NASA UPDATES SINCE CGMS-51 AND REPORT ON MEDIUM TO LONG-TERM FUTURE PLANS ON EARTH OBSERVATIONS

Presented to CGMS-52 Plenary Session, Agenda Item 3

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Report prepared based on inputs from numerous colleagues at NASA HQ, NASA Centers, and broader research community

Coordination Group for Meteorological Satellites

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NASA CGMS

REPORT HIGHLIGHTS

Launch of Plankton, Aerosol, Cloud and Ocean Ecosystem (PACE)

Small Satellite Technology Demonstrations

- Hyperspectral Thermal Imager
- Signals of Opportunity P-band Investigation (SNOOPI)

Instruments onboard the International Space Station

Future Satellite Systems

- Earth Systematic Mission
- Earth System Pathfinder
- NASA Response to Decadal Survey

Earth Science to Action Strategy

Retirement of DC-8 and Acquisition of B777-200ER

Plankton, Aerosol, Cloud and Ocean Ecosystem (PACE)

Launch and Instruments

Launched February 8 at 1:33 am EST from Cape Canaveral on a SpaceX Falcon 9

Ocean Color Instrument (OCI) - a hyperspectral imaging radiometer capable of acquiring observations in 315-895 nm (near infrared) wavelength range at 2.5 nm resolution (with bandwidths of 5 nm). Also includes 7 discrete bands from 940 nm to 2260 nm in the shortwave infrared (SWIR) spectrum. The telescope scans from west to east, acquiring Earth view data at a 1.2 km × 1.2 km ground sample footprint at the center of the scan (higher at the scan edges) and a ground swath width of ~2700 km.

Spectro-polarimeter for Planetary Exploration one (SPEXone) is a spectro-polarimeter that provides continuous wavelengths coverage in the range 385-770 nm. Spectral resolution is 2-5 nm for radiance and 10-40 nm for Degree of Linear Polarization (DoLP). It observes a ground pixel under 5 viewing angles (0°, ±22° and ±58° on ground), where the ±22° viewports will be used for cross calibration with OCI. SPEXone is a public-private initiative funded by the Netherlands Space Office (NSO), the Netherlands Organization of Scientific Research (NWO), Netherlands Institute of Space Research (SRON), and Airbus Defense and Space

The **2nd generation Hyper-Angular Rainbow Polarimeter (HARP-2)** is wide angle imaging polarimeter. Spectral bands (center wavelength): 441, 549, 669, 873 nm. Bandwidth: 15, 12, 16 and 43 nm, respectively. Polarization angles: 0, 45 and 90 degrees. 60 along track viewing angles for the 669 nm band, and 10 along track viewing angles for the other 3 bands (441, 549, and 873 nm). Developed by University of Maryland in Baltimore County Earth and Space Institute.

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Plankton, Aerosol, Cloud and Ocean Ecosystem (PACE)

