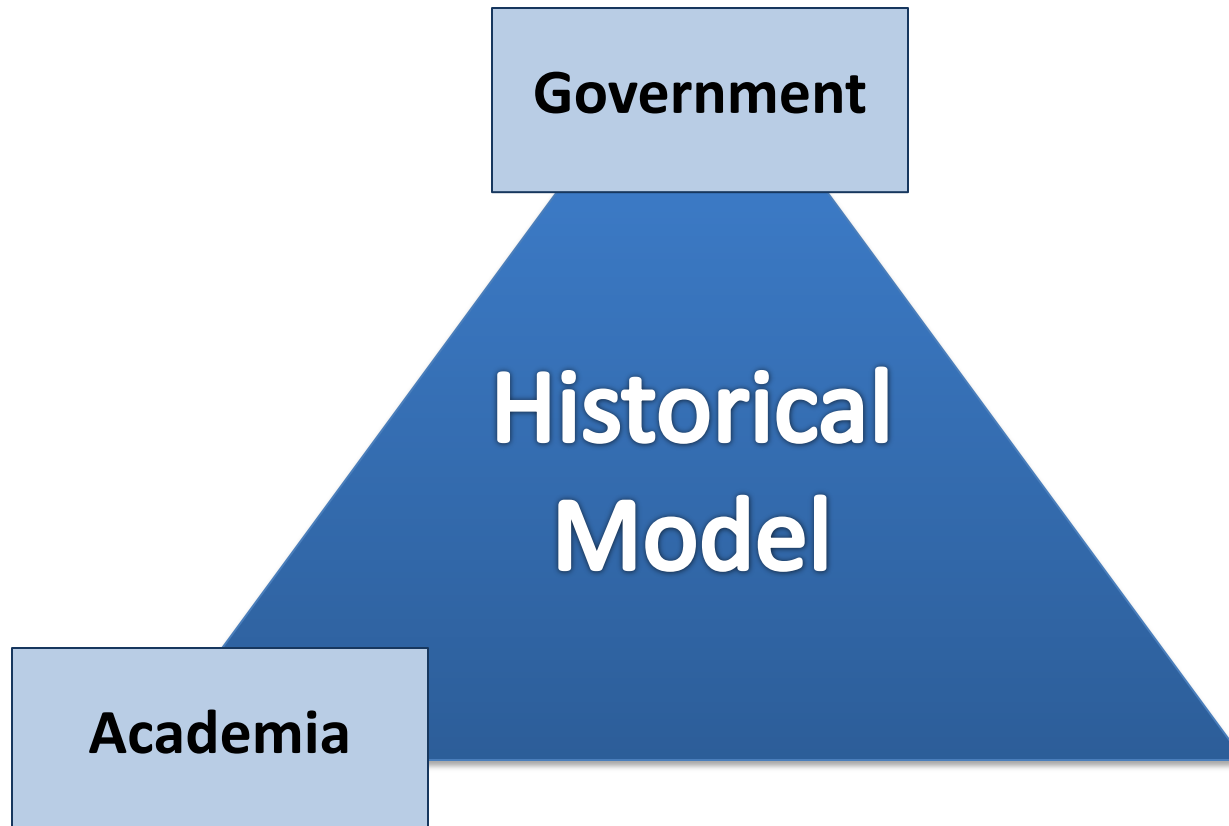
Courtesy of Kent Tobiska

## The Need: Majority of Users Care about Ionosphere

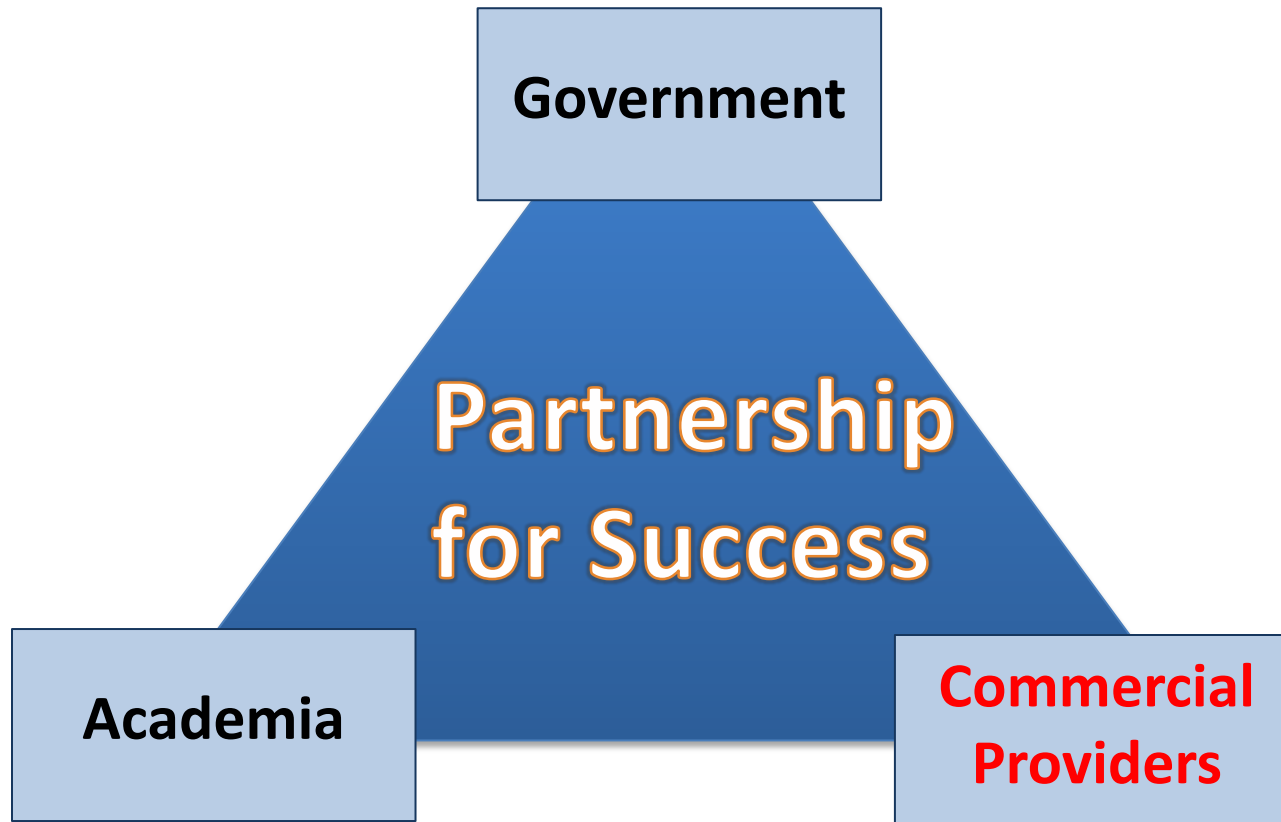


**UV Imagery from the GUVI instrument on TIMED, courtesy of Larry Paxton, APL**

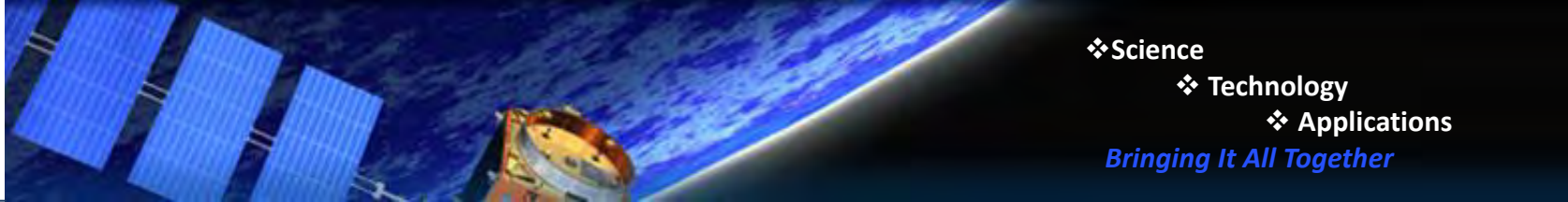
# Historical SpaceWeather Infrastructure (& Extreme Events)



# Modern Spaceweather Infrastructure (& Extreme Events)



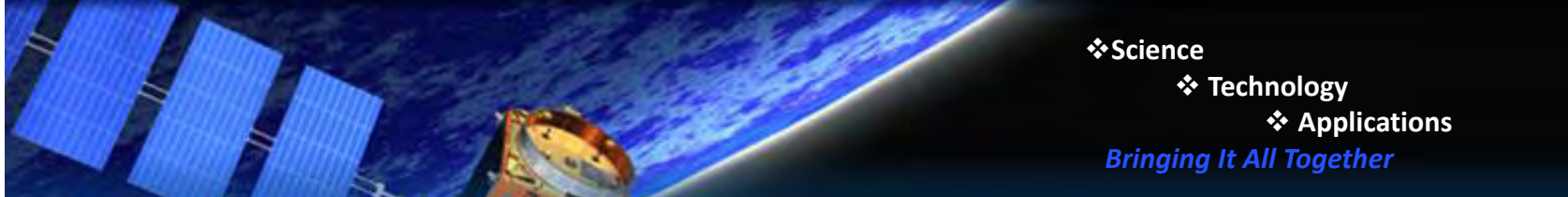
**New infrastructure for Space Weather & Extreme Events** →



# American Commercial Space Weather Association

**ACSWA is organizing commercial SpWx**

- **Founded in 2010**
- **9 commercial organizations**
  - ✓ **Providers of quality space weather data and services**
  - ✓ **Developing operational space weather best-practices**
  - ✓ **Represents interests of commercial SpWx providers**
  - ✓ **Represents commercial SpWx in nat'l & int'l arenas**
  - ✓ **Supports advisory services to government agencies**



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## New Group to Represent the Commercial Sector

**Louis J. Lanzerotti**

20 May 2011

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The relationships and roles among government and private service providers in the space weather working environment can often be difficult if clear communications pathways are not in place and if parties are not earnestly communicating with one another. With the current strong thrust in academia toward commercially exploiting research advances, the working environment becomes even more complex. Similar situations continue to exist in the realms of terrestrial weather forecasting and prediction, even given the maturity of this field compared to the relatively new space weather arena.

