In geospace science and technology, the Space Science Division (SSD) performs space, air, ground, and in-lab physics-based research, development, test, and evaluation (RDT&E) to observe, understand, model, and predict the extended operational environment, driven by meteorology from below and solar flux from above. This research uses in situ and remotely sensed data to advance global situational awareness and enable environmental exploitation, and to derive assimilative inputs for SSD’s whole atmosphere model. The goal of this extended model is to reliably forecast the geospace environment with 1-degree global spatial resolution and 3- to 7-day accuracy for the neutral and ionized geospace atmosphere, towards improving knowledge of geolocation and high-frequency (HF) signal propagation characteristics by traditional and innovative passive means. Major recent space instruments under the auspices of the SSD include the SSD-led Special Sensor Ultraviolet Limb Imager (SSULI) and the SSD-led Michelson Interferometer for Global High-Resolution Thermospheric Imaging (MIGHTI).

The DoD operational SSULI, which launched on the Defense Meteorological Satellite Program (DMSP) Flight-18 satellite in October 2009, continues its mission of providing operational space environment ionospheric density measurements to DoD’s Global Assimilation of Ionospheric Measurements (GAIM) operational model. Independent analysis of SSULI data in GAIM has determined strong impacts from SSULI data, particularly over the ocean and denied areas. The SSD-led MIGHTI instrument, which was selected by NASA for development by SSD in 2011, is scheduled for a 2019 launch from Cape Canaveral aboard the NASA Ionospheric Connection (ICON) Explorer mission. In orbit onboard ICON, MIGHTI will measure neutral winds and temperatures in the thermosphere, in order to assess the dramatic variability of Earth’s neutral atmosphere. Other SSD forefront instrument developments include the Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet Spectrograph (LITES) and the Global Positioning System Radio Occultation and Ultraviolet Photometer Co-located (GROUP-C) DoD Space Test Program (STP) experiments currently on the ISS.

Together, LITES and GROUP-C are testing new approaches for next-generation ionospheric sensors towards providing predictive ionospheric effects for Naval electromagnetic maneuver warfare and HF communications.
**Objective**

Measurement-based specification of the upper atmosphere and its response to solar and lower atmospheric drivers for these aims:

- Specification and prediction of the environment.
- Benchmark for calibrating and validating physical models and new measurements and measurement techniques.
- Interpolation and extrapolation of data.
- Initial and/or boundary condition for general circulation models.

**Space Science Division Approach**

- Collect all available contemporary and historical upper atmospheric data.
- Perform rigorous statistical analysis of the systematic response of the data to key drivers.
- Encapsulate the behavior of the data in a user-friendly model with physical constraints.
- Validate the model; identify biases among measurement techniques.
- Merge operational lower atmospheric meteorology with the U.S. Naval Research Laboratory's upper atmospheric empirical models to produce real-time atmospheric specification.

**Payoffs**

- Seamless, reliable, operation-ready whole-atmosphere models: NRLMSISE-00 model of total density, temperature and composition; Horizontal Wind Model (HWM) of 0-500 km altitude winds; ground-to-space (G2S) real-time atmospheric specification.
- Recent and older versions of these models are used operationally by the 557th Weather Wing (U.S. Air Force), the Defense Meteorological Satellite Program, the Space and Missile Defense Command (U.S. Army), the Air Force Technical Applications Center, the National Nuclear Security Administration, and many other agencies.
- The models are used extensively also by space weather research communities; MSIS is the #1 cited model in the *Journal of Geophysical Research: Space Physics* (over 5,000 citations).
- MSIS and HWM are components of the COSPAR International Standard Reference Atmosphere.
AT A GLANCE

**What is it?**
Global Assimilation of Ionospheric Measurements (GAIM) is the DoD operational near-real-time model that specifies and forecasts the three-dimensional electron density in the ionosphere globally for the mitigation of impacts and mission planning for radio-based systems.

**How does it work?**
GAIM assimilates near-real-time ionospheric measurements from satellites and ground stations into a physics-based ionospheric model in order to estimate of the current state of the ionosphere for DoD applications. Forecasts of the ionosphere are provided, based on the persistence of recent ionospheric conditions.