Science Objectives and Current Status

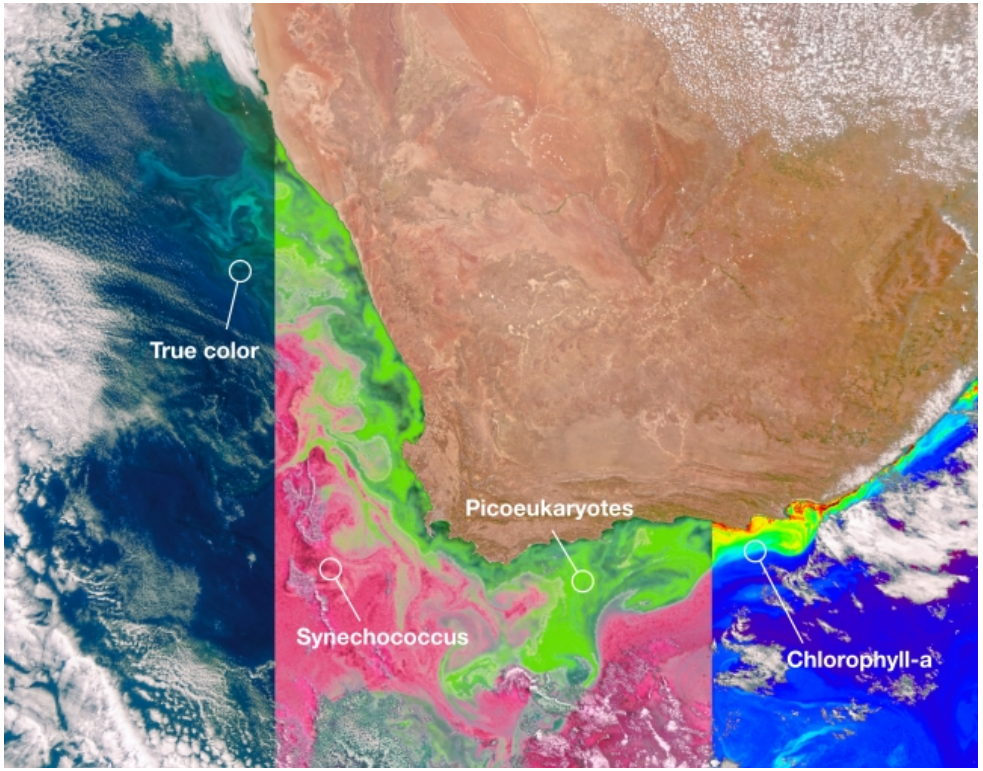
Science Objectives

Extend key systematic ocean biological, ecological, and biogeochemical climate data records and cloud and aerosol climate records.

Make new global measurements of ocean color to improve our understanding of the carbon cycle and ocean ecosystem responses to a changing climate.

Collect global observations of aerosol and cloud properties, focusing on reducing the largest uncertainties in climate and radiative forcing models of the Earth system.

Improve our understanding of how aerosols influence ocean biogeochemical cycles and ecosystems and how ocean biological and photochemical processes affect the atmosphere.

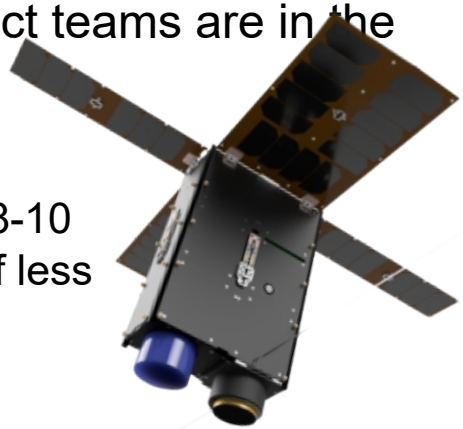


First image released from PACE's Ocean Color Imager (OCI) identifies two different communities of phytoplankton off the coast of South Africa on 28th February 2024. The central panel of this image shows Synechococcus in pink and picoeukaryotes in green. The left panel of this image shows a natural color view of the ocean, and the right panel displays the concentration of chlorophyll-a, a photosynthetic pigment used to identify the presence of phytoplankton. Credit: NASA

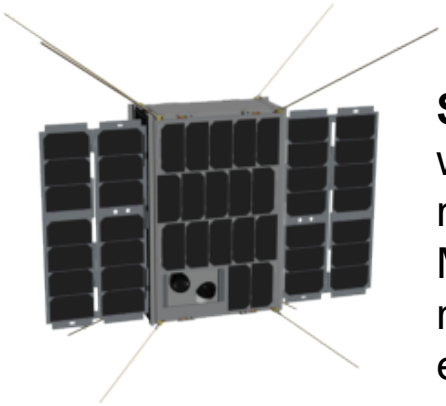
Small Satellite Technology Demonstrations

Hyperspectral Thermal Imager and the **Signals of Opportunity P-band Investigation (SNOOPI)** instruments were launched to the International Space Station on March 21, 2024, onboard NASA's SpaceX 30th Commercial Resupply Services mission.

Both CubeSats were deployed from ISS in April 2024, and project teams are in the process of commissioning.



Hyperspectral Thermal Imager is a 6U CubeSat which acquire high spectral and spatial resolution images in the long-wavelength range (8-10 micron), with narrow band noise equivalent variation in temperature of less than 150 milli-Kelvin.



Signals of Opportunity P-band Investigation (SNOOPI) will show how a 6U CubeSat can use direct and Earth's reflected signals of opportunity in the P-band (240 - 380 MHz) from geostationary communication satellites to retrieve root zone soil moisture (RZSM) and snow water equivalent (SWE).