To foster collaborative working relationships among private, governmental, and academic sectors, the annual Space Weather Workshop, hosted by the NOAA Space Weather Prediction Center in Boulder, Colo., brings stakeholders together with the practical goals of learning advances in the field of space weather, networking, and discussing and working out knotty “territorial” issues.

The 2011 workshop continued its past successes in fostering communications and dialogue, and workshop organizers deserve commendation. As in previous years, a roundtable discussion on growing the space weather enterprise was organized by the Commercial Space Weather Interest Group. The keynote speaker for the roundtable, former NOAA administrator and now vice president for science at the CSC Corporation, Retired Vice Admiral Conrad Lautenbacher, outlined global opportunities for growing the enterprise, both by commercial interests and by governments.



# Lets take a quick look at some of the capabilities of ACSWA members.....

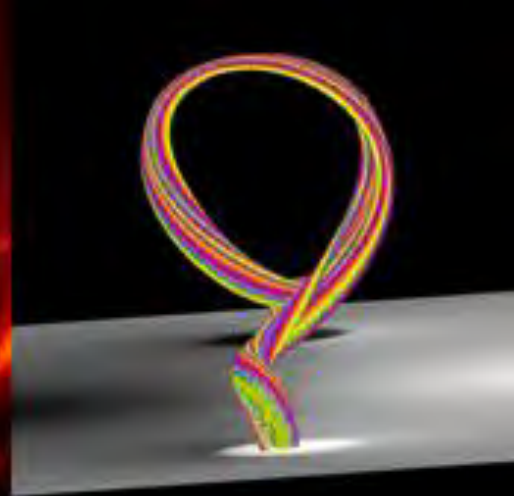
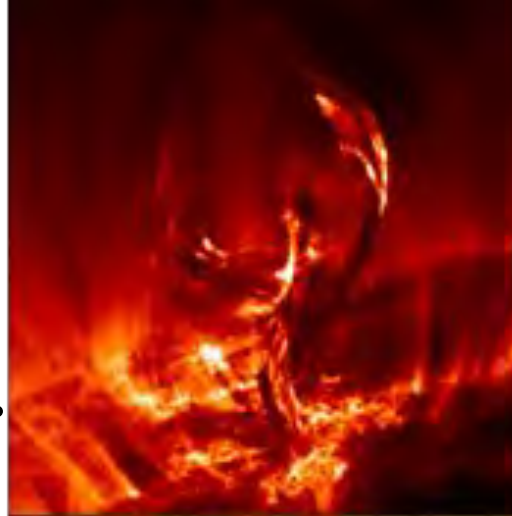
- **Predictive Science Inc**
- **Carmel Research Center**
- **Space Environment Technologies**
- **Q-up Now**
- **Atmospheric & Space Technology Research Associates**



Predictive Science, Inc.

