National Aeronautics and
Space Administration

EXPLORE

Science Mission Directorate

Airborne Science Program | 2024 Annual Report

COVER IMAGES:

Front top: An ER-2 science aircraft banks away during a flight over the southern Sierra Nevada. The high-altitude plane supports a wide variety of research missions, including the GEMx campaign, which is mapping critical minerals in the Western U.S. using advanced airborne imaging developed by NASA. Credit: Carla Thomas/NASA

Front middle: The NASA P-3 taxiing during ARCSIX. Credit: Dan Chirica/NASA

Front bottom: G-III takes off in Thailand for ASIA-AQ. Credit: Rafael Luis Méndez Peña

BACK COVER:

The DC-8 aircraft returned to NASA's Armstrong Flight Research Center Building 703 in Palmdale, California, on April 1, 2024, after completing its final mission supporting Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ). Credit: Steve Freeman/NASA

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Figures and Tables

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1. Leadership Comments

Bruce Tagg, Director of the Airborne Science Program.

Thank you for taking the time to learn about the NASA Earth Science Division (ESD) Airborne Science Program (ASP).

This ASP Annual Report highlights Fiscal Year 2024 (FY24) Airborne Science missions and the unique platforms, payloads, and capabilities that made them possible. The Program had another successful year in 2024 by supporting over 2,400 flight hours across every Earth Science Focus Area. Spaceborne instruments continued to launch at a steady PACE (pun intended); NASA aircraft frequently conducted underflights of satellites and ISS systems — including PACE, ICESat-2, EMIT, ECOSTRESS-ISS, GEDI-ISS, and GEMS — for calibration and validation.

Additionally, ASP supported important process, mapping, and modeling studies such as SnowEx, ARCSIX, ABoVE, PACE-PAX, and used Uncrewed Aerial Systems (UAS) to study fire sites. Finally, we also collaborated with international and interagency partners to support multiple missions, including GEMx, ASIA-AQ, AfriSAR II, BioSCape, and HAWC (see Appendix B: Acronyms).

When not directly supporting airborne projects, ASP worked to improve Program capabilities. In light of the DC-8's final flight in early 2024, we have continued to modify the recently acquired Boeing 777 to prepare it for flight operations in 2026. We have also modified our Gulfstream IV, which will serve as a developmental and operational platform for the UAVSAR follow-on mission, AirSAR-NG.

All of these accomplishments were made possible by the excellence, perseverance, and dedication of the ASP community: flight crew, instrument operators, principal investigators, logistics team, ESD program leads, students, collaborators, and more. Together, we will continue to ensure our Program and assets meet the ongoing and upcoming science requirements and ensure our missions are completed on time and within budget. Thanks to you for your support of NASA Earth Science! Please let us know if you have any comments or suggestions for ASP leadership.

Bruce A. Tagg
and the ASP Leadership Team
Airborne Science Program

2. Program Overview

The Airborne Science Program (ASP) is an important element of the NASA Science Mission Directorate (SMD) Earth Science Division (ESD) because of its involvement and support throughout the entire life cycle of Earth observing satellite missions. Aircraft modified with ports, inlets, internet, and communications systems support NASA Earth science missions by:

- Providing a platform for testing future satellite or International Space Station (ISS) instruments.
- Conducting underflights for calibration and validation of on-orbit missions.
- Simulating future satellite mission data for algorithm development with airborne prototype instruments.
- Supporting process studies to provide high-resolution temporal and spatial measurements of complex local processes, which can be coupled to global satellite observations for a better understanding of the complete Earth system.
- Leading workforce development through hands-on science and engineering opportunities.

ASP accomplishes these goals by providing support for operations of mission critical, or core, aircraft; engineering for instrument mechanical, electrical, and data system integration; and on-board data systems and communications capabilities. The Program also assists NASA Principal Investigators (PIs) with access to commercial aviation services and use of non-NASA aircraft and equipment for Earth Science, as needed.

Program Structure

The Program is administered through SMD/ESD, with oversight and close coordination from the Flight Projects and Research and Analysis (R&A) Programs (Figure 1). Aircraft operations and science support responsibilities are distributed among the multiple NASA flight centers – Armstrong Flight Research Center (AFRC), Langley Research Center (LaRC), Wallops Flight Facility (WFF), Johnson Space Center (JSC), and Ames Research Center (ARC) – where the aircraft and support personnel are based, as shown in Figure 2.

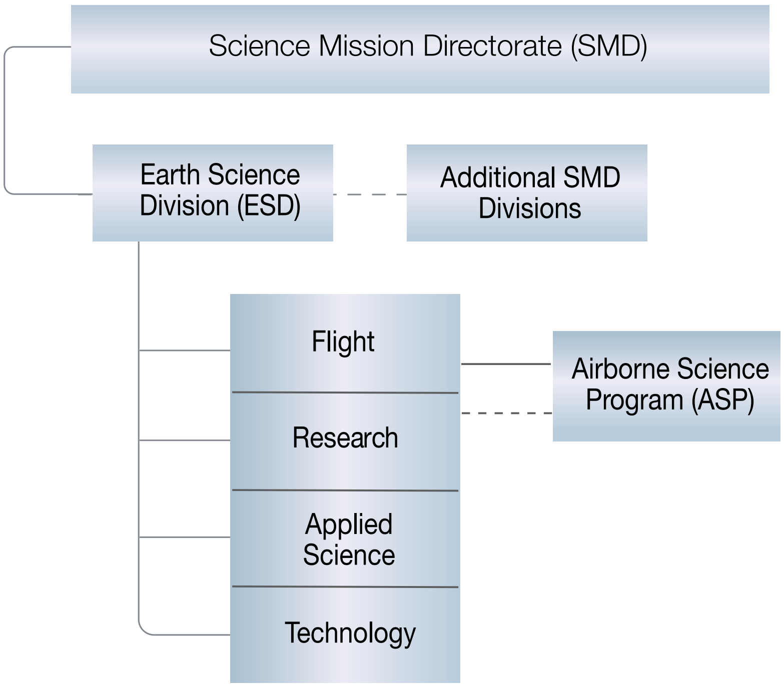

Figure 1. *Science Mission Directorate organization chart.*

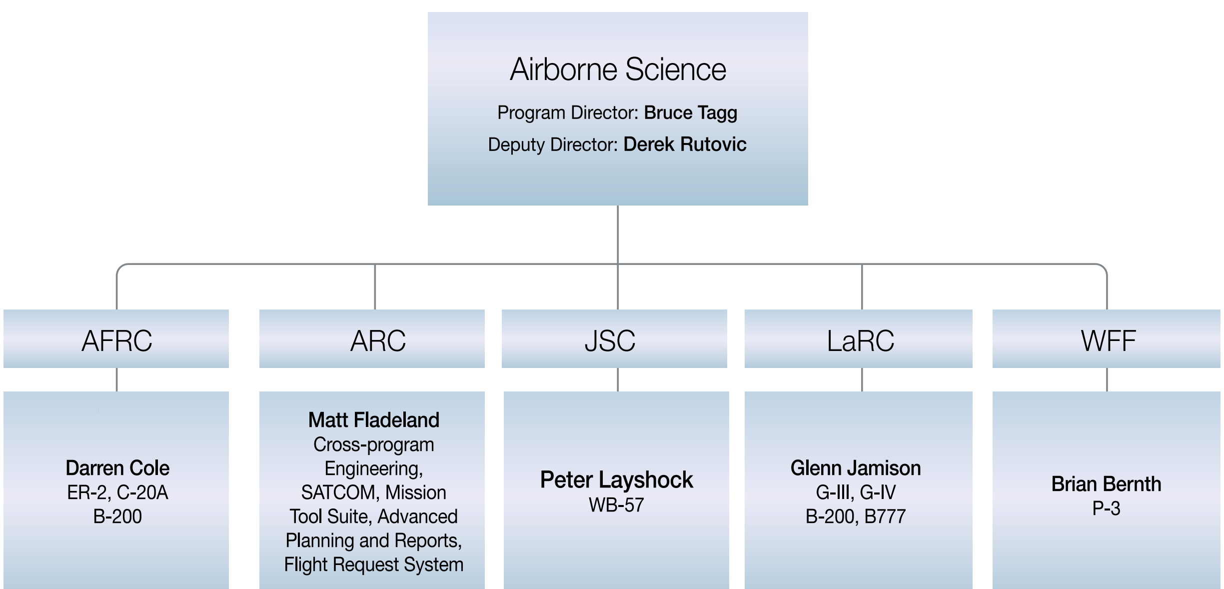

Figure 2. *Airborne Science Program organization chart.*

Flight Request System and Flight Hours

The Airborne Science Program (ASP) maintains science-capable aircraft and instrument assets for research use in support of NASA's Science Mission Directorate (SMD). The Science Operations Flight Request System (SOFRS) is a web-based tool used to track and facilitate the review and approval process for airborne science activities using ASP-supported aircraft, facility instruments, or any Earth Science Division (ESD) funded activities/missions using aircraft. The way to schedule the use of NASA SMD platforms and instrument assets is to submit a Flight Request (FR) through SOFRS (https://airbornescience.nasa.gov/sofrs). The SOFRS team strives for continuous improvement by refining the user interface and reports produced. This year there has been a major software and interface upgrade.

There were 108 Flight Requests submitted in Fiscal Year 24 (FY24) for flight activities using at least one of the following ASP components: an ASP-supported aircraft, ESD funding, or an ASP facility instrument (AVIRIS-3, AVIRIS-NG, AVIRIS-C, eMAS, LVIS, MASTER, NAST-I and UAVSAR (L-Band, P/Ka Bands)). A total of 53 Flight Requests were completed using 12 different aircraft flying a total of 2411.4 flight hours. The details are listed below.

Table 1 shows all SOFRS flight hours flown by all aircraft, including "Other (non-NASA) Aircraft," by funding source.

- Other NASA aircraft are NASA-owned aircraft but not subsidized by ASP.
- NASA ESD is under SMD. SMD (non-ESD) flight hours are those funded by SMD Program Managers not within ESD.

Table 2 shows the status of all Flight Requests and total flight hours by aircraft; Table 3 shows Flight Request status and total hours for the specific "Other (non-NASA) Aircraft" requested; Table 4 shows only ESD Flight Requests and flight hours flown by aircraft; Table 5 shows all SOFRS flight hours flown by funding source over the past five years (FY19 – FY24). Figure 3 is a histogram showing the history of total flight hours over the past five years (FY19 – FY24).

How to read Tables 1, 2, 3 and 4

- The "Total FRs" column includes Flight Requests submitted for fiscal year FY24.
- The "Total FRs Approved" column includes Flight Requests that were approved but may or may not have flown during FY24.
- The "Total Partial FRs" column includes Flight Requests for which the total approved hours were not fully expended during FY24 and have been rolled over to the following year.
- The "Total FRs Completed" column includes only Flight Requests with the final status of "Completed."

The "Total Hours Flown" column includes all "Flight Hours Flown" for Flight Requests with a status of "Completed" or "Partial" for FY24.

Table 1. NASA Airborne Science Total Hours Flown by Aircraft in FY24 (per funding source).

Aircraft	NASA ESD	NASA SMD	Other NASA	Non - NASA	Total
ASP Supported Aircraft					
DC-8 - AFRC	163.3	0	64.4	0	227.7
ER-2 - AFRC	129	0	0	158.6	287.6
C-20A/G-III - AFRC	348	0	0	0	348
G-IV - LaRC	478.2	0	0	21.6	499.8
GV - JSC	173	0	0	0	173
P-3 Orion - WFF	225.7	0	0	16.6	242.3
Other NASA Aircraft					
B-200	73.7	0	0	0	73.7
C-130H - WFF	49.7	0	0	0	49.7
Other	434	0	0	75.6	509.6
TOTAL	**2074.6**	**0**	**64.4**	**272.4**	**2411.4**

Table 1 shows all SOFRS flight hours flown by all aircraft, including "Other (non-NASA) Aircraft," by funding source. More details on other supported aircraft are shown in Table 4.

Table 2. FY24 FR Status & Hours Flown by Aircraft.

Aircraft	Total FRs	Approved	Partial	Completed	Total Hours Flown
ASP Supported Aircraft					
DC-8 - AFRC	5	4	0	4	227.7
ER-2 - AFRC	19	10	1	7	287.6
C-20A/G-III - AFRC	21	18	3	14	348
G-IV - LaRC	8	5	1	3	499.8
GV - JSC	14	2	0	2	173
P-3 Orion - WFF	8	4	0	4	242.3
Other NASA Aircraft					
B-200	9	7	1	3	73.7
C-130H - WFF	3	2	0	1	49.7
Other	21	17	1	15	509.6
TOTAL	**108**	**69**	**7**	**53**	**2411.4**

Table 3. *FY24 ESD Funded FR Status & Hours Flown by Aircraft.*

Aircraft	Total FRs	Approved	Partial	Completed	Total Hours Flown
ASP Supported Aircraft					
DC-8 - AFRC	4	3	0	3	163.3
ER-2 - AFRC	9	6	1	4	129
C-20A/G-III - AFRC	21	18	3	14	348
G-IV - LaRC	7	4	0	3	478.2
GV - JSC	10	2	0	2	173
P-3 Orion - WFF	7	3	0	3	225.7
Other NASA Aircraft					
B-200	8	7	1	3	73.7
C-130H - WFF	3	2	0	1	49.7
Other	13	11	1	9	434
TOTAL	**82**	**56**	**6**	**42**	**2074.6**

Table 4. *FY24 FR Status & Hours Flown by Other (non-NASA) Aircraft.*

Aircraft	Total FRs	Approved	Partial	Completed	Total Hours Flown
Other Aircraft					
A90 - Dynamic Aviation	1	1	0	1	35
B-200 - Dynamic Aviation	18	14	1	12	373.3
Twin Otter CIRPAS	2	2	0	2	101.3
TOTAL	**21**	**17**	**1**	**15**	**509.6**

Table 5. *Flight Hours Flown by Funding Source for the Last Five Years (FY19 - FY24).*

Fiscal Year	ESD	SMD	Other NASA	Non-NASA	Funding Sources Not Listed in FR	Total Funded Flight Hours
2019	2415.1	0	586.6	60.6	7.5	3069.8
2020	1614	0	129.9	0	0	1743.9
2021	2166	0	193.5	0	2.7	2424.9
2022	2111.8	0	233	390.6	12.7	2748.1
2023	2115	18.4	0	273.9	7.9	2415.2
2024	2074.6	0	64.4	272.4	0	2411.4

Figure 3. *Total annual funded ASP flight hours (FY19 through FY24).*

Figure 4 shows the flight tracks, including transit and science flights, of FY24 ASP airborne campaigns.

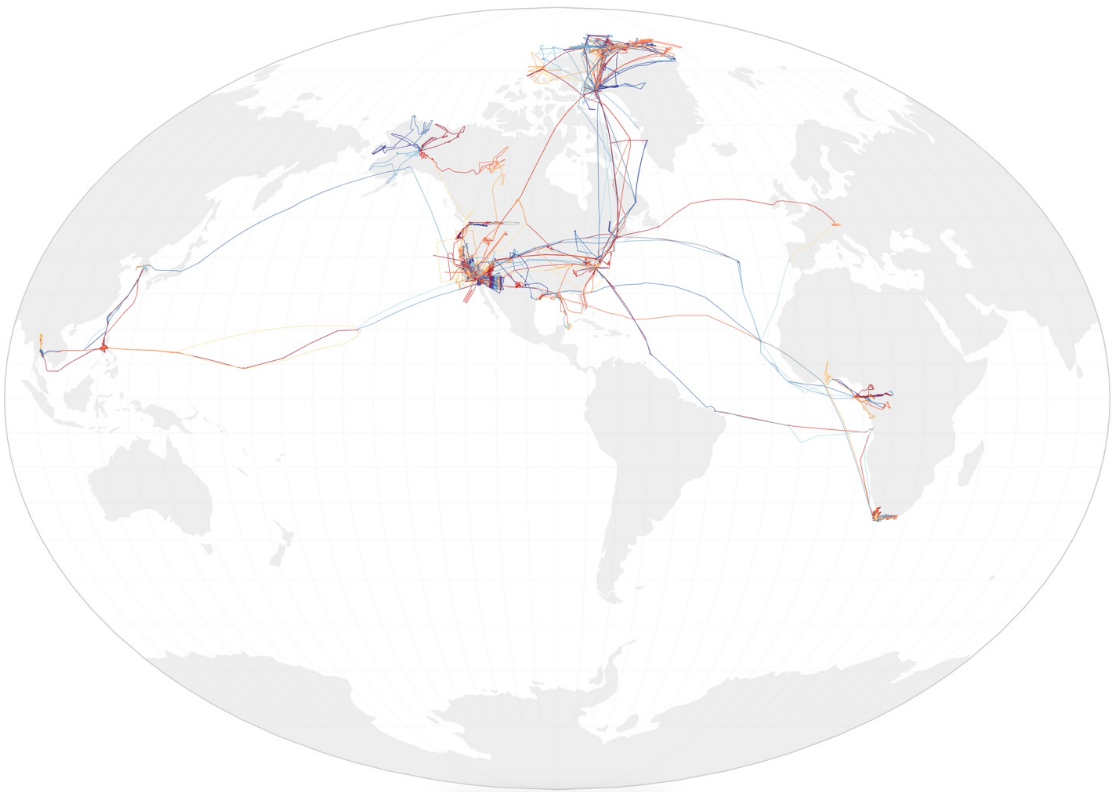

Figure 4. *Flight tracks in FY24 generated using ASP's Mission Tool Suite (MTS).* ***Credit:*** *Aaron Duley/NASA*

3. Science

Major Mission Highlights

In FY24, ASP conducted over 2,400 flight operation hours in support of Earth Science process studies, instrument flight-testing, and support for Earth Science space missions in all phases, from definition to validation. NASA campaigns intensively studied processes occurring within the country: SnowEx and ABoVE in Alaska, BlueFlux in Florida, PACE-PAX, CoSMIR-H, and MBARS in California, GEMx in the Southwestern United States, and more. NASA also deployed around the world to far-away international destinations (e.g., the Philippines, South Korea, Thailand, Greenland, Gabon, Ghana, Cameroon, South Africa, Canada). Table 6 shows locations for major ASP missions ordered by most flight hours.

Table 6. *Major science missions supported by ASP in FY24.*

Mission	Program	Flight Hours	Location	Aircraft
ASIA-AQ	Tropospheric Composition	377	Asia	DC-8, G-III
ARCSIX	Radiation Sciences	306.5	Thule AB, Svalbard	P-3, G-III
BioSCape	Biological Diversity	289.4	South Africa	GV, G-III
AfriSAR II	Earth Surface and Interior; Terrestrial Ecology	155.5	Western and Central Africa	C-20A
GHG Center	GHG Center	143.5	Southwestern U.S.	B-200 (DA)
PACE-PAX	Ocean Biology and Biogeochemistry; Radiation Sciences	141.2	California	ER-2, CIRPAS Twin Otter
GEMx	United States Geological Survey	140.9	Southwestern U.S.	ER-2
SARP	Research and Analysis	135.4	WFF, AFRC	P-3, B-200 (DA)
FireSense 2023, 2024	Tropospheric Composition	112.9	California	B-200 (DA, LaRC, AFRC)
ecoDemonstrator	Atmospheric Composition	64.4	Northwest U.S.	DC-8
ABoVE	Terrestrial Ecology	48.9	Alaska and Canada	C-20A

In addition to process studies and instrument testing, many of the ASP missions support spaceborne endeavors; this includes flying aircraft to support satellites and missions on the International Space Station (ISS). The Program provides platforms to collect data for algorithm development prior to launch, test instrument concepts for satellite/ISS payloads or airborne simulators and provide data for calibration or validation (cal/val) of satellite algorithms, measurements, or observations once missions are in orbit.

In FY24, NASA Airborne missions provided support to multiple operational and future Earth Science space-based missions. The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite, which launched in February 2024, received over 450 hours of support from ASP missions through not only the aptly named PACE Post-launch Airborne eXperiment (PACE-PAX) but also through Biodiversity Survey of the Cape (BioSCape) in advance of the launch. BioSCape also supported Global Ecosystem Dynamics Investigation (GEDI-ISS), Landsat 8, and Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS-ISS). The Arctic Radiation-Cloud-Aerosol-Surface-Interaction Experiment (ARCSIX) and a Lake Ice mission were flown in support of the Ice, Cloud, and Land Elevation Satellite 2 (ICESat-2), part of NASA's Earth Observing System.

This support was not limited to national assets; NASA ASP also supported international Earth Science space-based missions and collaborations. This included Airborne and Satellite Investigation of Asian Air Quality's (ASIA-AQ) support of South Korea's Geostationary Environment Monitoring Spectrometer (GEMS) and the European Space Agency's (ESA) Sentinel-5P TROPOspheric Monitoring Instrument (TROPOMI). The ER-2 flights during PACE-PAX supported the recent launch of Earth Cloud, Aerosol and Radiation Explorer (EarthCARE), a joint European and Japanese satellite.

Over 950 hours of FY24 NASA Airborne Science flights also supported future space-based satellites and instruments, including Surface Biology and Geology (SBG), Hyperspectral Infrared Imager (HyspIRI), NASA and ASI's Multi-Angle Imager for Aerosols (MAIA), and international missions such as Global Observing SATellite for Greenhouse gases and Water cycle (GOSAT-GW) from Japan. The Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) NASA facility instrument was especially busy in FY24, flying several missions on the C-20A for over 230 flight hours, partially in support of the future (~FY25) launch of NASA-ISRO Synthetic Aperture Radar (NISAR). Table 7 summarizes the satellite support that NASA ASP provided, both nationally and across the world, in FY24.

Table 7. *Airborne missions supporting various Earth Science space-based missions in FY24.*

Satellite	Status	Agency	Mission(s)	Location(s)	Flight Hours	Aircraft
U.S.- Based Agencies						
PACE	Launched 2024	NASA	PACE-PAX, BioSCape, Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	South Africa, California	453.6	ER-2, Twin Otter CIRPAS, GV, G-III, DA B-200
Landsat 8	Launched 2013	NASA, USGS	WDTS, BioSCape, Airborne Aquatic Science & Applications for the Sacramento-to-San Joaquin River Delta	California, South Africa	332.3	ER-2, GV, G-III, DA B-200
ICESat-2	Launched 2018	NASA	ARCSIX, ICESat-2 Lake Ice 2024	Greenland, WFF	323.1	P-3, G-III
ECOSTRESS-ISS	Launched 2018	NASA	BioSCape, Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	South Africa, California	312.4	GV, G-III, DA B-200
SBG	TBD	NASA	WDTS, BioSCape	California, South Africa	309.3	ER-2, GV, G-III
GEDI-ISS	Launched 2018	NASA	BioSCape, LVIS-GEDI-EDGE 2024	South Africa, WFF	295	GV, G-III, P-3
HyspIRI	TBD	NASA	WDTS, Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	California	42.9	ER-2, DA B-200
EMIT	Launched 2022	NASA	EMIT cal/val for GHG Center	CONUS	41.8	DA B-200
TEMPO	Launched 2023	NASA	SCOAPE-II	Gulf of America	40.1	DA B-200
International Agencies and Collaborations						
Sentinel-5P TROPOMI	Launched 2017	ESA	ASIA-AQ, SCOAPE-II, CHAPS-D	Asia (Philippines, South Korea, Thailand, and Taiwan), Gulf of America, LaRC	423.3	DC-8, G-III, B-200 (LaRC and DA)
NISAR	Launch planned 2025	NASA, ISRO	AfriSAR II, Germany Bistatic Experiment, engineering flights for P- and L-band, and various missions studying landslide kinematics, fault lines, land subsidence, earthquakes, and fires	Africa (Ghana, São Tomé and Príncipe, Cameroon, Gabon, Democratic Republic of the Congo, and Republic of the Congo), Europe (Germany), United States (CA, CO)	239.32	C-20A
GOSAT-GW	Launch planned 2025	JAXA, MOE, NIES	ASIA-AQ, CHAPS-D	Asia (Philippines, South Korea, Thailand, and Taiwan), LaRC	221.7	G-III, B-200
MAIA	TBD	NASA, ASI	ASIA-AQ, AirMSPI-2	Asia (Philippines, South Korea, Thailand, and Taiwan), AFRC	165.4	DC-8, ER-2
Biomass	Launch planned 2025	ESA	AfriSAR II	Africa (Ghana, São Tomé and Príncipe, Cameroon, Gabon, Democratic Republic of the Congo, and Republic of the Congo)	155.5	C-20A
EarthCARE	Launched 2024	ESA, JAXA, NICT	PACE-PAX	California	80.9	ER-2
SWOT	Launched 2022	NASA, CNES	ABoVE	Alaska, Canada	48.9	G-III

Select Missions on ASP Aircraft in FY24

The missions highlighted in this category flew ASP-supported aircraft in FY24 in support of studying Earth Science topics, including snow and ice, contrails and clouds, vegetation and biodiversity, air quality and pollution, lakes and oceans, and more.

