Space Science Research at NRL

Captain Paul Stewart, Naval Research Laboratory (NRL)

Space Weather Enterprise Forum

Session 3: 'The Future of Space Weather Science and Research Transition to Operations'

June 8, 2010

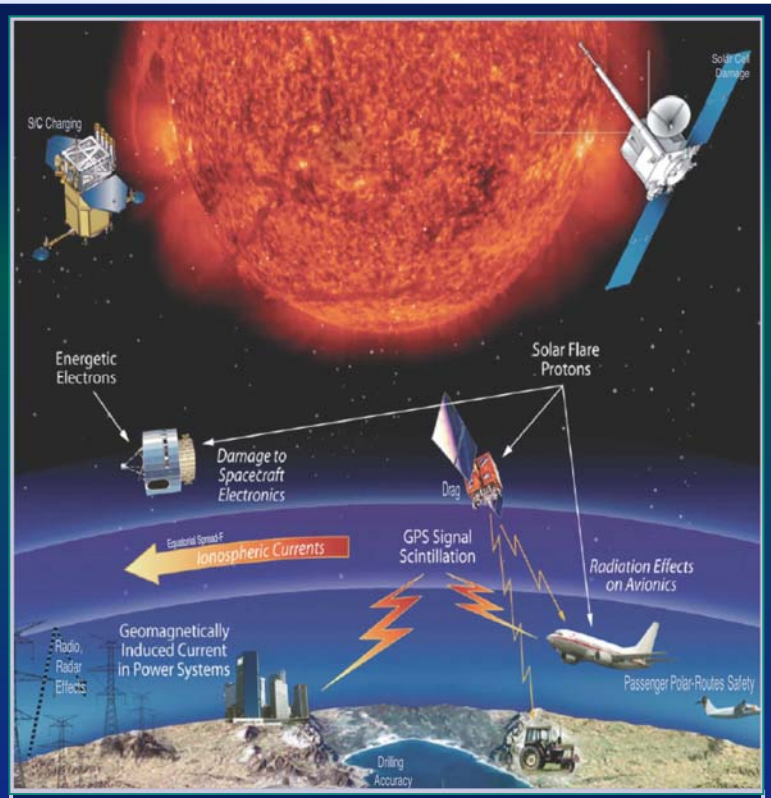
Experiment shown: NRL HREP, the HICO (Hyperspectral Imager for the Coastal Ocean) / RAIDS (Remote Atmospheric & Ionospheric Detection System) Experiment Payload

Extended Operational Environment

Definition: 'Space weather includes any and all conditions and events on the Sun, in the solar wind, in near-Earth space and in our upper atmosphere that can affect space-borne and ground-based technology systems and through these, human life and endeavor.'

☐One of the most taxing challenges facing *[us]* is an accurate and precise prediction of the date and time of arrival at the Earth, the Moon or Mars, of the particles or fields that are driven outwards from these very distant events *[… geomagnetic storms, proton events, x-rays, radio bursts]*. A decade ago specific predictions for the Earth were correct about a third of the time. Today the batting average is about 0.5, which is about the same as was the case with the prediction of severe meteorological storms - then a more mature field of study - in the 1960s.☐

[From: *A Guide to the Sun-Earth System*, Jack Eddy, NASA, 2010]



Comms on the Move; ISR; Missile Detection, Tracking, Intercept; Precision Engagement; Intell; S/C Anomaly Assessment; Attack Assessment; Power Grid Failures

‘How well can we weather a solar storm?’

February 26, 2010 [National Public Radio], NOAA – FEMA solar storm exercise:

‘A massive solar storm could leave millions of people around the world without electricity, running water, or phone service, government officials say. That was their conclusion after participating in a tabletop exercise that looked at what might happen today if the Earth were struck by a solar storm as intense as the huge storms that occurred in 1921 and 1859. .. Every few decades, .. the Sun experiences a particularly large storm. These can release as much energy as 1 billion hydrogen bombs.

The exercise, held in Boulder, Colorado, was intended to investigate “what we think could be close to a worst-case scenario,” says Tom Bogdan, who directs the Space Weather Prediction Center in Boulder [NOAA].

“It's important to understand that, along with other types of natural hazards, (solar) storms can cause impacts,” says Craig Fugate, Administrator of FEMA, who also took part in the tabletop exercise.

Bogdan and Fugate say that eventually there will be another storm as big as the ones in 1921 and 1859 — a sort of solar Katrina. But **the impact is likely to be far worse than in previous solar storms** because of our growing dependence on satellites and other electronic devices that are vulnerable to electromagnetic radiation.

In the tabletop exercise, the first sign of trouble came when radiation began disrupting radio signals and GPS devices, Bogdan says. Ten or 20 minutes later electrically charged particles “basically took out” most of the commercial satellites that transmit telephone conversations, TV shows and huge amounts of data we depend on in our daily lives.

The worst damage came nearly a day later, when the solar storm began to induce electrical currents in high voltage power lines. “The currents were strong enough to destroy transformers around the globe,” Bogdan says, “leaving millions of people in northern latitudes without power.” Without electricity, many people also lost running water, heat, air conditioning and phone service. … “A solar Katrina would cause damage in a much larger area than any natural disaster,” Fugate says. “For example, power could be knocked out almost simultaneously in countries from Sweden to Canada and the US.” ’

‘Orbital Blames *Galaxy 15* Failure on Solar Storm’

April 20, 2010 [Space News]

‘PARIS — The in-orbit failure of the Orbital Sciences-built Intelsat *Galaxy 15* telecommunications satellite April 5 *[2010]* was likely caused by unusually violent solar activity that week that damaged the spacecraft’s ability to communicate with ground controllers, Orbital officials said April 20.