**What will it accomplish?**
The extension of GAIM downward into the D-region (30–90 km in altitude) and upward into the plasmasphere (1400–19,000 km in altitude) supports improved estimation of the impacts on radio-based systems.

**For more information**


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**Objectives**
- Provide technical direction to the operational U.S. Air Force Global Assimilation Ionospheric Measurement (GAIM) program in order to maintain and improve estimation of the impacts on radio-based systems.
- Improve performance of radar, positioning, navigation, timing, and communication systems with signals passing through or reflecting off the ionosphere.

**Space Science Division Approach**
- The Space Science Division has been the technical lead for the DoD operational GAIM program since the program’s inception in 1998. The assimilative model transitioned to initial operational capability in February 2006, and has received many model upgrades since that time. GAIM, developed by Utah State University, is the centerpiece of a large team effort that includes the U.S. Naval Research Laboratory (NRL), the 557th Weather Wing (U.S. Air Force), the Space and Missile Systems Center (Air Force Space Command), the Air Combat Command (U.S. Air Force), Johns Hopkins Applied Physics Laboratory, Aerospace Corporation, Northrop Grumman, and a wide-ranging user community.
- NRL provides technical direction on GAIM operational performance, model enhancements, and existing and future ingest data types. NRL also provides technical advice and operational model output to DoD customers for evaluation purposes.

**Payoffs**
- Operational specification and forecasts of the ionosphere, providing the following:
  - Mitigation/correction of impacts to radio-based systems with signals passing through the ionosphere.
  - Frequency selection and mission planning for radar and communication systems with signals reflecting off the ionosphere, such as over-the-horizon radar and high-frequency communications.
Gravity Wave (GW) Ray Modeling
First Accurate Predictions of GW Influences on Operational Navy Assets at a Range of Altitudes

AT A GLANCE

What is it?
Gravity waves (GWs) are a fundamental class of atmospheric waves that grow larger in amplitude as they rise to higher altitudes, where the air is more rarified. If a GW becomes nonlinear and undergoes wave breaking, the wave will transfer its momentum to the mean flow and affect large-scale processes. Due to resolution constraints caused by finite computing resources, GWs are poorly predicted by current numerical weather prediction (NWP) systems.

How does it work?
Ray methods represent a fast, efficient, and accurate means of modeling atmospheric GW oscillations and their effects at a range of atmospheric altitudes.

What will it accomplish?
The U.S. Naval Research Laboratory’s GW ray models are finding wide applications, including forecasts of mountain wave-induced stratospheric turbulence for high-altitude aircraft, improved parameterizations of GW drag for NWP models, and models of thermospheric GWs from tropospheric weather systems.

For more information


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Left-hand panel (a): On July 14, 2014, the NSF/NCAR Gulfstream V research aircraft flew over the Auckland Islands. (The Gulfstream V is owned by the National Science Foundation and operated by the National Center for Atmospheric Research.) Middle panel (b): Onboard airglow imagers observed large-amplitude gravity waves (GWs) downstream of the islands at an altitude of ~80 km. Right-hand panel (c): The U.S. Naval Research Laboratory’s Fourier-ray code was used to model and understand this event. The code reproduced the amplitude, wavelength, and phases of the GW banding of the airglow observed by the aircraft.

Objectives
- Validated understanding of atmospheric gravity wave (GW) dynamics at all atmospheric heights.
- Development of fast efficient algorithms of GW dynamics, leading to new and improved GW prediction and parameterization schemes for DoD and Naval applications.

Space Science Division Approach
- Develop from first principles new ray-based methods for modeling all aspects of GW dynamics at heights throughout the atmosphere.
- Validate model output using available GW observations from ground-based, aircraft, and satellite observing platforms.