SnowEx

PI: Batuhan Osmanoglu (NASA GSFC)
Program: Terrestrial Hydrology
Aircraft: NPS CIRPAS Twin Otter
Payload: SWESARR

The 2023 NASA SnowEx campaign focused on studying snow in the tundra and boreal forest regions of Alaska. This comprehensive effort included a no-/ low-snow data acquisition in October 2022 and October 2023, a snow-on campaign in March 2023 utilizing airborne radar, radiometer, lidar, and stereophotogrammetry observations, and a snow melt campaign in April 2023 targeting hyperspectral data collection.

Ground-based measurements were crucial for validation, covering both ground and snow conditions such as soil moisture, freeze-thaw state, and snow characteristics. These measurements included soil samples, snow pits, snow depth transects, and microstructure assessments. Airborne observations complemented ground data with active/passive microwave using the GSFC Snow Water Equivalent (SWE) Synthetic Aperture Radar and Radiometer (SWESARR) instrument, lidar and stereo imagery from the University of Alaska Fairbanks, and hyperspectral data collection using the JPL AVIRIS-NG instrument. Coincident satellite observations further enhanced the dataset.

Instruments like SWESARR contributed significantly to data collection and algorithm enhancement by delivering multi-frequency active and passive microwave observations. Together with the ground measurements, the SWESARR data will help advance SWE retrieval algorithms and validate microwave radiative transfer models for SWE. SWESARR was flown on the NPS CIRPAS Twin Otter aircraft during the March and October 2023 Intensive Observing Periods, collecting 10 TB of data during 12 total flight days over three boreal forest and two tundra sites.

The SnowEx campaign addressed critical gaps in snow science, aiming to improve understanding and monitoring techniques for SWE and snow-surface energy balance,

Figure 5. *SWESARR flight crew in Fairbanks, AK in front of the NPS Twin Otter. The radar antenna is behind the yellow radome installed in the port-aft door.*

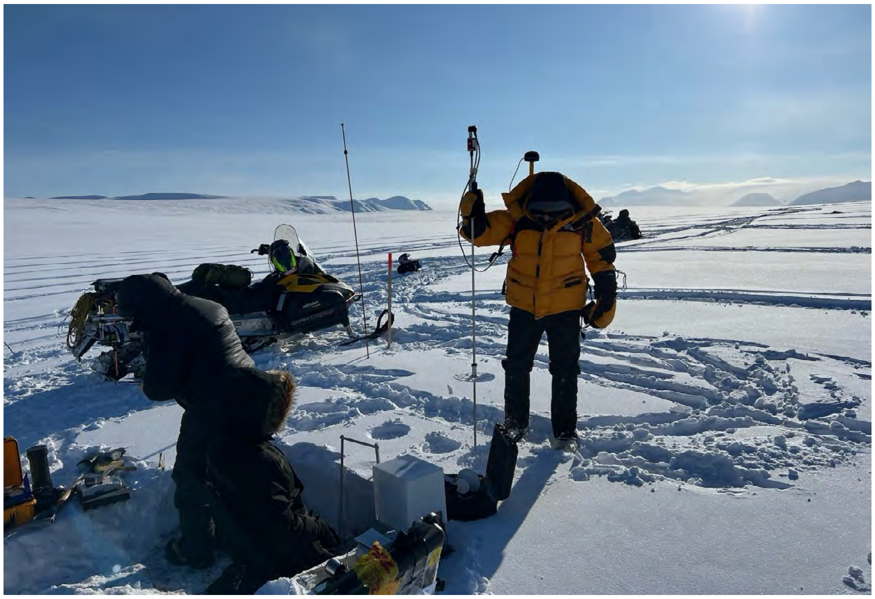

Figure 6. *Measuring snow profile information and depth at the SnowEx Upper Kuparuk-Toolik tundra site to compare against remotely sensed measurements from aircraft.* ***Credit:*** *S. Stuefer/ University of Alaska, Fairbanks*

and pave the way for future advancements in global snow monitoring and understanding. The campaign leveraged the expertise of scientists and students from multiple organizations and universities, aiming to expand the pool of experienced observers. Safety was paramount, with rigorous training and risk reduction measures implemented.

SnowEx 2023 supported the overall NASA Terrestrial Hydrology Program's goals by focusing on snow remote sensing challenges unique to tundra and boreal forest environments. The campaign's objectives included evaluating the impact of forest on SWE retrievals, assessing the accuracy of modeled snow microstructure, and understanding the temporal and spatial variability of snow reflectance/albedo and other snow physical properties. A unique sampling strategy was designed by the SnowEx leadership team, which included ground and airborne data over sites multiple sites in Alaska. By combining these distinct datasets, SnowEx 2023 will help meet the objectives and advance global science related to seasonal snow.

ecoDemonstrator

PIs: Richard Moore (NASA LaRC), Steve Baughcum (Boeing), Bill Griffin (Boeing)
Programs: Radiation Science, Tropospheric Composition, ARMD Advanced Air Vehicles, ARMD Advanced Air Transport Technologies Project
Aircraft: NASA DC-8, Boeing 737-10
Payload: DLH, DACOM, LARGE, DLR Aerosol, DLR CHEMEX, DLR Cloud, HALO, Aerodyne WV, MMS, S-HIS

Aircraft contrails are of great scientific interest given their ubiquity and potential for impacting the Earth's radiation budget. Yet, a recent scientific assessment indicates that contrail cirrus clouds being formed by jetliners today may have an even greater climate warming effect than the cumulative aviation CO_2 emissions since the dawn of the jet age (Lee et al., 2021). Sustainable aviation fuels (SAFs) hold great promise for the future of aviation by combatting both effects by reducing the emissions of fossil-derived carbon as well as the soot particles that seed contrails.

Recently, teams from NASA LaRC, AFRC, GRC, and ARC joined with Boeing, United, GE

Aerospace, DLR, FAA and other national and international partners to study how SAFs affect contrail formation in some of the cleanest-burning aircraft engines currently on the market – the CFM LEAP-1B engines on a Boeing 737-10. Through a series of 11 joint science sorties over the northwest United States in October 2023, the team garnered over 100 combined DC-8 and Boeing 737-10 flight hours sampling both contrail and clear air conditions. The twin-engine Boeing aircraft burned 100% SAF as well as two different conventional, petroleum-based Jet A fuels with low and moderate fuel sulfur content. The project was sponsored by the NASA ARMD Advanced Air Vehicles Program and the Radiation Sciences and Tropospheric Composition Programs within SMD's Earth Science Division.

The goal of this research was to understand how fuel composition impacts the engine particle emissions at cruise altitudes with specific interest in aromatics as non-volatile soot precursors and sulfur, organic, and oil compounds that can nucleate volatile particles. NASA has conducted similar past studies behind a German A320 during the 2018 ND-MAX flight test and behind the DC-8 itself during the 2014 ACCESS flight series, but the modern state-of-the-art LEAP-1B engines were a game changer that made it challenging for the researchers to discern almost any soot particles in the plume relative to the background atmosphere. The team is now actively working to quantify the effects of reduced soot particles and formation of volatile particles on the contrail ice crystal numbers and sizes, and they presented their initial findings at a project science team meeting in Washington, D.C. in May 2024.

Getting the project off the ground required a substantial effort from subject matter experts within NASA ARMD and ASP (notwithstanding the threat of a narrowly averted government shutdown). Initial efforts focused on modeling the formation and decay of wingtip vortices from the lead aircraft that could pose in-flight hazards to the trailing DC-8. The engineering team at NASA AFRC used these model calculations to establish the project flight rules and fly / no-fly zones, which in turn helped the airborne scientists to refine their instrument requirements.

Figure 7. *The NASA DC-8 and Boeing 737-10 fly over the northwest United States.* ***Credit:*** *A. Wolfe/Boeing*

Figure 8. *The DC-8 follows the wake of the Boeing 737-10 during ecoDemonstrator.* ***Credit:*** *P. Weatherman/ Boeing*

One new and exciting aspect of the project was the use of the HALO high-spectral resolution lidar to map the structure and descent of the contrail after the ice crystals become entrained in the vortices. Not only did this allow the scientists to study the microphysical and optical properties of the contrail (relevant for climate), but these data also feedback and improve the assumptions that went into the vortex hazard models.

The project also broke new ground in flight testing novel water vapor sensors currently being developed for commercial aircraft through NASA's Small Business Innovation Research (SBIR) Program. The DC-8 provided an ideal testbed to evaluate and advance these sensors alongside the state-of-the-art research sensors available through the Airborne Science Program, such as the Diode Laser Hygrometer (DLH). These low-TRL, NASA-funded technologies would then be infused throughout the commercial aviation fleet in order to improve the meteorology in contrail forecasting models by leveraging investments from industry and

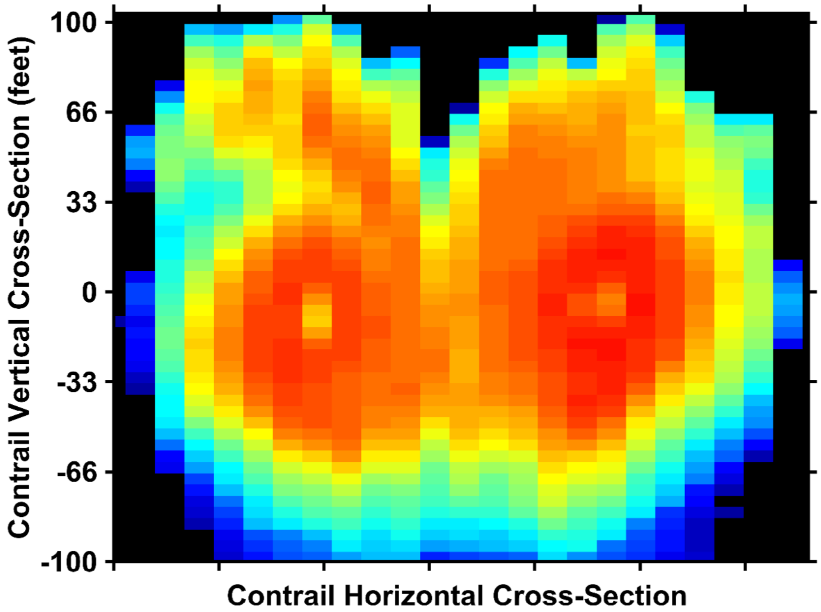

Figure 9. *Cross-sectional view of the two contrail vortices measured by the nadir High Altitude Lidar Observatory (HALO) instrument onboard the DC-8.* ***Credit:*** *Amin Nehrir/ NASA LaRC*

other government programs (e.g., ARPA-E Pre-Trails). The aviation sector is critical to the global economy, and this exciting collaboration between the SMD ASP and the ARMD Advanced Air Vehicles Program continues to advance the fuels, technologies, and operational models needed to ensure a sustainable future.

2023 ecoDemonstrator Emissions Test Sampling Approach and DC8 Fly Zones

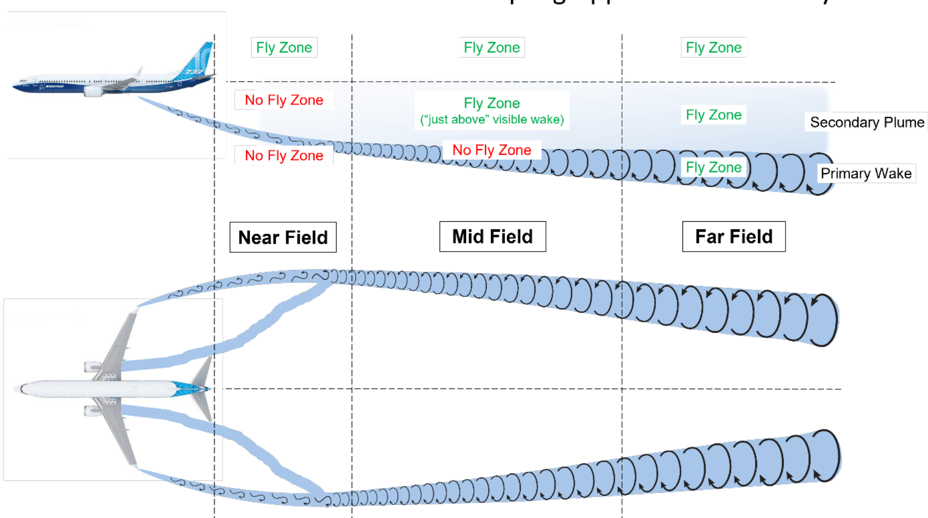

Figure 10. *Concept-of-operation and fly / no-fly zones for ecoDemonstrator. Most of the time was spent sampling the secondary emissions plume in situ just above the visible wake at about 5 miles in trail. Lidar remote sensing legs conducted with 3-5 kft vertical separation allowed the DC-8 to profile the contrail from the near field to the far field.* ***Credit:*** *NASA*

Biodiversity Survey of the Cape (BioSCape)

PI: Adam Wilson (University at Buffalo)
Program: Biological Diversity
Aircraft: GV, G-III
Payload: GV: HyTES, LVIS; G-III: AVIRIS-NG, PRISM

The Biodiversity Survey of the Cape (BioSCape) was NASA's first biodiversity-focused airborne campaign. The BioSCape domain in South Africa covers two global biodiversity hotspots, with the richest temperate flora and the third-highest marine endemism in the world. BioSCape tested the limits and potential of remote sensing for biodiversity applications worldwide and will take us one step closer to measuring biodiversity variables globally from space.

BioSCape's Unprecedented Dataset Focuses on Accessibility for Biodiversity Science

Concurrent measurements were captured across the region in October and November 2023: from the following NASA instruments: AVIRIS-NG, PRISM, HyTES, and LVIS. Such a spectrally extensive dataset is unprecedented in airborne science and, when coupled with structural lidar data, can increase the impact of current and upcoming satellite missions including ECOSTRESS, GEDI, EMIT, PACE, STV, and SBG. The GV (HyTES + LVIS) flew 16 science flights while the G-III (AVIRIS-NG + PRISM) flew 22 science flights, together covering ~45,000 km^2 and meeting the data priorities of all 18 PI-

Figure 11. *Members of the BioSCape Science, Aircraft, and Instrument teams in front of the JSC GV and the LaRC G-III in Cape Town, South Africa.* ***Credit:*** *Otto Whitehead*

led BioSCape projects. In addition to traditional L1 and L2 products, BioSCape will produce a co-registered mosaic of L2 data from all four instruments. This is the first time an airborne campaign has done this. This will dramatically increase the accessibility of the data, especially for new users. The current versions of the airborne data can be found at bioscape.io/data. Data access and analyses will be supported for both South African and U.S. data users via the "BioSCape Cloud" computing environment.

The airborne data were accompanied by a large amount of biodiversity field data, including the following:

- Over 600 vegetation survey plots across environmental gradients, and field spectroscopy measurements from all dominant species
- Phytoplankton, bio-optics, and water quality data from marine and freshwater systems
- eDNA surveys from rivers' source to sea
- Sound recordings and point counts of birds and frogs across the region to further understand

Figure 12. *BioSCape Science Team member Andrew Turner (CapeNature) deploying an Audiomoth acoustic logger in South Africa.* ***Credit****: Jeremy Shelton*

the ecosystems imaged by instruments on the aircraft

- Terrestrial lidar scans across a fire return-time gradient
- Quantification of essential biodiversity variables in estuaries along the coastline
- Detailed biodiversity and ecosystem function measurements in plots with varying levels of invasion by alien plants
- Species surveys and field spectroscopy measurements on kelp forests along the coastline.

This comprehensive collection of ground-based data is vital for interpreting and validating the insights gleaned from the airborne campaign.

BioSCape's Support for Decision-Making Needs in the Region and Globally

Since its conceptualization, BioSCape emphasized ensuring impact of the work, creating and maintaining deep and meaningful collaboration between researchers in the U.S. and South Africa and continuously emphasizing the importance of co-developing research. Early inclusion of South Africans led to a diverse Science Team of over 160 members, of which approximately half are affiliated with South African institutions and half with U.S. institutions. The U.S. participation on the team ensured global applicability, access to best-in-class technology, and bridged gaps in capacity. The strong South African presence on the team ensured that the research agenda for BioSCape was locally relevant and that local ecological expertise was incorporated. Many South African collaborators are embedded within local, provincial and national public conservation and environmental management agencies.

To take advantage of this, before starting data collection, we brought the science team and local stakeholders together for a five-day

Figure 13. *BioSCape PI Jinghui Wu (Columbia U) taking radiometric measurements of South African coastal ocean waters to measure phytoplankton functional types in support of coastal resource management.*
Credit: *Otto Whitehead*

Figure 14. *School students participating in NASA's GLOBE outreach program in Cape Town, South Africa (run by Brenna Biggs NASA ASP-GLOBE Engagement Coordinator).*
Credit: *Brenna Biggs*

Figure 15. *BioSCape Science Team members Jacob Nesslage (UC Merced) and Matthew Rossi (U Colorado) collecting environmental DNA samples in a river in South Africa.* ***Credit:*** *Jeremy Shelton*

in-person workshop to ensure the research was relevant for local decision-making needs for biodiversity conservation and natural resource management.

BioSCape's Support for Outreach and Capacity Building

BioSCape supported several community outreach events, including a public lecture attended by 150 local stakeholders, a school education program run by GLOBE that reached nearly 170 students from 10 schools, the development of a NASA Space Apps challenge attempted by 71 teams around the world as well as two local NASA SpaceApps events for high school students and the Graduate Student Conference for the South African Environmental Observation Network where 144 students had the opportunity to engage with BioSCape scientists. We also ran a workshop on the Nagoya Protocol (co-hosted by a U.S. and South African representative), which guided documentation of shared benefits of the research (i.e., ways in which both South African and U.S. counterparts benefit from the research). Such a document is vital for managing expectations and keeping teams focused on how South African and U.S. members benefit from working together. BioSCape also has a Code of Conduct that includes clear authorship guidelines, ran a pre-deployment Ethical Participation training course, and had zero reports of harassment or safety issues during the campaign.

BioSCape worked with NASA's Applied Remote Sensing Training (ARSET) program to host a training webinar series that focused

Figure 16. *BioSCape Science Team member Elhadi Adam (U Pretoria) collecting spectroscopy measurements of estuarine vegetation in South Africa.* ***Credit:*** *Jeremy Shelton*

Figure 17. *School students participating in NASA's SpaceApps Hackathon event organized by BioSCape's partners at the South African Environmental Observation Network in Cape Town, South Africa.* ***Credit:*** *Adam Wilson*

on the BioSCape sensors and how they could be applied to biodiversity monitoring. BioSCape also worked with NASA's ORNL DAAC to present a training webinar on the NASA DAACs, what they do, how to use them to archive your data, and data best practices. Most recently, the team hosted a 5-day joint ARSET and ORNL DAAC in-person training event, the "Field Spectroscopy and Data Skills Workshop" in Cape Town, South Africa from October 7 to 11, 2024. The workshop aimed to increase the ability of end users to access and use BioSCape and NASA Earthdata in their work and decision making. Specifically, it provided tools for participants to utilize field (terrestrial and aquatic), airborne (AVIRIS-NG, PRISM, HyTES, and LVIS), and orbital (EMIT, ECOSTRESS, PACE, and GEDI) data to engage with a range of biodiversity-related topics including: harmful algal blooms, water quality, post-fire recovery, invasive species, diversity indices, and plant functional traits.

Figure 18. *ORNL DAAC and ARSET partnered with BioSCape to host a 5-day in person capacity building workshop in Cape Town in October 2024.* ***Credit:*** *NASA*

Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)

PI: James Crawford (NASA LaRC)
Program: Tropospheric Composition
Aircraft: NASA DC-8, NASA G-III, numerous international partner aircraft
Payload: DC-8: SAGA, WAS, LARGE, ISAF, DACOM, AS-TEM, K-SP2D/K-SP2, PTR-MS, CHARON, MGA, TOGA, Chemilunimescence, HR-ToF-AMS, K-AMS, K-ACES, LGR-AAT, GT-CIMS, K-CIMS, CIT-CIMS, CAFS, K-CCN, OPALS, TILDAS, MMS; G-III: GCAS, HSRL-2, KT15

The Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ) mission was an international collaboration that aimed to understand the factors impacting air quality over major metropolitan areas in Asia.

Using models and stations on the ground, instruments on satellites, and airborne measurements from science aircraft, the ASIA-AQ study was a collaborative effort between NASA and many international partners to collect and analyze data samples across multiple locations in Asia. NASA partnered with Korea's National Institute of Environmental Research (NIER), the Philippines' Department of Environmental and Natural Resources (DENR), Thailand's Geo-Informatics and Space Technology Department Agency (GISTDA), Taiwan's Ministry of Environment (MOENV), Malaysia's University of Kebangsaan, and other local scientists, air quality agencies, and relevant government partners. More than 30 universities and 16 organizations worldwide supported this mission, and a shared-data policy facilitated meaningful scientific discourse throughout all phases of the study.

From February through March of 2024, researchers flew onboard NASA aircraft outfitted with scientific instruments specific to the ASIA-AQ mission. NASA's G-III aircraft flew 209 flight hours at high altitudes with GEOstationary Coastal and Air Pollution Events (GEO-CAPE) Airborne Simulator (GCAS) and High Spectral Resolution Lidar 2 (HSRL-2), remote

Figure 19. *DC-8 at Osan Air Base in Osan, South Korea.* ***Credit:*** *Thomas Matthews/ NASA AFRC*

sensing instruments which gathered information about the column densities of nitrogen dioxide and formaldehyde as well as the profiles of aerosols and ozone. The DC-8 aircraft flew a payload of 26 instruments for 161.5 flight hours at low altitudes measuring in situ parameters related to pollution, including gas-phase and aerosol composition.

Figure 20. *DC-8 shadow over the Yellow Sea during an ASIA-AQ science flight.* ***Credit:*** *S. Kim*

Together, the science team gathered comprehensive airborne datasets over the Philippines, South Korea, Thailand, and Taiwan, with the following goals:

- Validating and interpreting satellites (including South Korea's Geostationary Environment Monitoring Spectrometer, or GEMS)
- Quantifying and verifying emissions
- Evaluating models
- Understanding regional aerosol and ozone chemistry.

The collaborative and international spirit of ASIA-AQ endures, as scientific discussions of these gathered data continue today.

Figure 21. *Happy faces and thumbs-up onboard NASA G-III during a successful ASIA-AQ instrument check flight.* ***Credit:*** *NASA*

Figure 22. *G-III on the ramp at Osan Air Base in South Korea.* ***Credit:*** *Rafael Luis Méndez Peña*

ICESat-2 Lake Ice Calibration and Validation Campaign

PI: Nathan Kurtz (NASA GSFC)
Program: Cryospheric Science
Aircraft: NASA P-3
Payload: LVIS

Lakes provide unique insights into the effects and mechanisms of climate change. World-wide, the surface warming of lakes has been observed to be about 0.2 °C per decade. In the cold seasons, some lakes freeze over creating an ice cover that affects the nearby weather and climate, coastal erosion, shipping, and human safety. The Great Lakes in the U.S. have a particularly large influence on local weather and shipping but have widely varying ice coverage from year to year. The maximum extent of ice in the Great Lakes has varied from lows of around 10% to highs of 95% with a long-term average of about 53% observed since 1973. To fully understand lake ice dynamics and processes, however, we need to know the thickness of the ice in addition to the extent.

Figure 23. *Thin ice seen in southern Lake Huron.* ***Credit:*** *Nathan Kurtz/ NASA GSFC*

Figure 24. *Thick ice seen in northern Lake Huron.* ***Credit:*** *Nathan Kurtz/ NASA GSFC*

NASA's ICESat-2 mission uses laser altimetry to accurately determine surface height, which can be used to infer the amount of ice floating above the water surface and total thickness of the ice. This is done routinely over sea ice-covered regions in the polar oceans where ice is thick. However, more research is needed to verify whether similar retrieval algorithms could work over lake ice surfaces, which have thinner ice and more complex water surface topography.

In February and March 2024, the ICESat-2 mission launched an airborne calibration and validation campaign over the ice-covered Great Lakes. Two underflights of ICESat-2 tracks over lake ice-covered regions in Lake Huron were conducted with the NASA P-3 aircraft. The P-3 was equipped with the Land, Vegetation, and Ice Sensor (LVIS) taking wide swath laser altimetry measurements along with imagery data to calibrate and validate the ICESat-2 retrieval algorithms. The goal of the flights was to target different ice regimes of the Great Lakes. Unfortunately, 2024 was a year of low ice extent with limited targets to choose from, but underflights were conducted in a thin ice region in southern Lake Huron and a thick ice region in the northern part of the lake. Overall, excellent data were collected by both LVIS and ICESat-2 and are presently being analyzed to further develop lake ice retrieval algorithms from ICESat-2 and assess their accuracy for future data products.