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# *CARMEL RESEARCH CENTER (CRC)*

## CRC SPACE WEATHER FORECASTS

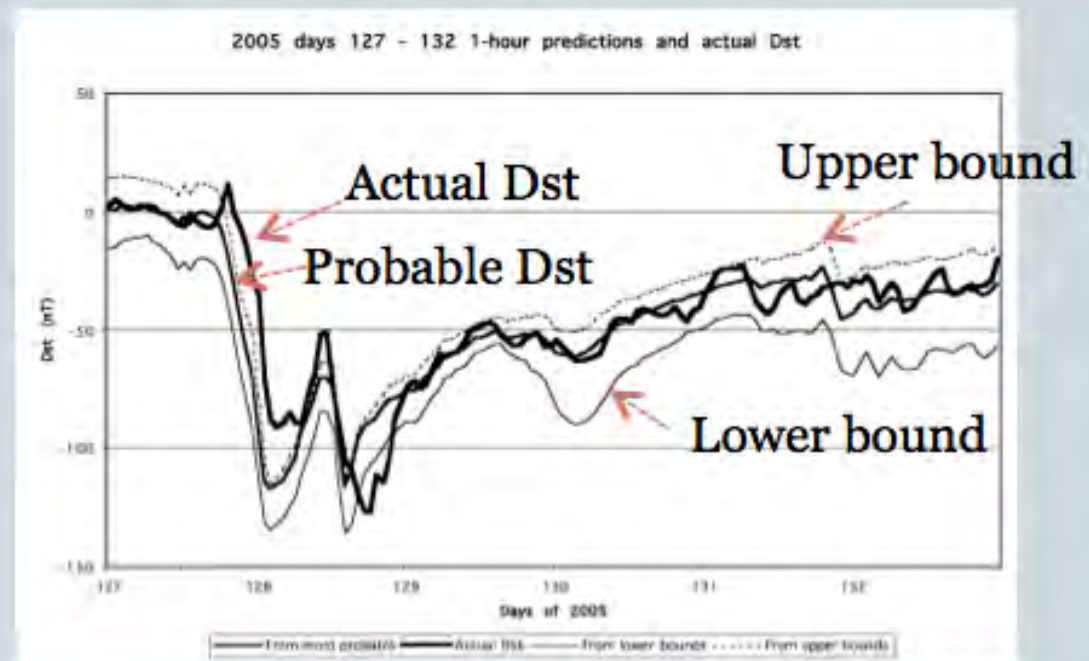


# CARMEL RESEARCH CENTER (CRC)

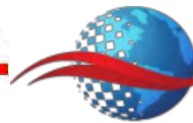
## CRC SPACE WEATHER FORECASTS



### ○ 1-5 hour forecast of Dst

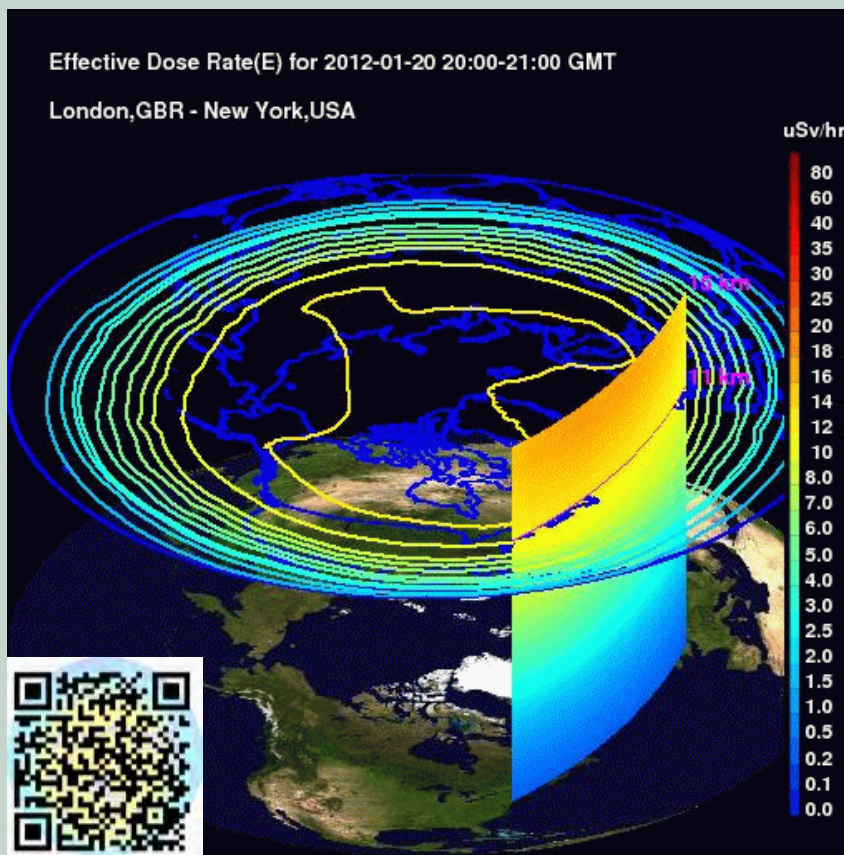


Courtesy of Devrie Intriligator

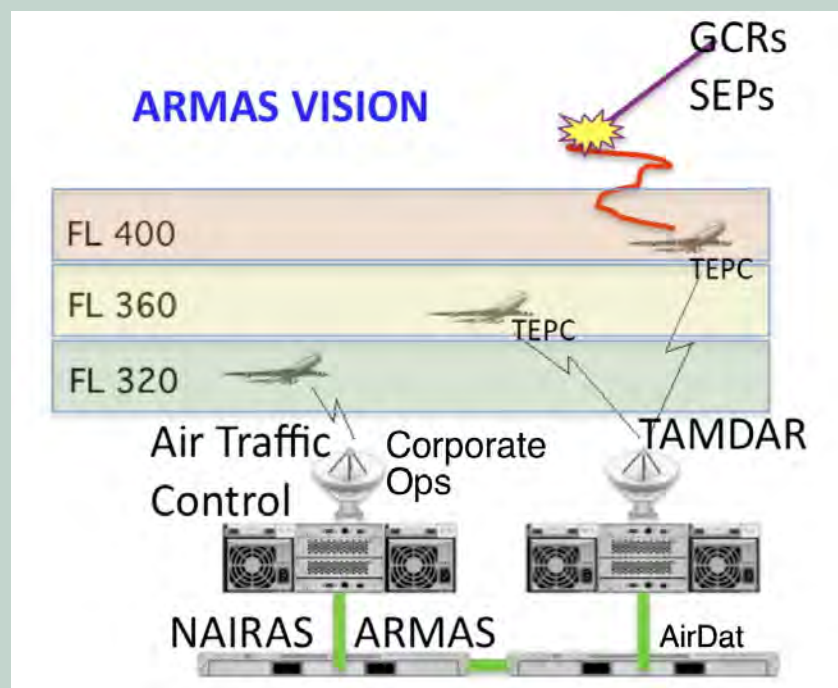


# Characterizing Radiation for Aviation Customers

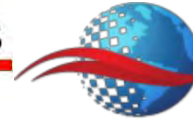