Payoffs
- The Mountain Wave Forecast Model (MWFM), a ray-based prediction model of stratospheric mountain-wave turbulence developed by the U.S. Naval Research Laboratory (NRL) for high-altitude long-endurance aircraft that transitioned to the 557th Weather Wing (U.S. Air Force) in 2009. In NRL’s award of the 2005 Roosevelt Gold Medal for Science, the MWFM was cited as one of the 50 top technologies developed by NRL between 1923 and 2005.
- Ray-based models of GW dynamics that improve parameterizations of orographic and nonorographic gravity wave dynamics within NAVGEM.
- Use of ray prediction models to validate theories that stratospheric GW seed vortex-wide polar stratospheric clouds implicated in Antarctic ozone loss.
- First dynamics-based models explaining how tsunamis produce ionospheric signatures via deep evanescent gravity-wave tunneling through wind jets.
- Future high-altitude ray-based gravity wave models for predicting outbreaks of traveling ionospheric disturbances due to tropospheric weather systems that affect high-frequency radio wave signal propagation.
The GROUP-C Experiment
GPS Radio Occultation and Ultraviolet Photometer Co-located

AT A GLANCE

What is it?
The Global Positioning System (GPS) Radio Occultation and Ultraviolet (UV) Photometer Co-located (GROUP-C) experiment comprises a downward-viewing high-sensitivity UV airglow photometer and a GPS radio occultation receiver that jointly measure horizontal and vertical ionospheric gradients from the International Space Station (ISS).

How does it work?
Naturally-occurring ionospheric airglow is mapped in the UV to reveal its horizontal structure below the ISS. GPS signals are monitored as GPS satellites set below the horizon, to provide vertical electron densities. Regional two-dimensional tomographic maps of ionospheric structures are obtained by combining the simultaneous vertical and horizontal measurements. GROUP-C and the Space Science Division’s Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet Spectrograph (LITES) experiment together form a powerful lower ionospheric observatory on the ISS.

What will it accomplish?
The GROUP-C and LITES low-cost, compact space sensors demonstrate advanced methods to characterize ionospheric structure on scales highly relevant to Naval operational systems, including over-the-horizon radar and precision geo-location.

For more information


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Objectives
- Measure Earth’s ionospheric electron density using GPS radio occultations and measure the nighttime ion density using UV airglow photometry.
- Investigate ionospheric morphology and variability relevant to global ionospheric models, electromagnetic signal propagation, and ionospheric disturbances which can cause scintillation.

Space Science Division Approach
- The GPS Radio Occultation and Ultraviolet Photometer Co-located (GROUP-C) experiment remotely senses the ionosphere passively to characterize both its vertical structure and the horizontal gradients in the orbital plane.
  - The software-defined dual-frequency GPS receiver derives vertical electron density and scintillation from GPS satellite occultations behind the ISS.
  - The high-sensitivity 135.6 nm ultraviolet photometer measures in-track horizontal ionosphere gradients directly beneath the ISS.
- Computerized tomography techniques combine horizontal and vertical data to generate a two-dimensional map of the ionosphere in the ISS orbital plane, particularly focused on the lower F-region ionosphere, relevant to DoD and Naval applications.

Payoffs
- GROUP-C serves as risk reduction for advanced ionospheric sensing techniques planned in future space missions, including the U.S.-U.K. Coordinated Ionospheric Reconstruction CubeSat Experiment (CIRCE) dual nanosatellite mission.
- GROUP-C can supply real-time space weather data for DoD’s GAIM operational model, which could mitigate coverage gaps arising from cancellation of DoD DMSP F20 meteorological satellite.

Left-hand panel: The GPS Radio Occultation and Ultraviolet (UV) Photometer Co-located (GROUP-C) experiment includes (counterclockwise from lower right) the UV photometer, support electronics, the GPS receiver, and the GPS patch antenna. The UV photometer was developed at the U.S. Naval Research Laboratory; the GPS receiver from Cornell University and the three patch antennas from the Aerospace Corporation were provided with support from the Office of Naval Research. Right-hand panel: The GROUP-C antenna array is the prominent “face” of the STP-H5 payload, launched to the International Space Station under the auspices of the DoD Space Test Program in February 2017.
The LITES Experiment
Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet Spectrograph

AT A GLANCE

What is it?
The Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet (EUV) Spectrograph (LITES) experiment images EUV and far ultraviolet airglow from Earth’s limb. The data are used to infer atmospheric density and composition of the ionosphere and thermosphere. The LITES experiment has been operating as part of the STP-H5 payload on the International Space Station since February 2017.