• • •

Similar events have occurred, if less severely, on other Orbital spacecraft over the years, and all of these satellites were returned to service. Company officials said they remain confident that once *Galaxy 15’s* commercial traffic has been off-loaded to another Intelsat satellite and full testing of the stricken spacecraft begins, *Galaxy 15* will recover its full operational status.

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The Orbital-built *Galaxy 15* satellite suffered failures in its ability to send telemetry to ground teams, and to receive commands, April 5. Satellite fleet operator Intelsat of Luxembourg and Washington is moving a spare in-orbit satellite, the Orbital-built *Galaxy 12*, to take over commercial service from *Galaxy 15.*

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VanBeber said Intelsat would decline to speculate on the causes of the *Galaxy 15* communication failure and the likelihood of a full recovery until the testing has concluded.

J.R. Thompson, Orbital’s chief operating officer, said unusually severe solar activity between April 3 and April 5 *[2010]* is “our best-informed guess” of what caused the *Galaxy 15* problem.

He said there are no indications that any other Orbital-built satellites were affected by the solar activity, but that over the past 15 to 20 years two or three Orbital spacecraft have suffered similar failures. Once the company has succeeded in reproducing the failure in ground tests, it will be able to design a software patch to send to *Galaxy 15.*

Thompson said the testing could take three to six weeks, “with the goal of returning *Galaxy 15* to full operational status by this summer” if the tests yield the expected results.’

On 10 March 2010 VADM Dorsett testified to the US Senate Armed Services Committee about Navy Space.

HEARING TO RECEIVE TESTIMONY ON MILITARY SPACE PROGRAMS IN REVIEW OF THE DEFENSE AUTHORIZATION FOR FISCAL YEAR 2011 AND TI YEARS DEFENSE PROGRAM

WEDNESDAY, MARCH 10, 2010

U.S. SENAT
SUBCOMMITTEE ON STRATEGIC F
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The subcommittee met, pursuant to notice, at 2 SR–232A, Russell Senate Office Building, Senat Nelson (chairman) presiding.

Committee members present: Senators Ben Ne Vitter.

Majority staff member present: Madelyn R. Cree

STATEMENT OF VADM DAVID J. DORSETT, USN, DEPUTY CHIEF OF NAVAL OPERATIONS FOR INFORMATION DOMINANCE (N2/N6), AND DIRECTOR OF NAVAL INTELLIGENCE

Admiral DORSETT. Mr. Chairman, thank you for the opportunity to be here, especially on behalf of the men and women of the U.S. Navy. It's a privilege for me to be able to testify before you today.

I want to reiterate one point for you, that I believe you're already aware of, and that's that the U.S. Navy is critically dependent upon space. Our ships, submarines, aircraft operate across the farflung reaches of the globe, often operating independently. And the one thing that keeps them tied together, I think, is space-based capabilities, whether that's communications, the networks that support them, whether it's the navigation and precision geolocation data that comes from space, weather and environmental sensing information is absolutely vital to the U.S. Navy.

And then, also, truly, when it comes down to precision weapons, we need that detailed precision geolocation information that can only come from space.

"The Navy is one of the largest 'users' of space in DoD, yet we rely on our partnership with the Air Force and the IC to develop and field the majority of our space systems.

The Navy depends on space capabilities now and expects the demand for space capabilities to grow in the future…"

NRL Mission

- To conduct a broadly based multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, systems and ocean, atmospheric, and space sciences and related technologies.
- Primary in-house research for the physical, engineering, space, and environmental sciences
- Broadly based applied research and advanced technology development program in response to identified and anticipated Navy and Marine Corps needs
- Broad multidisciplinary support to the Naval Warfare Centers
- **Space & space systems technology development & support**
- Designated as the Navy's corporate laboratory by SECNAV 1991

Navy and Marine Corps Corporate Laboratory

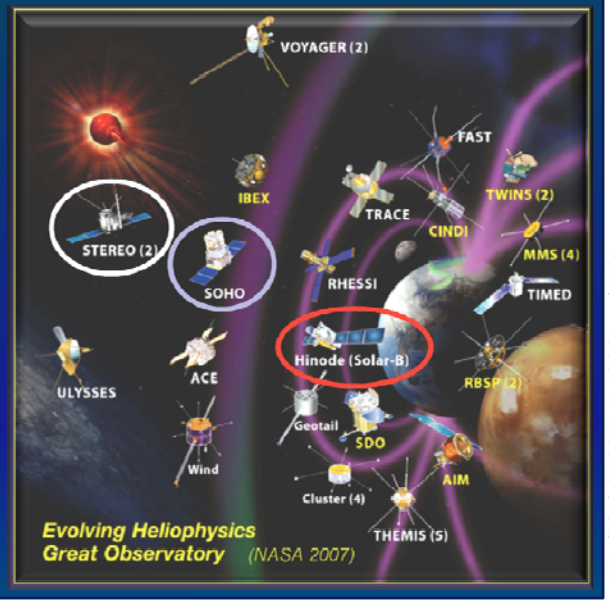
Purpose of NRL Space Science Research

Advance understanding and predictive capability of the space domain in order to exploit the extended operational environment and its impact on Navy/ Marine Corps and wider DoD activities, and to develop improved space technologies.