## NAIRAS



## ARMAS



Courtesy of Kent Tobiska



# Q-up: Corporate and Hams HF propagation



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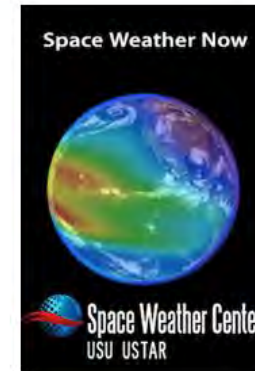
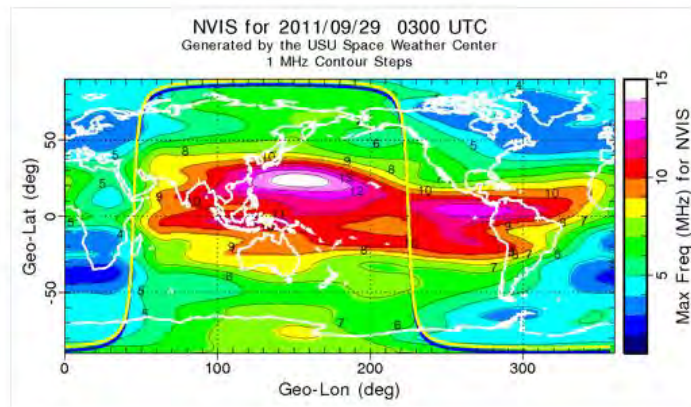
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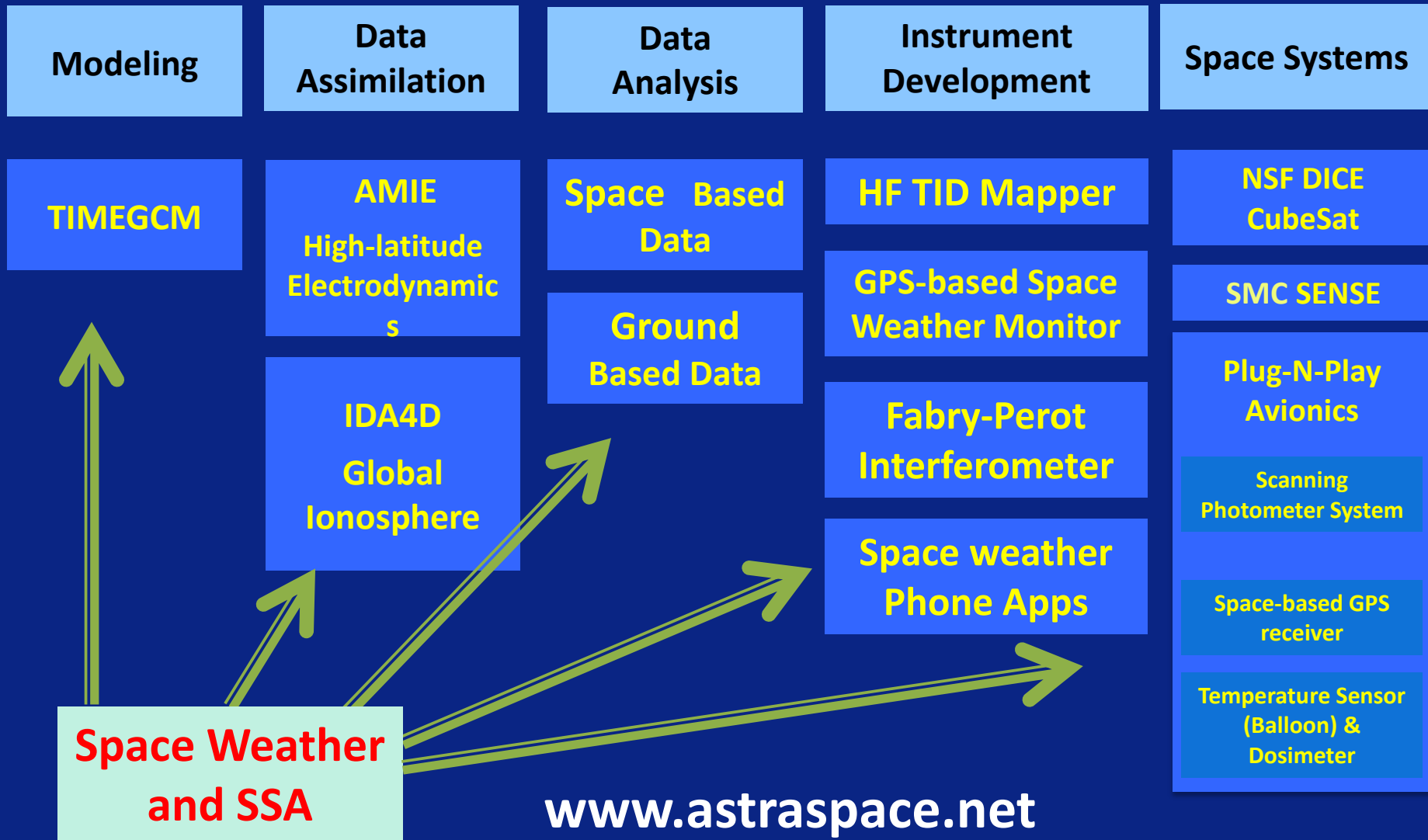
## Q-up Now



At Q-Up Now we are dedicated to providing the best, most accurate real-time and forecast High Frequency (HF) radio frequencies for propagation.

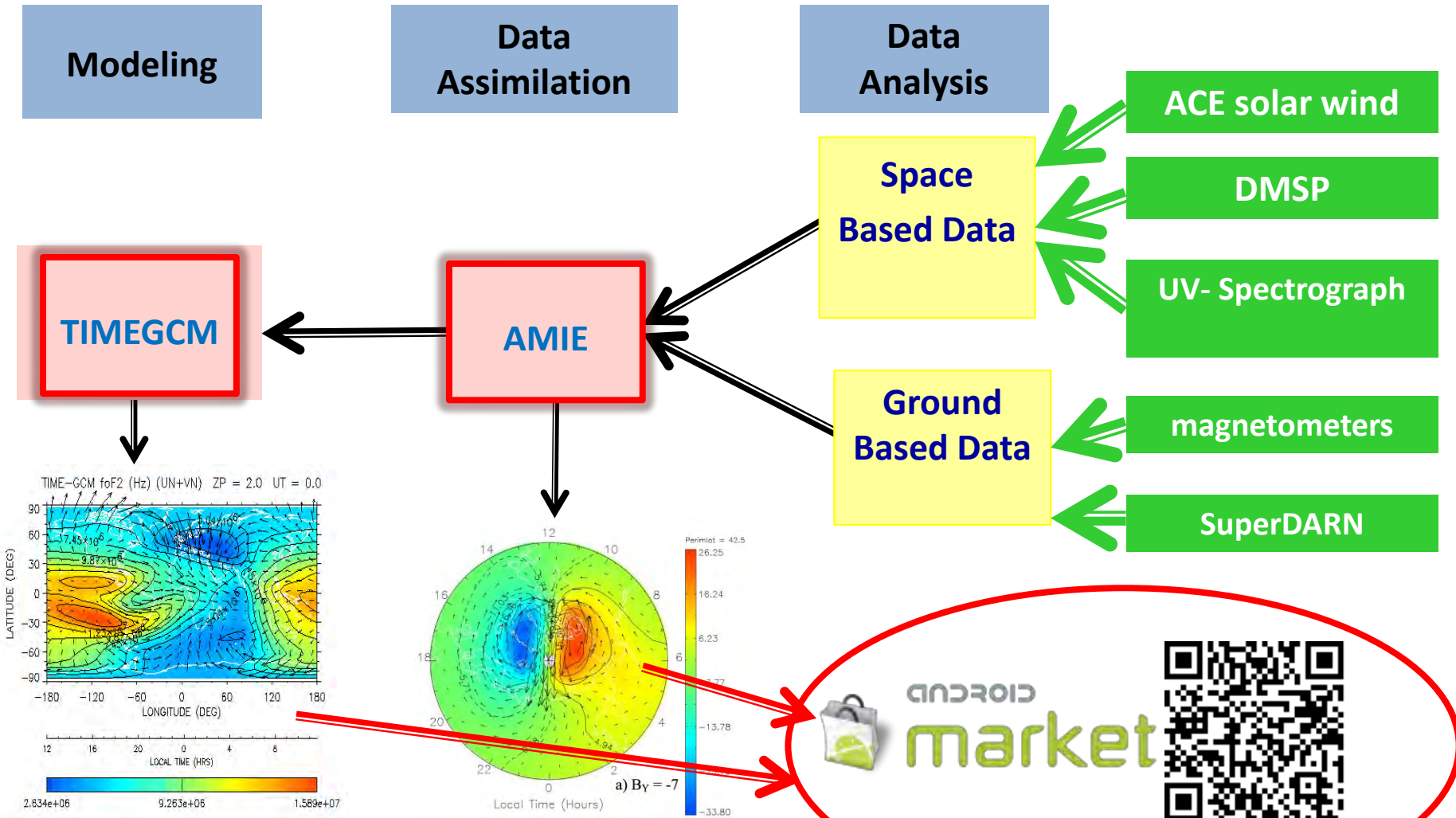
### What is Propagation?