Western Diversity Time Series (WDTS)

PI: Rob Green
Program: Biological Diversity; Earth Surface and Interior; Research and Analysis
Aircraft: NASA ER-2
Payload: AVIRIS C, MASTER

Since 2011, multi-spectral imagery has been collected annually over California locations using primarily the MODIS/ASTER Airborne Simulator (MASTER) and Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) instruments. This time-series dataset is invaluable for algorithm development and process understanding, as the imagery spans multiple seasons over many years. Originally planned for the future Hyperspectral InfraRed Imager (HyspIRI) mission, the data set now serves as precursor to Surface Biology and Geology (SBG) and will also be used in post-launch cal/val activities. This mission will provide critical information on natural disasters such as volcanoes, wildfires, and drought and create a benchmark on the state of the ecosystems against which future changes can be assessed. In FY24, the campaign flew 4 flights in June on the ER-2 for a total of 19.9 flight hours over California and Nevada.

Figure 25. *Sample imagery from WDTS in June 2024 showing Lake Tahoe, California.* ***Credit:*** *NASA*

Africa Synthetic Aperture Radar (AfriSAR) II

PI: Yunling Lou (NASA JPL)
Program: Terrestrial Ecology, Earth Surface and Interior
Aircraft: NASA C-20A
Payload: LVIS, UAVSAR / L-Band, UAVSAR / P-Band / AirMOSS

The AfriSAR II campaign, which occurred between May and July 2024, surveyed forests and wetlands to provide an unprecedented view of tropical ecosystems in Western and Central Africa. The NASA C-20A supported sequential deployments with two Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instruments, first carrying the P-band UAVSAR (5/20/24 to 6/11/24), then returning to California to pick up the L-band UAVSAR to support a second deployment (6/26/24 to 7/14/24).

This effort generated P-band coverage of 18 study sites in Ghana, São Tomé and Príncipe, Cameroon, Gabon, Democratic Republic of the Congo (DRC), and Republic of the Congo (RoC), collecting a total of 51 flight lines. The L-band also collected 66 L-band datasets

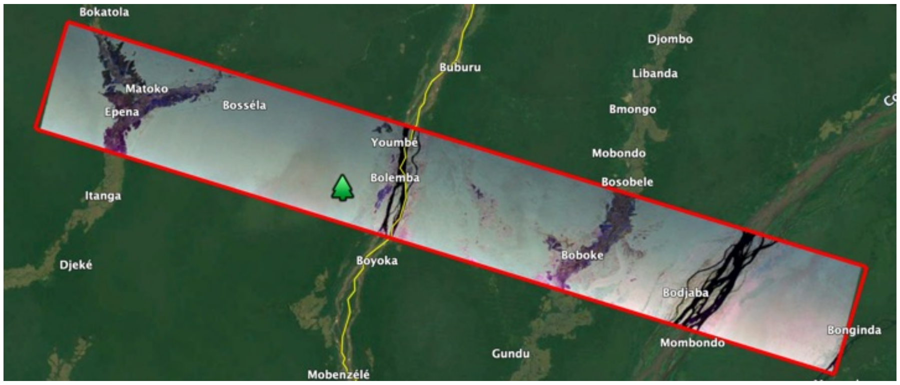

***Figure 26.** UAVSAR L-band imaging of forests and peatlands in DRC and RoC. **Credit:** Yunling Lou/NASA JPL*

covering 16 study sites in Cameroon, Gabon, DRC, and RoC.

***Figure 27.** The AfriSAR II team celebrates July 4th in São Tomé (L-R: K. Stallings, E. Torres, T. Renfro, J. Piotrowski, I. Mata, C. Worth, T. Miller, A. Vaccaro, and R. Applegate). **Credit**: J. Piotrowski/NASA AFRC*

The AfriSAR II campaign was designed to complement and augment the airborne observations from the German Aerospace Center's (DLR) Gabon-X 2023 campaign as well as from the Land Vegetation Ice Sensor (LVIS) sensor that flew aboard the NASA G-III in 2023. This joint effort has produced the richest airborne dataset to date of the Congo Basin, filling important knowledge gaps for scientists and fostering collaboration between NASA, the European Space Agency (ESA), DLR, and African institutions. The resulting studies will inform the design of biomass mapping algorithms by the NASA-ISRO SAR (NISAR) and

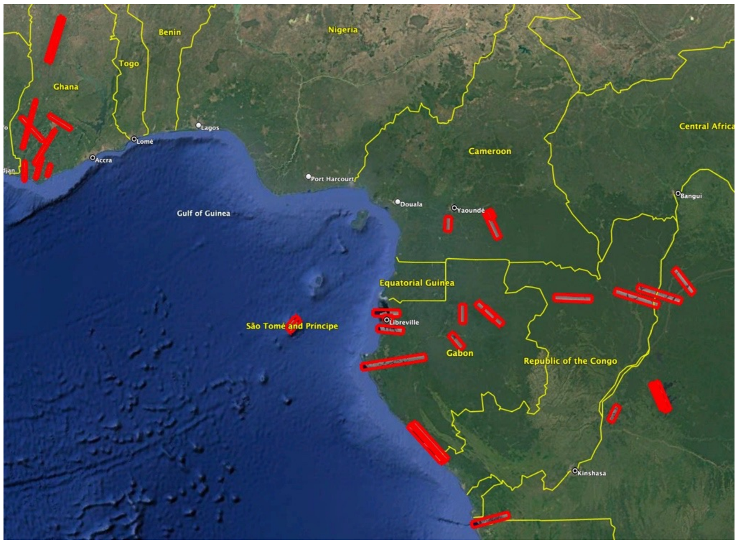

***Figure 28.** During the AfriSAR II 2024 campaign, UAVSAR's P-band and L-band radars imaged 26 study sites in Ghana, São Tomé and Príncipe, Cameroon, Gabon, RoC and DRC.*

ESA's Biomass missions; both include space-borne radars planned to launch in 2025.

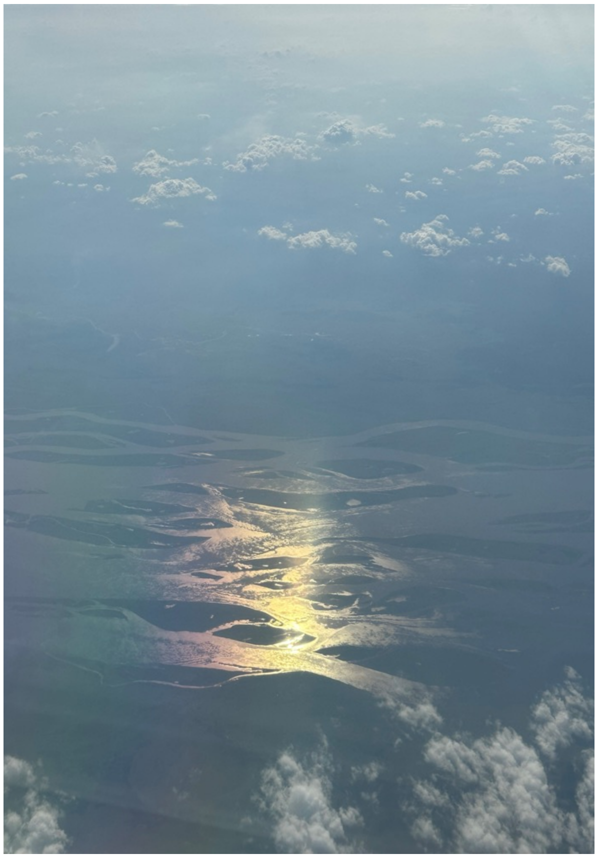

Figure 29. *A view of the Congo River from the NASA C-20A.* ***Credit:*** *J. Piotrowski/NASA AFRC*

Arctic Radiation-Cloud-aerosol-Surface-Interaction eXperiment (ARCSIX)

PI: Sebastian Schmidt (University of Colorado, Boulder)
Program: Radiation Science
Aircraft: NASA P-3, NASA G-III, SPEC Learjet
Payload: P-3: LVIS, ATOFMS, MARLi, FIMS, SPEC, DASH, BBR, CFDC, LARGE, RSP, Winds, DLH; G-III: AVIRIS-NG, HALO; SPEC Learjet: cloud microphysical measurements, cloud radar

The role of the Arctic within the global climate system is changing. Over the last 40 years, the Arctic sea ice pack transformed from a predominantly thick, multi-year sea ice to a predominantly thin, seasonal sea ice, termed the "New Arctic." This transformation of Arctic sea ice is not only impacting the Arctic climate system but sends ripples across the globe. Substantial uncertainty exists in understanding the atmosphere-surface interactions within the Arctic system, specifically the role and evolution of "goldilocks" clouds (i.e., clouds that have the ideal particle size to increase their albedo), limiting the ability to anticipate how the Arctic's role in the global climate system will change in the future.

Figure 30. *Pilots K. Stallings and C. Worth flying the NASA C-20A.* ***Credit:*** *J. Piotrowski/NASA AFRC*

Figure 31. *ARCSIX Science Team pose in front of the NASA P-3 and NASA G-III in a hangar in Greenland.*
Credit: *Dan Chirica/NASA*

To better understand these drastic Arctic changes, Arctic Radiation-Cloud-aerosol-Surface-Interaction eXperiment (ARCSIX), took place for approximately 7 weeks between May and August 2024. ARCSIX brought together scientists from more than 22 different domestic and international institutions. The campaign, which was based at Greenland's Pituffik Space Base, consisted of two airborne deployments: May 24 to June 16, 2024, and July 22 to August 16, 2024. These two periods were selected to capture sea ice properties and atmospheric characteristics at the beginning and near the end of the sea ice melt season.

ARCSIX science was guided by three broad science questions that encapsulate the key influences of radiation-cloud-aerosol-sea ice coupling and a remote sensing and modeling objective:

- Science Question 1 (Radiation): What are the impacts of the predominant summer Arctic cloud types on the radiative surface energy budget?
- Science Question 2 (Cloud Life Cycle): What processes control the evolution and maintenance of the predominant cloud regimes in the summertime Arctic?
- Science Question 3 (Sea Ice): How do the two-way interactions between surface properties and atmospheric forcings affect the sea ice evolution?
- Remote Sensing and Modeling Objective: Enhance long-term space-based monitoring and predictive capabilities of Arctic sea ice, clouds, and aerosols.

The ARCSIX campaign was highly successful and collected a first-of-its-kind dataset that will be used for decades to understand the drivers of Arctic climate. ARCSIX flew the NASA P-3,

Figure 32. *Chris Youngblood, P-3 crew, with the propeller of the P-3 aircraft during the ARCSIX campaign.* ***Credit:*** *Dan Chirica/NASA*

the NASA G-III, and the SPEC Learjet together, successfully coordinating all three aircraft on four cloud walls and accomplishing over a dozen satellite coordination events.

The G-III—the high-flyer—served as a bridge to satellite observations by surveying with remote sensing instruments from above while the P-3—the low-flyer—acquired in situ aerosol, cloud, atmospheric, and surface properties along with radiation below, above, and inside cloud layers. The SPEC Learjet carried a full suite of cloud microphysical measurements and a newly developed cloud radar. ARCSIX collected approximately 347 science flight hours total:

- NASA P-3 completed 19 science flights (179.5 flight hours traversing >47,000 miles)
- NASA G-III completed 15 science flights (127 flight hours traversing >52,000 miles)
- SPEC Learjet completed 10 science flights (>40 flight hours)

Over the course of the campaign, the surface conditions changed dramatically from snow-covered sea ice to widespread melt ponds. There was a ~0.5 meters (~1.5 feet) loss of sea ice thickness from the sea ice buoys, a major sea ice loss event off the northeast coast of Greenland that extended to the pole, many cases of newly formed ice crystals in “warm” ice clouds (temperatures from -2 to -7 °C), and a wide range of atmospheric aerosol types (e.g., dust, smoke, soot, and marine aerosol). These unique data will enable the team to quantify the contributions of surface properties, clouds, aerosol particles, and precipitation to the Arctic summer surface radiation budget and sea ice melt, and much more.

Arctic-Boreal Vulnerability Experiment (ABoVE)

PI: Charles Miller (NASA JPL)
Program: Terrestrial Ecology
Aircraft: NASA C-20A
Payload: UAVSAR/L-Band

The Arctic-Boreal Vulnerability Experiment (ABoVE) team conducted airborne L-band SAR surveys across northwestern Canada, Alaska, and British Columbia from August 13-26, 2024. They hosted Canadian First Nations VIPs, graduate students, and ABoVE colleagues. They also held open house events in Yellowknife, Northwest Territories (NT) and Fairbanks, Alaksa, attended by approximately 200 and 150 people, respectively.

The 2024 ABoVE airborne campaign covered approximately 75 transects that had been flown for repeat pass interferometry since 2017. The flights in 2024 used the L-Band UAVSAR instrument on the NASA C-20A and focused on areas that were devastated by the record-setting 2023 Canadian fires, particularly the transect extending over Enterprise, NT and Hay River, NT. This was also the first opportunity to observe the damage to the Scotty Creek Research Station caused by the October 2022 fires; the team plans to use before and after imagery to study the impacts of the fires on the station.

The airborne team coordinated flights with the field teams to make simultaneous on-the-ground measurements to validate their data products. Additionally, the teams coordinated

Figure 33. *Canadian students being interviewed by CBC Radio after their flight with the ABoVE L-band SAR team on 15 August 2024.* ***Credit:*** *NASA*

Figure 34. *Visitors queued up to tour NASA-802 in Yellowknife, NT on 15 August 2024. More than 200 people attended the ABoVE open house.* ***Credit:*** *NASA*

Figure 35. *The contrail of NASA C-20A casts its shadow onto Kluane Lake, Yukon, Canada.* ***Credit:*** *Peter Griffith/ GSFC*

flights over the Fort Yukon, AK area with members of the Surface Water Ocean Topography (SWOT) science team, validating the SWOT lake and river water surface elevation products.

This work was highlighted in an *Eos* article in December 2024, which covered how ABoVE researchers are using the airborne SAR data to map the impacts of beaver hydraulic engineering on Alaska's Seward Peninsula: https://eos.org/articles/arctic-beavers-advance-north-and-accelerate-permafrost-thaw.

More information about ABoVE can be found here: https://above.nasa.gov/.

Figure 36. *The ABoVE L-band SAR team after completing a survey of the Mackenzie Valley and northeastern Alaska on August 18, 2024.* ***Credit:*** *NASA*

Figure 37. *Visitors queued up to tour NASA-802 in Yellowknife, NT on 15 August 2024. More than 200 people attended the ABoVE open house.* ***Credit:*** *NASA*

FireSense

PI: Jacquelyn Shuman (NASA ARC)
Program: Carbon Cycle and Ecosystems
Aircraft: Alta-X
Payload: anemometer, radiosonde

Over the past 30 years, only 2% of fires in the United States have escalated into large fires, yet these account for most of the fire-related costs, acres burned, and public threats. Preventing new fires from becoming large or effectively managing existing large fires is crucial for improving wildland fire outcomes. One effective approach is to improve weather forecasts focusing on wind.

Wind is a major factor in fire fatalities, public threats, and unexpected fire growth. To better predict and respond to extreme fire behavior, wind shear, and super-heated gases, there is a need for enhanced tactical microclimate wind forecasting. Additionally, wildfire flame fronts and convection columns containing superheated gases can impair aircraft performance and safety during wildland fire operations. Collecting real-time or near-real-time three-dimensional atmospheric data during wildland fire operations is vital for both ground activities and aviation safety. Traditionally, weather balloons have been used for vertical soundings to identify boundaries signifying changes in the atmosphere, but their use is now restricted due to aircraft operations. New technologies are needed to fill this critical measurement gap.

Figure 38. *The Alta-X UAS taking off in Missoula, MT, on August 27, 2024 in support of the NASA FireSense Project.* ***Credit:*** *Milan Loiacono/NASA ARC*

The NASA FireSense project is focused on delivering NASA's unique Earth science and technological capabilities to operational agencies, striving to address challenges in U.S. wildland fire management. FireSense is focusing on four use-cases to support decisions before, during, and after wildland fires:

- Pre-fire fuels conditions
- Active fire dynamics
- Post-fire impacts and threats
- Air quality forecasting

Each of these were co-developed with identified wildland fire management agency stakeholders.

Addressing the need for enhanced tactical microclimate wind forecasting aligns with the FireSense use cases. Using a holistic approach, technology transfer also pairs with understanding what data to collect, where, and when it will lead to better forecasts. Further exploration into artificial intelligence (AI) computing, along with airborne weather sensors and data links is required.

Figure 39. *Preparing for a weather balloon launch in Missoula, MT, on August 27, 2024 in support of the NASA FireSense Project.* ***Credit:*** *Milan Loiacono/NASA ARC*

In collaboration with MITRE Corporation and Environmental Systems Research Institute, Inc. (Esri), a technology demonstration of Uninhabited Aerial Systems (UAS) for atmospheric vertical soundings was held in Missoula, MT, from August 27 to 29, 2024. This demonstration featured a NASA-designed payload on an Alta-X drone—consistent with current United States Forest Service (USFS) UAS operational platforms—and included co-located balloon soundings for data validation. Missoula was selected for its complex mountain terrain, which produces erratic, historically unpredictable wind behavior.

Over the course of the three-day campaign, a UAS team from NASA LaRC conducted eight UAS flights to collect data. Before each drone flight, student teams from the University of Idaho and Salish Kootenai College launched a weather balloon carrying the same type of sensor to validate the drone data.

As data were gathered from both the balloon and the drone platforms, they were sent to two on-site data teams. MITRE tested high-resolution AI meteorological models and Esri created comprehensive visualizations of flight paths, temperature, and wind to establish what and how conditions were changing.

This was an organized, cohesive field demonstration highlighting promising technology—which speaks to the strength of the collab-

Figure 40. Preparing the Alta-X for takeoff in Missoula, MT on August 27, 2024 in support of the NASA FireSense Project. ***Credit:*** *Milan Loiacono/ NASA ARC*

orations displayed during the deployment. Developing this technology didn't begin in Missoula, and it won't end there. This campaign leveraged almost a decade of research, development, engineering, and testing. UAS flight capability can now be used across NASA, continuing to improve.

The NASA Alta-X and its sensor payload will head to the Southeastern United States in 2025, incorporating improvements identified in Montana, where it will perform another sounding demonstration in active fire conditions, in front of practitioners in a different region who may employ this technology in the near future.

Plankton, Aerosol, Cloud, ocean Ecosystem Postlaunch Airborne eXperiment (PACE-PAX)

PI and Co-Is: Kirk Knobelspiesse (PI; NASA GSFC); Ivona Cetinić (Co-I; NASA GSFC / Morgan State University), Brian Cairns (Co-I; GISS)
Aircraft: NASA ER-2, NPS CIRPAS Twin Otter
Ship: NOAA R/V Shearwater
Payload: ER-2: AirHARP, HSRL-2, PICARD, PRISM, RSP, SPEX Airborne; CIRPAS Twin Otter: LARGE, PI-Neph, facility in situ instruments; NOAA R/V Shearwater: Cimel 318-T, SeaSTAR, NASA GSFC Field Support Group, NOAA facility instruments and others

The PACE Postlaunch Airborne eXperiment (PACE-PAX) was a field campaign conducted in September 2024 in California and nearby coastal areas for the purposes of validating data from the newly launched Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission. As its name

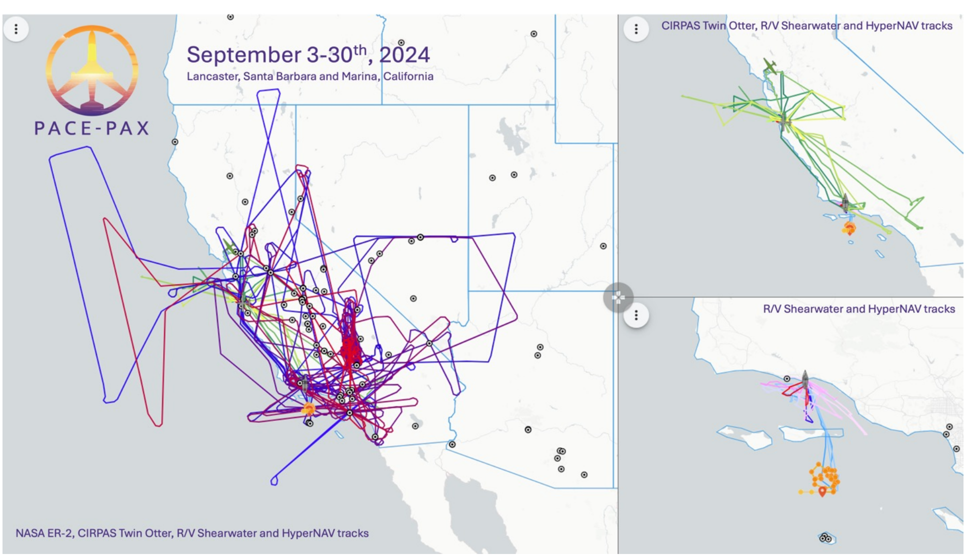

Figure 41. *PACE-PAX airborne and water-borne tracks.* ***Credit:*** *PACE-PAX Science Team*

Figure 42. *The Bridge Fire in the San Gabriel Mountains as seen from the ER-2, September 10, 2024.* ***Credit:*** *Kirt Stallings*

suggests, PACE is a multi-disciplinary mission, so validation requires measurements of many parameters in varied conditions. PACE-PAX also gathered data to validate the ESA Earth Cloud Aerosol and Radiation Explorer (EarthCARE), which was also launched in early 2024.

Twenty-five individual validation objectives drove the PACE-PAX design. The ER-2, based at NASA AFRC, carried remote sensing instruments, some of which had similar characteristics to sensors on PACE and served as measurement proxies. Others were valuable for validating EarthCARE. The NPS CIRPAS Twin Otter aircraft had a complement of in situ aerosol and cloud sampling instruments, and flew from Marina, California. The NOAA R/V Shearwater, a Channel Islands National Marine Sanctuary research vessel, operated day trips from Santa Barbara, California, and carried in-water, surface and upward-looking

Figure 43. *The Golden Gate and San Francisco on September 12, 2024 from the CIRPAS Twin Otter during PACE underflights.* ***Credit:*** *Luke Ziemba*

Figure 44. *The CIRPAS Twin Otter team in Marina, California during PACE-PAX.* ***Credit:*** *PACE-PAX Science Team*

instruments from the NASA GSFC Field Support Group, NOAA, and others from the PACE Validation Science Team (PVST). Logistical support for PACE-PAX was provided by NASA ESPO, and aerosol modeling support was provided by NASA GMAO.

PACE-PAX also collaborated with externally funded groups, such as the R/V Blissfully operating from Long Beach, California, University of Delaware autonomous ocean gliders, and Oregon State University HyperNav vicarious calibration ocean floats. Coordinated observation with these assets and under PACE and EarthCARE was a key aspect of PACE-PAX.

Thanks to the dedication and teamwork of its distributed team, PACE-PAX met its baseline validation objectives, achieving the following:

- 13 NASA ER-2 science flights, totaling 80.9 flight hours
- 17 CIRPAS Twin Otter science flights, totaling 60 flight hours
- 15 NOAA R/V Shearwater day trips
- 16 days of targeted observations during a PACE overpass
- 6 days of targeted observations during an EarthCARE overpass

As expected, PACE-PAX encountered generally cloud-free conditions over land, and a mix

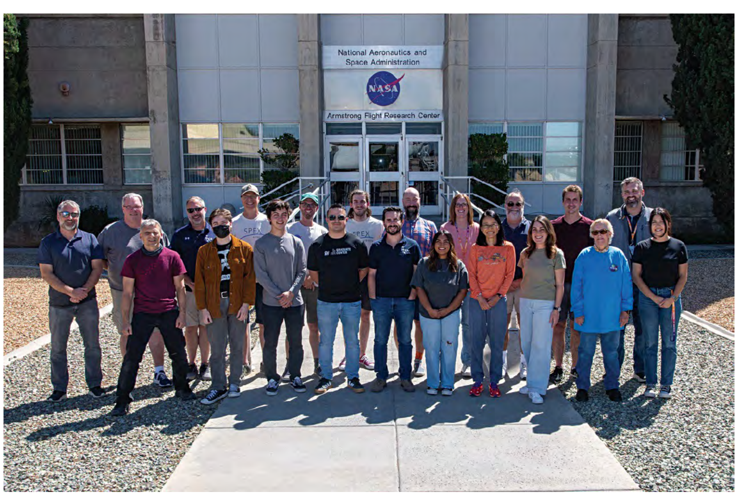

Figure 45. *The ER-2 team at NASA Armstrong Flight Research Center.* ***Credit:*** *PACE-PAX Science Team*

Figure 46. *The R/V Shearwater team in Santa Barbara, California.* ***Credit:*** *PACE-PAX Science Team*

of cloud and cloud-free conditions over the ocean. PACE-PAX also observed major simultaneous fires in the Los Angeles region, including the Bridge, Line, and Airport fires.

PACE-PAX data are currently being used for validation of PACE and EarthCARE, and will become available to the general public after March 2025. Most data will be available at the Atmospheric Science Data Center (ASDC), while ocean datasets will be archived at the SeaWiFS Bio-optical Archive and Storage System (SeaBASS).