NRL Space Researchers -

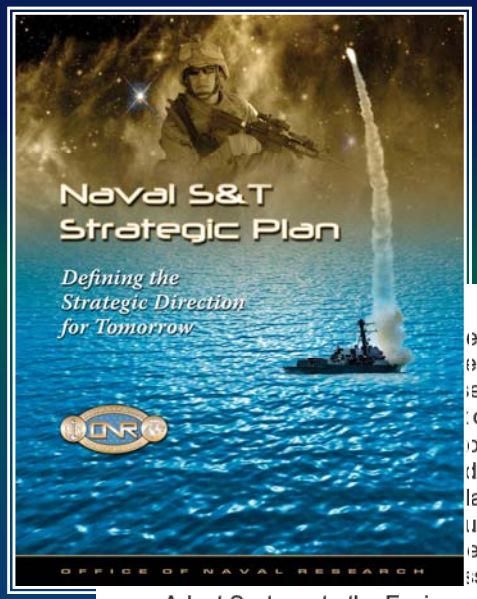
- Perform foundational research to study the atmospheres of the Sun and the Earth, including solar activity and its effects on the Earth's ionosphere, upper atmosphere and near Earth space, and the unique physics and properties of celestial sources;

- Envision, design, fabricate, integrate, test, launch, operate and experiment with world-leading space instrumentation for a comprehensive 'Mud to Sun' extended operational environment view, towards understanding and exploitation.



NRL (SSD) SECCHI,* LASCO* and EIS*

Naval S&T Strategic Plan



Naval S&T Focus Area	Objective Categories	S&T Research Areas
Operational Environments	• Mobile Autonomous Environmental Sensing • Match Predictive Capabilities to Tactical Planning Requirements • Adapt Systems to the Environment	• Unmanned Sea Vehicle Technologies • Unmanned Air Vehicles • Intelligent and Autonomous Systems • Bio-sensors, Bio-processes, and Bio-inspired Systems • Physical Oceanography • Marine Meteorology • Ocean Acoustics • Littoral Geosciences, Optics and Biology • Space Environmental Effects • Marine Mammals • ASW Performance Assessment

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ons
o Tactical Planning Requirements
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es at global, regional and tactical scales to
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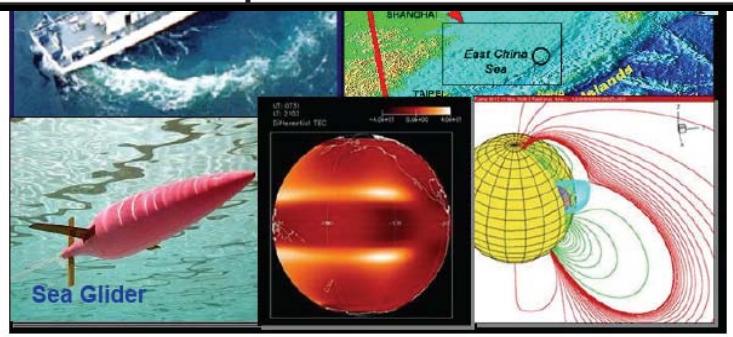
- Adapt Systems to the Environment
  - Methods to account for acoustic and electromagnetic propagation, scattering, ambient noise, and bottom effects
  - Automated sensor and weapons performance prediction and reconfiguration
  - Impact/response for space environmental effects



NRL space research activities also relate and contribute to these Naval S&T Focus Areas: MDA (spacecraft systems, networked sensors, communications and networks, WMD detection, navigation and precision timekeeping, intelligent and autonomous systems); Asymmetric and Irregular Warfare (UAVs and UGVs, intelligent and autonomous systems); Information Superiority & Communications (comms & networks); Distributed Operations (communications & networks, expeditionary ISR); and, Survivability & Self Defense (platforms, solid-state electronics).

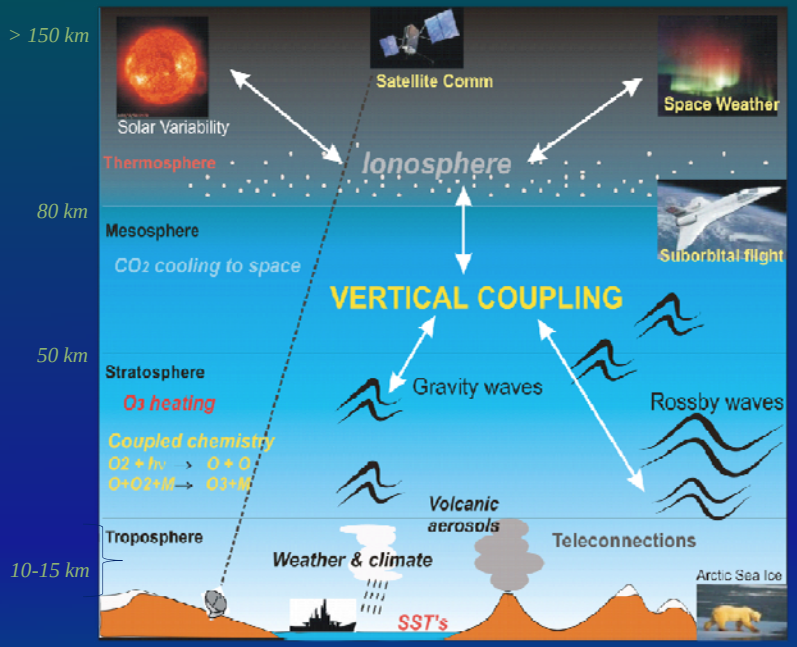
NRL Extended Operational Environment Research

Includes <u>software</u> research, to forecast the atmospheres of the Sun and the Earth, including solar activity and its effects on the Earth's ionosphere, upper atmosphere and near-Earth space.

Objective:

Develop reliable and accurate ground-to-space Earth prediction system with coupled surface, ion-neutral chemistry, and electrodynamics to revolutionize future Naval capability in maritime domain and space situational awareness to ensure dominance in new frontiers in horizon (Arctic), altitude (ground-to-space), and time (days to decades).

