NASA's Airborne Science Program

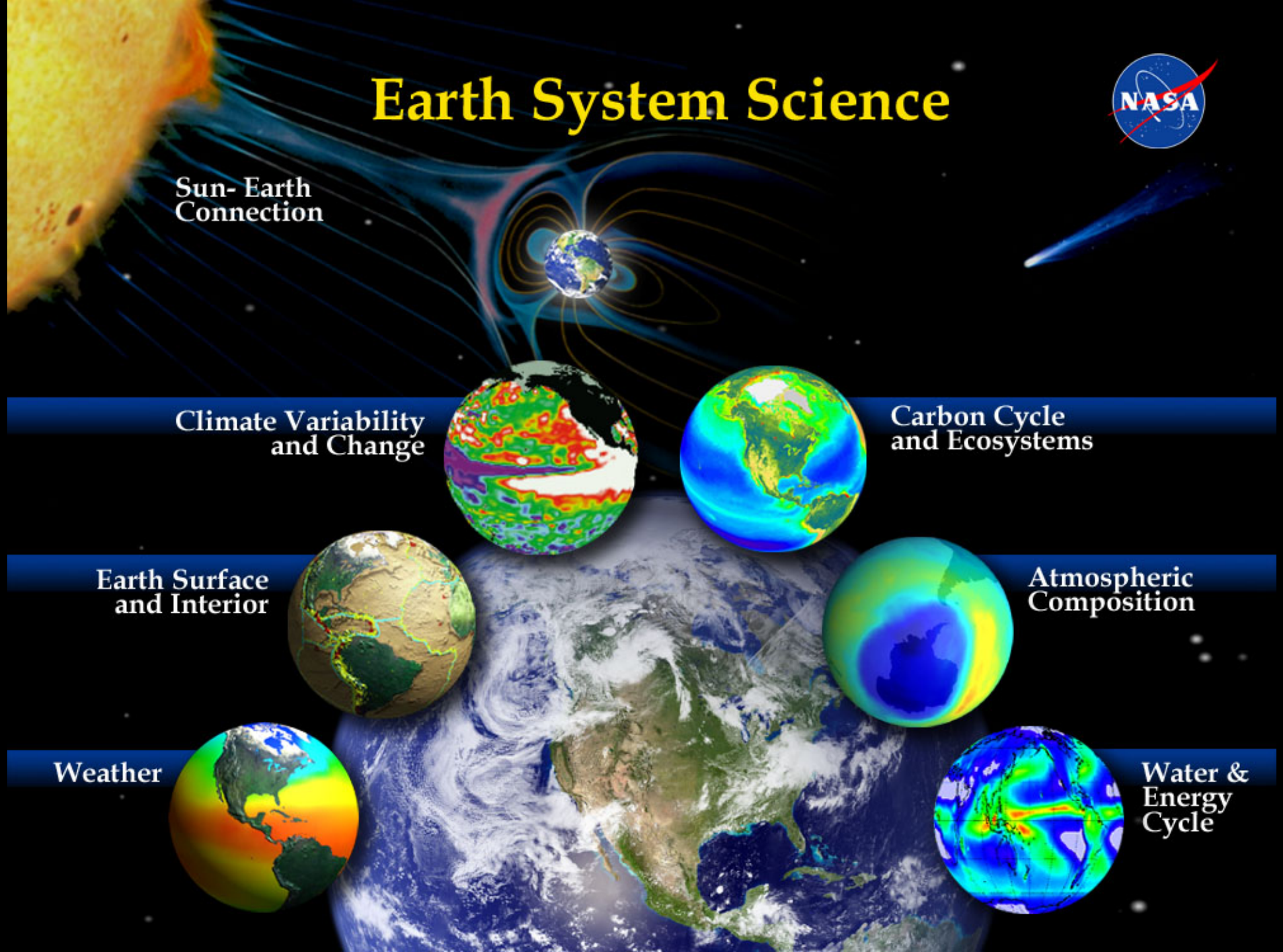
Matthew Fladeland

Deputy Division Chief (Acting),
Airborne Science Manager

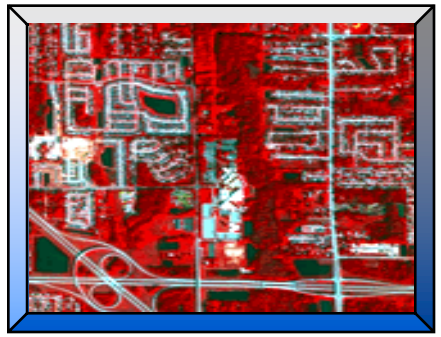
NASA Ames Research Center

NASA Earth Science Technology Forum, June 12th 2019

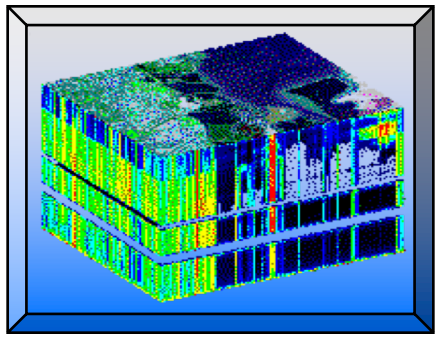
Earth System Science



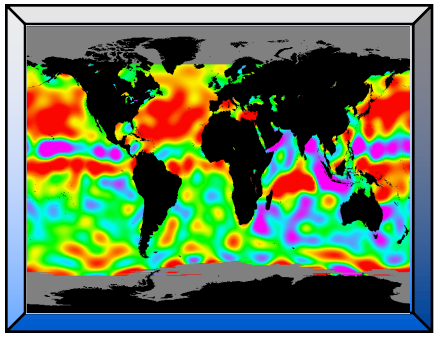
Multiple Remote Sensing Approaches to address science questions