Radio propagation is the transmission, including reflection, of a radio wave in a specific direction through a



# Transition of AMIE & TIMEGCM Models

Assimilative Mapping of Ionospheric Electrodynamics  
Thermosphere-Ionosphere-Mesosphere-Electrodynamics-GCM

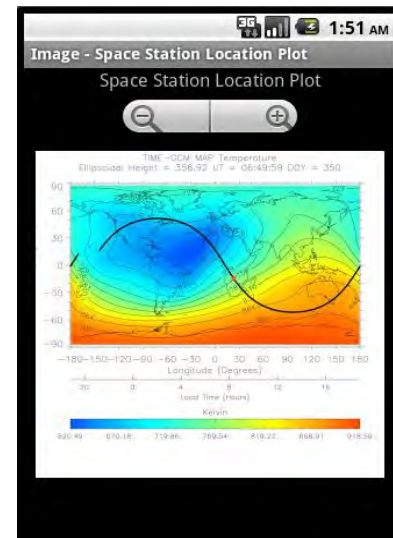
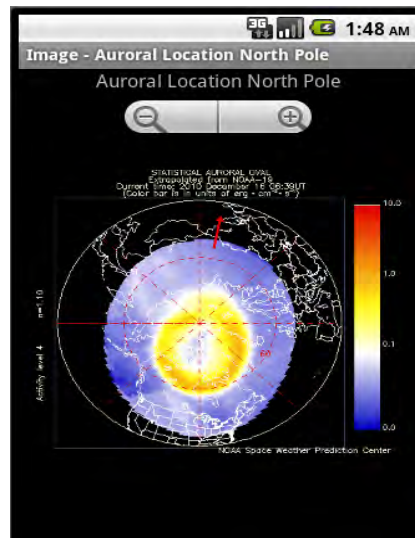
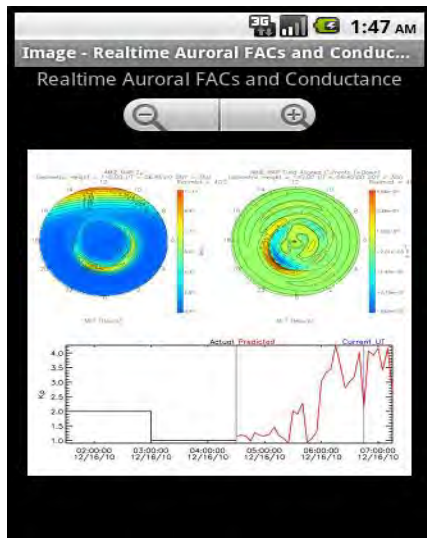
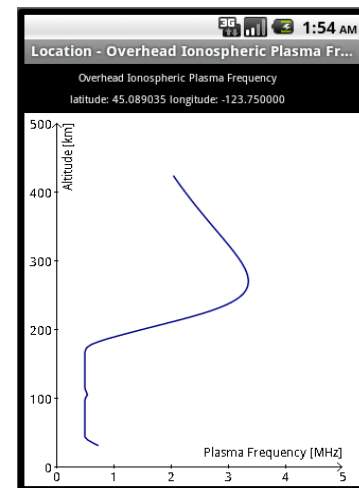
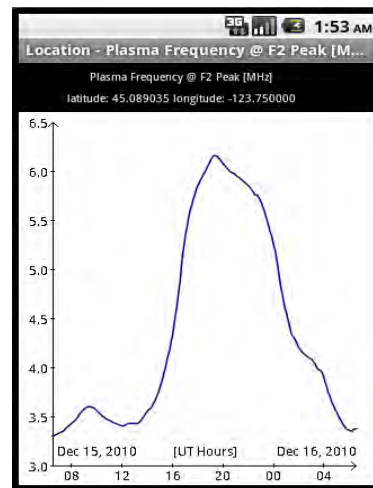
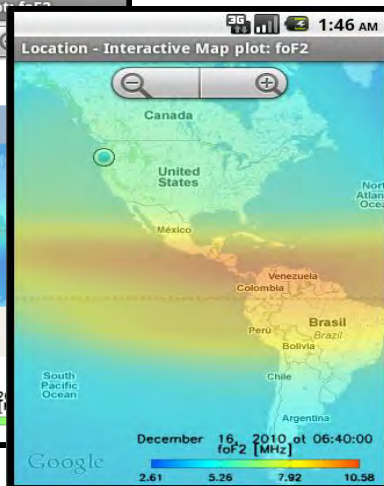
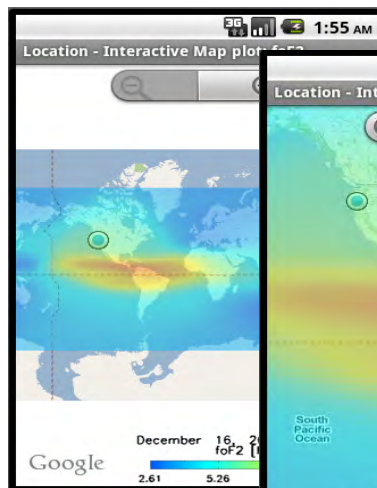
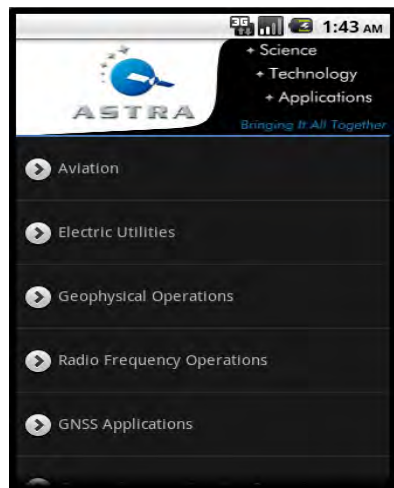