Multiscale prediction capability to understand and assess environmental change and in support of Navy's long-term strategic plans. Extended Navy forecast and data assimilation capabilities to hundred of kilometers altitude, enabling ground-to-space prediction and instrument development/ mission planning capability.



David Siskind and Melinda Peng

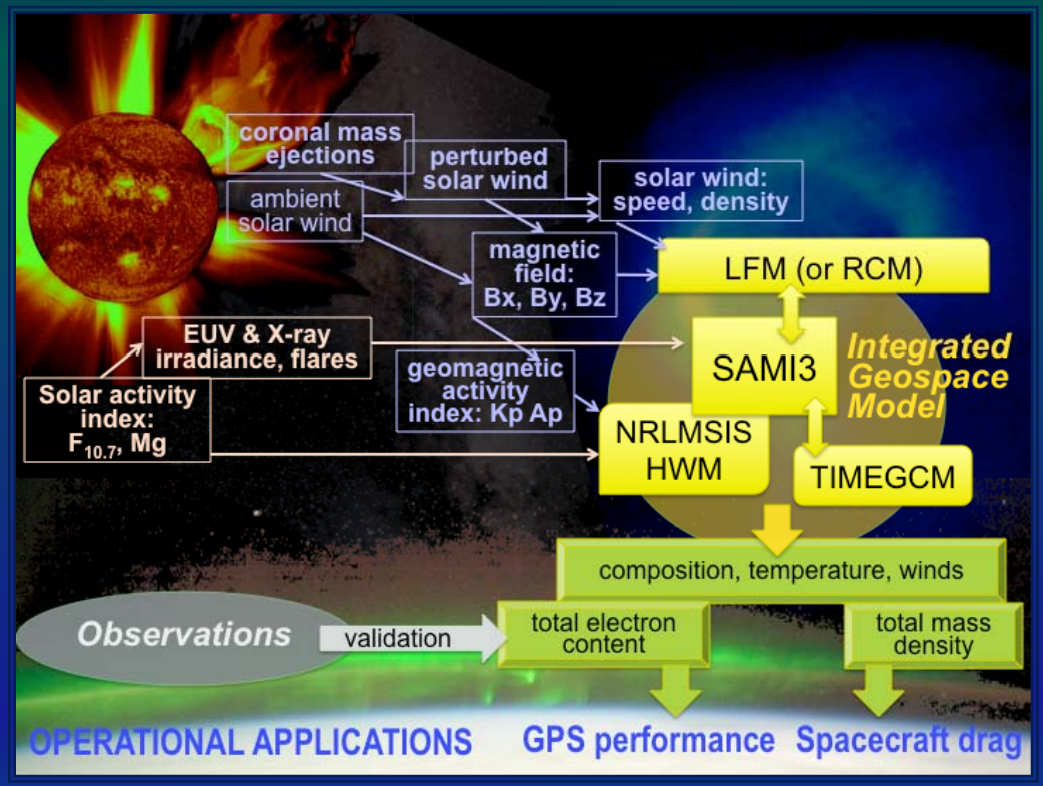
ISES-OE: Integrating the Sun Earth System

NRL Space Science & Plasma Physics Divisions

Physical models and observations are used to characterize and simulate the multiple chains of interactive processes that alter electrons, ions and neutrals in the ionosphere and thermosphere, to mitigate and exploit operational impacts of the space environment, and to advance space science.

- Systematic exploration of 4D space-time thermosphere-ionosphere using NRL ISES, a fully coupled physical space environment model, validated with observations.
- Multiple, systematic runs with measured and modeled solar and heliospheric drivers.
- Interdisciplinary space data validation with observed densities, total electron content.
- Advance knowledge about targeted geophysical phenomena, including: semi-annual oscillation, geomagnetic storms, solar rotation, cycle.

This work is leading research towards a DoD in-house, first-principles model to combat space environment impacts on increasingly sophisticated and space-based military operations.



Components include integrated geospace models (yellow) with SAMI at the core, solar EUV photon (orange) and solar wind (purple) drivers of geospace variability, and observations of thermosphere and ionosphere densities for model validation.