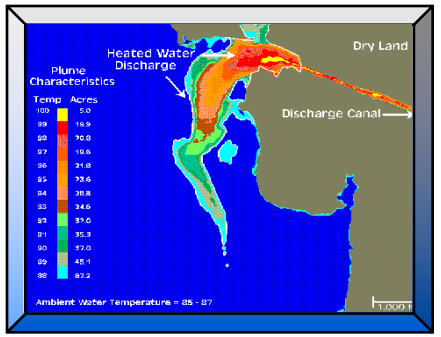
Multispectral



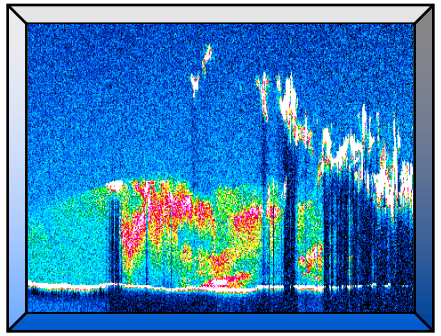
Hyperspectral



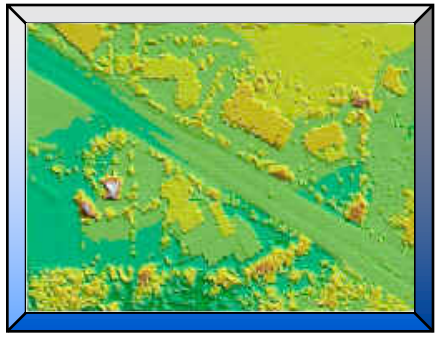
RADAR & SAR



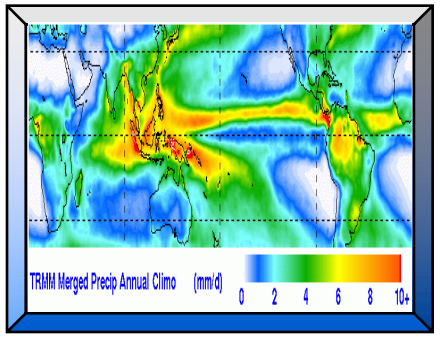
Thermal



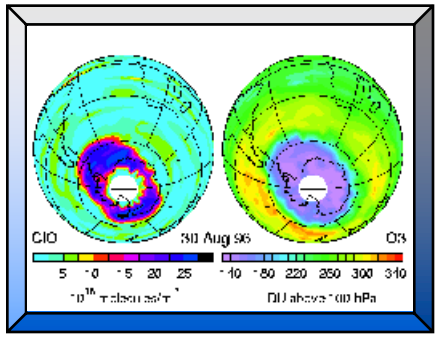
Atmospheric LIDAR



Surface LIDAR

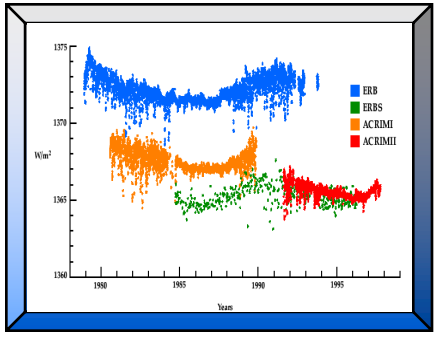


Passive Microwave

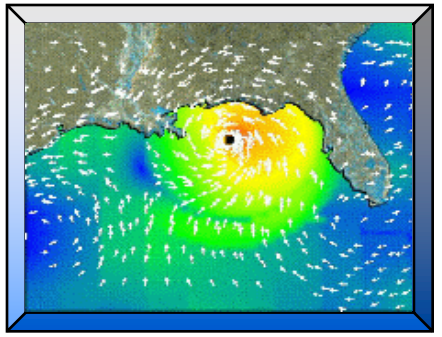


Limb Sounding

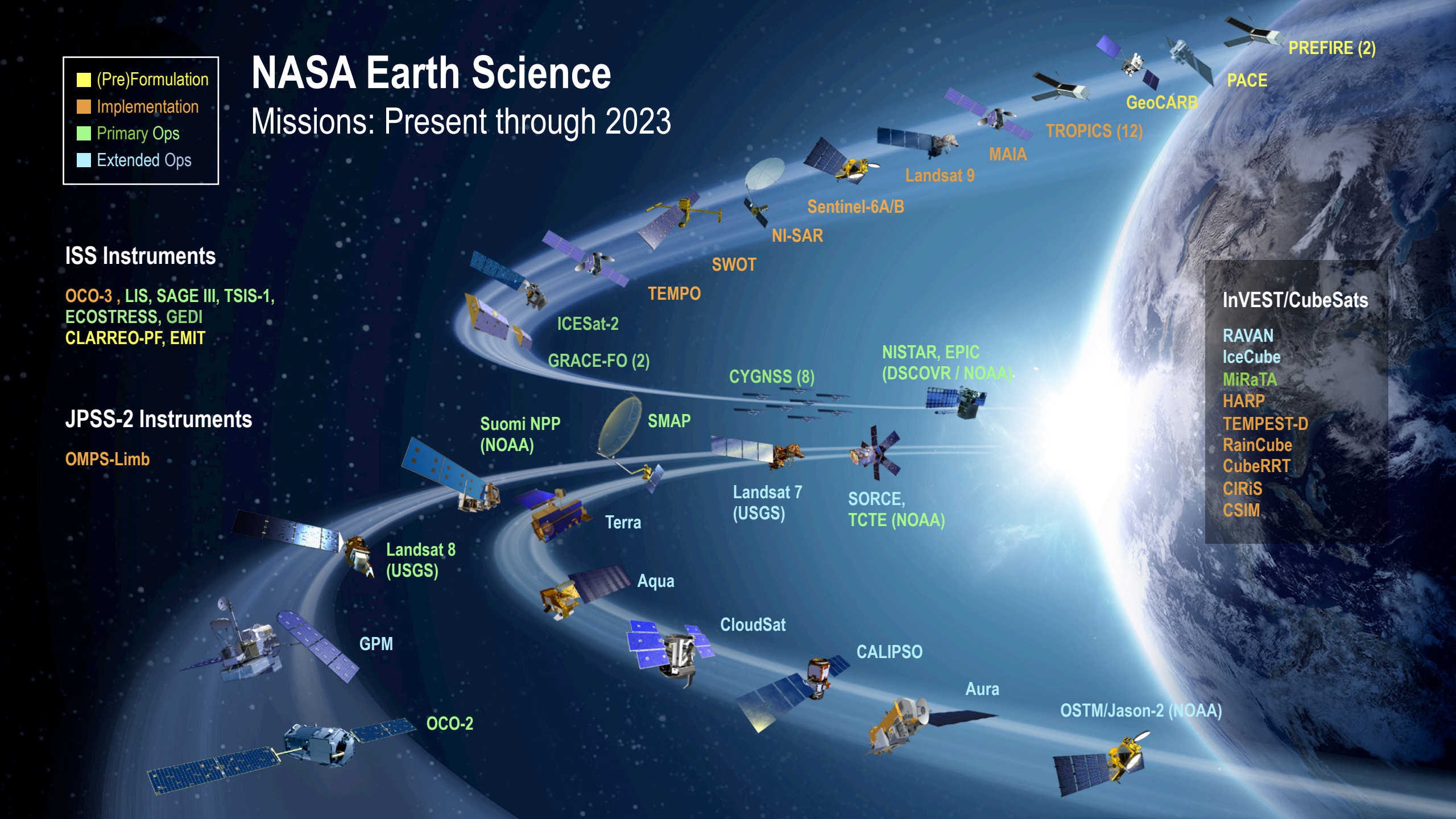
Microwave Ranging

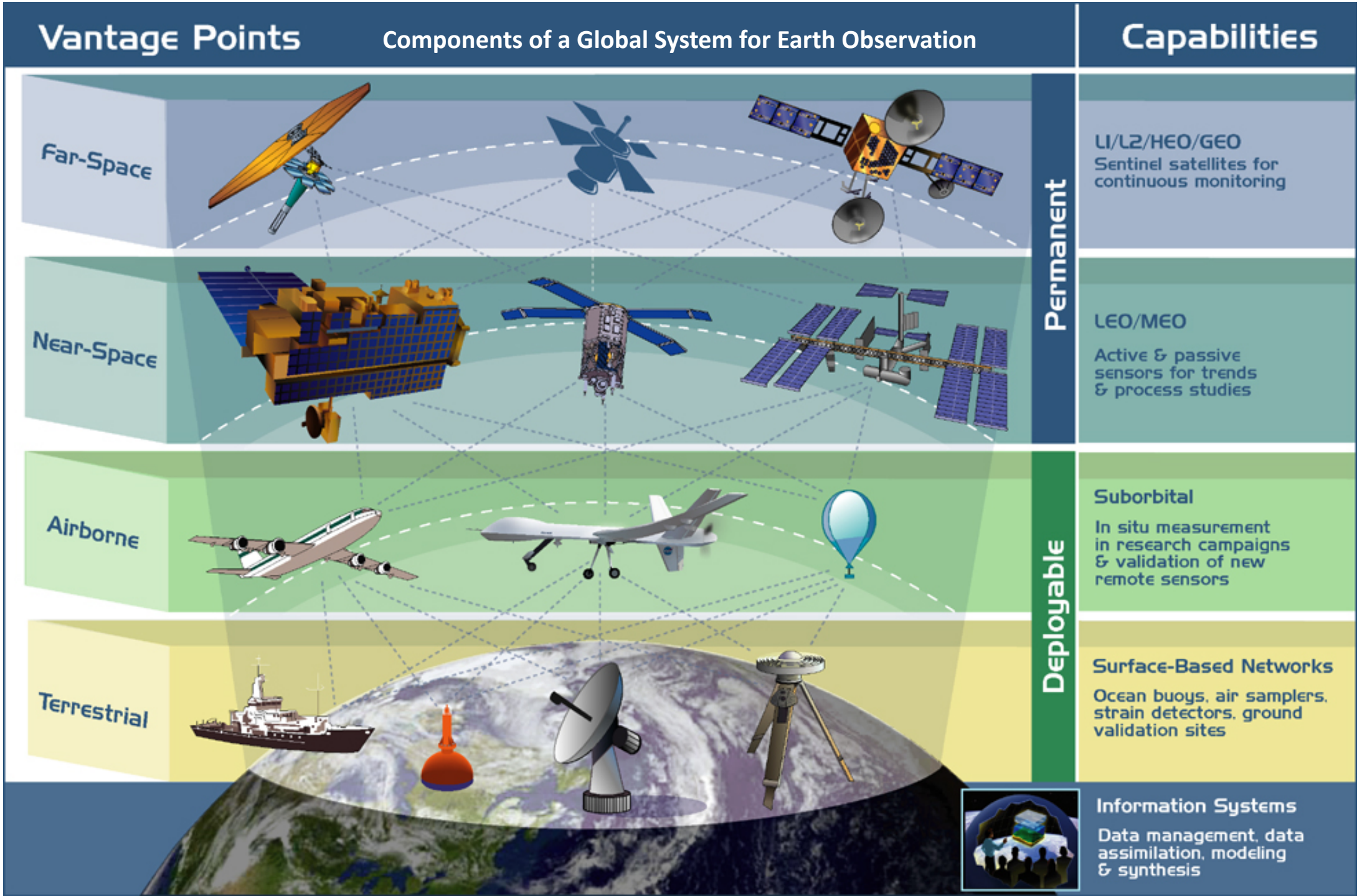


Irradiance/Photometry



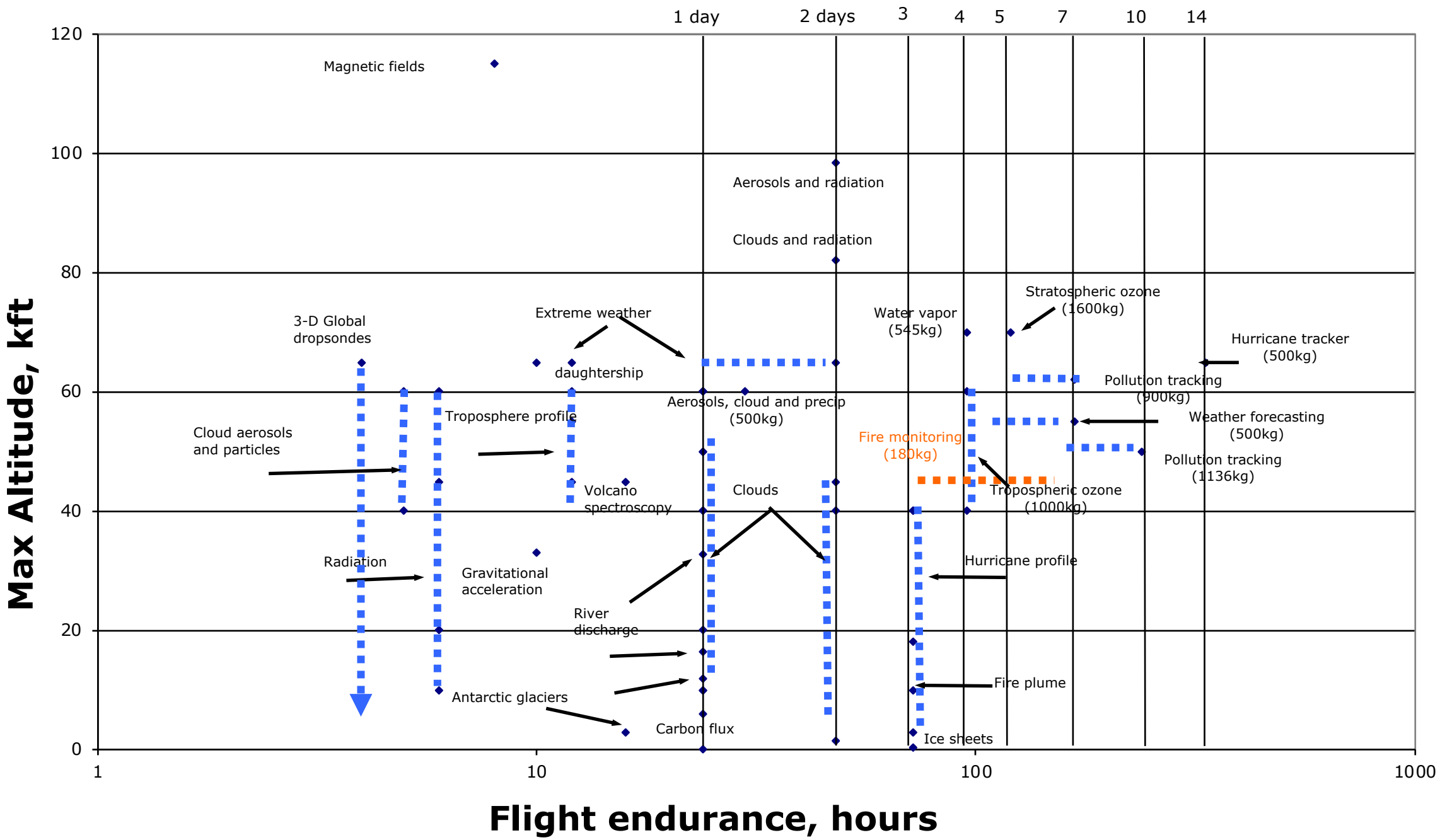