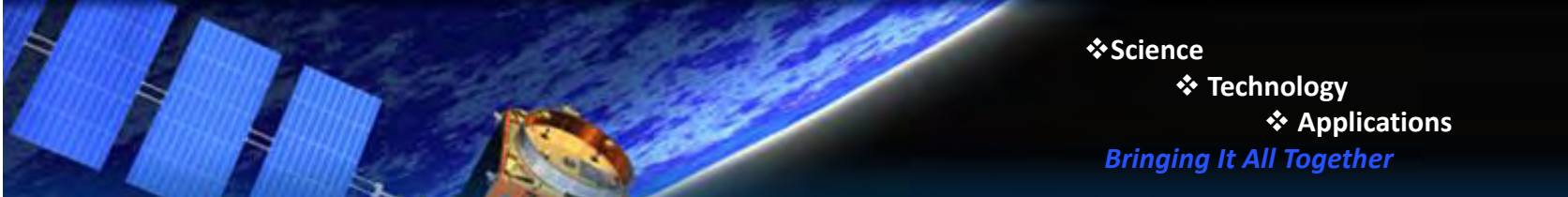




# A LOOK INTO ASTRA's Space Weather App

❖ Science  
❖ Technology  
❖ Applications  
*Bringing It All Together*



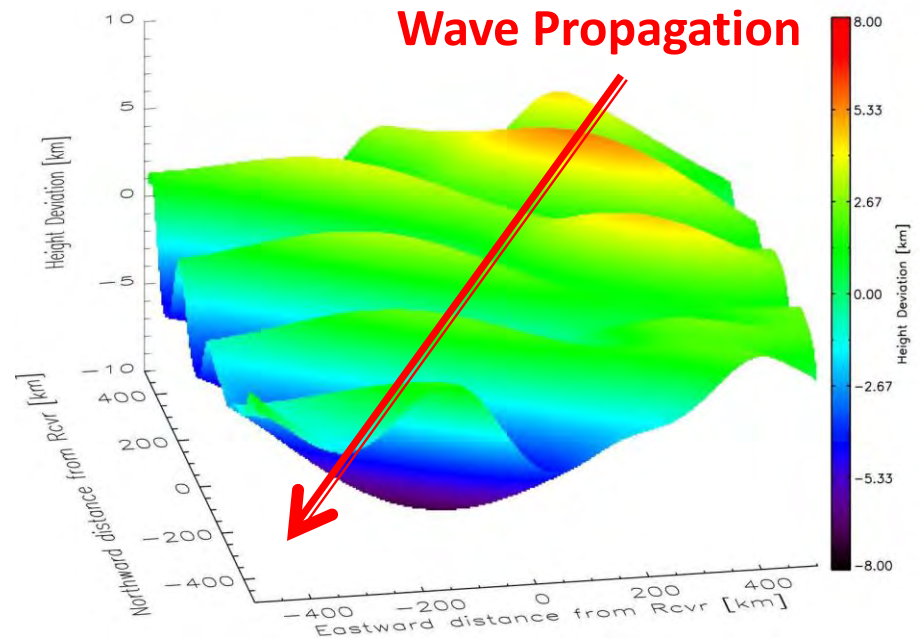
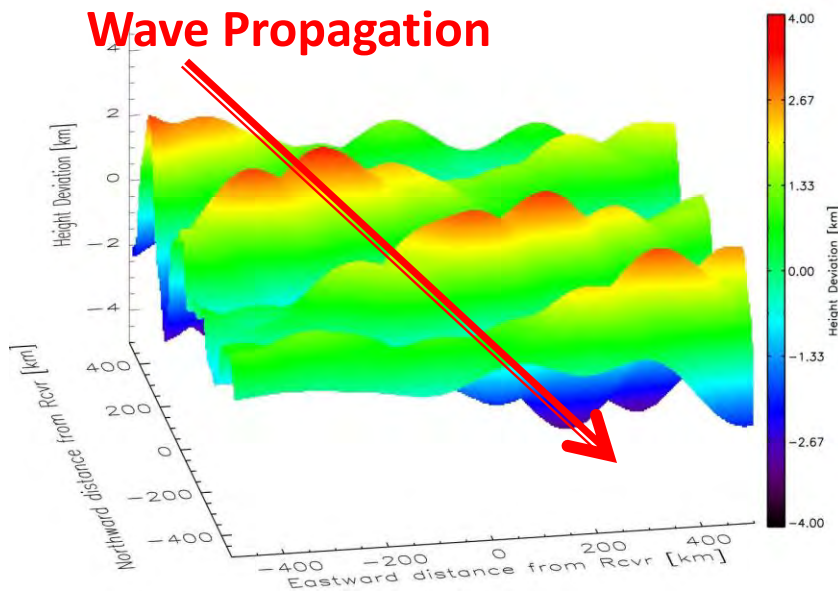


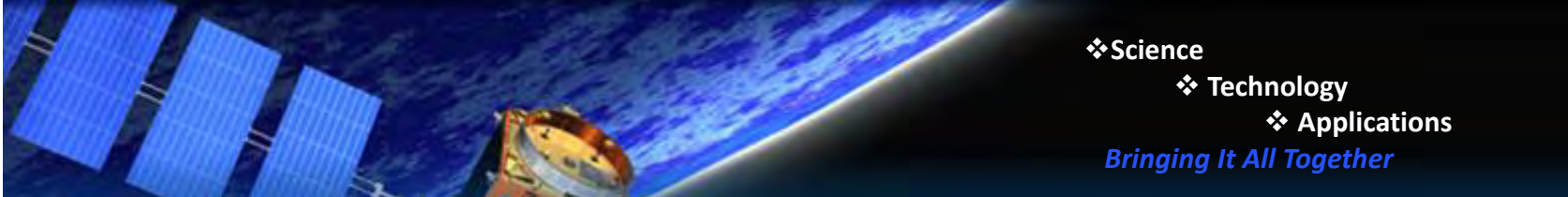
# Mapping Ionospheric Waves

ASTRA's TIDDBIT Sounder maps traveling ionospheric disturbances (TIDs) that can affect comms and surveillance systems

**18 UT**

**21 UT**





# ASTRA's GPS-Based Space Weather Monitor

- Dual Frequency GPS software receiver
- Provides navigation solution PLUS Space Weather monitoring
- Space Weather Parameters: TEC, Scintillation parameters
- Designed for robust operation in scintillation environments
- Multiple communication options, including realtime Internet