NOGAPS-ALPHA Collaborative Initiative

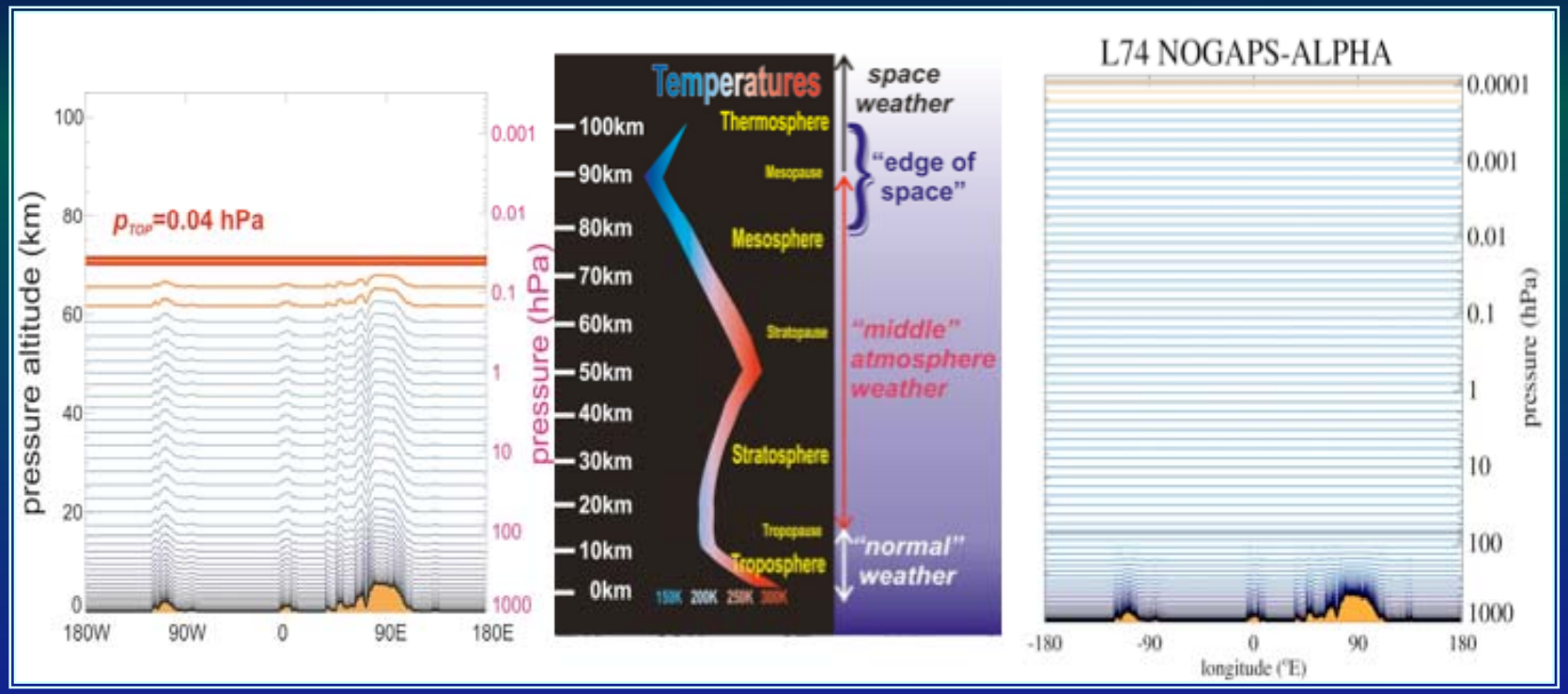
NRL Space Science, Remote Sensing, and Marine Meteorology Divisions

Current Operational NOGAPS (until 9/09)

[Navy Operational Global Atmospheric Prediction System]

New High-Altitude NOGAPS-ALPHA Prototype

[-Advanced Level Physics High Altitude]



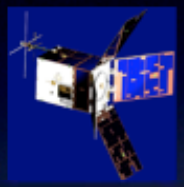
NOGAPS-ALPHA has new mathematical framework, new near-space physics, and uses an extended set of atmospheric data for assimilation.

The Navy Administrative Model Oversight Panel has approved NOGAPS-ALPHA through the first level of a three-level transition decisions process.