Figure 47. *CIRPAS Twin Otter overflight of the R/V Shearwater, with platform scientist Michael Ondrusek in the foreground.* ***Credit:*** *PACE-PAX Science Team*

Select ASP Campaigns on Commercial Aviation Service (CAS) Platforms

As noted in the Program description (Section 2), many Earth Science missions fly on non-NASA aircraft. Some of these aircraft are commercially contracted, known as Commercial Aviation Service (CAS). The following highlights select missions that flew on CAS platforms.

The Blue Carbon Prototype Products for Mangrove Methane and Carbon Dioxide Fluxes (BlueFlux)

PI: Glenn Wolfe (NASA GSFC)
Program: Ocean Biology and Biogeochemistry
Aircraft: DA B-200
Payload: CARAFE (i.e., wind probe, Picarro G2401m Gas Concentration Analyzer and Picarro G2311f Gas Concentration Analyzer)

The Blue Carbon Prototype Products for Mangrove Methane and Carbon Dioxide Fluxes (BlueFlux) Campaign was initially a three-year (2021 – 2024) mission under NASA's Carbon Monitoring System. BlueFlux used field, aircraft, and satellite data to study the impact of both natural and anthropogenic pressures on South Florida's coastal ecology, particularly investigating the relationship between tropical wetlands and greenhouse gases.

Wetlands, like the Florida Everglades, absorb carbon dioxide from the atmosphere with impressive efficiency. But the future of this biodiversity hotspot — which is not only an important reservoir for atmospheric carbon, but a source of drinking water for millions of Floridians — is uncertain due to disturbances like sea level rise, population increase, hurricanes, and changes in ocean salinity.

To help resolve this uncertainty, NASA is developing a machine-learning model that estimates gaseous flux (i.e., the rate at which gas is exchanged between the planet's surface and atmosphere) using observations made by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Aqua and Terra satellites. The goal is to improve local and global estimates of carbon dioxide levels and help stakeholders evaluate wetland restoration efforts. To help ensure the satellite-based model is making accurate predictions, Everglades

Figure 48. *BlueFlux had the first all-female crew and onboard science team in NASA history during their July 2024 flights. From L to R: Piper Read, Erin Delaria, Captain Katharina 'KT' Kinne, and 1st Officer Lillia Farr.* ***Credit:*** *Glenn Wolfe/NASA GSFC*

Figure 49. *The BlueFlux mission collected flux measurements from 90 m (300 ft) above Florida's mangrove forests.* ***Credit:*** *Nathan Marder/NASA GSFC*

researchers have historically compared its outputs to ground-based measurements at local flux towers, but there are only a handful in the region.

To augment existing datasets and fill in the gaps between the towers, the BlueFlux mission has deployed to Florida 5 times between 2022 and 2024 with over 34 carefully planned flights. In FY24, BlueFlux flew 35 flight hours in the Florida Everglades region on the DA B-200 aircraft equipped with the CARbon Airborne Flux Experiment (CARAFE), which measures concentrations of methane, carbon dioxide, and water vapor using a wind probe and two optical spectroscopy instruments manufactured by Picarro: the G2401m Gas Concentration Analyzer and the G2311f Gas Concentration Analyzer. Tentatively, BlueFlux may have additional airborne campaigns in FY26, and data analysis from previous deployments is still ongoing.

Combined with information about the aircraft's speed and orientation, the team can estimate rates of gaseous flux at fixed points along each flight path. The team used flux data from both

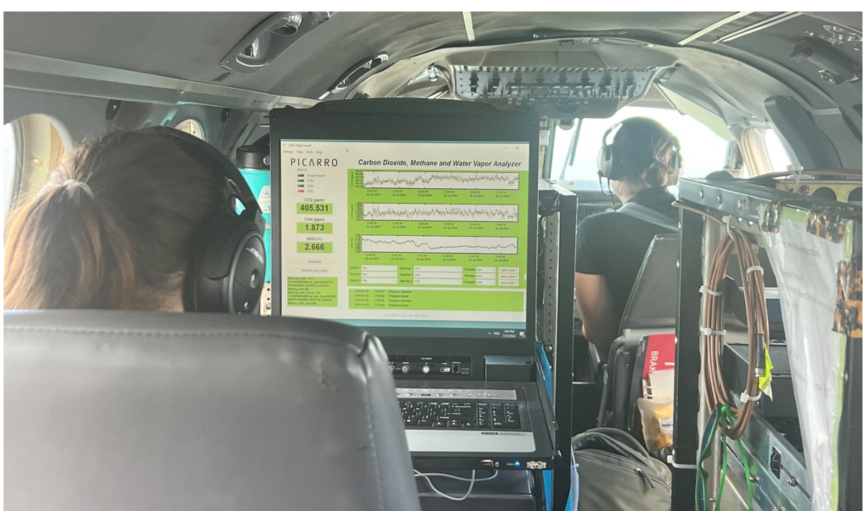

Figure 50. *The airborne CARAFE payload for measuring trace gas fluxes and high resolution 3D winds at low altitudes.* ***Credit:*** *Nathan Marder/NASA GSFC*

Figure 51. *A flux tower in the Florida Everglades measuring atmospheric conditions above a dense grove of red, black, and white mangroves, comparing ground and airborne techniques enabling scaling to landscape and regional flux estimates during BlueFlux.* ***Credit:*** *Nathan Marder/NASA GSFC*

the towers and CARAFE to train the MODIS machine-learning model, ensuring the accuracy of flux data generated from satellite data alone.

Early findings from space-based flux data confirm that, in addition to acting as a sink of carbon dioxide, tropical wetlands are a significant source of methane, an even more potent greenhouse gas. In fact, researchers estimate that Florida's entire wetland expanse produces enough methane to offset the benefits of wetland carbon removal between 20 and 90% depending on the time of year (Delaria, 2024).

BlueFlux provided a framework for the development of a satellite-based data product that will estimate daily rates of gaseous flux across coastal ecosystems in Florida and the Caribbean. As new policies and infrastructure are designed to support Everglades restoration, researchers hope NASA's daily flux product will help local officials evaluate their restoration efforts in real time — and adjust the course as needed. The prototype of the product, called **Daily Flux Predictions for South Florida,** will be available for public use in early 2025, accessible through NASA's Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC). An additional Earth Engine tool using BlueFlux data has also been developed. The tool allows users to plot and download the carbon flux products for different years since 2000 and look at year-to-year changes, showing obvious effects of hurricanes.

Satellite Coastal and Oceanic Atmospheric Pollution Experiment II (SCOAPE-II)

PI: Ryan Stauffer (NASA GSFC)
Program: Tropospheric Composition
Aircraft: DA B-200
Ship: R/V Point Sur
Payload: AVIRIS-3

In early June 2024, scientists from NASA GSFC on the SCOAPE (Satellite Coastal and Oceanic Atmospheric Pollution Experiment) research team partnered with the U.S. Department of the Interior (DOI) Bureau of Ocean Energy Management (BOEM) to measure air pollutants, including nitrogen dioxide and methane. The

second iteration of the campaign (SCOAPE-II) validated measurements taken by TEMPO, from the seas and in the air above the Gulf of America. The study area is concentrated with oil and natural gas (ONG) platforms, which are major sources of pollutants.

From space, TEMPO collects measurements of the "total column" of air, measuring the concentrations of a pollutant from the surface all the way up to the top of the atmosphere. The SCOAPE and SCOAPE-II campaigns help to break down that measurement by focusing on the air that people breathe and by helping scientists better understand the data collected from space.

Researchers collected data at about sea level from the R/V Point Sur, owned by the University of Southern Mississippi and operated by the Louisiana Universities Marine Consortium, as well as from a DA B-200 aircraft equipped with the AVIRIS-3 imaging spectrometer flying over the campaign site. The DA B-200 flew over 40 flight hours in the region. SCOAPE-II helped to explore the ability of NASA resources to monitor and quantify the effects of Gulf of America ONG emissions on coastal U.S. air quality.

ASP Support for Instrument Development

Aircraft provide an important test vehicle to determine the readiness of payloads for spaceflight missions. In FY24, ASP provided significant support to the Earth Science Technology Office (ESTO) under the Office's Instrument Incubator Program (IIP) and Airborne Instrument Technology Transition Program (AITT). ESTO demonstrates and provides technologies that can be reliably and confidently applied to a broad range of science measurements and missions. Some of the instruments are being developed specifically for airborne use, while others are being developed as precursors or simulators for satellite instruments.

In FY24, Airborne Multiangle SpectroPolarimetric Imager-2 (AirMSPI-2), Aerosol Wind Profiler (AWP), Compact Hyperspectral Air Pollution Sensor Demonstrator (CHAPS-D), Conical Scanning Millimeter-wave Imaging Radiometer – Hyperspectral (CoSMIR-H), Microwave Barometric Attenuation Radar and Sounder (MBARS), Spatial Heterodyne Observation of Water (SHOW), and SToRM SAR flew on NASA aircraft to support numerous Earth and space science missions.

Table 8. *NASA Airborne Science FY24 support for next-generation satellite instruments.*

Mission	Flight Hours	Location	Aircraft
AirMSPI-2	3.9	AFRC	ER-2
AWP (with ecoDemonstrator)	64.4	California and Washington	DC-8
CHAPS-D	6.2	LaRC	B-200
CoSMIR-H	16	AFRC	ER-2
MBARS	8.3	Pacific Coast	ER-2
SHOW	17.7	California	ER-2
SToRM SAR	19.3	JSC	GV

The following select missions highlight how ASP supports instrument development.

Airborne Multiangle SpectroPolarimetric Imager-2 (AirMSPI-2)

PI: David Diner (NASA JPL)
Programs: AITT, Tropospheric Chemistry
Aircraft: NASA ER-2
Payload: AirMSPI-2

In mid-2023, ESTO's Airborne Instrument Technology Transition (AITT) work on the second generation Airborne Multiangle SpectroPolarimetric Imager (AirMSPI-2) culminated with a series of engineering flights on the NASA ER-2 out of AFRC in FY24.

The effort was focused on improving the optical and electrical performance of the UV-SWIR AirMSPI-2 camera, installation of an on-board polarized light source for verifying polarimetric performance in flight, and upgrading the vacuum system required for cold operation of the SWIR detector array. Improvements are underway to further enhance instrument reliability and performance, including installation of a new computer board and cryocooler.

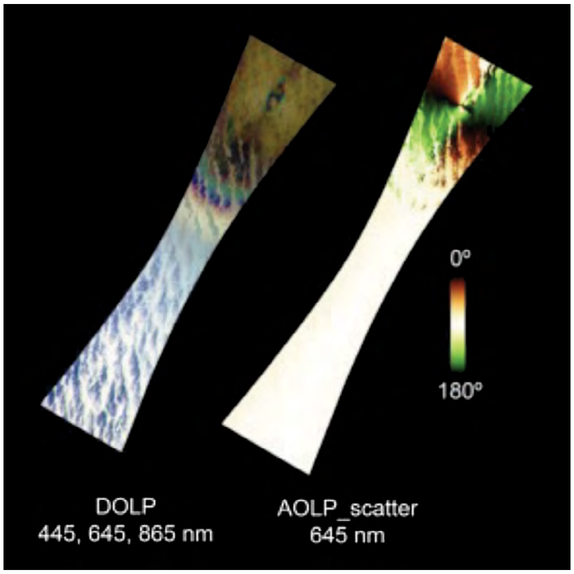

***Figure 52.** Degree and angle of linear polarization in sweep mode over Pacific Ocean. **Credit:** NASA*

The Multi-Angle Imager for Aerosols (MAIA) Earth Venture Instrument (EVI) project is planning to use AirMSPI-2 data to support pre-launch aerosol and cloud mask algorithm testing. These efforts also will pave the way for AirMSPI-2's participation in future airborne science campaigns.

The Conical Scanning Millimeter-wave Imaging Radiometer – Hyperspectral (CoSMIR-H) and the Microwave Barometric Radar and Sounder (MBARS)

PI: Rachael Kroodsma (NASA GSFC)
Program: Weather and Atmospheric Dynamics
Aircraft: NASA ER-2
Payload: CoSMIR-H, MBARS, NAST-I

Engineering check flights are an essential step when operationalizing new airborne instruments. Two new instruments, the Conical Scanning Millimeter-wave Imaging Radiometer – Hyperspectral (CoSMIR-H) and the Microwave Barometric Radar and Sounder (MBARS), flew on the NASA ER-2 out of NASA AFRC in July 2024 for the first time. Both instruments were funded by the NASA Earth Science Technology Office (ESTO). They performed extremely well throughout the brief campaign, and observations collected from the five check flights provided valuable information to the instrument teams to further optimize instrument performance prior to flying again in the Westcoast & Heartland Hyperspectral Microwave Sensor Intensive Experiment (WH^{2}yMSIE) campaign in FY25.

Figure 53. *The ER-2 lands at Edwards Air Force Base after completing a flight.* ***Credit:*** *Carla Thomas/ NASA*

Modified from the well-established CoSMIR sensor, CoSMIR-H is a passive hyperspectral microwave (HMW) sounder developed at NASA GSFC. It uses new digital spectrometer technology to provide thousands of channels at high spectral resolution around the oxygen absorption lines at 50-58 GHz and the water vapor absorption line at 183 GHz. Observations from CoSMIR-H will advise on current knowledge gaps in HMW sounding and inform decisions on future spaceborne HMW sensors.

MBARS, jointly developed by GSFC and LaRC, is a combined active/passive microwave sensor in the oxygen absorption V-band (64-70 GHz). It consists of an innovative scanning multi-channel differential absorption radar (DAR) to estimate column oxygen and dry air surface pressure over ocean. Observations from MBARS will demonstrate the technology to retrieve atmospheric surface pressure from aircraft and satellites, enabling key remote sensing data over oceans worldwide.

The ER-2 flight plans were focused on providing calibration and validation for the new instruments. The flight tracks included observations over buoys and pressure gradients for MBARS, and a MetOp-B satellite overpass and water vapor gradient mapping for CoSMIR-H. The National Airborne Sounder Testbed – Interferometer (NAST-I) from LaRC also flew as a piggyback instrument to test a new installation location on the ER-2. All three instruments were part of a larger payload on the ER-2 in FY25 for WH^{2}yMSIE, which served as a NASA Planetary Boundary Layer (PBL) mission prototype.

Figure 54. *CoSMIR-H and MBARS teams perform instrument checkouts prior to the first campaign flight on the ER-2 aircraft.* ***Credit:*** *Steve Freeman/NASA*

Aerosol Wind Profiler (AWP)

PIs: Kristopher Bedka (NASA LaRC) and John Marketon (NASA LaRC)
Program: NOAA Joint Venture Program
Aircraft: G-III
Payload: AWP, HALO, AVAPS

The Aerosol Wind Profiler (AWP) is a new NASA airborne Doppler wind lidar (DWL) instrument developed jointly between NASA LaRC and Beyond Photonics LLC with support from ESTO, ESD, and LaRC Science and Engineering Directorates. AWP detects winds based on the following premises:

1. Aerosol or cloud particle movement causes a Doppler shift to the frequency of backscattered light.
2. After accounting for aircraft (or spacecraft) airspeed, heading, and attitude, the Doppler shift signal can be used to retrieve a vertical wind profile when sufficient aerosol backscatter intensity is detected.

AWP was selected by the NOAA Joint Venture Program 3-D Wind Demonstration opportunity to demonstrate suborbital DWL wind measurement capability and simulate spaceborne DWL measurements. AWP conducted the initial phase of the 3-D Wind Demonstration on the DC-8 while piggybacking on the October 2023 NASA ecoDemonstrator campaign. In September 2024, AWP integrated on the LaRC G-III to complete the 3-D Wind Demo project.

AWP was successfully installed into the G-III forward port area, which had just been enlarged prior to this mission to accommodate the AWP aircraft interface plate and transceiver. AWP was installed while the High Altitude Lidar Observatory (HALO) was already integrated on the aircraft from the ARCSIX mission and in preparation for the WH^{2}yMSIE/APEX mission that immediately followed the 3-D Wind Demo, which added some complexity to the installation (Figure 57). This was the first time that two lidar instruments were simultaneously flown on the G-III. The combination of AWP, HALO, and the AVAPS dropsonde systems enabled simul-

Figure 55. *AWP (forefront) and HALO (rear) integrated aboard the NASA G-III during the AWP mission.* ***Credit:*** *Kristopher Bedka*

taneous, high spatial and vertical resolution measurements of wind, water vapor, aerosol, and temperature profiles, a combination of data critical to better understand weather and planetary boundary layer processes.

The 3-D Wind Demo project encompassed 10 flights and 47 flight hours from 18 September to 16 October 2024. The flights covered a broad area of the Eastern U.S. and offshore waters (Figure 58). A variety of weather conditions and phenomena were sampled including the following:

- The environment around Hurricane Helene
- Jet streams
- Low- and high-pressure systems
- Mountain waves over the Appalachians
- Aerosol emissions from major Northeast U.S. metropolitan areas

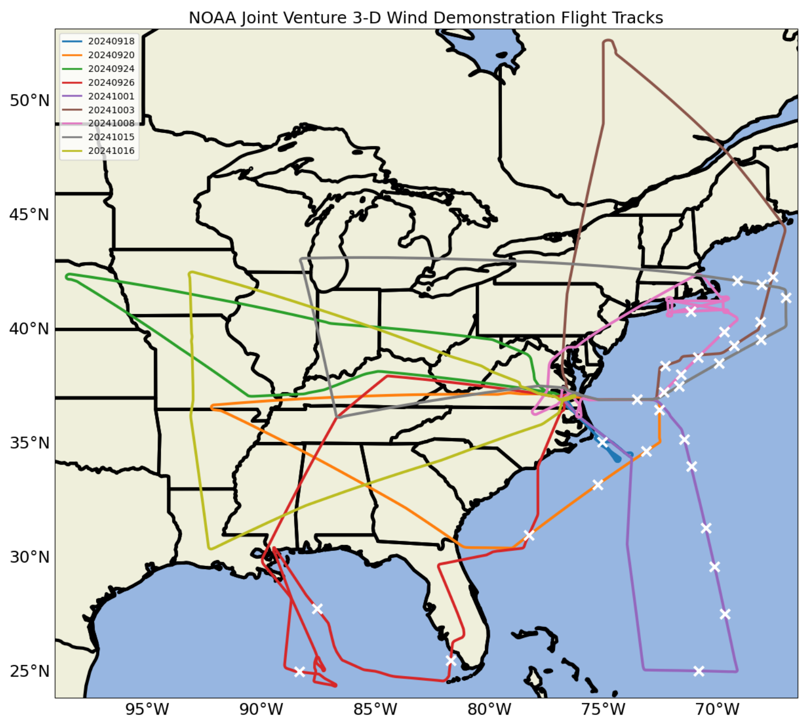

Figure 56. *G-III NOAA 3-D Wind Demonstration flight tracks with locations of AVAPS dropsonde releases shown as white x's.* ***Credit:*** *Kristopher Bedka*

- A severe thunderstorm environment over Kentucky
- The NOAA Wind Forecast Improvement Project-3 (WFIP-3) domain with numerous wind turbines offshore of Massachusetts and Rhode Island

Thirty AVAPS dropsondes were released for AWP and HALO profile validation. Preliminary analysis of co-located AWP and AVAPS data indicated excellent agreement. An example of AWP and AVAPS data is provided in Figure 59, showing the remarkable detail in the aerosol, cloud, and wind data measured by AWP on 15 October 2024, and a tight correlation between AWP and AVAPS data. After the 3-D Wind Demo, AWP continued to collect data during the FY25 WH^2yMSIE/APEX in October and November 2024.

Additional ASP Partnerships and Interagency Support

NASA ASP projects extend beyond ESD, often partnering with other national or even international agencies for highly collaborative projects. In FY24, these projects included the following:

- ASIA-AQ (detailed above) included partnerships between NASA and DENR (Philippines), NIER (South Korea), GISTDA (Thailand), MOENV (Taiwan), and the University of Kebangsaan (Malaysia).
- BioSCape (detailed above) had a Science Team made of approximately 50% U.S.-based and 50% South African researchers.
- AWP instrument development (detailed above); AWP was selected by the NOAA Joint Venture Program 3-D Wind Demonstration opportunity.
- AfriSAR II (detailed above) coordinated airborne campaign activities with ESA and

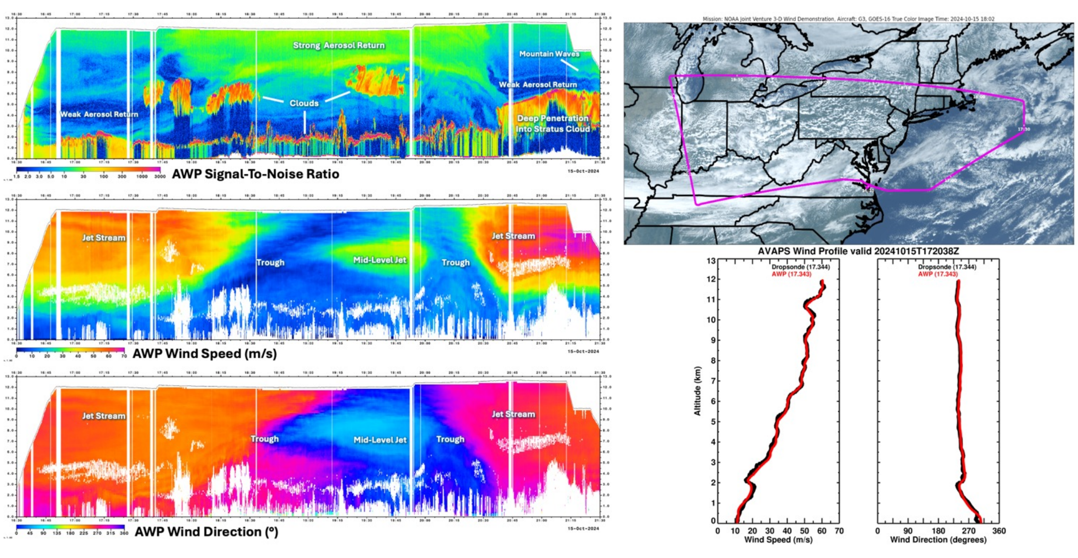

Figure 57. *(left panels) AWP Signal-to-Noise Ratio (SNR), wind speed, and wind direction curtains for a flight on 15 October 2024. (upper-right) G-III flight track for the 15 October flight, overlaid atop a GOES-16 satellite image. (lower-right) A comparison of AWP wind speed (red, left) and wind direction (right) profiles co-located with an AVAPS dropsonde wind profile (black).* ***Credit:*** *Kristopher Bedka*

the German Space Agency at DLR research teams to generate a common dataset over African ecosystems and foster collaborations between NASA, ESA, and African research communities.

- Geological Earth Mapping Experiment (GEMx), a joint mineral mapping venture between NASA and USGS. More details below.
- High-altitude Aerosols, Water vapor and Clouds (HAWC) mission with the Canadian Space Agency (CSA). More details below.
- Strategic Tac Radio and Tac Overwatch (STRATO) flight project, which used a high-altitude balloon to enable real-time communication between firefighters and command posts during fires.

Geological Earth Mapping Experiment (GEMx)

PI: Raymond Kokaly (USGS)
Programs: USGS, Earth Surface and Interior
Aircraft: ER-2
Payload: AVIRIS-C, MASTER

The Geological Earth Mapping Experiment (GEMx) is a joint campaign between NASA and the USGS to map portions of the southwest United States for critical minerals using advanced airborne imaging.

In 2022, the U.S. was 100% dependent on imports for 10 critical mineral commodities (e.g., arsenic, asbestos, cesium, graphite), and was at least 50% dependent on imports for another 33 critical mineral commodities (e.g., peat, tin, cobalt, zinc, nickel, aluminum). Many of these critical minerals are used for the development of green infrastructure such as renewable energy generation. The U.S. needs better natural resource mapping to understand how to best mitigate this risk.

GEMx is a joint, multi-year campaign collecting measurements spanning visible through infrared over 500,000 km^2 of the Southwestern U.S. to identify and map minerals at 15 m^2 resolution. In the 2024 campaign (April to June 2024), the following instruments flew over 311,000 km^2 in 140 science flight hours on the NASA ER-2, collecting new information about Earth's surface and atmosphere to help scientists understand Earth's geology:

- NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-C)
- MODIS/ASTER Airborne Simulator (MASTER)

This project will complement data from several of NASA's instruments on the International Space Station (ISS), including the Earth Surface Mineral Dust Source Investigation (EMIT), which maps the mineral dust source composition of Earth's arid regions to better understand mineral dust's role in climate change, as well as other instruments and missions like ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) and the upcoming Surface, Biology, and Geology (SBG) mission, part of NASA's Earth System Observatory (ESO).