How does it work?
LITES images the vertical (altitude) scene in one dimension while dispersing the spectral fingerprint of upper atmospheric constituents in the other; see figure, top of page. The novel, robust LITES design achieves high sensitivity and cadence with no moving parts.

What will it accomplish?
LITES achieves a cost-effective potential follow-on to the U.S. Naval Research Laboratory Special Sensor Ultraviolet Limb Imager (SSULI) program that currently provides DoD operational space environmental specification data from the Defense Meteorological Satellite Program satellite. The compact design of the LITES experiment makes it adaptable for any operating platform. Its high effective sensitivity improves the accuracy of data being ingested into current (and future) ionospheric models, and hence also improves model real-time (and forecast) accuracy.

For more information

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LITES (below), images altitude profiles of atmospheric species, as shown to the left, with a compact optical design that can continuously observe plasma structures at high sensitivity without incurring the delay and risk of moving parts.

Objectives
- Measure density and composition of the global ionosphere and thermosphere and characterize the evolution of structures embedded in the ionosphere and thermosphere.
- Demonstrate a novel, compact, high-sensitivity ultraviolet (UV) sensor for the next generation of operational near-Earth space weather remote sensing.

Space Science Division Approach
- Observe altitude profiles of naturally occurring UV (60–140 nm) airglow that originates from ionospheric and thermospheric species, and analyze the observational data using state-of-the-art algorithms.
- Results will be validated using extensive ground-based digisonde network.
- The LITES optical configuration provides persistent observations and imaging capability without the need for moving parts.

Payoffs
- Experimentation with and risk reduction for flight hardware development for the DMSP SSULI follow-on, with potential to fill upcoming space weather specification data gaps.
- Data products can be ingested into operational space weather models to improve ionospheric forecasting and specification used for Navy and DoD applications, such as over-the-horizon radar and precision geo-location.
- The Space Science Division’s Global Positioning System Radio Occultation and UV Photometer Co-located (GROUP-C) experiment, as part of STP-H5 payload aboard the International Space Station, is providing co-located views to enable two-dimensional tomographic maps of ionospheric structures.

LITES and GROUP-C are flying together on the STP-H5 payload aboard the ISS. LITES images the dim, naturally occurring UV airglow above the limb of the Earth, looking directly aft from the ISS. The GROUP-C experiment uses a high-sensitivity photometer to measure this same airglow as it passes directly beneath the ISS, while its three radio antennae observe ionospheric plasma density and scintillation using GPS satellite signals. Together, these experiments form a powerful observatory to image ionospheric structures, including depletions. Understanding how these structures form and develop will help to predict their appearance for Naval needs.
Thermospheric Wind Sensor: MIGHTI
Michelson Interferometer for Global High-Resolution Thermospheric Imaging

Objective

- Gain quantitative understanding of the physical processes that drive the near-Earth space environment. Develop high-precision, passive, pace-based remote sensing technologies to monitor the space environment for analysis and assimilation.

Space Science Division Approach

- The U.S. Naval Research Laboratory (NRL) is the lead institution for MIGHTI, the wind and temperature sensor on NASA’s Ionospheric Connection (ICON) Explorer Mission. The interferometric measurement technique used by MIGHTI was co-invented by NRL and emerged from an NRL 6.2 Base Program on Doppler Asymmetric Spatial Heterodyne (DASH) Spectroscopy. The approach has heritage from the NRL SHIMMER (Spatial Heterodyne Imager for Mesospheric Radicals) instrument, which successfully flew onboard STPSat-1 and observed Polar Mesospheric Clouds from 2007 to 2009. MIGHTI measures winds using the Doppler shift of naturally occurring atmospheric emission lines in the visible spectrum. It also measures temperature using the spectral shape of a naturally occurring infrared atmospheric emission band.