Validating NOGAPS-ALPHA

Polar mesospheric clouds and analyzed humidity at the edge of space

NRL SSD SHIMMER on STPSat-1



PMC photo taken from the ISS by NASA

Labstracts

Over 85 years of progress through research — for the Navy and the Nation

News from the Naval Research Laboratory, Washington, DC

August 4, 2008

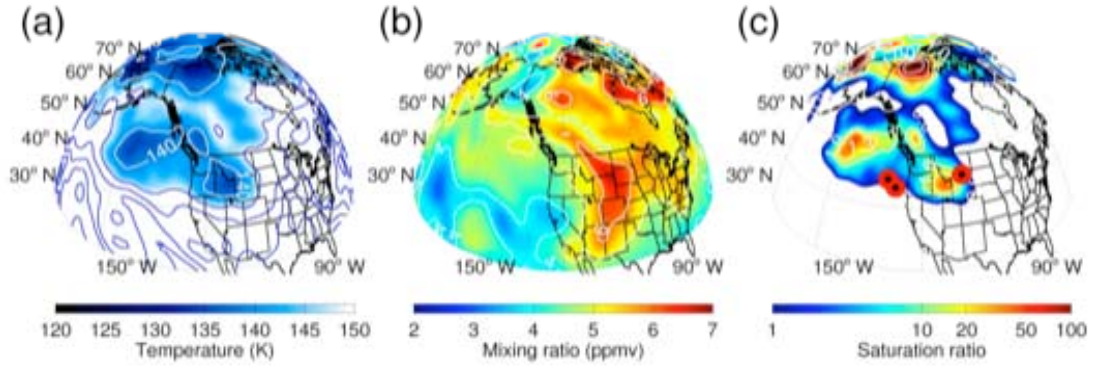
STPSat-1 operations transfer to NRL

Donna McKinney
Public Affairs Office, Code 1030

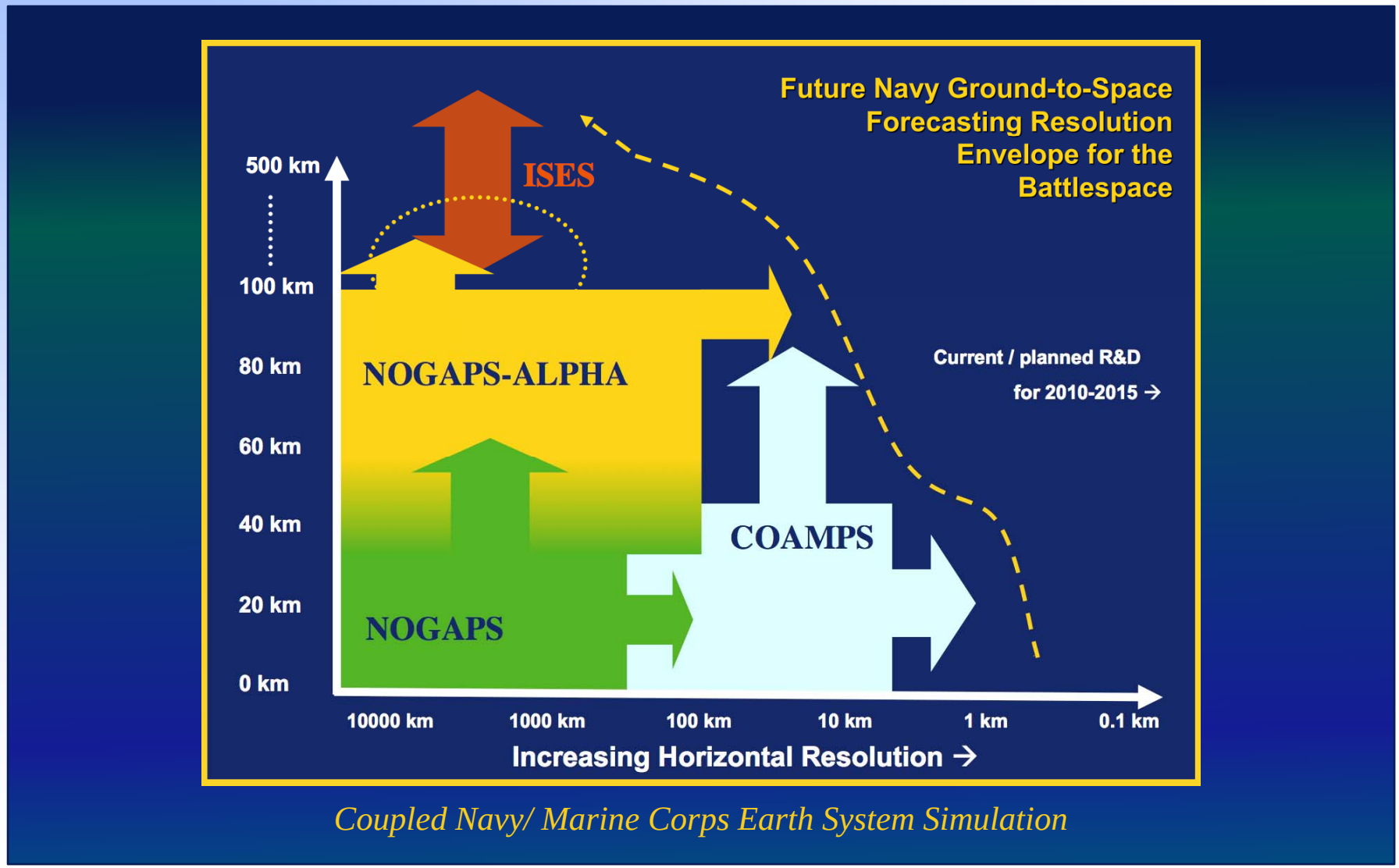
The operations for Space Test Program Satellite-1 (STPSat-1), which launched on March 8, 2007, have been transferred to NRL, as of June 1, 2008. Both of the science payloads aboard STPSat-1, the Spatial Heterodyne Imager for Mesospheric Radicals (SHIMMER) and the Scintillation and Ionospheric Plasma Sensor in Space (CITRIS), were designed and provided by NRL. During this past year, [illegible] the NRL investigators to [illegible] quality scientific data while demonstrating new technologies in on-orbit with the CITRIS and SHIMMER instruments.

STPSat-1 Decommissioned October 2009

Reanalysis Data for 18UT, June 13, 2007, 82 km



NRL Extended Operational Environment Research
Future Software Directions



Coupled Navy/ Marine Corps Earth System Simulation

NRL Extended Operational Environment Research

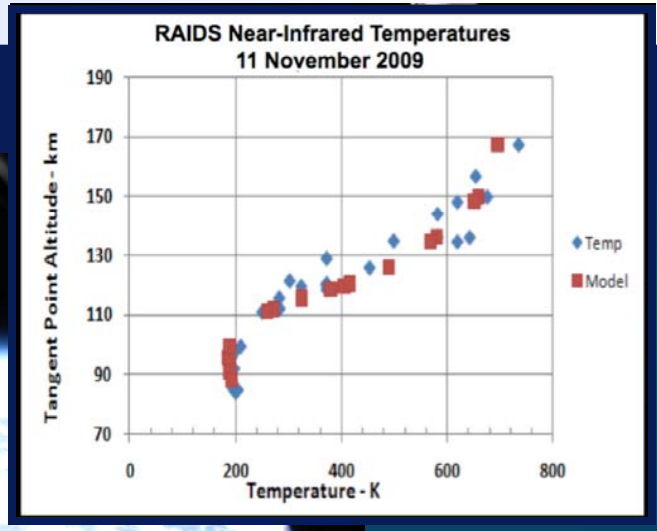
Includes envisioning, designing, fabricating, integrating, testing, launching, operating, and experimenting with world-leading instrumentation hardware for a comprehensive 'Mud to Sun' extended operational environment view, towards understanding & exploitation.

Launch Date	NRL-led Space Activities Launched in 2009	Principal Investigator	
15 March 2009	Shuttle Ionospheric Modification with Pulsed Localized Exhaust (SIMPLEX VI and VII, K4, K5, K6, K7)	Paul Bernhardt	SWx related
15 July 2009	Atmospheric Neutral Density Experiment 2 (ANDE-2)	Andrew Nicholas	SWx related
15 July 2009	Shuttle Exhaust Ionospheric Turbulence Experiment (SEITE I and II)	Paul Bernhardt	SWx related
10 September 2009	HICO/RAIDS Experiment Payload (HREP)	Davidson Chen	
10 September 2009	Hyperspectral Imager for the Coastal Ocean (HICO)	Michael Corson	
10 September 2009	Remote Atmospheric and Ionospheric Detection System (RAIDS)	Scott Budzien	SWx related
14 September 2009	Helium Resonance Scattering in the Corona and Heliosphere (HERSCHEL)	J. Daniel Moses	SWx related
19 September 2009	Charged Aerosol Release Experiment I (CARE-I)	Paul Bernhardt	SWx related
18 October 2009	Special Sensor Ultraviolet Limb Imager (SSULI)	Andrew Nicholas and Sean Lynch	SWx related
16 November 2009	Materials on the International Space Station Experiment #7 (MISSE7)	Phillip Jenkins	

Many of these experiments were integrated and launched under the auspices of the DoD Space Test Program.