Scatterometry


(Pre)Formulation
Implementation
Primary Ops
Extended Ops
NASA Earth Science
Missions: Present through 2023
ISS Instruments
OCO-3 , LIS, SAGE III, TSIS-1,
ECOSTRESS, GEDI
CLARREO-PF, EMIT
JPSS-2 Instruments
OMPS-Limb
PREFIRE (2)
PACE
GeoCARB
TROPICS (12)
MAIA
Landsat 9
Sentinel-6A/B
NI-SAR
SWOT
TEMPO
ICESat-2
GRACE-FO (2)
CYGNSS (8)
NISTAR, EPIC
(DSCOVR / NOAA)
Suomi NPP
(NOAA)
SMAP
Landsat 7
(USGS)
SORCE,
TCTE (NOAA)
Terra
Landsat 8
(USGS)
Aqua
CloudSat
GPM
CALIPSO
Aura
OCO-2
OSTM/Jason-2 (NOAA)
InVEST/CubeSats
RAVAN
IceCube
MiRaTA
HARP
TEMPEST-D
RainCube
CubeRRT
CIRiS
CSIM

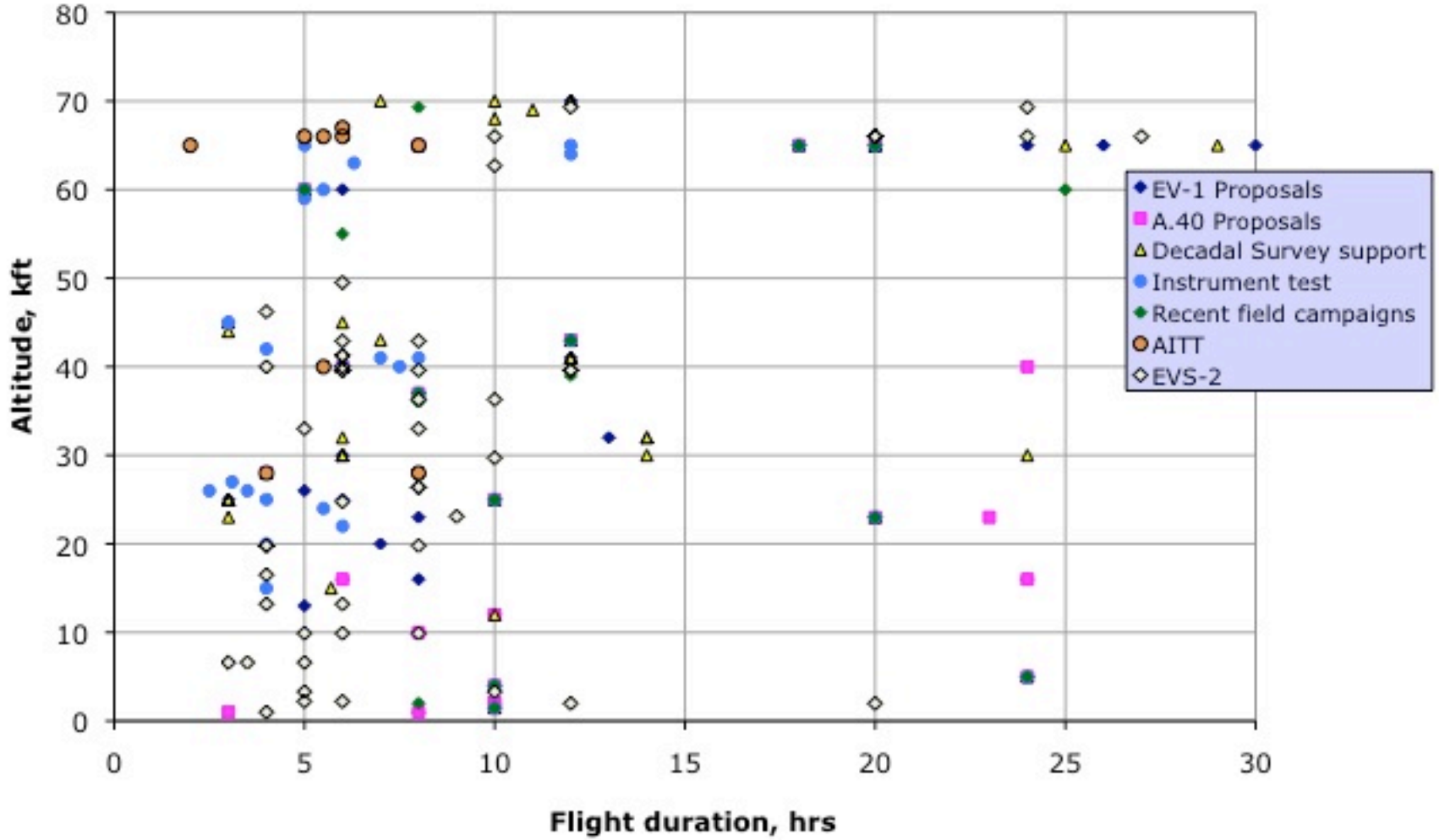

Vantage Points
Components of a Global System for Earth Observation
Capabilities
Far-Space
Near-Space
Airborne
Terrestrial
Permanent
Deployable
L1/L2/HEO/GEO
Sentinel satellites for continuous monitoring
LEO/MEO
Active & passive sensors for trends & process studies
Suborbital
In situ measurement in research campaigns & validation of new remote sensors
Surface-Based Networks
Ocean buoys, air samplers, strain detectors, ground validation sites
Information Systems
Data management, data assimilation, modeling & synthesis