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Instruments onboard the International Space Station (ISS)

- The Lightning Imaging Sensor (LIS) instrument **was decommissioned and removed from its position on the ISS in November 2023.**
- The OCO-3 instrument placed in temporary storage in November 2023, **is expected to resume science operations later in 2024.**
- The GEDI instrument placed in temporary storage in March 2023, was successfully relocated to its operational location in April 2024, and **is expected to resume science operations in June.**

Mission	Description	Launch Date
SAGE-III (Stratospheric Aerosol and Gas Experiment)	Solar Occultation Instrument for measuring the vertical distribution of aerosols, ozone, water vapor and other trace gases in Earth's stratosphere and troposphere to enhance understanding of O_3 recovery, climate change processes in the upper atmosphere	19 Feb 2017
TSIS-1 (Total Spectral Irradiance Sensor)	Measure total and spectral Solar irradiance (TSI & SSI) to better understand the Sun's natural influence on Earth's ozone layer, atmospheric circulation, clouds, and ecosystems	15 Dec 2017
ECOSTRESS (Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station)	Thermal infrared radiometer for measuring evapotranspiration to provide insight to plant-water dynamics and how ecosystems change with climate	29 Jun 2018
GEDI (Global Ecosystem Dynamics Investigation)	A LIDAR for providing high-resolution observations of forest vertical structure to characterize the effects of changing climate and land use on ecosystem structure and dynamics and enable significantly improved quantification and understanding of the Earth's carbon cycle and biodiversity	05 Dec 2018
OCO-3 (Orbiting Carbon Observatory)	A grating spectrometer for acquiring measurements of atmospheric carbon dioxide to characterize sources and sinks on regional scales and over seasons	04 May 2019
EMIT (Earth Surface Mineral Dust Source Investigation)	VSWIR spectrometer for measuring the different wavelengths of light emitted by minerals on the surface of deserts and other dust sources to determine their composition to better understand how dust warms or cools the atmosphere	14 Jul 2022

Future Satellite Systems - Earth Systematic Mission (2024-2027)

Mission	Description	Launch Date
NISAR (NASA-ISRO Synthetic Aperture Radar)	L- and S-band Synthetic Aperture Radar for measuring changes in Earth's surface to improve risk and resource management by understanding the response of ice sheets to climate change; likelihood of solid earth hazards, like earthquakes; and dynamics of carbon storage in various ecosystems	2024
TSIS-2 (Total and Spectral Solar Irradiance Sensor-2)	Measures the total solar irradiance and spectral solar irradiance to maintain continuity from TSIS-1 to understand solar radiation impacts on Earth's climate	2025
Sentinel-6B*	Measures the ocean surface height to monitor global sea level; provide tropospheric temperature and humidity data to improve weather forecasts, climate models, and hurricane tracking	2026
CLARREO-PF (Climate Absolute Radiance and Refractivity Observatory)	Provides high-accuracy, SI-Traceable calibration measurements of Earth's solar reflectance to enable detection of climate change trends decades sooner	Not earlier than 2027
CRISTAL* (Copernicus Polar Ice and Snow Topography Altimeter)	Measures and monitors surface elevation of glaciers and ice caps and contribute to global ocean topography and coastal/inland water applications	2027

*Sentinel-6B and CRISTAL are partner led missions

Future Satellite Systems - Earth System Science Pathfinder

Mission	Description	Launch Date
PREFIRE (Polar Radiant Energy in the Far-InfraRed Experiment)	Two CubeSats with Thermal Infrared Spectrometers (TIRS) for providing full spectral measurements of Far InfraRed (FIR) radiation over the Arctic and Antarctic to allow more accurate predictions of Arctic warming, sea ice and glacier melt, and influence on global sea level and weather systems	2024 (First of a pair of CubeSat launched on 25 May 2024 NZT)
MAIA (Multi-Angle Imager for Aerosols)	Two push broom spectro-polarimetric camera on a two-axis gimbal for collecting radiometric and polarimetric measurements to characterize sizes, compositions, and quantities of particulate matter in air pollution to combine with health records to better understand connections between air pollution and health problems	2025
Libera on JPSS-4	Four electrical substitution radiometers (ESRs) for collecting shortwave, split shortwave, longwave, and total radiation measurements to continue and enhance the Earth radiation budget data record needed to recognize changes to the climate system and constrain future predictions	2027
INCUS (Investigation of Convective Updrafts)	Cross-track scanning microwave radiometer and Ka-band radar with five beams for measuring vertical transport of air and water, known as convective mass flux (CMF), to address why convective storms, heavy precipitation, and clouds occur exactly when and where they do	2027
GLIMR (Geosynchronous Littoral Imaging and Monitoring Radiometer)	Measure electromagnetic spectra from the Gulf of Mexico, southeast US coast, and Amazon River plume to observe and enable rapid response to coastal water disasters like harmful algal blooms and oil spills	TBD
PolSIR (Polarized Submillimeter Ice-cloud Radiometer)	Measure the radiant energy emitted by clouds to significantly improve our understanding of how ice clouds change and respond throughout the day in response to a changing climate	TBD