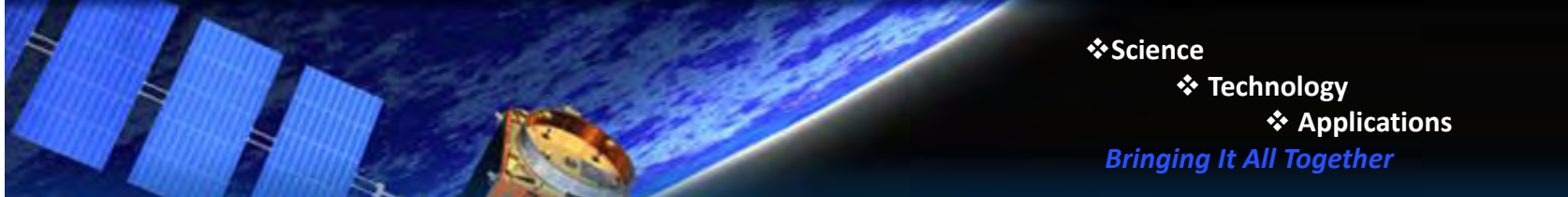


**Two form factors**

Antarctic  
Version

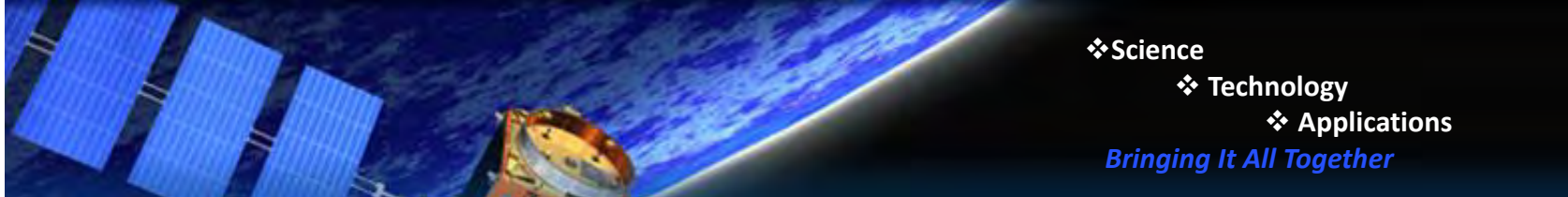
Standard  
version

- Multiple systems currently deployed
- Reliable operation
- [www.astraspacespace.net](http://www.astraspacespace.net)

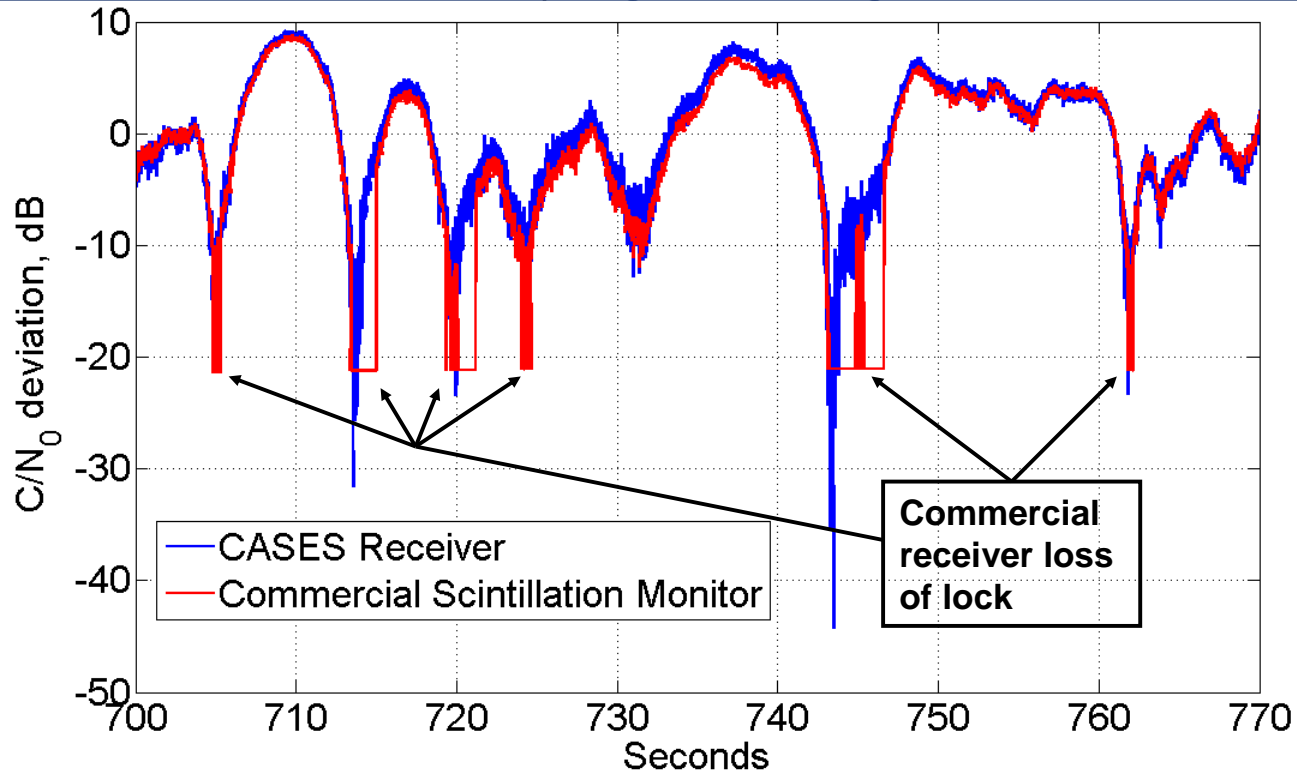


### CASES On-Board Data Products

	Per Channel High Rate	Per Channel Low Rate	Scintillation Params	Navigation Solution
<b>Default Rate</b>	<b>100 Hz</b>	<b>1 Second</b>	<b>100 Second</b>	<b>1 Second</b>
<b>Configurable Rate?</b>	Yes 50 or 100 Hz	Yes >= 1 Second	Yes	Yes >= 1 Second
<b>Parameters</b>	I's, Q's, Integrated Carrier Phase	Pseudorange- based <b>TEC</b>	<b>S4, <math>\sigma_{\phi}</math>, <math>T_0</math></b>	<b>Position Velocity</b>
		Phase-based <b>Delta-TEC</b>	Scint. Power Ratio	
		Integrated Carrier Phase		
		Pseudorange		
		Doppler Frequency		