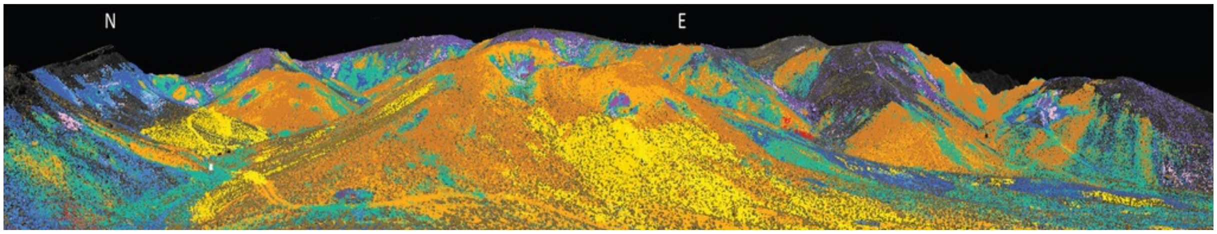

Figure 58. *Various minerals are revealed in vibrant detail in this sample mineral map of Cuprite, Nevada, following processing of imaging spectrometer data.* ***Credit:*** *USGS*

__Figure 59.__ A photo of the NASA ER-2 high-altitude aircraft with the AVIRIS and HyTES instruments installed for the USGS GEMx project. __Credit:__ NASA

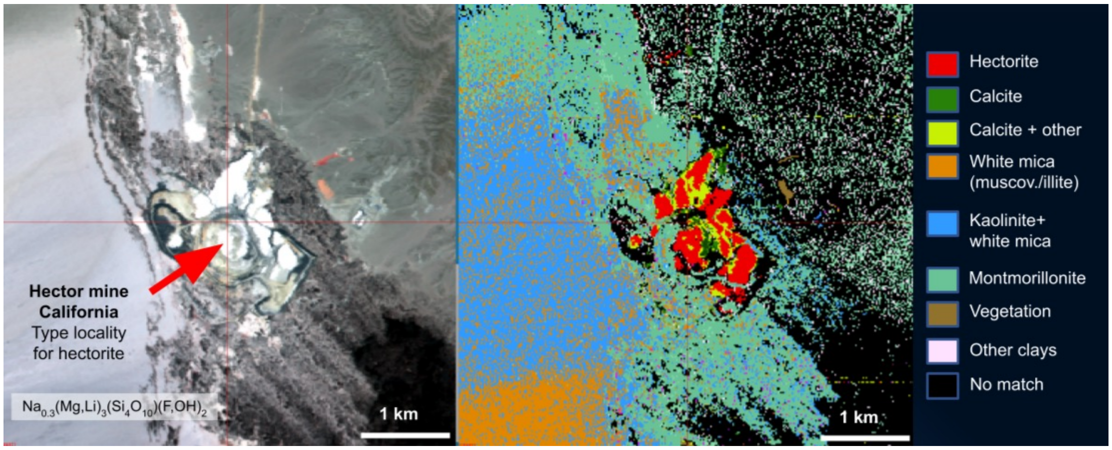

__Figure 60.__ An example of data from GEMx showing lithium-bearing minerals in Nevada and California. __Credit:__ Raymond Kokaly/USGS

High-altitude Aerosols, Water vapor and Clouds (HAWC)

PIs: Adam Bourassa (PI of ALI; University of Saskatchewan), Doug Degenstein (PI of SHOW; University of Saskatchewan)
Program: Upper Atmosphere Research, Advanced Payload Development (CSA)
Aircraft: NASA ER-2
Payload: ALI, SHOW

The High-altitude Aerosols, Water vapor and Clouds (HAWC) airborne capability demonstration occurred in November and December 2023 on the ER-2 at AFRC. HAWC is an upcoming Canadian satellite mission consisting of the following three Canadian instruments that will fly in a polar orbit as part of a four-satellite constellation on NASA's Atmosphere Observing System (AOS):

- Aerosol Limb Imager (ALI)
- Spatial Heterodyne Observations of Water (SHOW)
- Thin Ice Clouds in Far InfraRed Emissions (TICFIRE)

HAWC is supported by the University of Saskatchewan, the Université du Québec à Montréal, and the Canadian Space Agency (CSA) through a Space Act Agreement with NASA. The airborne mission leveraged Canada's exceptional strengths in atmospheric and

Figure 61. *Members of the HAWC team during the first flight of the HAWC ER-2 campaign based at AFRC in Palmdale, California.* ***Credit:*** *P. Loewen*

climate science and represents an outstanding opportunity to launch a new era of innovation and discovery that is driven by university, government, and industry partnerships.

This was the first suborbital flight demonstration campaign for HAWC. It included airborne prototypes of ALI and SHOW, instruments that were integrated in the starboard wing pod to make measurements of limb-scattered sunlight spectra that were used to retrieve distributions of aerosol and water vapor above clouds. SHOW observed the limb through a window in the front of the forebody, and ALI measured the same scene using a periscope mounted below the aft body.

The campaign included one engineering flight and two science flights which focused on collecting coincident measurements with multiple satellite and ground-based instruments. The first science flight path headed north along the Microwave Limb Sounder (MLS) track over the ocean and a strong low-pressure system. The ER-2 then turned east to catch a Stratospheric Aerosol and Gase Experiment III/International Space Station (SAGE III/ISS) observation and then south along the Ozone Mapping and Profiler Suite (OMPS) trajectory. The flight concluded with a flyover of a Frost Point Hygrometer (FPH) balloon launched at Table Mountain. The second science flight path was similar but also included an overpass with OMPS-JPSS-2.

ALI experienced a radiofrequency driver failure during descent on the engineering flight and operated in safe mode during the first science flight. The team rallied and were able to procure and install a replacement part in time for the second science flight with only a couple days delay!

Preliminary analysis of the data showed compelling synergy between ALI and SHOW. ALI-retrieved aerosol and cloud top are used in the SHOW forward model, and these agree very well with the measurements. The full impact of aerosol scattering on the SHOW water vapor retrievals has not yet been studied but is important future work.

Figure 62. *Top: Photo from cockpit of starboard wing pod during flight. Middle: SHOW (L) and ALI (R) integrated in the wing pod before flight. Bottom: NASA ER-2 aircraft during the HAWC campaign. Credit: P. Loewen*

Strategic Tac Radio and Tac Overwatch (STRATO)

PI: Don Sullivan (NASA ARC)
Program: Space Technology Mission Directorate (STMD) - Flight Opportunities (FO)
Platform: Aerostar Thunderhead Balloon
Payload: Cellular LTE transmitter, RGB camera, and infrared cameras

The rugged and often remote locations where wildland fires burn mean cell phone service can be very limited, posing significant challenges for emergency management professionals who coordinate real-time firefighting activities.

To address this, NASA collaborated with the U.S. Forest Service (USFS), Aerostar and Motorola on the Strategic Tac Radio and Tac Overwatch (STRATO) flight project.

Aerostar's Thunderhead high-altitude balloon system flies at 50,000+ feet above the Earth and can stay in the air for months at a time. The system can also be directed to "station keep," staying within a radius of few miles. Providing cellular communication from above, from a vehicle that can move as the fire changes, enables real-time communication between firefighters and command posts. The balloon's payload also uses an infrared sensor to provide valuable heat and spatial information, providing more accurate data on the fire's characteristics.

STRATO in Action: 2024 Campaign

STRATO's first test flight launched from Idaho on August 4, 2024 over the SNAG wildfire, demonstrating significant opportunities to support firefighting operations.

Figure 63. *The Aerostar stratospheric station-seeking balloon is released, carrying the USFS/NASA communications and imaging payload. The balloon appears deflated because it will expand as it rises to higher altitudes where pressures are lower.* ***Credit:*** *Austin Buttlar/ Colorado Division of Fire Prevention and Control Center of Excellence for Advanced Technology Aerial Firefighting*

The balloon was fitted with a cellular LTE transmitter and visual and infrared cameras. To transmit between the balloon's cell equipment and the wildland fire incident command post, the team used a SpaceX Starlink internet satellite device.

When tested, the onboard instruments provided cell coverage for a 20-mile radius. By placing the transmitter on a gimbal, that cell service coverage could be adjusted as ground crews moved through the region. The onboard cameras gave fire managers and firefighters on the ground a bird's-eye view of the fires as they spread and moved, opening the door to increased situational awareness and advanced tracking of firefighting crews.

On the ground, teams use an app called Tactical Awareness Kit (TAK) to identify the locations

Figure 64. *Lead NASA investigator Don Sullivan compares connectivity of a STRATO-enabled TAK phone with a terrestrial-enabled TAK phone during the Boulder fire on August 11, 2024.* ***Credit:*** *Austin Buttlar/ Colorado DFPC Center of Excellence for Advanced Technology Aerial Firefighting*

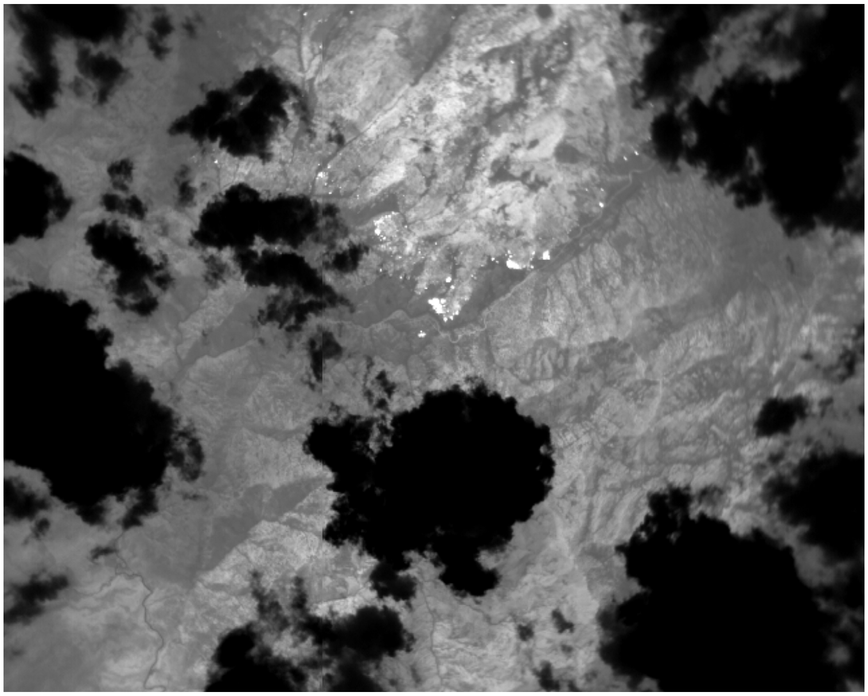

Figure 65. *Example image from the STRATO infrared imaging payload where white is hot and black is cold, in this case clouds below the balloon.* ***Credit:*** *Aerostar/Range and Bearing*

of crew and equipment. Connecting the STRATO equipment to TAK provides real-time location information that can help crews pinpoint how the fire moves and where to direct resources while staying in constant communication.

Additionally, the Ames Mission Tools Suite team successfully assimilated and relayed STRATO's balloon location, Earth observation and infrared imagery, and LTE connectivity information to the USFS TAK server, which then supplied situational awareness to firefighters using iTAK and ATAK handheld devices used by the USFS, and to an AirTAK instance in the Incident Command Post.

What's Next

The team plans to optimize balloon locations as a constellation to maximize coverage and anticipate airflow changes in the stratosphere where the balloons fly. The team may also adapt the scientific equipment aboard the balloons to support other wildland fire initiatives at NASA.

4. Aircraft

NASA maintains and operates a fleet of highly modified aircraft, based at NASA Centers, able to uniquely support Earth observations. ASP-supported aircraft have direct funding support from ASP for flight hours and personnel. Other NASA aircraft are also available for science missions. In addition, NASA missions employ commercial aviation services (CAS) under protocols established by NASA Headquarters. More information about using these aircraft is provided on the ASP website at: https://airbornescience.nasa.gov. The annual "Call Letter," also available on the ASP website, is an excellent source of information describing how to request airborne services (https://airbornescience.nasa.gov/sofrs/).

FY2024 Aircraft Highlights

The ASP fleet includes aircraft that can support low-and-slow flights, as well as those capable of flying high and fast. The aircraft also have a wide variety of payload capacities. One of the most exciting recent enhancements to the ASP fleet is the acquisition of a Boeing 777-200 Extended Range (B777-200ER or B777), which was acquired to replace and extend the capabilities of the NASA DC-8, which retired in 2024. The newly acquired B777 is currently undergoing modifications to include several nadir and window ports, power, data and communications systems, and instrument operator accommodations. The first NASA B777 science operations are planned for 2027 from LaRC.

ASP Fleet Summary Characteristics

ASP aircraft performance characteristics and payload accommodation summaries are provided in Table 9. The fleet of aircraft is shown in Figure 68. The altitude, endurance, and range capabilities are shown in Figure 69. Figure 70 indicates payload capability for each aircraft.

Table 9. *ASP aircraft and their performance capabilities.*

Platform Name	NASA Center	Payload Accommodations	Duration (Hours)	Useful Payload (lbs)	Max Altitude (ft)	Airspeed (knots)	Range (Nmi)
ASP Supported Aircraft							
B777	LaRC	nadir ports, dropsondes, in situ sampling	18	75,000	43,000	500	9,000
ER-2 (2)	AFRC	Q-bay (2 nadir ports), nose (1 nadir port), wing pods (4 nadir, 3 zenith ports), centerline pod (1 nadir port)	12	2,900	>70,000	410	5,000
G-III/C-20A	AFRC	UAVSAR pod	7	2,610	45,000	460	3,000
G-III	LaRC	2 nadir ports, dropsonde / sonobuoy	7	2,610	45,000	460	3,000
G-IV	LaRC	AirSAR next gen (future)	7.5	5,610	45,000	459	5,130
P-3	WFF	1 large and 3 small zenith ports, 3 fuselage nadir ports, 4 P-3 window ports, 3 DC-8 window ports, nose radome, aft tailcone, 10 wing mounting points, dropsonde	14	14,700	32,000	400	3,800
WB-57	JSC	Nose cone, 12 ft of pallets for either 3 ft or 6 ft pallets, 2 spearpods, 2 superpods, 14 wing hatch panels	6.5	4,100	35,000	275	1,250
Other NASA Aircraft							
B-200	AFRC	2 nadir ports	6	1,850	30,000	272	1,490
B-200	LaRC	2 nadir ports, wing tip pylons, zenith site for aerosol inlet, lateral ports	6.2	4,100	35,000	275	1,250
Cirrus SR22	LaRC	Unpressurized belly pod	6	932	17,500	175	970
SIERRA-B (UAS)	ARC	Interchangeable nose pod for remote sensing and sampling, 1 nadir port	10	100	12,000	60	600

Figure 66. *NASA Airborne Science Program-supported aircraft.*

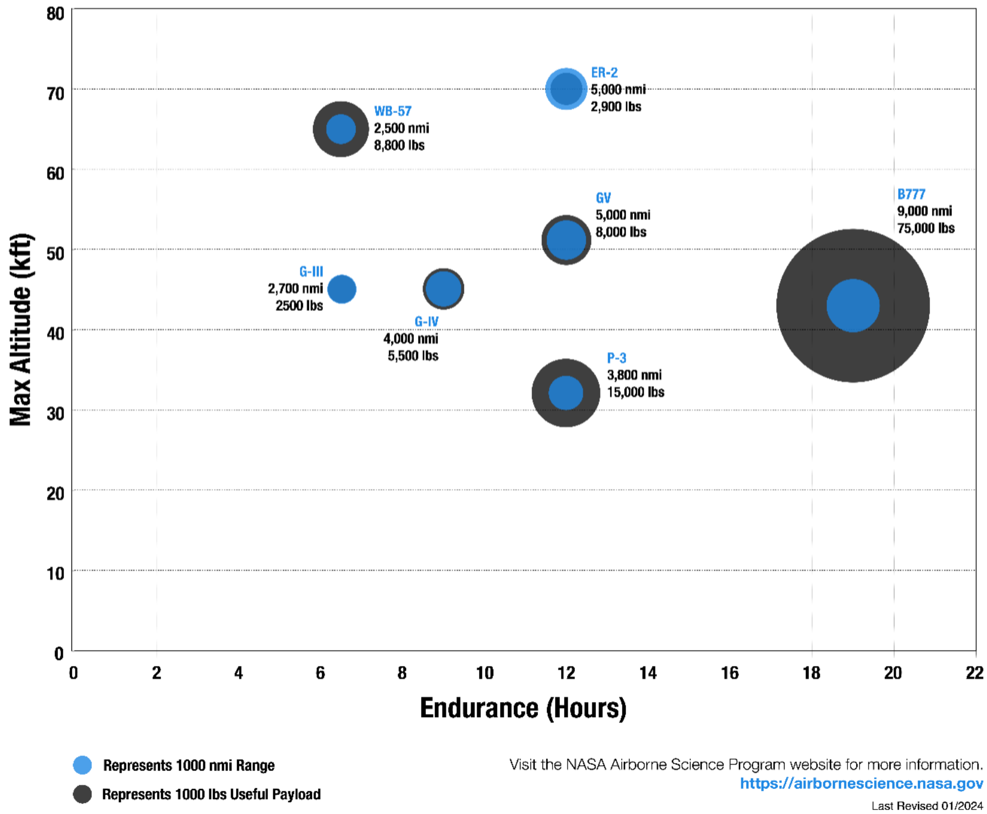

Figure 67. *NASA Science Aircraft capabilities in altitude, range, and relative payload weight capacity.*

National Aeronautics and Space Administration

AIRBORNE SCIENCE PROGRAM

AIRCRAFT PERFORMANCE

PLATFORM	MAX ALTITUDE (FT)	USEFUL PAYLOAD (LBS)	RANGE (NMI)	ENDURANCE (HOURS)
ER-2	70,000	2,900	5,000	12
WB-57	65,000	8,800	2,500	6.5
GV	51,000	8,000	5,000	12
G-IV	45,000	5,500	4,000	9
G-III	45,000	2,500	2,700	6.5
B777	43,000	75,000	9,000	19
P-3	32,000	15,000	3,800	12

Visit the NASA Airborne Science Program website for more information.
https://airbornescience.nasa.gov

Last Revised 01/2024

Figure 68. *ASP-supported aircraft fleet.*

ASP-Supported and Partially Supported Aircraft

ASP directly supports eight platforms with subsidized flight hours: two ER-2 high-altitude aircraft, one P-3 Orion, one C-20A (G-III), one G-III, one G-IV, one B777, and a partially supported WB-57 at JSC. The DC-8 retired in FY24 and the JSC GV is only available to ESD missions on a limited, fully reimbursable basis.

DC-8 Flying Laboratory

Operating Center:
NASA AFRC

Aircraft Description:
The DC-8 airborne laboratory was a four-engine jet aircraft with a range in excess of 5,000 Nm, a ceiling of 41,000 ft, and an experiment payload of 30,000 lbs (13,600 kg). This aircraft, extensively modified as a flying laboratory, was operated for the benefit of airborne science researchers. It retired in 2024 after completing its final mission, ASIA-AQ.

Figure 69. *The DC-8 aircraft returned to NASA's Armstrong Flight Research Center Building 703 in Palmdale, California, on April 1, 2024, after completing its final mission supporting Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ).* ***Credit:*** *Steve Freeman/NASA*

FY24 Science Flight Hours: 225.9

Table 10. *DC-8 FY24 missions.*

Mission/Project	Location	Science Program Area
ASIA-AQ	Asia	Tropospheric Composition
ecoDemonstrator	California	Tropospheric Composition

B777 Flying Laboratory

Operating Center:
NASA LaRC

Aircraft Description:
The B777 airborne laboratory is a twin-engine, long-range commercial airliner that is being modified for NASA Airborne Science. It has a range of 9,000 Nm, a duration of up to 18 hours, a ceiling of 43,000 ft, and an experiment payload of 75,000 lbs (34,019 kg). This unique flying laboratory will have truly global reach, enabling data collection for NASA projects to include sensor development, satellite sensor calibration, data product validation, and field studies to better understand earth system processes to improve models and decision-making. First operations are planned for January 2027 from NASA Langley Research Center.

Figure 70. *The B777 is currently being modified and prepared as a replacement for the DC-8, which retired in FY24.* ***Credit:*** *NASA*

Website:
https://airbornescience.nasa.gov/aircraft/NASA_B777

ER-2 High-Altitude Aircraft

Operating Center:

NASA AFRC

Aircraft Description:

NASA operates two ER-2 aircraft (N806NA, N809NA) as readily deployable high-altitude sensor platforms to collect remote sensing and in situ data on earth resources, atmospheric chemistry and dynamics, and oceanic processes. The aircraft also are used for electronic sensor research and development, satellite calibration and satellite data validation. The aircraft can carry a useful payload of up to 2,900 lbs (1,315 kg) for up to 8 hours.

Operating at 70,000 feet (21.3 km), the ER-2 acquires data above ninety-five percent of the earth's atmosphere. ER-2 sensors acquiring earth imagery or conducting atmospheric sounding replicate spatial, spectral and atmospheric characteristics of data collected by earth observing sensors aboard orbiting satellites.

Figure 71. *The ER-2 conducted over 80 flight hours in service of the PACE-PAX mission. The ER-2 is uniquely qualified to conduct the high-altitude scientific flights that this project required.* ***Credit:*** *Genaro Vavuris/NASA*

FY24 Science Flight Hours: 287.6

Table 11. *ER-2 FY24 missions on N806NA and N809NA platforms.*

Mission/Project	Location	Science Program Area
WDTS	AFRC	Biological Diversity; Earth Surface and Interior; Research and Analysis
HAWC (SHOW/ALI)	California	Canadian Space Agency
MBARS	AFRC	ESTO Instrument Incubation Program
CoSMIR-H	AFRC	Weather and Atmospheric Dynamics
PACE-PAX	AFRC	Ocean Biology and Biogeochemistry; Radiation Sciences
GEMx	California, Nevada, and Arizona	United States Geological Survey
AirMSPI-2	AFRC	Atmospheric Composition; Airborne Instrument Technology Transition

FY24 ER-2 Modifications and Impacts on Performance and Science:

None

Significant Upcoming Maintenance Periods:

- On N806NA:
  - 600-hour maintenance from 17 October 2024 to 14 March 2025
- On N809NA:
  - None

Website:

http://airbornescience.nasa.gov/aircraft/ER-2

WB-57 High Altitude Aircraft

Operating Center:
NASA JSC

Aircraft Description:
The WB-57 is a mid-wing, long-range aircraft capable of extended operation from sea level to altitudes greater than 60,000 feet with a range of up to 2,500 Nm. The sensor equipment operator (SEO) station contains navigational equipment and controls for operation of the payloads located throughout the aircraft. The WB-57 can carry up to 8,800 pounds of useful payload. JSC maintains three WB-57 aircraft (N926NA, N927NA, N928NA).

Note: The Airborne Science Program has provided partial funding to support the annual fixed costs of operating the WB-57 aircraft. Within this limited scope, subsidized flight hour rates are available to science mission customers. Contact Airborne Science and WB-57 program management for details.

Figure 72. *Render of WB-57 aircraft.* ***Credit:*** *NASA*

FY24 Science Flight Hours: 0

FY24 WB-57 Modifications and Impacts on Performance and Science:

None

Significant Upcoming Maintenance Periods:

- N926NA:
  - Maintenance from 3 April 2025 to 3 July 2025
- N927NA:
  - Maintenance from 18 July 2024 to 14 February 2025
- N928NA:
  - Major Inspection on Indefinite Hold from 8 June 2021 to 31 December 2025

Website:
http://airbornescience.nasa.gov/aircraft/WB-57

Gulfstream III Business Jet

Operating Center:
NASA LaRC

Aircraft Description:
The Gulfstream III (G-III) is a twin-turbofan business-class aircraft supporting routine flight at 40,000 feet with a useful payload of 2,610 lbs (1,184 kg) for a range of up to 3,767 Nm. The NASA G-III has the following features: an engine hush kit, research power distribution system, intercom system, drop-sonde capability, and two nadir portals in the fuselage. The hush kit enables the aircraft to be Stage III noise compliant, allowing the aircraft to deploy nationwide and worldwide without requiring engine noise waivers. The nadir portals allow the aircraft to install earth science sensors.

Figure 73. *G-III parked near Asian Aerospace FBO at Clark International Airport in the Philippines during ASIA-AQ.* ***Credit:*** *Rafael Luis Méndez Peña*

FY24 Science Flight Hours: 499.8

Table 12. *G-III FY24 missions.*

Mission/Project	Location	Science Program Area
BioSCape	Capetown, South Africa	Biological Diversity
ARCSIX	Thule AB, Svalbard	Radiation Sciences
ASIA-AQ	Philippines, South Korea, Thailand	Tropospheric Composition
AWP Demo	LaRC	Weather and Atmospheric Dynamics

FY24 G-III Modifications and Impacts on Performance and Science:

None

Significant Upcoming Maintenance Periods:

The following upgrades will enhance SA and comply with required phased Mx activities which will occur in various intervals throughout FY25 Q1-Q4.