Payoffs

- The overall ICON mission will gather comprehensive data to improve our fundamental understanding of the upper atmosphere, which is essential for the creation of next-generation DoD ionospheric forecasting capabilities. These data are critical for performance prediction of radio communication and electromagnetic maneuver warfare. The sensor technology advances are aimed at future operational capabilities that are currently unavailable, with a goal of reliable and affordable specification and forecasting of the electromagnetic propagation environment.
- The ICON mission, led by the University of California, Berkeley, is the newest NASA Explorer mission. ICON is scheduled for spacelift launch in 2019.
**AT A GLANCE**

**What is it?**
The Navy Global Environmental Model (NAVGEM) is the Navy's state-of-the-art operational numerical weather prediction system.

**How does it work?**
NAVGEM combines a semi-Lagrangian global forecast model containing state-of-the-art physical parameterizations with a four-dimensional variational (4DVAR) data assimilation algorithm using 80-member ensembles to define background error covariances. (This is termed "hybrid 4DVAR.")

**What will it accomplish?**
The progressive extension of the NAVGEM upper boundary beyond the mesosphere and into the thermosphere will provide the Navy with accurate actionable global forecasts from the ground through the edge of space and beyond, for a range of Navy operational and prototype assets (see figure, right).

**For more information**


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**Objectives**
- To extend the Navy Global Environmental Model (NAVGEM) as the DoD’s bridge strategy to a future Earth System Prediction Capability (ESPC), from its current upper boundary at ~65 km altitude to altitudes of ~100 km and above, for improved accuracy.
- Transition new high-altitude capabilities into the operational NAVGEM run at the Fleet Numerical Meteorology and Oceanography Center (FNMC).

**Space Science Division Approach**
- Extend global semi-Lagrangian forecast model to ~100 km altitude and above.
- Add new physical parameterizations to the forecast model that are important for prediction skill at these new high-altitude atmospheric regions.
- Build new ensemble prediction and assimilation capabilities for upper altitudes, to improve the range and skill of forecasting.
- Assimilate new high-altitude atmospheric observations into the system.
- Validate new high-altitude forecasts against independent stratospheric and mesospheric observations, quantify the impacts on prediction skill at all altitudes.
- Continuous close collaboration among scientists in the Space Science (Code 7600), Marine Meteorology (Code 7500), and Remote Sensing (Code 7200) divisions of the U.S. Naval Research Laboratory.

**Payoffs**
- Successful world-first development and demonstration of a prototype global numerical weather prediction system extending from the ground to the edge of space at ~100 km altitude.
- Successful inaugural operational transition of NAVGEM to FNMC on Feb. 13, 2013, work recognized by the 2012 Navy Acquisition Excellence Technology Transfer Award.
- NAVGEM is the Navy’s ongoing bridge strategy to a future ESPC that provides the operational Navy with seamless global predictions from ground to space and on timescales from days to months.
**AT A GLANCE**

**What is it?**
The Orbital Proximity Awareness via Light-Sheet Sensor (OPALS) is a low-power, local space situational awareness sensor concept. Applications range from detection of small space debris for anomaly resolution and debris mapping to assisting with proximity operations.

**How does it work?**
OPALS consists of a camera with a wide-field lens and a light-sheet that is created using a collimated light source and a shaped mirror (e.g., a conic mirror). Objects in the vicinity of the sensor that penetrate the light-sheet will scatter light into the camera, which allows determination of the object’s position in three full dimensions.

**What will it accomplish?**
The OPALS concept was initially envisioned for application to the detection of small space debris (a few centimeters or smaller) for host satellite anomaly attribution. The concept is also applicable to debris mapping, especially in debris clouds, and to proximity operations.

**For more information**


**Objective**
- Provide on-orbit, local space situational awareness (SSA) by means of an auxiliary hosted payload. Local SSA is of increasing importance for military, civilian government, and commercial space assets. Lethal space debris in the centimeter range, which is not observable from the ground, and the expected launch of thousands of commercial communication and imaging satellites in the coming years contribute to the congested space environment.