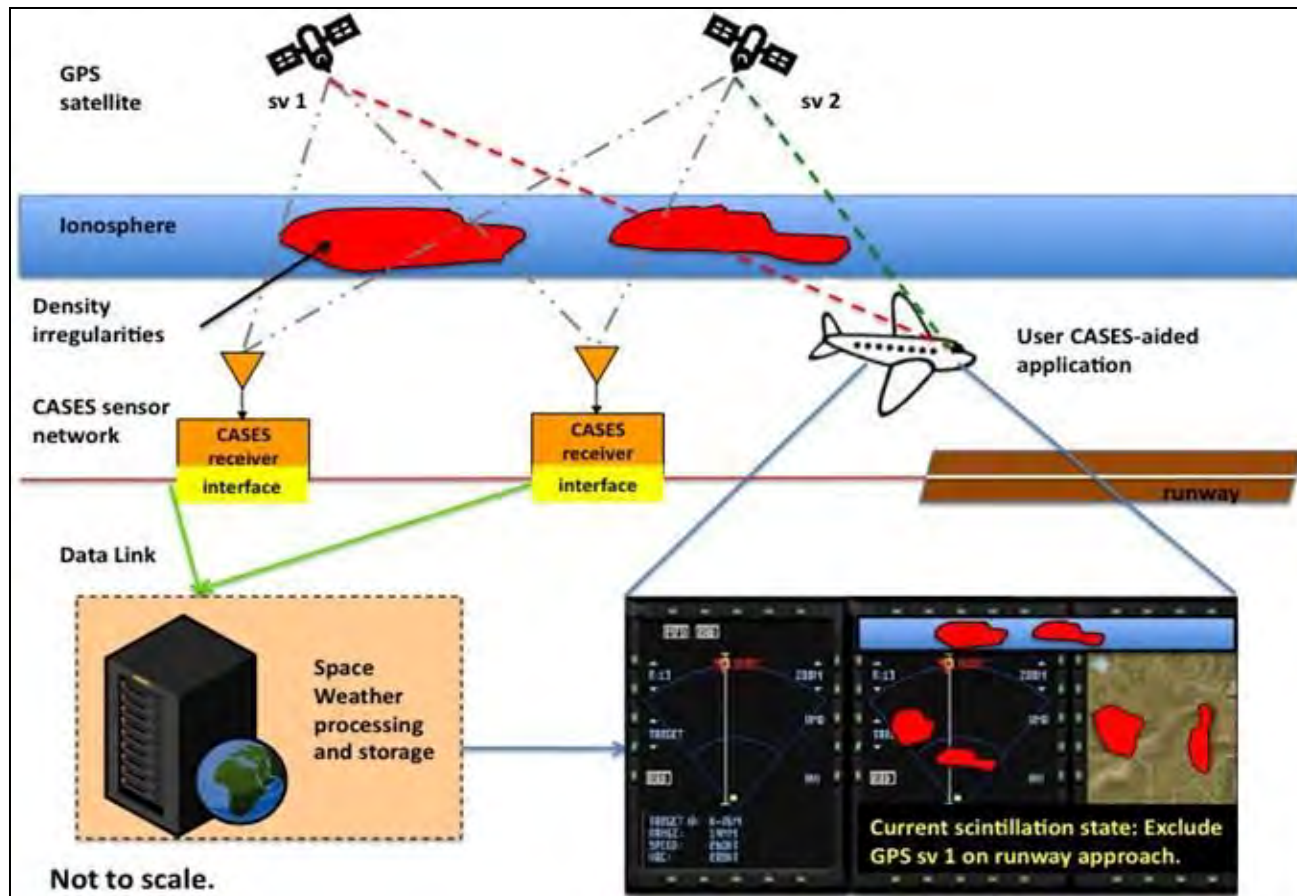
## ASTRA's CASES Receiver Tracks Through Weak Signals better than Competitors

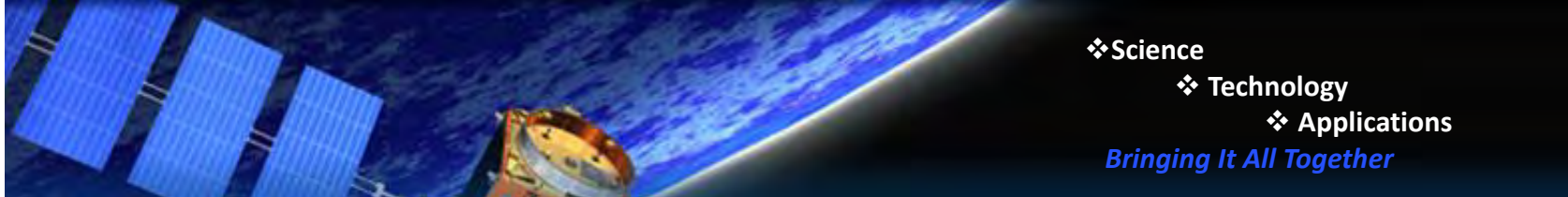


The CASES specialized tracking loop (blue trace) allows robust tracking during scintillations versus other receivers using fixed bandwidth PLL (red trace) which lose lock. **Data collected from Jicamarca, Peru at magnetic equator.**

Courtesy of Brady O'Hanlon

## Conceptual Illustration of Aircraft Navigation System Using Multiple CASES Receivers





# GPS Space Weather Monitor: Customer Service Options

ASTRA Product Options	Service Includes
Level 1	CASES Receiver, ASCII data extraction software
Level 2	Level 1 + customer licenses ASTRA post-processing and data visualization software
Level 3	Level 1 + Access to ASTRA generated quality controlled, post-processed data and visualization for customer's CASES receivers

- Postulated a modern infrastructure for Space weather (& Extreme Events)
- Differs from historical model



- Our nation can no longer afford to ignore commercial capabilities
- Commercial providers are among the best scientists in the field
- Skills and insights to share; sophisticated tools available
- Some of these tools equal or exceed capabilities of Govt and Academia
- **Space Weather infrastructure should be modeled on the successful meteorological community: highly collaborative Govt-Academia-Commercial relationship, e.g. National Weather Service obtains data/forecast services from commercial providers**
- This new infrastructure needs to be in place before an Extreme Event occurs



## BIOGRAPHY OF SPEAKER

Geoff Crowley is the CEO and Chief Scientist for ASTRA LLC. ASTRA performs fundamental research in space science, and develops new technology and applications for customers based on our scientific knowledge.

Prior to founding ASTRA, Dr. Crowley worked in four large organizations: NCAR, AFRL (as a contractor via U.Lowell), APL and SwRI, where he performed fundamental research on various areas of space physics and space weather. He has published over 100 scientific articles on his research. He is best known for his work on the thermospheric neutral gas at high latitudes, including his discovery of the cellular structures that occur there, and his modeling of high density features in the cusp region for the first time.

He is the Principal Investigator on the NSF-funded Cubesat mission called “Dynamic Ionosphere Cubesat Mission (DICE)”, which launched in October 2011 on a NASA satellite from Vandenberg Air Force Base. He recently led the development of a commercially available GPS-based software-defined space weather monitor that measures the ionospheric total electron content (TEC) and scintillation parameters that affect communications, navigation and surveillance systems. He also developed an HF radio sounding system for mapping traveling ionospheric disturbances in the ionosphere. ASTRA has developed several smart-phone Apps for the delivery of space weather information on Apple and Android platforms.

Dr. Crowley was a co-founder of the American Commercial Space Weather Association (ACSWA), and currently serves on the Executive Committee of ACSWA.