- Installation of new Intercom system, to enhance crew and pilot situational awareness, improve communications reliability. Also add Ground crew COM capability to enhance operations safety.
- Add SATCOM capability.
- "Red Mx" period in progress 1Q25-2Q25, "Orange Mx" 3Q25, 150 hr Mx 4Q25, Yellow Mx period planned 4Q25.
- Installation/Overhaul of Aircraft Engines

Website:
https://airbornescience.nasa.gov/aircraft/Gulfstream_III_-_LaRC

C-20A Business Jet

Operating Center:
NASA AFRC

Aircraft Description:
The C-20A can support a single science flight (up to 6.0 flight hours) or two science flights in one day (up to 9.0 total flight hours) with one ground crew. This platform has been structurally modified and instrumented to carry the payload pod for the three versions of JPL's UAVSAR instrument (L-band, P-band, Ka-band).

Figure 74. *The NASA C-20A parked at Yellowknife Airport in Northwest Territories, CA in August 2024 for ABoVE.* ***Credit:*** *Caelan Beard/Cabin Radio*

FY24 Science Flight Hours: 341.12

__Table 13.__ C-20A FY24 missions.

Mission/Project	Location	Science Program Area
AfriSAR West + East Africa	Ghana, Gabon, Cameroon, Republic of Congo, Tanzania, Kenya, and Mozambique	Earth Surface and Interior; Terrestrial Ecology
AfriSAR West Africa	Ghana, Gabon, Cameroon, and Nigeria	Earth Surface and Interior
ABoVE L-band continuation flights	Alaska and Canada	Terrestrial Ecology
AirMOSS for Ice Sounding	Greenland	Cryospheric Sciences
Germany Bistatic Experiment	Germany	Geodetic Imaging
UAVSAR L-Band Engineering	California	Geodetic Imaging
UAVSAR P-Band Engineering	California	Geodetic Imaging
Landslide kinematics in response to ongoing climate shifts	California	Earth Surface and Interior
Where the Fault Meets the Road: Structure, Deformation and Rheology of the Urban Hayward Fault	California	Earth Surface and Interior
FASMEE Prescribed Burn	Colorado	FireSense
Repeat-Pass InSAR for Estimating SWE	Western US	Earth Surface and Interior
Western US Change Detection	California	Earth Surface and Interior
Laurentides STV	Quebec, Canada	Terrestrial Ecology
Central Valley Land Subsidence	California	Earth Action Water Resource; Earth Surface and Interior
Remote quantification of evolving stability conditions in deep-seated landslides from InSAR displacement rate measurements, structural mapping, and geomechanical modeling	Colorado	Earth Surface and Interior
Southern California Wildfires	California	Earth Surface and Interior

FY24 C-20A Modifications and Impacts on Performance and Science:

None

Significant Upcoming Maintenance Periods:

- Dec 4 – Feb 10
- Upcoming Ops 1 & 3 Nov 24 – Dec 19

Website:

https://airbornescience.nasa.gov/aircraft/Gulfstream_C-20A_GIII_-_AFRC

G-IV Business Jet

Operating Center:
LaRC (pre-February 2024), AFRC (post-February 2024)

Aircraft Description:
The G-IV aircraft is twin turbofan business-class aircraft with a maximum of ten onboard operators. The G-IV can fly for a maximum of 8 hours with a useful payload of up to 5,610 pounds (2,545 kg). It can reach a maximum of 45,000 feet at an air speed of 459 knots over a range of up to 5,130 Nm.

Figure 75. *The G-IV flying over the Antelope Valley to analyze aircraft performance before modification and upgrades.* ***Credit:*** *Carla Thomas/NASA*

FY24 Science Flight Hours: 0

FY24 G-IV Modifications and Impacts on Performance and Science:

The aircraft was transferred to AFRC to conduct aircraft communication and power modifications, as well as a structural modification for the AirSAR-NG radars. The structural modification contract was awarded in August 2024 to Avenger Aerospace Solutions. The communication and power modifications are being conducted by AFRC concurrently. Return to science is expected in late FY26.

Significant Upcoming Maintenance Periods:

In addition to the structural modification, the contract included the 96-month (8C checks) maintenance and will be done concurrently with the modification described above.

Website:
https://airbornescience.nasa.gov/aircraft/Gulfstream_IV_-_AFRC

P-3 Turboprop

Operating Center:
WFF (FY24), LaRC (FY25 onwards)

Aircraft Description:
The P-3 is a four-engine turboprop aircraft designed for endurance (up to 12 hours) and range (up to 3,800 Nm). The aircraft can fly up to 32,000 feet with a useful payload of 18,000 lbs (8,165 kg). The P-3 is used for a wide range of scientific activities including ecology, meteorology, atmospheric chemistry, cryospheric research, oceanography, soil science, biology, and satellite calibration/validation. The P-3 is also used as a technology test bed for new airborne and satellite instrumentation.

The P-3 has been extensively modified to support airborne scientific research. Features include zenith ports, three nadir ports (aft of the wings), and seven windows that have been modified to provide externally mounted experiments. Additionally, there are tail cone ports, nose radome ports, and ten mounting locations on the wings. Most of the fuselage ports are contained within the pressurized cabin environment while a custom fairing allows the unpressurized bomb bay to be converted into experimenter ports. This fairing creates two large nadir ports and several oblique ports for large sensors and antennas. When the bomb bay fairing is removed and the bomb bay doors installed, the doors are functional in flight to support aerial deployments. Dropsonde and sonobuoy deployment systems are also available.

Figure 76. *NASA P-3 on the tarmac in Greenland during ARCSIX.* ***Credit:*** *Joseph Schlosser/NASA*

FY24 Science Flight Hours: 242.3 hours

Table 14. *P-3 FY24 missions*

Mission	Location	Science Program Area
ICESat-2 Lake Ice	Thule AB, Svalbard	Cryospheric Sciences
ARCSIX	WFF	Radiation Sciences Program
SARP	WFF, AFRC	Resarch and Analysis
LVIS-GEDI EDGE	WFF	GSFC Laser

FY24 P-3 Modifications and Impacts on Performance and Science:

None

Current and upcoming maintenance periods:

The aircraft is under a Conditions-Based Maintenance (CBM) program starting in FY24. There are no upcoming maintenance periods that require the aircraft to be unavailable for mission use. The CBM program allows for maintenance activities to be performed around mission activities to maximize aircraft availability.

Website:

https://airbornescience.nasa.gov/aircraft/P-3_Orion_-_WFF

Other NASA Earth Science Aircraft

Other NASA aircraft, as described here, on the Airborne Science website, and in the annual ASP Call Letter, are platforms operated by NASA centers. Although not subsidized by the ASP program, these aircraft are also modified to support Earth-observing payloads. These aircraft are available for science through direct coordination with the operating center.

Table 15. *Other NASA aircraft available for Earth science missions.*

Aircraft	Operating Center
B-200 King Air	LaRC, AFRC, or contracted
GV	JSC
Small UAS	AFRC, ARC, LaRC, JPL

B-200 Turboprop

Operating Center:
LaRC, AFRC

Aircraft Description:
The Beechcraft B-200 King Air is a twin-turboprop aircraft capable of mid-altitude flight (up to 30,000 ft) with up to 1,000 pounds (454 kg) of useful payload for up to 6 hours. LaRC operates a conventional B-200 and AFRC operates a Super King Air B-200 modified for downward-looking payloads.

Figure 77. *NASA B-200 and Dynamic Aviation B-200 stationed for FireSense sampling and USFS-NASA public field day in Richfield, Utah.* ***Credit:*** *Milan Loiacono/ NASA*

FY24 Science Flight Hours: 43.9 (LaRC); 29.8 (AFRC)

Table 16. B-200 Turboprop FY24 missions.

Mission	Aircraft	Location	Science Program Area
FireSense 2023	B-200 (AFRC)	AFRC	Tropospheric Composition
FireSense 2023	B-200 (LaRC)	AFRC	Tropospheric Composition
ARCSIX Check Flight	B-200 (LaRC)	LaRC	Radiation Sciences
Compact Hyperspectral Air Pollution Sensor — Demonstrator	B-200 (LaRC)	LaRC	ESTO Instrument Incubator

FY24 B-200 Modifications and Impacts on Performance and Science:

None

Current and upcoming maintenance periods:

LaRC B-200:

Maintenance Period (FY25 Q1-2): The following upgrades are in progress for FY25 on LaRC B-200 (N529NA) to improve handling performance/safety. Upgrades also bridge (speed/altitude) performance-offering gaps between B-200 and G-III aircraft that enable science mission cost and planning efficiencies.

- Raisbeck 5-bladed Swept Composite Propellers
- Raisbeck High Flotation Landing Gear Doors
- Raisbeck Dual Aft Body Strakes
- Centex HALO 275 Conversion
- Centex Saddle Tank Kit

AFRC B-200:

Maintenance Period: None

Websites:

LaRC B-200:
https://airbornescience.nasa.gov/aircraft/B200_-_LARC

AFRC B-200:
https://airbornescience.nasa.gov/aircraft/B200_801_-_AFRC

Gulfstream V Business Jet

Operating Center:
NASA JSC

Aircraft Description:
The Gulfstream V (GV) is a long-range, large business jet aircraft built by Gulfstream Aerospace, derived from the Gulfstream IV. It flies at speeds up to Mach 0.885, an elevation of up to 51,000 feet, and has a range of 5,000 nautical miles. JSC procured the GV in 2016 as part of a shared usage agreement between the ISS program and NASA ESD. The ISS program would use the GV for Crew Return missions and ESD would use it to support airborne science missions in remote locations around the world.

Note: The aircraft remains in the Agency to support increasing requirements for the human spaceflight program and is only available to ESD missions on a limited, fully reimbursable basis.

Figure 78. *GV in South Africa for BioSCape.* ***Credit:*** *Otto Whitehead*

FY24 Science Flight Hours: 173

Table 17. *GV FY24 missions.*

Mission	Location	Science Program Area
BioSCape	South Africa	Biological Diversity
SToRM SAR	Houston, TX	ESTO Instrument Incubator Program

FY24 GV Modifications and Impacts on Performance and Science:

None

Current and upcoming maintenance periods:

None

Website:
https://airbornescience.nasa.gov/aircraft/Gulfstream_V_-_JSC

5. Education, Training, and Outreach

Student Airborne Research Program (SARP)

In August 2024, 47 students from NASA's Student Airborne Research Program (SARP) gathered to present their final research, split between the University of California, Irvine (UCI) on the West Coast and NASA LaRC on the East Coast.

SARP is an eight-week summer internship for undergraduate students, hosted in two cohorts: this year SARP West operated out of Ontario Airport and UCI in California, while SARP East operated out of WFF and Christopher Newport University in Virginia. After research introductions from faculty, instrument scientists, and staff, students are assigned to a research team in the areas of atmospheric science, ocean biology, or terrestrial ecology. Each group is led by a faculty researcher who is a specialist in that field, along with a graduate student mentor. Over the course of the summer, under the

Figure 79. *SARP 2024 students pose in front of a replica of the Mars 2020 Perseverance Rover at the Jet Propulsion Laboratory in Pasadena, CA.* ***Credit:*** *NASA*

Figure 80. *SARP 2024 students on a guided tour at the Great Dismal Swamp National Wildlife Refuge in southeastern Virginia.* ***Credit:*** *NASA*

direction of the faculty researcher, each intern develops their own research project using the data that they collected and analyzed from the field component of the program.

"You really see them become scientists in their own right," said Stephanie Olaya, SARP Project Manager. "A lot of these projects are at the graduate level: they are making important contributions in Earth Science research and applications. They don't even realize the magnitude of the things they've accomplished until the end of the program."

Research is not the only focus of the program, however. Throughout the program, the students not only get to experience a typical field campaign but also grow in confidence and develop a strong sense of camaraderie with their peers. Building a sense of community is an important

Figure 81. *SARP 2024 students pose in front of NASA's P-3 aircraft at Wallops Flight Facility in Wallops Island, VA.* ***Credit:*** *NASA*

Figure 82. *SARP 2024 students pose in front of NASA's P-3 aircraft in Ontario, CA.* ***Credit:*** *NASA*

aspect of the program, which bonds the student cohort through shared interests, communal living, and regular group dinners and outings, in addition to the hours of team fieldwork, data collection, and laboratory analyses.

The summer of research culminates in August with the final presentations, which are another critical element of the program as they teach students how to communicate scientific research and results. Both the East Coast and West Coast presentations are attended in person by mentors, professors, and NASA personnel, and online by families and friends.

The final event of the summer finished with remarks by Barry Lefer, SARP Program Scientist. "I want to welcome you to the SARP family," Lefer said, "and to the NASA family."

Students Participate in NASA Airborne Science Missions

NASA Airborne Science missions are not only a unique way to collect data for process studies, satellite calibration and validation, and instrument development, but also a great opportunity to involve students in the exciting scientific process. Through in-person and/or virtual outreach experiences, learners (i.e., students) of all ages hear more about NASA Science, ask questions to scientists, and often have a chance to collect their own relevant data to support the mission. These opportunities lower the barrier that often makes it difficult for students to access scientific resources and to be heard.

Three airborne campaigns, BioSCape, ASIA-AQ, and PACE-PAX, received comprehensive outreach support in FY24. The following text highlights these campaigns from an outreach perspective.

BioSCape

The BioSCape mission in Cape Town, South Africa provided a unique opportunity for local South African learners to not only learn about a large-scale scientific effort happening in their own "backyards," but also a chance to be a part of that effort. In November 2023, approximately 170 learners from 10 schools learned about the mission and collected their own Global Learning and Observations to Benefit the Environment

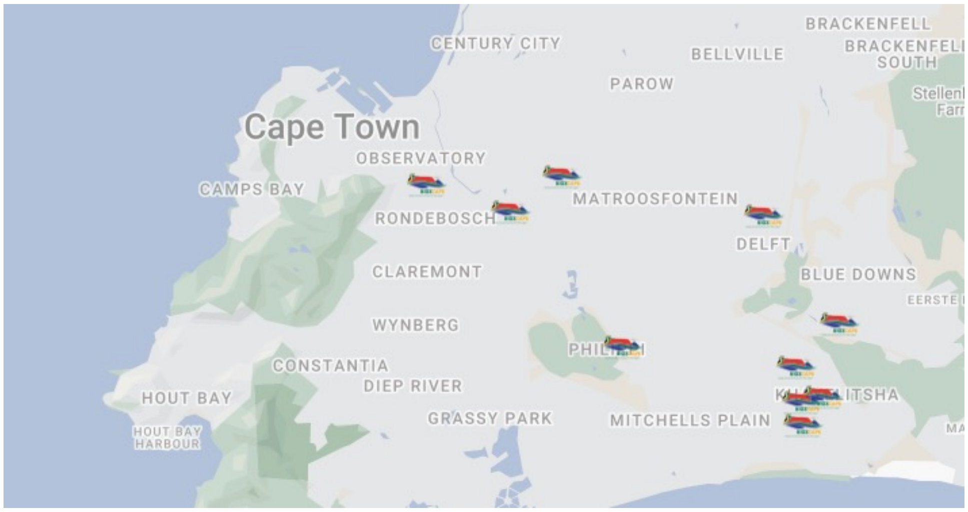

Figure 83. *A map of all local schools that attended a BioSCape outreach event.*

(GLOBE) Program data for Clouds (~20 measurements total) and Sea Surface Temperature (30 measurements total).

The GLOBE Program was launched in 1995 as an international science and inquiry-based education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process and contribute meaningfully to our understanding of the Earth system and global environment. The GLOBE Program has standardized protocols, or methods of collecting Earth Science data, that are used by all participants all over the world. These protocols fall into one of the following categories: Atmosphere, Pedosphere, Biosphere, or Hydrosphere. Nearly 130 countries belong to the GLOBE network, which means they can collect, upload, and use GLOBE data in their own projects or to satiate their own curiosity.

South Africa belongs to the GLOBE Program and their activity is monitored and facilitated by the Africa Regional Coordinator and South Africa Country Coordinator. BioSCape presented a wonderful opportunity to leverage the GLOBE network in South Africa to allow high school

Table 18. *List of all schools, locations, and student counts. Schools marked with an asterisk were from townships. There were ten schools in total; 60% were from townships.*

School Name	Location	# Students
Thandokhulu HS	Mowbray	25
Isilimela SS	Langa	20
Manzomthombo SS*	Mfuleni	25
Bulumko SS*	Khayelitsha	17
Luhlaza SS Usasazo HS* Sophumelela SS	Khaya Victoria Mxenge Mitchells Plain	13
Delft HS*	Delft 1 and 2	18
Athlone HS	Athlone	10
COSAT*	Khayelitsha	16

learners to be part of the BioSCape data collection team. Preparations for activities began in early 2023, with leadership from the BioSCape team facilitating outreach progress before handing the role over to the South African Environmental Observation Network (SAEON) later in the year. Over the course of planning, additional local players were added to the outreach team, notably the Cape Winelands Biosphere Reserve (CWBR), South African Agency for Science and Technology Advancement (SAASTA), Cape Town Science Centre (CTSC), and Enviroworks. In total, ten schools participated in outreach events. Notably, six of these schools were from townships, or historically impoverished areas created because of apartheid. These schools would not have been safe or accessible to go to directly, so all schools were invited to join at the Department of Forestry, Fisheries, and the Environment (DFFE) Marine Research Aquarium in Sea Point, South Africa.

Student outreach days typically consisted of hosting one school during a morning session (9:00 AM – 12:00 PM) and one school during an afternoon session (12:30 PM – 3:30 PM). The agenda for the sessions was identical:

- Introduction to biodiversity and BioSCape
  - Short interactive presentation explaining what biodiversity is, why we should protect it, and what BioSCape is doing to help. Timing was very flexible to account for loadshedding (i.e., planned power outages), which happened twice at the Aquarium.
- STELLA spectrometer demo to explain remote sensing
  - A handheld Science and Technology Education for Land/Life Assessment (STELLA) spectrometer and accompanying data visualization site allowed learners to see in real time the spectral difference between plants that humans can only perceive as “green.” Local plants were procured from a South African store; they were donated to volunteers after BioSCape was completed.
- Introduction to GLOBE and overview of relevant GLOBE protocols
  - GLOBE protocols for studying clouds and sea surface temperature were explained in detail.

Figure 84. *High school learners from Thandokhulu High School complete an Atmosphere: Clouds GLOBE learning activity before going outside to collect data.* ***Credit:*** *Brenna Biggs*

Figure 85. *High school learners from Isilimela Secondary School measuring sea surface temperature using the Hydrosphere: Water Temperature protocol.* ***Credit:*** *Brenna Biggs*

- Data collection at Sunset Beach
  - In groups of 4 to 5 people, students collected data about Sea Surface Temperature and Clouds. They inputted their results on a volunteer's cell phone using the GLOBE Observer App.
- Educational fun with CWBR
  - The CWBR brought a mobile unit filled with fun interactive activities. Learners got to play educational games, use telescopes and binoculars, and learn a little local geography with the team.

Additionally, a "Train the Trainer" session was held for South African volunteers, educators, and administrators to learn more about BioSCape and GLOBE. They collected additional data about clouds, biometry, and land cover using GLOBE protocols. In total, the group collected about sixty Biosphere measurements. Groups also collected additional Atmosphere: Clouds measurements at the world-famous Kirstenbosch Botanical Garden. Over the course of the two-day training,

Figure 86. *High school learners from Thandokhulu High School learn how to use binoculars and telescopes to check out their natural surroundings. Many learners enjoyed aiming the tools towards hikers on the famous Lion's Head peak nearby.* ***Credit:*** *Brenna Biggs*

Figure 87. *Volunteers, educators, and learners from Delft High School strike a silly pose on Sunset Beach after collecting GLOBE data.* ***Credit:*** *Thomas Mtontsi*

Figure 88. *"Train the Trainer" attendees learning how to collect Atmosphere: Cloud measurements on Sunset Beach using the GLOBE Observer app.* ***Credit:*** *Brenna Biggs*

~30 Clouds data points were collected by the Trainers.

Overall, the GLOBE outreach portion of the BioSCape campaign was impactful, forging lasting connections to kick off the new school year in January 2024. Personalized certificates were handmade for all 170 learners plus the volunteers, so they had a keepsake to commemorate their contribution to BioSCape.

Figure 89. *Attendees at the GLOBE "Train the Trainer" workshop at Kirstenbosch National Botanical Garden before venturing off to collect data.* ***Credit:*** *Brenna Biggs*

Figure 90. *Enviroworks representatives at the "Train the Trainer" workshop learning how to collect Tree Circumference data using the diameter at breast height (DBH) level.* ***Credit:*** *Brenna Biggs*

ASIA-AQ

During ASIA-AQ outreach, approximately 5,267 students from at least 96 schools learned about ASIA-AQ through in-person and virtual interactions. In total, 26 in-person events (2,010 minutes / 33.5 hours) were completed, reaching 2,812 students. In-person attendees had the opportunity to participate in different activities:

- Presentation about the ASIA-AQ mission (all events).
- "Make Your Own Clouds" craft: Students, especially younger students (i.e., equivalent to American 6th grade or below) enjoyed the opportunity to make their own clouds using colored paper and glue. In total, 52 students from two schools completed a cloud craft activity.
- Data collection using GLOBE Atmosphere – Clouds protocols: In total, 2,265 students at 14 different outreach events participated in this activity and uploaded 71 GLOBE Cloud observations – 35 in the Philippines, 17 in South Korea, and 19 in Thailand – to the international GLOBE database.
- Data collection using Whole Air Sampling (WAS) canisters: The canisters used for outreach were identical to those used onboard the DC-8 during ASIA-AQ to collect airborne samples. All samples were shipped back to a university laboratory, where they were analyzed using gas chromatography to identify and quantify over one hundred volatile organic compounds. This generous act empowered them to collect their own air quality data as part of the mission. In total, about 40 WAS samples were collected at outreach events in Philippines, South Korea, and Thailand.
- Trivia and prizes: At many of the longer events, a trivia portion was included by 1) bringing a list of prepared science questions, 2) asking questions based on the ASIA-AQ presentation, or 3) using questions the school had prepared

Figure 91. *Students at Wenzao University of Languages in Kaohsiung City, Taiwan pose for a photo with Brenna Biggs after a virtual outreach event. The week following the event, students tracked the DC-8 on the NASA Airborne Science Program tracker and caught a photo of it (below) over their school.* ***Credit:*** *Brenna Biggs and Armin Ibitz/WZU*

Figure 92. *A student from a local Thai school at a GISTDA / IPST event at Space Inspirum, Si Racha, Thailand helps Angelique Demetillo, ASIA-AQ G-III instrument operator, fill out information for WAS sample collection.* ***Credit:*** *Brenna Biggs*

Figure 93. *Students at Pandaras Integrated School in the Philippines learning how to take a WAS sample.* ***Credit:*** *Brenna Biggs*

to quiz students and hand out prizes. Prizes included the following: NASA logo tote bags, astronaut drawstring bags, temporary tattoos, lanyards, logo and mission stickers; DENR books, notebooks, umbrellas, water bottles, and tote bags.

- Sharing what was learned: When time allowed, students were welcome to share what they learned from the outreach event – which was an additional way they could earn prizes. Many students shared what they learned about air quality, air pollution, NASA, clouds, and more.

In addition to the in-person events, thirty virtual events were completed (1,590 minutes / 26.5 hours), reaching 2,285 people in 12 countries (i.e., United States, Canada, South Africa, Philippines, South Korea, Taiwan, Micronesia, Nepal, Vietnam, Thailand, India, Mongolia). Virtual events occurred for multiple reasons, such as 1) the school was in an ASIA-AQ partner country, but too far to visit in person, 2) the school was in a country that was interested, but that the mission would not visit, 3) the school found

Figure 94. *Pilots-in-training collect GLOBE Clouds data using the GLOBE Observer mobile application at the First Aviation Academy in Subic Bay, Philippines.* ***Credit:*** *Eric Comendador/DENR*

Figure 95. *Elementary school students at Pyeongtaek Sujae Elementary School in South Korea help DC-8 crew member Julio Trevino fill out information for a WAS sample at their school.* ***Credit:*** *Brenna Biggs*

out about the mission after ASIA-AQ had left their country. Overall, the outreach portion of the ASIA-AQ campaign was a resounding success, forging lasting connections with international partners hopefully well into the future.