Airborne Platforms Provide Opportunities To Study the Earth System and its Components

- Help **bridge scales** between the (typically) global scales of satellite observations and the very local observations of surface-based in situ measurements.
- Way of doing comprehensive **process-oriented studies** that can focus on specific regions and times of interest.
- Initial sense about Earth system parameters and their variability before satellite observations are possible.
- Focused **calibration/validation** observations (e.g., coincident measurements) for satellite remote sensing.
- Opportunities to **test new instrumentation** in an environment that can provide some similarities to space-based platforms/viewing.
- **Targeted observations** when needed for applications (e.g., disaster response).
- Opportunities for **training of investigators** who see through all phases of a project (instrument development, operation/use, analysis/interpretation, results dissemination, public communication).

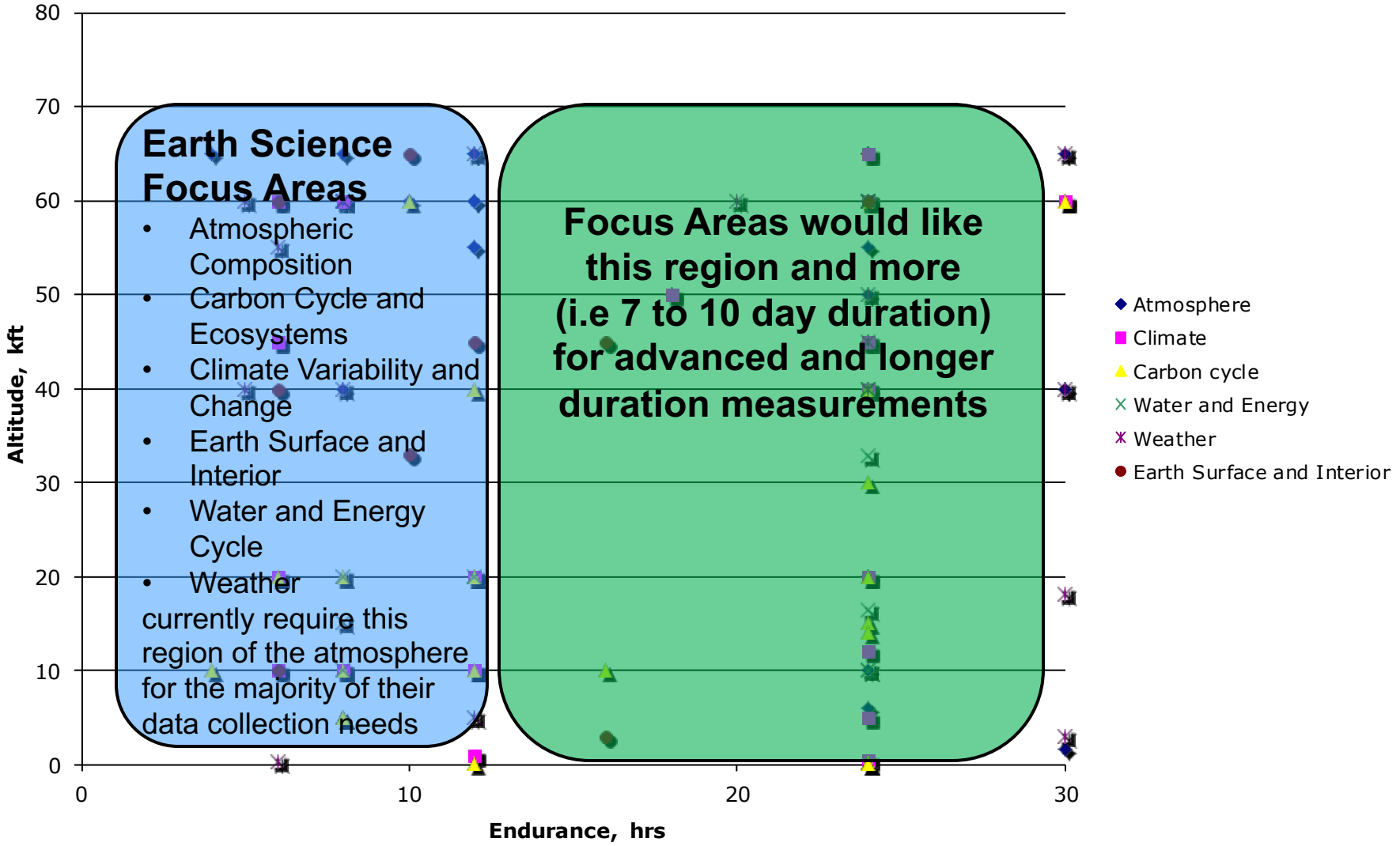

1 day
2 days
3
4
5
7
10
14
120
100
80
60
40
20
0
Max Altitude, kft
1
10
100
1000
Flight endurance, hours
Magnetic fields
Aerosols and radiation
Clouds and radiation
3-D Global dropsondes
Extreme weather
daughtership
Water vapor (545kg)
Stratospheric ozone (1600kg)
Hurricane tracker (500kg)
Pollution tracking (900kg)
Aerosols, cloud and precip (500kg)
Troposphere profile
Weather forecasting (500kg)
Cloud aerosols and particles
Fire monitoring (180kg)
Pollution tracking (1136kg)
Volcano spectroscopy
Clouds
Tropospheric ozone (1000kg)
Radiation
Gravitational acceleration
Hurricane profile
River discharge
Fire plume
Antarctic glaciers
Carbon flux
Ice sheets