Future Satellite Systems - Earth System Observatory (2018-2022)

- Following release of the Decadal Survey (DS) report in early 2018, ESD initiated studies to explore implementation options for observing systems to address the DS's five Designated Observables (DO): Aerosols (A); Clouds, Convection, and Precipitation (CCP); Mass Change (MC); Surface Biology and Geology (SBG); and Surface Deformation and Change (SDC).
- After an extensive multi-year study phase to assess a broad trade space of potential architectures, NASA initiated pre-formulation studies in spring of 2021 for all except the SDC Designated Observable mission
- In spring 2022, AOS (formerly A and CCP), SBG, and GRACE-C (formally named Mass Change) underwent Mission Concept Reviews that examined each mission's objectives and their ability to fulfill those objectives.
- In early 2023, the AOS, SBG, and GRACE-C missions transitioned into Phase A formulation to further assess the feasibility of the mission architectures.
- Following recommendations of the Internal Review Board (IRB), the AOS mission undertook Phase-A architecture studies to identify cost-saving and risk reduction opportunities.
- GRACE-C and SBG missions refined their mission concepts, system-level requirements, and technical management plans and passed their System Requirements Reviews.
- GRACE-C transitioned into Phase B formulation in late 2023 where it will work to further improve the fidelity and realism of the cost and schedule estimates prior to moving into implementation and establishing baseline requirements.

Future Satellite Systems - Earth System Observatory Updates

In early 2024, the NASA Earth Science Division introduced a “decouple, partner, and compete” approach that provides greater flexibility and maximizes the science achievable from the Surface Biology and Geology (SBG) and Atmospheric Observing System (AOS) missions.

- Management of the two SBG instruments will be decoupled to allow the Thermal Infrared (TIR) component to launch when ready ahead of the Visible Short-Wave Infrared (VSWIR) component. The TIR component is being developed in partnership with Agenzia Spaziale Italiana (ASI).
  - The TIR instrument will be hosted on Italian PLATINO-2 spacecraft along with an Italian visible and near infrared imaging camera. ASI will provide the launch vehicle (Vega-C).
- The cost target for AOS mission was reduced, and it will now be a pursued through a mix of directed and at least one competed mission with multiple international partners and decoupled schedules. International contribution to the AOS mission includes:
  - Ku-band Radar from Japan Aerospace Exploration Agency (JAXA)
  - Ku-band Microwave radiometer from Centre National d’Études Spatiales (CNES)
  - Multi-wavelength Lidar from Agenzia Spaziale Italiana (ASI)
  - Near Infrared Imaging Radiometer and Limb-imaging observatory from the Canadian Space Agency (CSA)

Future Satellite Systems - Earth System Explorers (1)

In summer 2023, NASA initiated the Earth System Explorers program designed to enable high quality Earth system science investigations through Principal Investigator-led missions that acquire and deliver measurements of one or more observables identified in the 2017 Decadal Survey as Earth System Explorer Targeted Observables (TO): Atmospheric Winds, Greenhouse Gases, Ice Elevation, Ocean Surface Winds and Currents, Ozone and Trace Gases, Snow Depth and Snow Water Equivalent, and Terrestrial Ecosystem Structure.

The total mission cost cap is $310 million for each chosen investigation, excluding the rocket and access to space, which will be provided by NASA.

In May 2023, NASA finalized a two-step competitive process and released the final Announcement of Opportunity (AO) for the Earth System Explorers (ESE) missions. Proposal were received in August 2023.

In May 2024, as the first step of a two-step selection process, NASA selected four proposals (listed on the next slide) for nine-month Phase A mission concept studies.