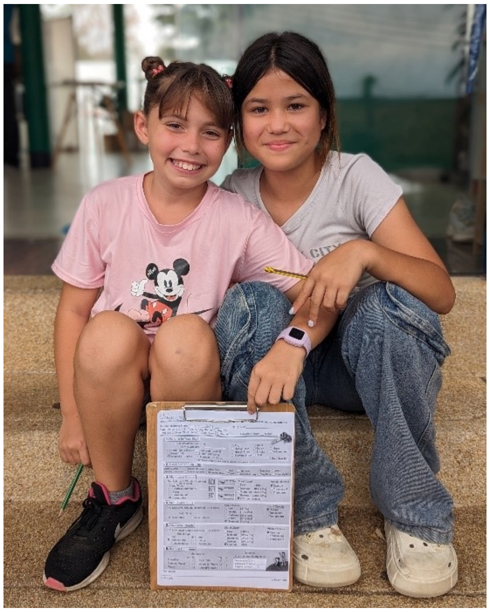

Figure 96. *Students from Odyssey International School in Pattaya, Thailand with their completed GLOBE Clouds observations during ASIA-AQ.* ***Credit:*** *Brenna Biggs*

PACE-PAX

PACE-PAX mission outreach focused on Californian students, as the state was the main deployment location for multiple aircraft and research vessels. Through 63 customized virtual outreach opportunities, about 2,600 students from Grades TK through 12 were reached. These students represented 25 schools in 3 countries (United States, Philippines, and South Africa) and 6 U.S. states (CA, IL, OH, MD, NH, TX). Over 50% of schools were located in California to highlight the state as the mission's hub.

Each outreach event consisted of a customized presentation with a duration ranging from 10 minutes to an hour based on students' grade level and class availability, followed by a question-and-answer (Q&A) session for students to ask about PACE-PAX, NASA, or whatever they wanted.

On some occasions, special guests from PACE-PAX were included in content creation, Q&A, presentations, or tours. For example, PACE-PAX scientists gave virtual tours of a University of California, Santa Barbara laboratory to small groups of Grade 5 students also from Santa Barbara, CA, and a PACE-PAX oceanographer gave tours of her scientific instruments on the R/V Blissfully to 65 students from Grades 3, 5, and 6. The outreach volunteers greatly enhanced the students' experiences through these virtual opportunities.

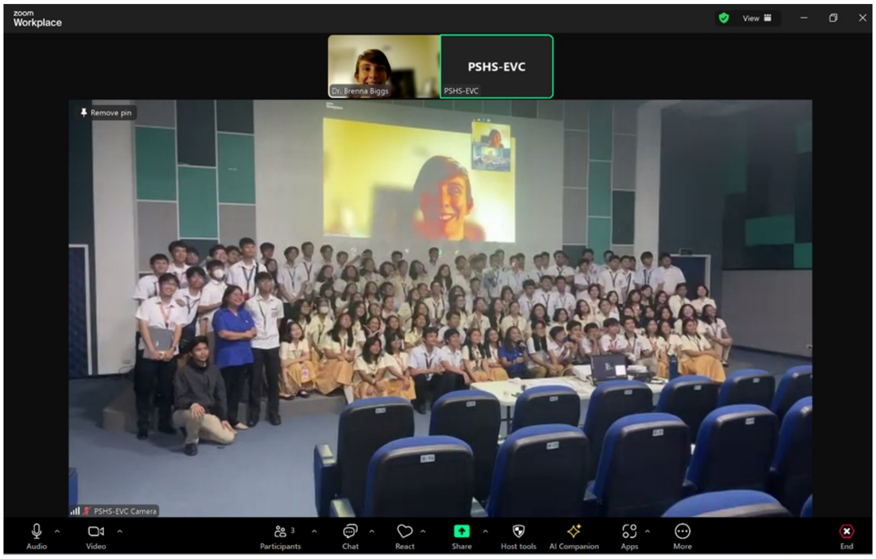

Figure 97. *Students at Philippine Science High School Eastern Visayas Campus pose for a picture after a PACE-PAX outreach event.* ***Credit:*** *Brenna Biggs*

Figure 98. *Students at Empangeni High School in South Africa during a PACE-PAX outreach event.* ***Credit:*** *Brenna Biggs*

6. Major Program Changes and Updates

FY24 brought many exciting changes to the Airborne Science Program. As we continued to prepare the newly acquired B777 for its first science mission, we said goodbye to the DC-8, moved assets to new homes, and continued to modify our existing fleet.

B777 Development

The program to transform NASA's Boeing 777 (B777) from a passenger jet to an airborne research laboratory made strong progress in FY24 on multiple fronts. The most significant of these activities was the design and analysis of the major structural portals, crucial to transforming the aircraft into a remote sensing and in situ platform. The second half of FY23 was marked by persistent contracting struggles to get this design underway leading to an acquisition strategy change to start FY24. Following a robust proposal review and evaluation, L-3 Harris was awarded the structural portal design and analysis contract in December 2024. One month later, the team assembled at the aircraft to kick the project off to discuss requirements, analyze concepts, and scan the aircraft. The solid start continued all the way through the end of FY24 as L-3 was able to complete the Critical Design Review for all modifications including four cabin window viewports (17" x 24"), four "small" nadir viewports (20" x 28"), two "large" nadir viewports (40" x 44"), and all aircraft systems that needed to be moved or rerouted to accommodate. This was no small feat completed in such a short time, as this modification was not just some small component installation: major load bearing elements that "hold the airplane together" must be cut, replaced, and reinforced to support such wide openings.

In addition, the B777 had significant scheduled maintenance that needed to be addressed prior to active service for the Airborne Science Program, and this was completed in FY24. The aircraft was flown to Citadel Completions in Lake Charles, LA, where all open, scheduled heavy checks were completed, included the

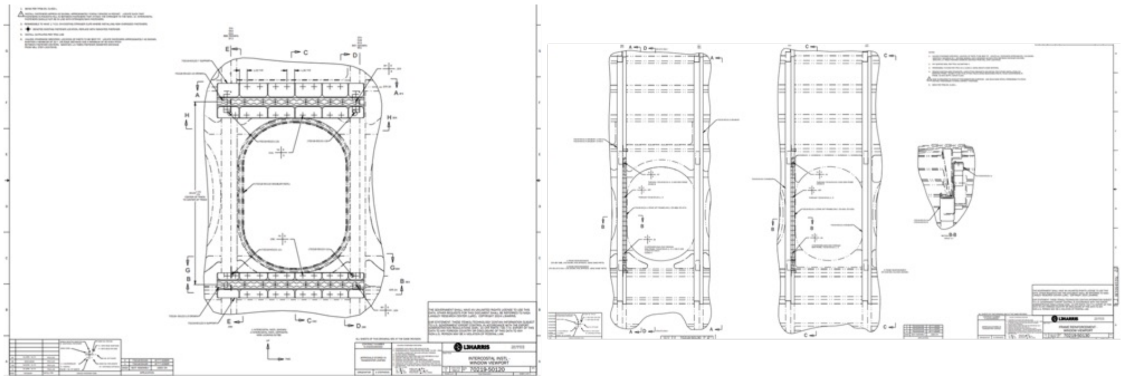

Figure 99. *B777 cabin window viewport design.* ***Credit:*** *NASA*

Figure 100. *B777 scheduled maintenance.* ***Credit:*** *NASA*

replacement of the landing gear system, in four months. A few service bulletins and airworthiness directives need to be completed over the next two years. However, the B777 is well-placed from a maintenance perspective to support airborne research operations.

The LaRC team also installed a portion of the internal “in-house” modifications required to connect the aircraft systems to researcher payloads and systems. Much of this effort focused on the research power, data, and communications systems culminating in a successful test of the power system. This test drew nearly 100 kW from the aircraft and proved that the modification did not impact the B777’s Electrical Loads Management System (ELMS), verified the operation of newly installed load-side differential protector current transformers, and validated the predicted maximum allowable ride-through power during ground-to-engine power transitions.

Looking ahead to FY25 – FY26, efforts will be focused on the completion of necessary activities to ready the aircraft for the first mission slated to start in January 2027. This includes the aircraft being flown to L-3 Harris in Waco, TX, early in FY25 to compete the major structural portal modification.

Figure 101. *B777 cabin experimenter station interface panel.* ***Credit:*** *NASA*

DC-8 Retirement and Continued Legacy

After 37 years of groundbreaking airborne science, the DC-8 completed its final science mission, ASIA-AQ, and returned to AFRC Building 703 in Palmdale, California, on April 1, 2024. The DC-8 was acquired by NASA in 1985 and supported airborne missions from 1987 onwards. The world's largest flying laboratory loyally served the world's scientific community – including scientists, researchers, and students from NASA and other government, state, academic, and international institutions.

The DC-8's legacy continues even through retirement at its new home at Idaho State University (ISU) in Pocatello, Idaho, where it will be used to train future aircraft technicians by providing real-world experience in the university's Aircraft Maintenance Technology program. The DC-8 flew from AFRC to ISU in May 2024 – its final flight after decades of service.

NASA ASP celebrated the DC-8 at the "Contributions of the DC-8 to Earth System Science at NASA: A Workshop" in October 2024, where anecdotes and statistics were shared and

Figure 102. *Idaho State University class of 2025 poses with their new hands-on learning tool, the DC-8 aircraft, after it was retired from NASA in May 2024 and arrived in Pocatello, Idaho.* ***Credit:*** *Idaho State University*

***Figure 103.** The DC-8 flies low for the last time over AFRC in Edwards, California, before it retired to ISU in Pocatello, Idaho. **Credit:** Genaro Vavuris/ NASA*

documented for generations to come. Although the DC-8 is gone, ASP is excited about continuing the science on its next large flying laboratory, the B777.

Vacating AFRC Building 703 in Palmdale, CA

In the monumental task of exiting the NASA AFRC Building 703 (B703) hangar in Palmdale, CA, AFRC's Logistics Team achieved what some were calling "impossible." For years, NASA was leasing B703 from Los Angeles World Airports (LAWA). With the SOFIA and DC-8 Programs sunsetting, NASA no longer required the hangar and so an expedited exit was planned in order to conserve budget.

B703 was once home to 5 aircraft, over 200,000 spare aircraft parts, over 80 CONEX boxes, and long hallways filled with shelves, property, and hardware. After much deliberation, AFRC was officially tasked with exiting Building 703 by September 30, 2024, a year earlier than planned.

On September 13th, 2024, NASA successfully transferred the B703 Palmdale hangar back to the possession of LAWA. Many of the materials and assets were moved to the AFRC main campus in Edwards, CA, while some were sent to other NASA Centers.

This feat required unparalleled leadership and coordination from multiple entities, who successfully managed the clearing of a combined asset footprint spanning 19,200 ft^2 across 71 NASA-owned containers and vacated 70,860 ft^2 of fully occupied indoor warehouse space. This colossal endeavor not only freed NASA from substantial leasing costs but also set a new standard for large-scale asset management and operational efficiency.

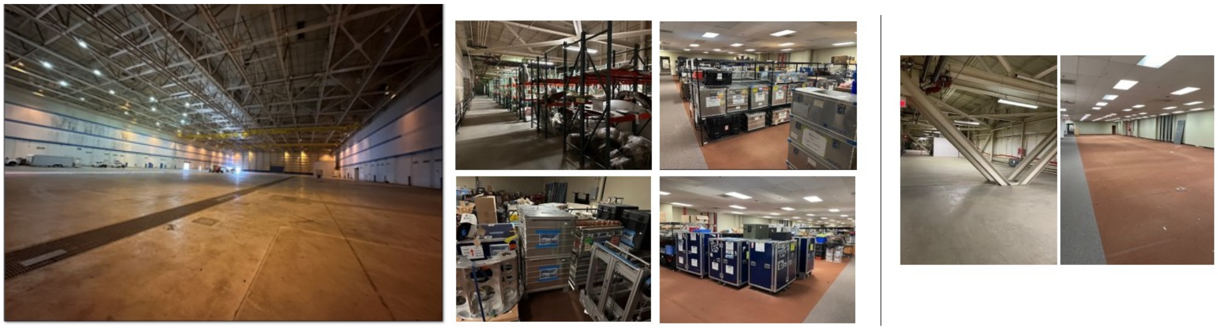

***Figure 104.** NASA AFRC B703 before (Middle) and after (Left, Right) it was cleaned out. **Credit:** Taylor Mcquain/NASA AFRC*

7. Aircraft Cross-Cutting Support and IT Infrastructure

Onboard Data and Communications

All aircraft in the ASP fleet have been modified to enable acquisition, processing, and telemetry of data from their primary payloads to maximize the science return of each flight. Science teams access these data through the Mission Tools Suite (MTS). The sensor network architecture includes standardized electrical interfaces for payload instruments using a common Experimenter Interface Panel (EIP); the NASA Airborne Science Data and Telemetry (NASDAT) system, an airborne network server and satellite communications gateway; and a web-based application programming interface (API) for interfacing to customer software and other agencies.

A high bandwidth Ku-band system, which uses a large steerable dish antenna, is installed on the WB-57. Inmarsat Swift Broadband (SBB) multi-channel systems, using electronically steered flat panel antennas, are available on many ASP core and other NASA aircraft. All aircraft in the ASP Fleet have been equipped with BlueSky's Skylink 7100 Certus Mid-band transceiver, which provides a baseline 88/22kbps worldwide. This system also provides for up to two high fidelity voice lines available using a Android or iOS device on the aircraft's payload network.

NASA cross-program engineering also operates and distributes science support data to primary payloads. These instruments collect important reference information used as a foundation for instrument data processing. These instruments include trajectory, aircraft performance and meteorological measurements, visible still and video imagery, and other airborne instrumentation.

Table 19. *Satellite communications systems on ASP aircraft.*

Satcom Type	Channels	Data Rate, Nominal	Supported Platforms	Support Group
Ku-band	1 channel systems	>1 Mb/sec	WB-57	JSC
Inmarsat BGAN	2 channel systems	432 Kb/sec per channel	DC-8, WB-57, P-3, ER-2, GV	ARC/NSRC, JSC
Iridium	Certus	88 kbps in / 22 kbps out	Most ASP Platforms	ARC/NSRC

NASA cross-program engineering also operates and distributes science support data to primary payloads. These instruments collect important reference information that is used as metadata for instrument data processing. These instruments include meteorological measurements, visible still and video imagery, and other airborne instrumentation.

Table 20. *ASP science support instruments.*

Airborne Science Program Facility Equipment		
Instrument/Description	**Supported Platforms**	**Support Group**
Dew Point Hygrometers	DC-8, P-3	NSRC
IR Surface Temperature Pyrometers	DC-8, P-3	NSRC
LN-251 Embedded GPS/INS Position and Orientation System	DC-8, P-3	NSRC
Combined Altitude Radar Altimeter	DC-8	NSRC
Forward and Nadir 4K Video Systems	DC-8, P-3	NSRC
Total Air Temperature Probes	DC-8, P-3	NSRC
Ice Detector	DC-8	NSRC
MVIS 2K Video Camera (Nadir)	ER-2	NSRC
FLIR Vue Pro R 640 IR Camera (45° and Nadir)	DC-8	NSRC
45° HD Video Camera	DC-8	NSRC

EOS and R&A Program Facility Instruments				
Instrument		**Description**	**Supported Platforms**	**Support Group**
MASTER	MODIS/ASTER Airborne Simulator	50 ch multispectral line scanner V/SWIR-MW/LWIR	B-200, DC-8, ER-2, P-3, WB-57	ASF/ARC
eMAS	Enhanced MODIS Airborne Simulator	38 ch multispectral scanner	ER-2	ASF/ARC
PICARD	Pushbroom Imager for Cloud and Aerosol R&D	400-2450 nm range, $\Delta\lambda$10 nm	ER-2	ASF/ARC
AVIRIS-NG	Airborne Visible/Infrared Imaging Spectrometer-Next Generation	Imaging spectrometer 380-2510 nm range, $\Delta\lambda$ 5 nm	Twin Otter (CAS), B-200	JPL
PRISM	Portable Remote Imaging Spectrometer	350-1050 nm range, $\Delta\lambda$ 3.5 nm	Twin Otter (CAS), ER-2, GV, LaRC G-III	JPL
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer	Classic imaging spectrometer 400-2500 nm range, $\Delta\lambda$ 10 nm	ER-2, Twin Otter (CAS)	JPL
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar	Polarimetric L-band synthetic aperture radar capable of differential interferometry	G-III/C-20A	JPL
NAST-I	National Airborne Sounder Tester-Interferometer	Infrared imaging interferometer 3.5 -16 mm range	ER-2, DC-8	LaRC

NASA ASP Mission Tools Suite (MTS)

The Airborne Science Mission Tools Suite (MTS) is a decision-support and situational awareness system designed to enhance the execution of airborne missions. Its primary purpose is to serve as a central interface for tracking program assets, reporting, and accessing onboard instrument telemetry. MTS also integrates observations from land- and space-based systems to support mission operational objectives. By fostering more responsive and collaborative measurements across instruments on multiple aircraft, satellites, and ground-based systems, MTS aims to maximize the scientific value of mission data.

Advancing to MTS Version 3

Over the past few months, the MTS team has initiated development of the next major system release, Version 3 (v3). Since its inception, MTS has prioritized user feedback to shape its capabilities, resulting in over a decade of customer-focused mission support. The upcoming release seeks to refine existing features and incorporate user insights to deliver the next generation of advanced situational awareness and decision-support applications for ASP and its partners.

Key priorities for the MTS v3 release include:

1. **Leveraging Modern Web Technologies:** MTS has consistently adopted the latest web-based technologies and standards. Recent enhancements in browser and native source code capabilities present opportunities for performance optimizations, improved software reliability, and a robust foundation for future expansions.
2. **Enhancing User Experience:** As a platform serving diverse stakeholders (e.g., Instrument Teams, Mission Scientists, Managers), MTS offers extensive features. The user experience will be optimized to better meet the needs of first-time and recurring users.
3. **Improving Data Integration and Collaboration:** MTS aggregates mission-relevant data sources and products. To enhance interoperability with third-party situational awareness tools, new

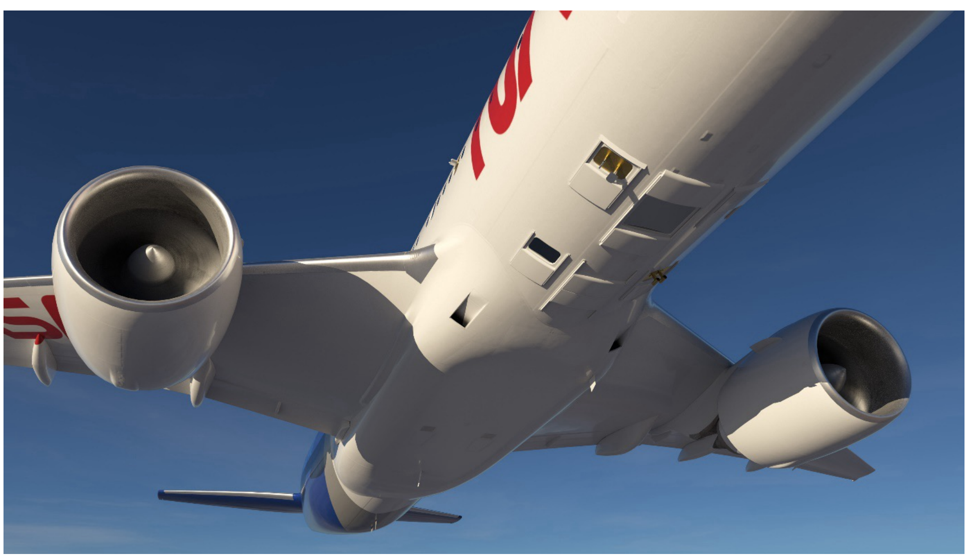

Figure 105. *The planned nadir viewport design for the B777 showing 2 large and 4 small viewports with shutters.*

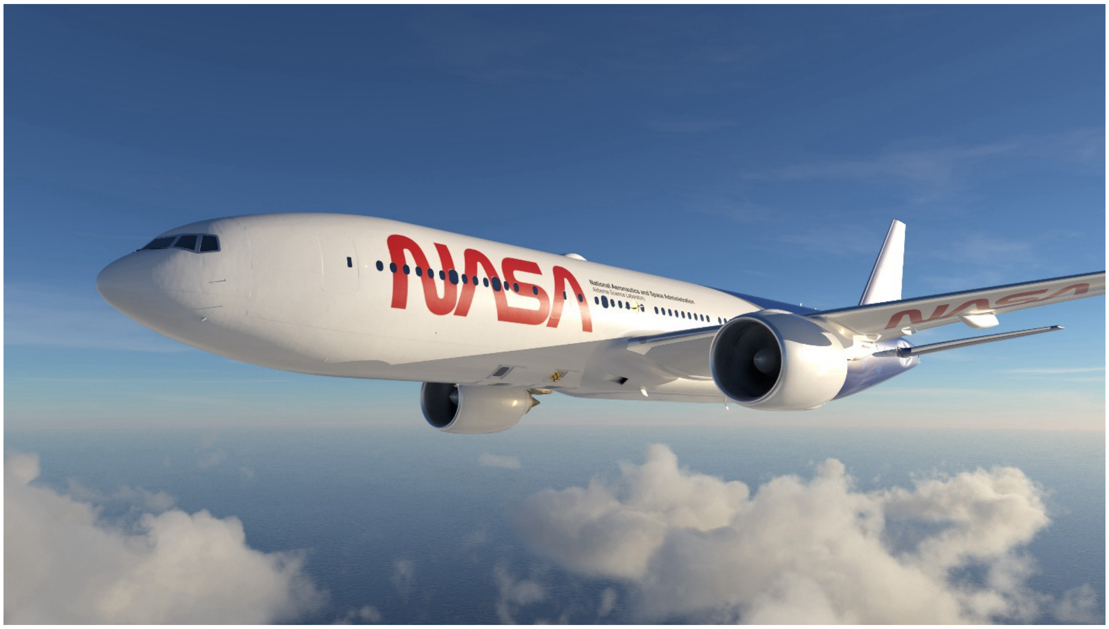

Figure 106. *The B777 features 4 modified window viewports on the port side and 2 on the starboard side of the aircraft (not pictured). The B777 base model is built to conform to a 3D scan of the aircraft for accurate dimensions. Surface details are captured and reproduced in the texture channel via tangent space normal mapping techniques.*

features such as native Tactical Airfare (TAK) server integration will be introduced, facilitating better interagency collaboration.

4. **Exploring Advanced AI Capabilities:** The team is investigating the use of large language models (LLMs) and retrieval-augmented generation pipelines to provide context-aware updates. These technologies aim to enable complex queries across ASP content and real-time mission information.

The overarching goal for MTS v3 is to deliver an exceptional system that meets operational needs during missions while laying the groundwork for advanced capabilities to benefit the Airborne Science user community.

Communication and Outreach Services

Beyond mission support, MTS plays a pivotal role in producing high-quality mission graphics for outreach and official program communications. As the B777 aircraft prepares to come online by 2027, the MTS team is developing a base model for visualizations. These graphics will highlight key features of the platform and serve as media resources.

Additionally, MTS creates mission-specific communication and outreach materials tailored for field campaigns (e.g., Figure 109 illustrating recent samples from PACE-PAX, ARCSIX, and ASIA-AQ). These visuals are instrumental in engaging stakeholders and conveying the Program's impact.

By focusing on both operational excellence and effective communication, MTS continues to serve as a cornerstone of ASP, ensuring mission success and fostering collaboration across diverse scientific endeavors.