HICO/RAIDS, a Space Science Achievement

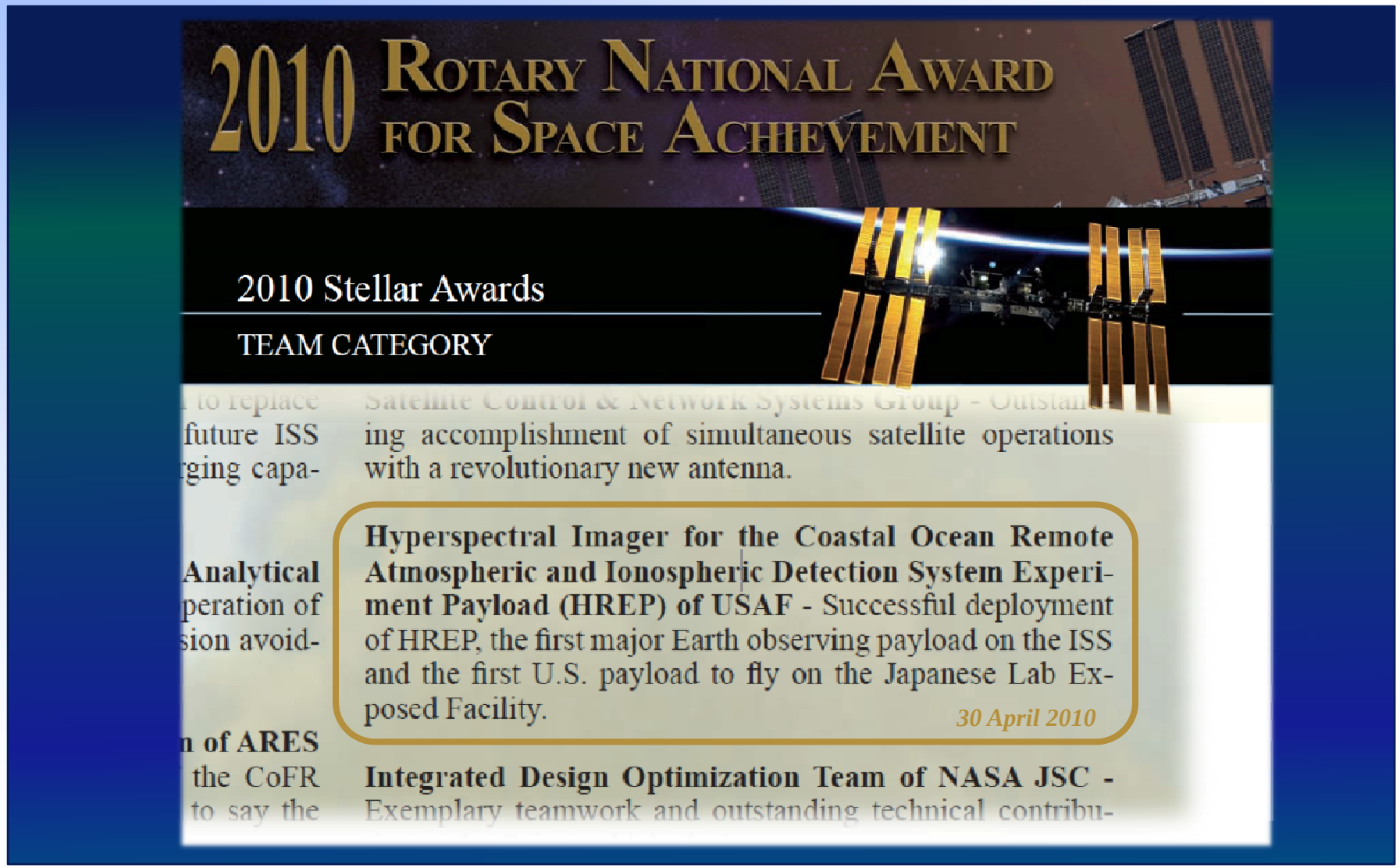
NRL Space Experiment Example:
HICO/RAIDS on the ISS



South China Sea

NRL HREP: HICO (Hyperspectral Imager for the Coastal Ocean) / RAIDS (Remote Atmospheric & Ionospheric Detection System) Experiment Payload

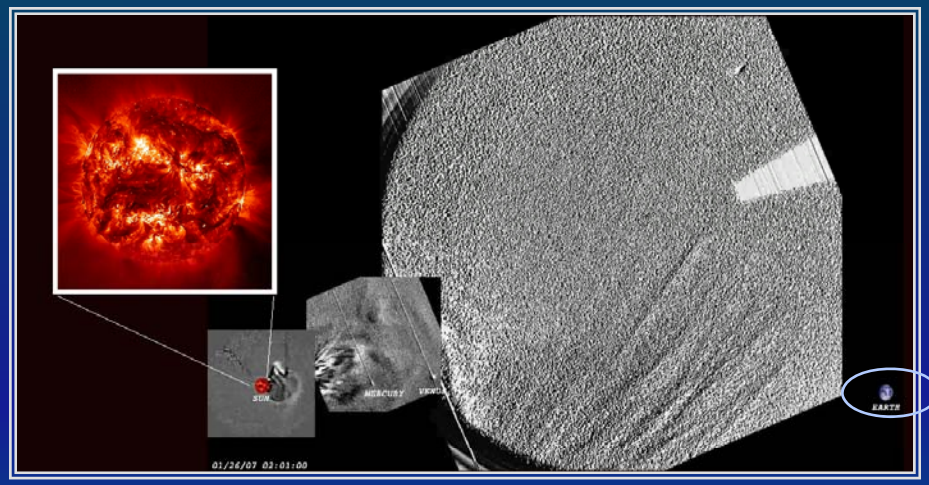
HICO/RAIDS, a Space Achievement



NRL HREP: HICO (Hyperspectral Imager for the Coastal Ocean) / RAIDS (Remote Atmospheric & Ionospheric Detection System) Experiment Payload