**Space Science Division Approach**
- A low size, weight, and power (SWaP) payload that creates a light-sheet and detects light scattered by an object penetrating the sheet. The OPALS concept can be adapted to individual applications. For example, the detection range can be increased with a stronger light source; two light-sheets can be used to retrieve information about object trajectories; and spectral filters can be used to match the light source in order to increase signal to noise. False alarms due to signals from high-energy radiation penetrating the camera can be avoided by comparing two simultaneously recorded images, either on the same focal plane or on two different focal planes.

**Payoffs**
- A low-SWaP payload for a wide range of DoD SSA capabilities.

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**Objectives**

- Accurate predictions of upper atmospheric neutral (thermospheric) and ionized (ionospheric) density 7–10 days in advance, to reduce uncertainty (green ellipsoids in the figure) of satellite and debris trajectories.
- Accurate estimation of density forecast uncertainty and propagation of the error to orbit predictions.

**Space Science Division Approach**

- Develop solar extreme-ultraviolet (EUV) irradiance forecasting techniques using empirical time series analysis, solar magnetic flux transport modeling, solar far-side helioseismic data, and physical modeling of solar upper atmosphere composition.
- Improve thermospheric density modeling, including new physics and data in the NRLMSISE-00 empirical model and incorporation of terrestrial weather effects using assimilative modeling by the Navy Global Environmental Model (NAVGEM) and the Highly Integrated Thermosphere and Ionosphere Demonstration System (HITIDES).

**Payoffs**

- Reduced uncertainty of satellite and debris trajectories effectively provides more room to operate in space.
- Accurate estimation of satellite and debris trajectory uncertainty provides reliable collision risk assessments, fewer false alarms, and fewer avoidance maneuvers.
- Developed prototype EUV forecasts are at least 30% more accurate than current operational forecasts and are ready for technology demonstration and validation.
- Currently, ~12,000 low-Earth orbit objects larger than ~10 cm are cataloged. The ~150,000 objects as small as 1 cm are also deadly to operating spacecraft and much more susceptible to atmospheric drag. Density forecast improvements will facilitate collision avoidance with this smaller particles population, which will soon be routinely tracked and cataloged.
- Presage-developed solar EUV forecasting tools and thermospheric modeling also will benefit ionospheric applications such as radio wave propagation models; EUV irradiance is the primary source of upper atmospheric ionization, and thermospheric composition strongly affects ionospheric electron density.
Using the Stratosphere and Mesosphere for Seasonal Prediction

AT A GLANCE

Why?
Naval and DoD operations require atmospheric prediction capabilities beyond medium-range (10-day) out to sub-seasonal (30-day) and seasonal (90-day) timescales.

How does it work?
Winds in the stratosphere and mesosphere (10–85 km altitude) are a source of predictability for surface teleconnection patterns, which occur long distances apart. Current wind forecasts in this altitude region lack skill after 20 days. This project, in collaboration with the Marine Meteorology Division (Code 7500) of the U.S. Naval Research Laboratory, incorporates new physical parameterizations into the Navy’s Earth System Prediction Capability (ESPC) initiative that will extend the forecast skill to 90 days.

What will it accomplish?
This research exploits dynamical coupling between the lower and upper atmospheric regions to meet stated ESPC needs for (1) increased forecast accuracy at 30- to 90-day lead times, (2) new capabilities for accurate forecasts in the Arctic, and (3) probabilistic seasonal prediction tools global mission planning.

For more information

Objective
- Develop a new seasonal prediction capability that exploits both ocean atmospheric coupling (“predictability from below”) and observed dynamical coupling between winds in stratosphere and mesosphere (10–85 km altitude) and global surface weather patterns, which is termed “predictability from above.”

Space Science Division Approach
- Implement new stratospheric and mesospheric physics in the Navy Global Environmental Model (NAVGEM) to eliminate existing biases in upper-level wind forecasts by accurately modeling, from first principles, highly predictable features such as the quasi-biennial oscillation (QBO, or 28- to 29-month oscillation of the equatorial zonal wind between easterlies and westerlies) in equatorial stratospheric winds.
- Generate ensembles of 90-day NAVGEM forecasts with new stratospheric and mesospheric physics to understand the observed coupling between the QBO and surface teleconnection patterns such as the North Atlantic Oscillation (or fluctuations in atmospheric pressure between the Icelandic low and Azores high).