Community Requirements for Airborne Measurements



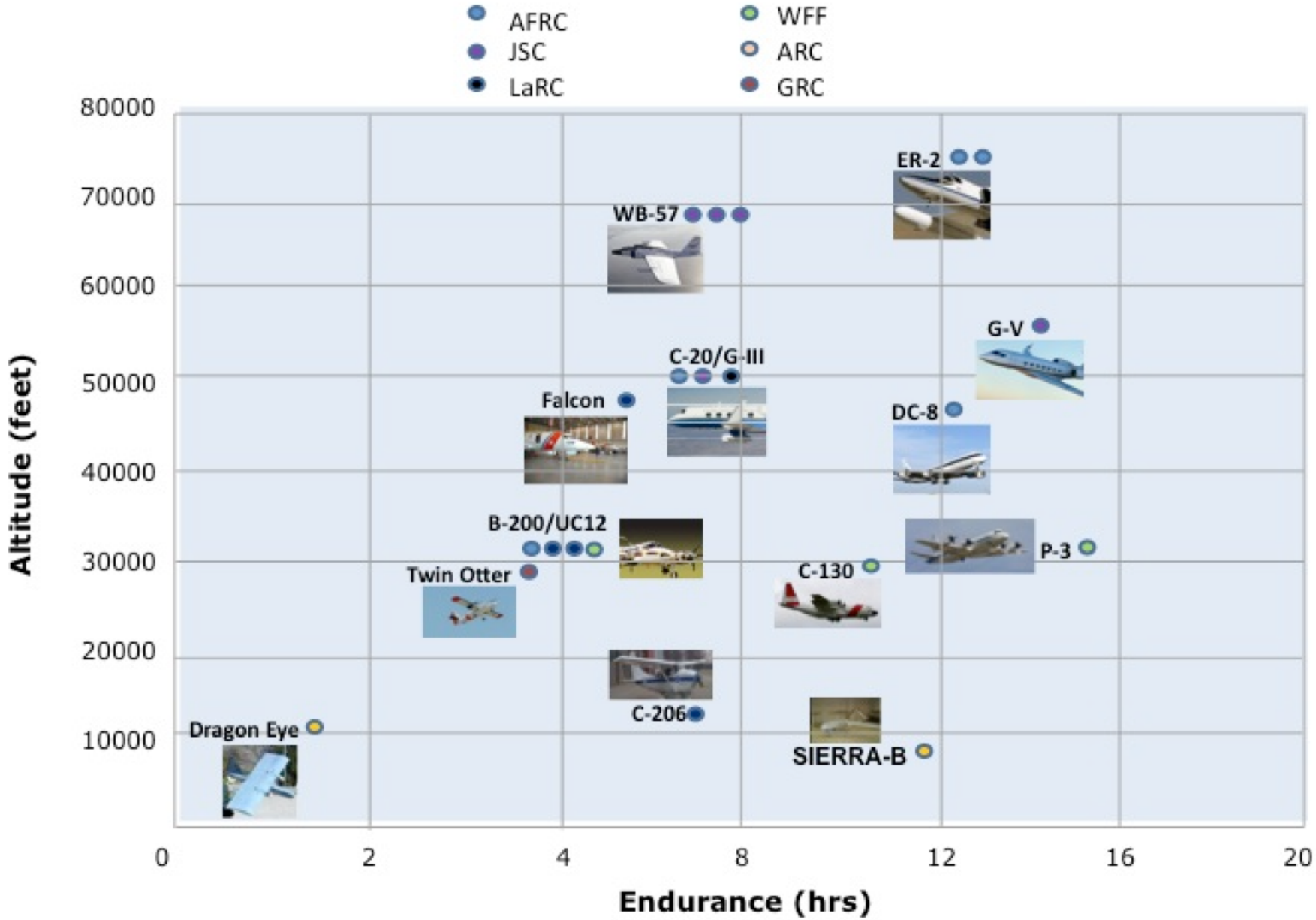
Earth Science Requirements

Platform performance required/desired from science community



Bottom Line – cost effective data collection from 500 - 70kft and from 2 - 30 plus hours and beyond (7 to 10 days)