Space Science Research at NRL

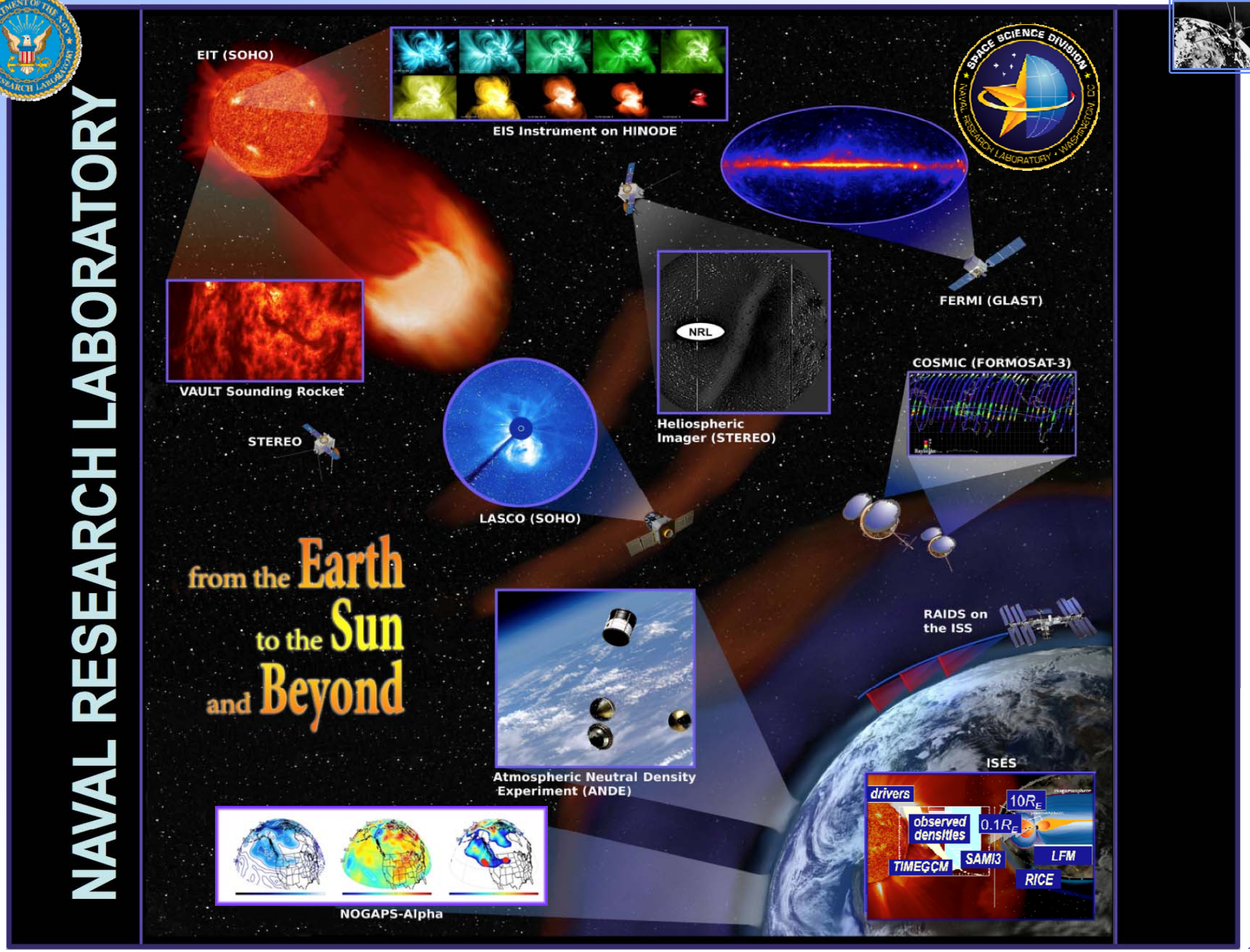
The Naval Research Laboratory space research vision is to advance understanding and predictive capability of the space domain, to exploit the extended operational environment and its impact on Navy / Marine Corps and wider DoD activities, including: C4ISR, precision navigation and timing; and, maritime domain awareness.



NASA STEREO/ SECCHI [Sun Earth Connection Coronal & Heliospheric Investigation] composite image of the Sun and a solar storm propagating through the heliosphere.

(NRL is SECCHI PI institution for NASA.)

Earth is located at the far lower right hand edge of the image.


NAVAL RESEARCH LABORATORY
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SPACE SCIENCE DIVISION
NAVAL RESEARCH LABORATORY • WASHINGTON DC
FERMI (GLAST)
NRL
VAULT Sounding Rocket
Heliospheric Imager (STEREO)
COSMIC (FORMOSAT-3)
STEREO
LASCO (SOHO)
from the Earth to the Sun and Beyond
RAIDS on the ISS
Atmospheric Neutral Density Experiment (ANDE)
ISES
drivers
observed densities
TIMEGCM
SAMI3
LFM
RICE
NOGAPS-Alpha