Figure 107. *This figure shows various mission-specific program and communication graphics for field campaigns including PACE-PAX, ARCSIX, ASIA-AQ. The graphics are designed to capture the mission domain, payload configuration, mission instruments and NASA and partner aircraft platforms.*

Appendices

Appendix A

5-Year Plan

Atmospheric Composition

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Tasks	PS/PE/PM	Sat	Hours	2025–2030
NASA - P&W - Airbus Chase Plane Study	Van Zante (AATT)	GOES-R	20	
Boeing ecoDemonstrator Explorer Contrail Optical Depth Experiment (CODEX)	Van Zante (AATT)	GOES-R	20	G-III (LaRC)
GHG Center Methane Surveys - 25	Kavvada (GHG Center), Kaye, Lefer, Margolis and Pavlick	EMIT	100	B-200 (other)
Aboveground Carbon Stock Changes in Dynamic Tropical Forests	Hibbard			Other
ESA EarthCARE ATLID Night Validation Flights	Lefer, Maring	EarthCARE	56	B-200 (LaRC)
SARP + VAMOS 2025	Lefer, Argyro Kavvada (GHG Manager)	TEMPO	80	Dynamic Aviation Dash-8

Tasks	PS/PE/PM	Sat	Hours	2025–2030
SARP 25	Lefer, Kim, Kaye			B-200 (DA) P-3
HALO + MethaneAir 2025	Lefer			G-III (LaRC)
ESA EarthCARE ATLID Night Validation Flights	Lefer, Maring	EarthCARE	54	G-III (LaRC)
AirMSPI-2 / MAIA Airborne Science	Maring	MAIA	20	ER-2
ASIA-GHG	Lefer, Kaye	GOSAT GW (Japan)	140	B-200 (LaRC) G-III (LaRC)
FarmFlux - animals (previously NTERFAACE) 26	Lefer, Pavlick, Jucks	TEMPO, CrIS		B-200 (LaRC)
ESA-NASA COSENSE	Lefer, Maring, McCarty	PACE, EarthCare	120	G-III (LaRC)
Student Airborne Research Program (SARP) 2026	Lefer		50	P-3

Atmospheric Composition

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Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
INjected Smoke and PYRocumulonimbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100								ER-2																
INjected Smoke and PYRocumulonimbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100								WB-57																
TASC-CH4 - AMAZON - 26	Lefer, Kaye	OCO-2, OCO-3									G-III (LaRC)																
NOAA Airborne and Remote sensing Methane and Air Pollutant Surveys	Lefer		160								P-3																
HAMAQ (Hemispheric Airborne Measurements of Air Quality) - Mexico City	Lefer	TEMPO, GOES-R, PACE, TROPOMI	90										B777														

Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
HAMAQ (Hemispheric Airborne Measurements of Air Quality) - Mexico City	Lefer	TEMPO, GOES-R, PACE, TROPOMI	100										G-III (LaRC)														
FarmFlux	Lefer, Pavlick, Jucks	TEMPO, CrIS	190											P-3													
Farmflux - animals (previously NTERFAACE) 27	Lefer, Pavlick, Jucks	TEMPO, CrIS												B-200 (LaRC)													
HAMAQ (Hemispheric Airborne Measurements of Air Quality) - Domestic	Lefer	TEMPO, GOES-R, PACE, TROPOMI	90											B777													
HAMAQ (Hemispheric Airborne Measurements of Air Quality) - Domestic	Lefer	TEMPO, GOES-R, PACE, TROPOMI	100											G-III (LaRC)													
TASC-CH4 - AMAZON - 27	Lefer, Kaye	OCO-2, OCO-3												G-III (LaRC)													

Atmospheric Composition

OPEN | APPROVED | No FR

Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126			B-200 (LaRC)			
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126			B-200 (AFRC)			
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126			Other			
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126			P-3			

Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
INjected Smoke and PYRocumulon imbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100			ER-2			
INjected Smoke and PYRocumulon imbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100			WB-57			
Boeing ecoDemonstra tor Chase Plane Study	Van Zante (AATT)	11/19/27					B777		
Hemispheric Airborne Measurements of Air Quality: Mexico City (HAMAQ 2028)	Lefer	TEMPO, TROPOMI, GOES-R, PACE	90				P-3		
Hemispheric Airborne Measurements of Air Quality: Domestic (HAMAQ 2028)	Lefer	TEMPO, TROPOMI, GOES-R, PACE	90				P-3		

Atmospheric Composition

OPEN | APPROVED | No FR

Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126																Other								
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126																P-3								

Weather and Atmospheric Dynamics

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Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
PBL Tech Demo (this is actually NURTURE)	Emory, McCarty	PBL Incubation	150						G-III (LaRC)																		
ESA-NASA COSENSE	Lefer, Maring, McCarty	PACE, EarthCare	120							G-III (LaRC)																	
INjected Smoke and PYRocumulon imbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100								WB-57																
NURTURE - 27	McCarty		200										B777														
PolSIR (Polarized Submillimeter Ice-cloud Radiometer) cal/val campaign	McCarty	PolSIR	50										ER-2														
ALOFT Follow-On	McCarty		60											ER-2													

Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
INjected Smoke and PYRocumulon imbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100												ER-2												
INjected Smoke and PYRocumulon imbus Experiment (INSPYRE)	Lefer, McCarty, Jucks		100												WB-57												
ESTO NIMBUS IIP	McCarty															ER-2											
ESTO PBL DSI instrument demo	McCarty																										
AOS Suborbital Prep	McCarty	AOS															B777 ER-2 P-3										

Climate Variability and Change

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Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
Joint SASSIE/SWOT cal/val	Shiffer	SWOT							
NISAR cal/val - 27	Kaye	NISAR	250			Other			
Possible joint Norwegian cryo mission (Antarctica SCAR/rings)	Markus								

Water and Energy Cycle

OPEN | APPROVED | No FR

Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
LACCE (Landslide Climate Change Experiment)	Bawden		24		G-III (AFRC)				
LACCE (Landslide Climate Change Experiment)	Bawden		24		G-III (AFRC)				
Terrestrial Ecology field campaign (ARID or PANGEA)	Pavlick, McCarty (ground water component of ARID)	SBG				B-200 (DA)			
GLIMR cal/val	Lorenzoni	GLIMR							
LACCE (Landslide Climate Change Experiment)	Bawden		100					G-IV	
LACCE (Landslide Climate Change Experiment)	Bawden		100					G-IV	
Snow4Flow								Other	

Carbon Cycle and Ecosystems

OPEN | APPROVED | No FR

Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
AVIRIS-3 Calibration and Validation	Hibbard		20	B-200 (DA)					
AVIRIS-5 Calibration and Validation	Hibbard		20	B-200 (DA)					
BLUEFLUX 2 - 25	Lorenzoni	OCO-2, ECOSTRESS-ISS, TEMPO, SMAP	72	A90 (DA) B-200 (AFRC) B-200 (LaRC)					
GHG Center Methane Surveys - 25	Kavvada (GHG Center), Kaye, Lefer, Margolis and Pavlick	EMIT	100	B-200 (other)					
Costa Rica Airborne research on foresT Ecosystem Response to volcanic emissions (CRATER)	Phillips, Pavlick		35	Black Swift S2					
GEDI cal/val (Singapore and Brunei) - 25	Pavlick, Whitehurst	GEDI-ISS	150	G-III (LaRC)					

Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
GEDI cal/val - 25	Pavlick	GEDI-ISS	100	GV					
Western Diversity Time Series - 25	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2					
Uncertainty and scaling of wildland fire emissions: Integrating variability in fuel properties for biomass burning carbon emissions inventory	Falkowski, Hibbard	SBG / NISAR		B-200 (in general) G-IV					
Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	Nicholas Rasmussen (CA Dept. of Water Resources), Keith Gaddis (Biological Diversity and Ecological Forecasting)	PACE, HyspIRI, Landsat 8, ECOSTRESS-ISS, GEO-CAPE	40	B-200 (DA)					

Timeline columns are divided into Q1, Q2, Q3, Q4 for each year.

Carbon Cycle and Ecosystems

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Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Spatio-Temporal Dynamics of Nearshore Processes and Their Impacts on the Coastal Arctic Ecosystem - 25	Lorenzoni	Landsat 8, PACE, ICESat II, WorldView-2/3, Sentinel-2 (MSI), Sentinel-3 (OLCI), Landsat 9	30				B-200 (DA)																				
REPMUS 2025	Lorenzoni																										
BlueFlux 2	Lorenzoni (OBB)	OCO II, ECOSTRESS-ISS, TEMPO, SMAP	72					B-200 (DA) B-200 (in general)																			
air-LUSI Operational Campaign 02	Jack Kaye (Research and Analysis), Laura Lorenzoni (Ocean Biology and Biogeochemistry), Bruce Tagg (Airborne Science Program)	PACE, Aqua, Terra, SUOMI-NPP, Landsat 8, air-LUSI supports all satellite programs that use the Moon for calibration purposes.	20					ER-2																			

Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
GEDI cal/val - 26	Pavlick, Whitehurst	GEDI							GV																		
FarmFlux - animals (previously NTERFAACE) 26	Lefer, Pavlick, Jucks	TEMPO, CrIS								B-200 (LaRC)																	
Western Diversity Time Series - 26	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45							ER-2																	
Ocean Color opportunity	Lorenzoni									G-III (LaRC)																	
Uncertainty and scaling of wildland fire emissions: Integrating variability in fuel properties for biomass burning carbon emissions inventory	Falkowski, Hibbard	NISAR	12								G-IV																

Carbon Cycle and Ecosystems

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Tasks	PS/PE/PM	Sat	Hours	2025–2030 (Q1–Q4)
Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	Nicholas Rasmussen (CA Dept. of Water Resources), Keith Gaddis (Biological Diversity and Ecological Forecasting)	PACE, HyspIRI, Landsat 8, ECOSTRESS-ISS, GEO-CAPE	40	B-200 (DA)
Arctic-COLORS (Arctic-COastal Land Ocean inteRactionS) - 26	Lorenzoni		100	
Terrestrial Ecology field campaign (ARID or PANGEA)	Pavlick, McCarty (ground water component of ARID)	SBG		B-200 (DA)
FarmFlux	Lefer, Pavlick, Jucks	TEMPO, CrIS	190	P-3
Farmflux - animals (previously NTERFAACE) 27	Lefer, Pavlick, Jucks	TEMPO, CrIS		B-200 (LaRC)
Western Diversity Time Series - 27	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2
Evaluating the influence of forest structure and water stress on Amazon forest growth and mortality	Pavlick	ECOSTRESS		Other
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126	B-200 (LaRC)
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126	B-200 (AFRC)
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 27	Lefer, Lorenzoni		126	Other

Carbon Cycle and Ecosystems

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Tasks	PS/PE/PM	Sat	Hours	2025–2030 (Q1–Q4)
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126	P-3
Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	Nicholas Rasmussen (CA Dept. of Water Resources), Keith Gaddis (Biological Diversity and Ecological Forecasting)	PACE, HyspIRI, Landsat 8, ECOSTRESS-ISS, GEO-CAPE	40	B-200 (DA)
Arctic-COLORS (Arctic-COastal Land Ocean inteRactionS) - 25	Lorenzoni		100	
Western Diversity Time Series - 28	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2

Tasks	PS/PE/PM	Sat	Hours	2025–2030 (Q1–Q4)
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126	Other
FORTE (Arctic Coastlines–The Frontlines of Rapidly Transforming Ecosystems) - 28	Lefer, Lorenzoni		126	P-3
Airborne Aquatic Science & Applications for the Sacramento-San Joaquin River Delta	Nicholas Rasmussen (CA Dept. of Water Resources), Keith Gaddis (Biological Diversity and Ecological Forecasting)	PACE, HyspIRI, Landsat 8, ECOSTRESS-ISS, GEO-CAPE	40	B-200 (DA)
Western Diversity Time Series - 29	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2

Carbon Cycle and Ecosystems

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Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
				Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4
ESE - EDGE (Earth Dynamics Geodetic Explorer) cal/val		EDGE, STV							
Western Diversity Time Series - 30	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45						
SaltFlux	Pavlick		80						
EMIT cal/val for GHG Center - 25	Argyro Kavvada (GHG Center), Hibbard, Pavlick, Whitehurst	EMIT	150						

Earth Surface and Interior

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Tasks	PS/PE/PM	Sat	Hours	2025	2026	2027	2028	2029	2030
				Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4
Costa Rica Airborne research on foresT Ecosystem Response to volcanic emissions (CRATER)	Phillips, Pavlick		35	Black Swift S2					
NISAR Launch	Bawden	SDC, NISAR							
Geological Earth Mapping Experiment (GEMx) - FY25	Phillips		300				ER-2		
Western Diversity Time Series - 25	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2					
Examining the extent and triggering of fault creep in the Salton Trough using UAVSAR, GNSS, and creepmeter data	Ben Phillips	n/a	6		G-III (AFRC)				

Earth Surface and Interior

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Tasks	PS/PE/PM	Sat	Hours	2025–2030 (Q1–Q4)
NISAR Calibration / Validation: Solid Earth	Bawden	NISAR	36	G-III (AFRC)
NISAR Calibration / Validation: ABoVE	Bawden (Interior and Terrestrial Hydrology Program)	NISAR	54	G-III (AFRC)
Airborne Surface Cryosphere Ecosystem and Nearshore Topography (ASCENT) - East Coast	Phillips	STV	35	DA G-IV
Airborne Surface Cryosphere Ecosystem and Nearshore Topography (ASCENT) - Costa Rica	Phillips	STV	34	DA G-IV
Examining the extent and triggering of fault creep in the Salton Trough - 26	Bawden	NISAR, GNSS	6	G-IV
GEMx/EMRI (USGS) - 26	Phillips	Landsat/ SBG/EMIT	100	ER-2
Western Diversity Time Series - 26	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45	ER-2
LACCE (Landslide Climate Change Experiment)	Bawden		100	G-IV
LACCE (Landslide Climate Change Experiment)	Bawden		100	G-IV
Snow4Flow				Other
LACCE (Landslide Climate Change Experiment)	Bawden		24	G-III (AFRC)
LACCE (Landslide Climate Change Experiment)	Bawden		24	G-III (AFRC)
Airborne Surface Cryosphere Ecosystem and Nearshore Topography (ASCENT) - West Coast	Phillips	STV	40	DA G-IV

Earth Surface and Interior

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Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
NISAR cal/val - 27	Kaye	NISAR	250									Other															
Terrestrial Ecology field campaign (ARID or PANGEA)	Pavlick, McCarty (ground water component of ARID)	SBG											B-200 (DA)														
Examining the extent and triggering of fault creep in the Salton Trough - 27		NISAR, GNSS	6										G-IV														
GEMx/EMRI (USGS) - 27	Phillips	Landsat/ SBG/EMIT	100											ER-2													
Western Diversity Time Series - 27	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45											ER-2													
Western Diversity Time Series - 28	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45															ER-2									
UAVSAR - Landslides and Faults - 28	Phillips	NISAR	20																G-IV								
Western Diversity Time Series - 29	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45																			ER-2					

Tasks	PS/PE/PM	Sat	Hours	2025				2026				2027				2028				2029				2030			
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
ESE - EDGE (Earth Dynamics Geodetic Explorer) cal/val		EDGE, STV																									
Western Diversity Time Series - 30	Kaye, Phillips, Turner / ?	SBG, HyspIRI, Landsat 8	45																								
Eel River Landslide kinematics	Phillips	NISAR	24																								

Appendix B

Acronyms

3-D, 3D	three-dimensional

A

ABoVE	Arctic-Boreal Vulnerability Experiment
ACCESS II	Alternative Fuel Effects on Contrails and Cruise Emissions II
ACES	Airborne Cavity Enhanced Spectrometer
AFRC	Armstrong Flight Research Center
AfriSAR	Africa Synthetic Aperture Radar
AI	artificial intelligence
AirHARP	Airborne Hyper-Angular Rainbow Polarimeter
AirMOSS	Airborne Microwave Observatory of Subcanopy and Subsurface
AirMSPI-2	Airborne Multiangle SpectroPolarimetric Imager-2
AirSAR-NG	Next Generation Airborne Synthetic Aperture Radar
AITT	Airborne Instrument Technology Transition
ALI	Aerosol Limb Imager
AMS	Aerosol Mass Spectrometer
AOS	Atmospheric Observing System
APEX	Active and Passive PBL Profiling EXperiment
API	Application Programming Interface
ARC	Ames Research Center
ARCSIX	Arctic Radiation-Cloud-Aerosol-Surface-Interaction Experiment
ARMD	Aeronautics Research Mission Directorate
ARPA-E	Advanced Research Projects Agency–Energy
ARSET	Applied Remote Sensing Training
ASDC	Atmospheric Science Data Center
ASIA-AQ	Airborne and Satellite Investigation of Asian Air Quality
ASP	Airborne Science Program
AS-TEM	Aerosol Sampler for Transmission Electron Microscopy
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATAK	Android Team Awareness Kit

ATOFMS	Aerosol Time-of-Flight Mass Spectrometry
AVAPS	Advanced Vertical Atmospheric Profiling System
AVIRIS, AVIRIS-C	Airborne Visible/Infrared Imaging Spectrometer Classic
AVIRIS-3	Airborne Visible/Infrared Imaging Spectrometer 3
AVIRIS-NG	Airborne Visible/Infrared Imaging Spectrometer-Next Generation
AWP	Aerosol Wind Profiler

B

BBR	Broadband Radiometers
BioSCape	Biodiversity Survey of the Cape
BGAN	Broadband Global Area Network
BlueFlux	Blue Carbon Prototype Products for Mangrove Methane and Carbon Dioxide Fluxes
BOEM	Bureau of Ocean Energy Management

C

CAFS	Charged-coupled device Actinic Flux Spectroradiometer
Cal/Val	calibration/validation
CARAFE	CARbon Airborne Flux Experiment
CAS	Commercial Aviation Services
CBC	Canadian Broadcasting Corporation
CBM	Conditions-Based Maintenance
CCN	Cloud Condensation Nuclei
CFDC	Continuous Flow Diffusion Chamber
CHAPS-D	Compact Hyperspectral Air Pollution Sensor Demonstrator
CHARON	CHemical Analysis of aeRosol ON-line
CHEMEX	Chemical Exchange
CIMS	Chemical Ionization Mass Spectrometer
CIRPAS	Center for Interdisciplinary Remotely Piloted Aircraft Studies
CIT-CIMS	California Institute of Technology-Chemical Ionization Mass Spectrometer
CNES	Centre National d'Etudes Spatiales
CONEX	Container Express

CONUS	contiguous U.S.
COSAT	Centre of Science and Technology
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
CoSMIR-H	Conical Scanning Millimeter-wave Imaging Radiometer-Hyperspectral
CSA	Canadian Space Agency
CTSC	Cape Town Science Centre
CWBR	Cape Winelands Biosphere Reserve

D

DA	Dynamic Aviation
DAAC	Distributed Active Archive Center
DACOM	Differential Absorption Carbon monOxide Measurement
DAR	differential absorption radar
DASH	Differential Aerosol Sizing and Hygroscopicity
DBH	diameter at breast height
DENR	Department of Environment and Natural Resources
DFFE	Department of Forestry, Fisheries, and the Environment
DFPC	Division of Fire Prevention and Control
DLH	Diode Laser Hygrometer
DLR	The German Aerospace Center
DOI	Department of the Interior
DRC	Democratic Republic of the Congo
DWL	Doppler wind lidar

E

EarthCARE	Earth Cloud, Aerosol and Radiation Explorer
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
EDGE	Earth Dynamics Geodetic Explorer
eDNA	environmental deoxyribonucleic acid
EIP	Experimenter Interface Panel
ELMS	Electrical Loads Management System
eMAS	Enhanced MODIS Airborne Simulator

EMIT Earth Surface Mineral Dust Source Investigation

ER Extended Range

ESA European Space Agency

ESD Earth Science Division

ESO Earth System Observatory

ESPO Earth Science Project Office

Esri Environmental Systems Research Institute, Inc.

ESTO Earth Science Technology Office

EVI Earth Venture Instrument

F

FAA Federal Aviation Administration

FIMS Fast Integrated Mobility Spectrometer

FO Flight Opportunities

FPH Frost Point Hygrometer

FR Flight Request

FY Fiscal Year

G

GCAS GeoCAPE Airborne Simulator

GE Aerospace General Electric Aerospace

GEDI Global Ecosystem Dynamics Investigation

GEMS Geostationary Environment Monitoring Spectrometer

GEMx Geological Earth Mapping Experiment

GEO-CAPE GEOstationary Coastal and Air Pollution Events

GHG greenhouse gas

GISS Goddard Institute for Space Studies

GISTDA Geo-Informatics and Space Technology Department Agency

GLOBE Global Learning and Observations to Benefit the Environment

GMAO Global Modeling and Assimilation Office

GOES Geostationary Operational Environmental Satellite

GOSAT-GW Global Observing SATellite for Greenhouse gases and Water cycle

GPS	Global Positioning System
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
GT-CIMS	Georgia Institute of Technology-Chemical Ionization Mass Spectrometer

H

HALO	High Altitude Lidar Observatory
HAWC	High-altitude Aerosols, Water vapor and Clouds
HMW	hyperspectral microwave
HR-ToF-AMS	High-Resolution Time-of-Flight Aerosol Mass Spectrometer
HS	High School
HSRL	High Spectral Resolution Lidar
HSRL-2	High Spectral Resolution Lidar-2
HyspIRI	Hyperspectral Infrared Imager
HyTES	Hyperspectral Thermal Emission Spectrometer

I

ICESat	Ice, Cloud, and land Elevation Satellite
IIP	Instrument Incubator Program
INS	Inertial Navigation System
InSAR	Interferometric Synthetic Aperture Radar
IPST	Institute for the Promotion of Teaching Science and Technology
IR	infrared
ISAF	In Situ Airborne Formaldehyde
ISRO	Indian Space Research Organization
ISS	International Space Station
ISU	Idaho State University
iTAK	iOS Android Team Awareness Kit

J

JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center

K

K-ACES	Korean-Airborne Cavity Enhanced Spectrometer
K-AMS	Korean-Aerosol Mass Spectrometer
K-CCN	Korean-Cloud Condensation Nuclei
K-CIMS	Korean-Chemical Ionization Mass Spectrometer
K-SP2	Korean-Single Particle Soot Photometer

L

LaRC	Langley Research Center
LARGE	Langley Aerosol Research Group Experiment
LAWA	Los Angeles World Airports
LEAP	Leading Edge Aviation Propulsion
LGR-AAT	Los Gatos Research Ammonia Analyzer
LiDAR	Light Detection and Ranging
LLM	large language models
LTE	Long Term Evolution
LVIS	Land, Vegetation, and Ice Sensor

M

MAIA	Multi-Angle Imager for Aerosols
MARLi	Multi-function Airborne Raman Lidar
MASTER	MODIS/ASTER Airborne Simulator
MetOp	Meteorological Operational
MBARS	Microwave Barometric Attenuation Radar and Sounder
MGA	MIRO Gas Analyzer
MLS	Microwave Limb Sounder
MMS	Meteorological Measurement System
MODIS	Moderate Resolution Imaging Spectroradiometer
MOE	Ministry of the Environment
MOENV	Ministry of Environment
MTS	Mission Tools Suite
Mx	Maintenance

N

NASA	National Aeronautical and Space Administration
NASDAT	NASA Airborne Science Data and Telemetry
NAST-I	National Airborne Sounder Tester-Interferometer
NIER	National Institute of Environmental Research
NIES	National Institute for Environmental Studies
NISAR	NASA-ISRO Synthetic Aperture Radar
NOAA	National Oceanographic and Atmospheric Administration
NPS	Naval Postgraduate School
NSRC	National Suborbital Research Center
NT	Northwest Territories
OMPS	Ozone Mapping and Profiler Suite

O

ONG	oil and natural gas
OPALS	Open-Path Ammonia Laser Sensor
ORNL	Oak Ridge National Laboratory

P

PACE	Plankton, Cloud, and ocean Ecosystem
PACE-PAX	PACE Post-launch Airborne eXperiment
PBL	Planetary Boundary Layer
PI	Principal Investigator
PICARD	Pushbroom Imager for Cloud and Aerosol Research and Development
PRISM	Portable Remote Imaging Spectrometer
PTR-MS	Proton Transfer Reaction Mass Spectrometry
PVST	PACE Validation Science Team

Q

Q&A	question-and-answer

R

R&A	Research and Analysis
RGB	Red Green Blue

RoC	Republic of the Congo
RSP	Research Scanning Polarimeter
R/V	research vessel

S

SAASTA	South African Agency for Science and Technology Advancement
SAEN	South African Environmental Observation Network
SAF	Sustainable Aviation Fuel
SAGA	Soluble Acidic Gases and Aerosols
SAGE III	Stratospheric Aerosol and Gase Experiment III
SAR	Synthetic Aperture Radar
SARP	Student Airborne Research Program
SATCOM	Satellite Communications
SBB	Swift Broadband
SBG	Surface Biology and Geology
SBIR	Small Business Innovative Research
SCOAPE-II	Satellite Coastal and Oceanic Atmospheric Pollution Experiment II
SeaBASS	SeaWiFS Bio-optical Archive and Storage System
SeaSTAR	Sea-going Sky-Scanning Sun-tracking Atmospheric Research Radiometer
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SEO	Sensor Equipment Operator
S-HIS	Scanning High-Resolution Interferometer Sounder
SHOW	Spatial Heterodyne Observation of Water
SIERRA	Sensor Integrated Evaluation Remote Research Aircraft
SMD	Science Mission Directorate
SNR	Signal-to-Noise Ratio
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOFRS	Science Operations Flight Request System
SP2	Single Particle Soot Photometer
SPEC	Stratton Park Engineering Company
SPEX	Airborne Spectro-Polarimeter for EXploration
SS	Secondary School
STELLA	Science and Technology Education for Land/Life Assessment

STMD	Space Technology Mission Directorate
SToRM SAR	Satellite Tomography of Rain and Motion using Synthetic Aperture Radar
STRATO	Strategic Tac Radio and Tac Overwatch
SWE	Snow Water Equivalent
SWESARR	Snow Water Equivalent Synthetic Aperture Radar and Radiometer
SWIR	shortwave infrared
SWOT	Surface Water and Ocean Topography

T

TAK	Tactical Awareness Kit
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TICFIRE	Thin Ice Clouds in Far InfraRed Emissions
TILDAS	Tunable Infrared Laser Direct Absorption Spectrometer
TOGA	Trace Organic Gas Analyzer
TRL	Technology Readiness Level
TROPOMI	Tropospheric Monitoring Instrument

U

U	University
UAS	Uncrewed Aerial System
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar
UC	University of California
UCI	University of California, Irvine
US, U.S.	United States
USFS	United States Forest Service
USGS	United States Geological Survey
UV	ultraviolet

V

v	Version

W

WAS	Whole Air Sampler
WDTS	Western Diversity Time Series
WFF	Wallops Flight Facility
WFIP-3	Wind Forecast Improvement Project-3
WH^{2}yMSIE	Westcoast & Heartland Hyperspectral Microwave Sensor Intensive Experiment

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