- Perform fully coupled ocean-atmosphere seasonal forecasts using NAVGEM in the Navy’s Earth System Prediction Capability (ESPC) system to quantify the impact of the stratosphere and mesosphere on extended range forecast skill.

Payoffs
- Development and demonstration of a new ensemble-based seasonal forecast capability for surface pressure patterns, storm track location, and sea ice distribution to support Naval and DoD operations throughout the Arctic region and globally.
- Development and demonstration of improved medium-range forecast capability for winds in the “data poor” tropical upper troposphere and lower stratosphere (10–15 km altitude) that affect tropical cyclone formation.
- Development and demonstration of improved long-range prediction of upper atmosphere initial conditions for next-generation whole atmosphere modeling capabilities extending from surface to the thermosphere/ionsphere region. Ray-based models of GW dynamics that improve parameterizations of orographic and nonorographic gravity wave dynamics within NAVGEM.

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**What is it?**

The Wind Ion Neutral Composition Suite (WINCS) is a suite of miniature spaceflight instruments that measure in situ properties of the thermosphere and ionosphere between 120 km and 55 km in altitude.

- Volume: 7.62 cm x 7.62 cm x 7.11 cm
- Mass: 585 g (CubeSat version)
- Power: 1.2 W

**How does it work?**

WINCS uses three sensors to execute four spectrometer functions: (1) wind-temperature spectrometer (WTS), (2) neutral mass spectrometer (NMS), (3) ion mass spectrometer (IMS), and (4) ion-drift temperature spectrometer (IDTS), with the NMS and IMS sharing a single mass spectrometer of the gated electrostatic mass spectrometer (GEMS) type.

**What will it accomplish?**

WINCS provides a proof of concept for miniature low-cost sensor suites capable of acquiring operationally relevant data. The intent is to demonstrate operational utility of data from CubeSat and other small satellite busses. WINCS is ideal for an operational constellation of 30 to 50 sensors as secondary payloads to larger satellites or as a primary instrument on CubeSats.

**For more information**


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**Objective**

Develop and demonstrate a low size, weight, and power (SWaP) space weather experiment suite that acquires simultaneous, co-located, in situ measurements of upper atmospheric density, composition, and winds of both ions and neutrals.

**Space Science Division Approach**

The U.S. Naval Research Laboratory is the lead institution for the Wind Ion Neutral Composition Suite (WINCS), a suite of instruments that provide the following measurements: neutral winds, neutral temperature, neutral density, neutral composition, ion drifts, ion temperature, ion density, and ion composition. The WINCS sensors are CubeSat compatible.

**WINCS Measurement Capabilities**

<table>
<thead>
<tr>
<th>Spectrometer</th>
<th>Parameter</th>
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<th>Resolution</th>
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<td>&lt;3%</td>
</tr>
<tr>
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<td>Temperature</td>
<td>1000-4000 K</td>
<td>&lt;1%</td>
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<tr>
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<tr>
<td>NMS</td>
<td>Composition</td>
<td>$10^3$-$10^7$ cm$^{-3}$</td>
<td>&lt;3%</td>
</tr>
<tr>
<td>IDTS</td>
<td>Density</td>
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<tr>
<td>IDTS</td>
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<tr>
<td>IMS</td>
<td>Composition</td>
<td>$10^3$-$10^7$ cm$^{-3}$</td>
<td>&lt;3%</td>
</tr>
</tbody>
</table>

**Payoff**

WINCS provides space environmental specification data essential for our understanding of the dynamics of the upper layers of our atmosphere — the thermosphere and ionosphere. Phenomena ranging from solar storms to the aurora energize the atmosphere in a variety of regions and scales, and can propagate across the globe. WINCS data will contribute to upper atmospheric weather models via validation and/or assimilation and increase technology readiness for potential future operational space weather missions.