After the study period, NASA will choose up to two proposals to go forward to launch with readiness dates expected in 2030 and 2032.

Future Satellite Systems - Earth System Explorers (2)

The **Stratosphere Troposphere Response using Infrared Vertically-Resolved Light Explorer (STRIVE)** mission would provide near global daily measurements of temperature, various atmospheric elements, and aerosol properties from the troposphere to the mesosphere. It would also measure vertical profiles of ozone and trace gasses to monitor and understand ozone recovery. (Principal Investigator: Lyatt Jaegle at the University of Washington in Seattle)

The **Ocean Dynamics and Surface Exchange with the Atmosphere (ODYSEA)** mission would measure ocean surface currents and winds to improve our understanding of air-sea interactions and surface current processes that impact weather, climate, marine ecosystems, and human wellbeing. (Principal Investigator: Sarah Gille at the University of California in San Diego)

The **Earth Dynamics Geodetic Explorer (EDGE)** mission would observe the three-dimensional structure of terrestrial ecosystems and the surface topography of glaciers, ice sheets, and sea ice as they are changing in response to climate and human activity. (Principal Investigator: Helen Amanda Fricker at the University of California in San Diego).

The **Carbon Investigation (Carbon-I)** mission would enable simultaneous, multi-species measurements of critical greenhouse gases and potential quantification of ethane to provide unprecedented spatial resolution and global coverage that would help better understand the carbon cycle and the global methane budget. (Principal Investigator: Christian Frankenberg at the California Institute of Technology in Pasadena.

Earth Science to Action Strategy

In early 2024, NASA Earth Science Division released the Earth Science to Action Strategy with the goal of better integrating its scientific knowledge, engineering assets, and partnerships to meet societal needs more comprehensively. Through this strategy, NASA will build the momentum to create a global framework that will allow constructing a comprehensive digital description of the Earth syst

A schematic representation of Earth Science to Action Strategy, highlighting the virtuous cycle through which foundational knowledge is employed to address user needs, and the unaddressed and emerging needs inform the next iteration of programs, missions, and initiatives.

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Retirement of DC-8 and Acquisition of B777-200ER

After nearly 40 years of service to NASA Science, DC-8 was retired from service at the end of March when it returned from Asia Air Quality (ASIA-AQ) campaign.

The aircraft was donated to Idaho State University's Aircraft Maintenance Program by the federal government, where it will help the university train highly-skilled technicians ready to meet industry needs.

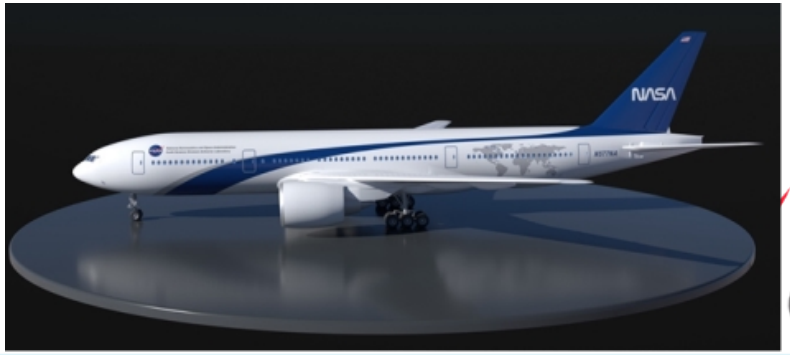
The NASA DC-8 has been a foundational platform for the scientific community for nearly four decades. With several downward and upward looking ports, gas sample inlets, onboard computing and communications, room for 50 investigators, and a range of more than 5,000 miles, the DC-8 has supported instrument development and process studies across nearly every Earth science discipline and conducted missions around the world.

To celebrate the achievements and contribution of DC-8 and airborne Earth system science that it enabled, a workshop is planned for Summer/Fall 2024.

Accepting NASEM recommendations, NASA acquired a Boeing 777-200ER in December 2022.

The aircraft is currently undergoing modifications and is expected to be ready for research flights in 2026.

Aircraft	Payload Weight (pounds)	Fuel load (percent)	Range (miles)	Endurance (hours)
DC-8	50,000	100	5,000	11
B777-200 ER	50,000	55	5,400	11.7
	50,000	100	9,000	19
	100,000	85	7,400	15.6



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Thank You