NASA Earth Science Research Capable Aircraft

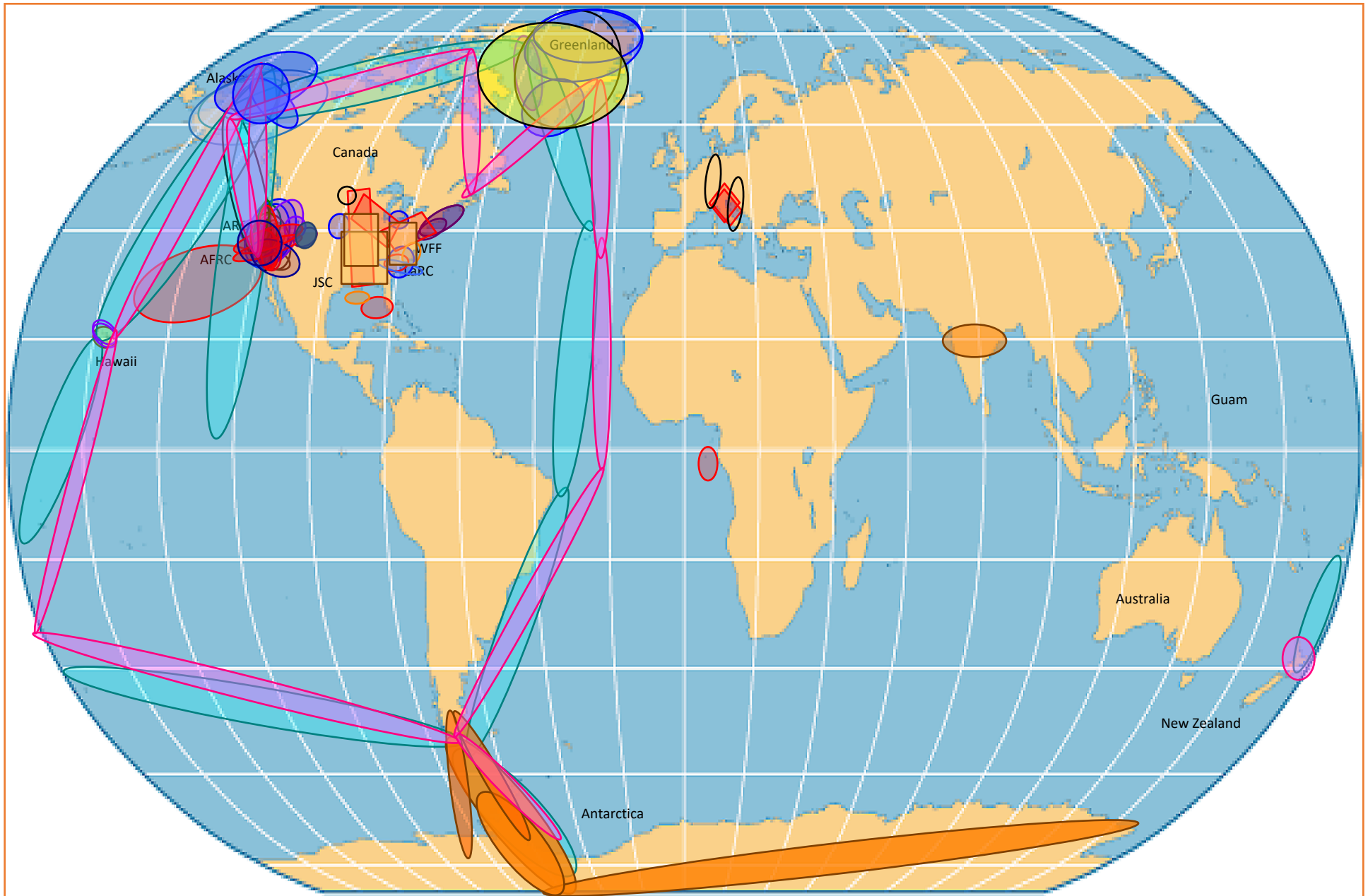


National Aeronautics and Space Administration

Airborne Science Program


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AIRBORNE SCIENCE PROGRAM
2019 PROGRAM PLATFORMS

FY2018 Airborne Campaigns

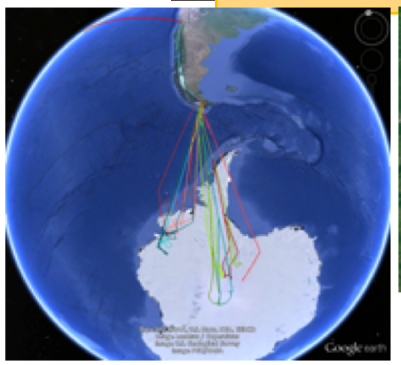


Recent Accomplishments

(as of June 2019)

- **Hours Flown –over 3800 in FY17, over 3100 in FY18**
- **Completed Major Campaigns**
  - **Operation IceBridge: Antarctic deployment, Arctic deployment**
  - **GV first science: SWOT and GEDI cal/val**
  - **EVS-2: Act-America, ATom, OMG, ORACLES**
  - **ABoVE continuity**
  - **Long Island Sound Tropospheric Ozone Study**
  - **HysplRI CA and Hawaii**
  - **GLiHT Forest Health**
  - **Kilauea Response**
  - **ACEPOL**
  - **Airborne Snow Observatory**
  - **Multiple UAVSAR ESI investigations**
  - **SARP**
- **Major Platform Updates**
  - **GV completed two missions, two upcoming**
  - **Acquired GIII, mods ongoing**
  - **C-20A maintenance**
  - **ER-2 CARE ongoing**

ATOM Science Team

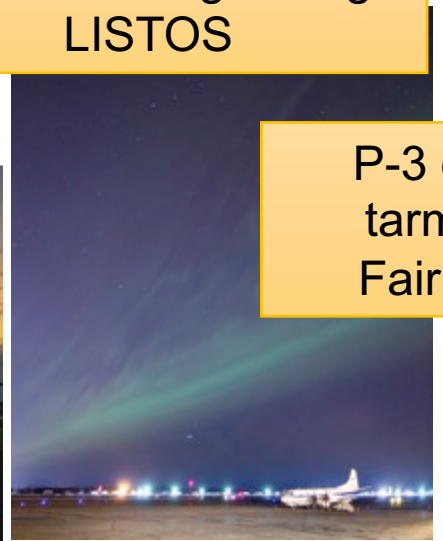


DC-8 Antarctic Flights 2018

Flight-tracking during LISTOS

ER-2 in Hawaii for Hyspiri/HyTES

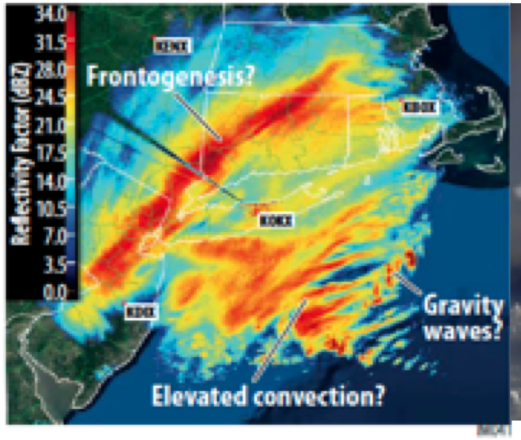
P-3 in Sao Tome for ORACLES



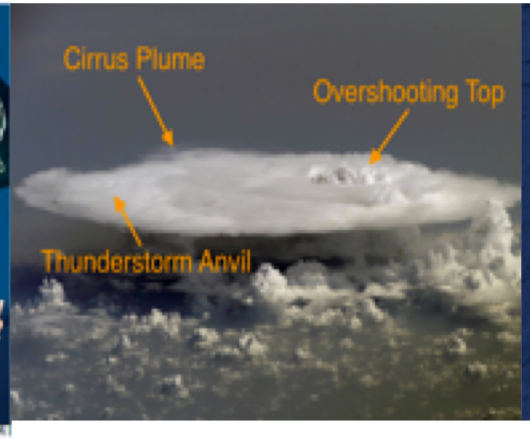
P-3 on the tarmac in Fairbanks

NASA EVS-3 Draft Flight Schedule

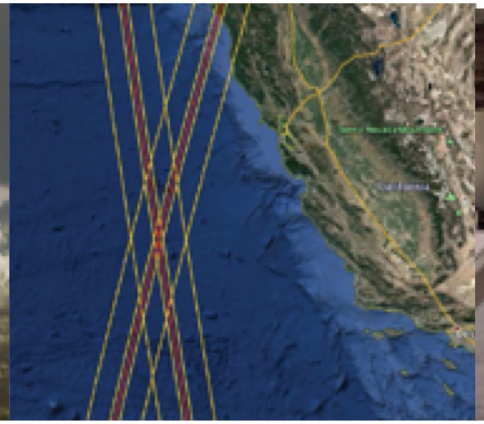
IMPACTS



DCOTSS

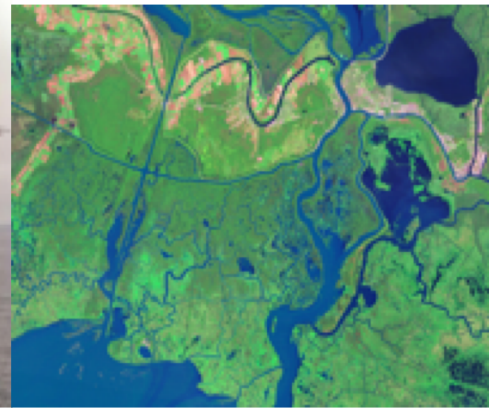


S-MODE



ACTIVATE

DELTA-X

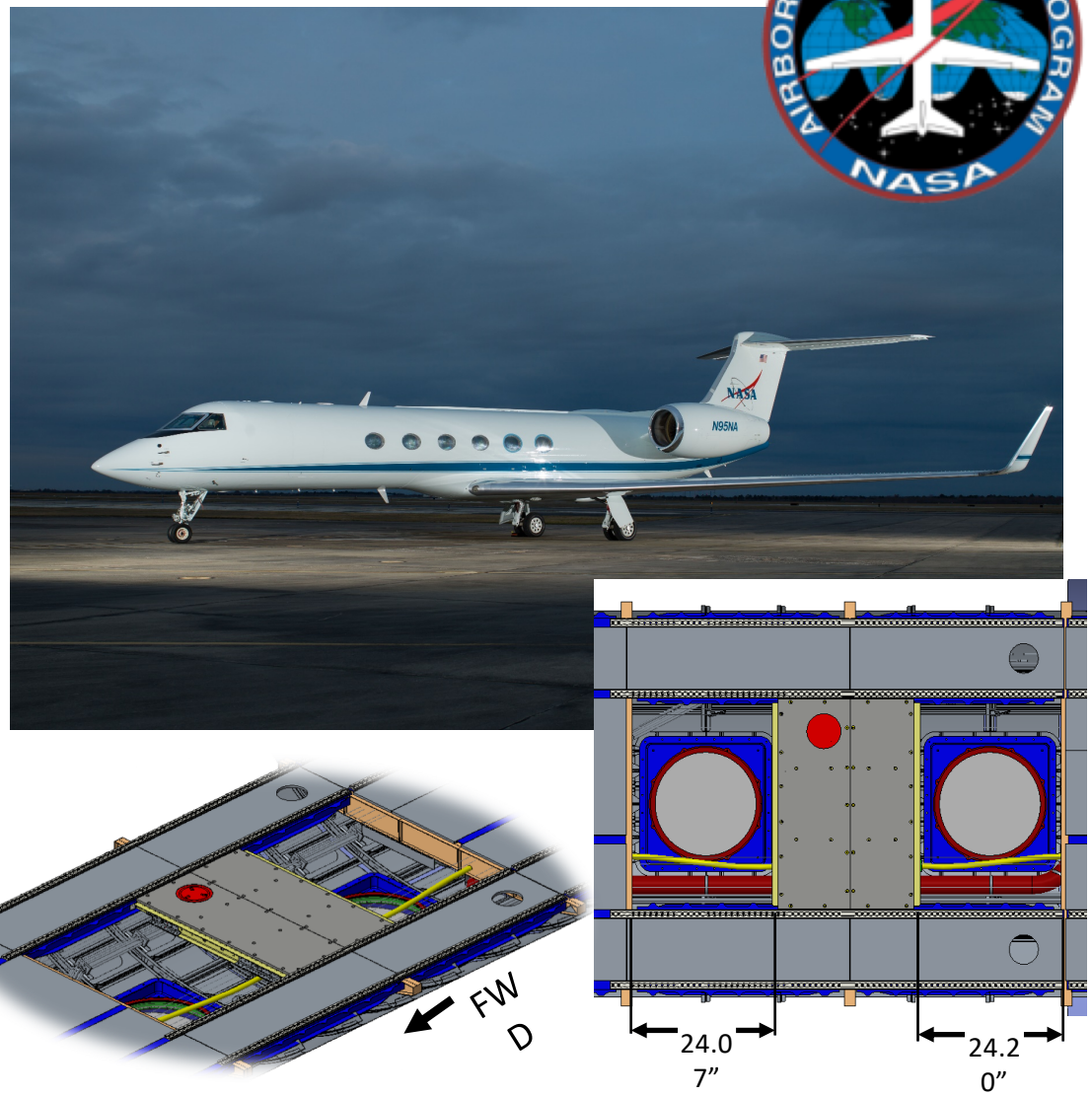


Mission	Location	Aircraft	CY2019				CY2020				CY2021				CY2022		
IMPACTS	U.S. East Coast	P-3, ER-2				■	■			■	■			■	■		
DCOTSS	Based from Salinas, Kansas	ER-2					■		■			■	■				
S-MODE	Pacific Ocean off Monterey	G-V, B-200						■				■	■				
ACTIVATE	Western North Atlantic	HU-25, B-200					■	■			■	■			■	■	
Delta-X	Mississippi River Delta	G-III, B-200 (2)						■	■		■			■		■	■

New Aircraft for NASA Earth Science

- Gulfstream V (N95NA)
  - Serial 672, built in 2002
  - Service Ceiling: 51,000ft
  - Max Speed: Mach 0.885
  - Normal cruise range: >5,000nm
  - Max Payload: 8,300lbs

➢ Two downward-facing viewports installed in forward cabin
  - FS 290.5 and 339.5
  - 20.75” x 20.75” opening
    - ⇨ Window viewable area will be smaller, circular
  - Includes mounting ring capable of ~350lb load (minus window pack)
  - Sealing blank for non-science flights



Gulfstream III (NASA 520)
Aircraft Metrics

- Gulfstream III
  - Serial 478, built in 1986 as U. S. Air Force C-20B
  - Service Ceiling: 45,000 ft
  - Max. Gross Weight: 69,700 lbs
  - Max. Mission Duration: 8.5 hr
  - Max. Cabin Payload: 2610 lbs
  - Max. Speed: Mach 0.85
  - Normal Cruise Range: 3767 n.mi.

Two Identical Portals

- 18.16 x 18.16 in. portal “see through” opening
- 19.00 x 19.00 in. vertical portal flange
- 21.00 x 21.00 in. mounting flange

SIERRA
Sensor Integrated Environmental Remote Research Aircraft

Phil Schulyer, SIERRA crew chief with the aircraft carrying a GP-SAR antennae and modified nose

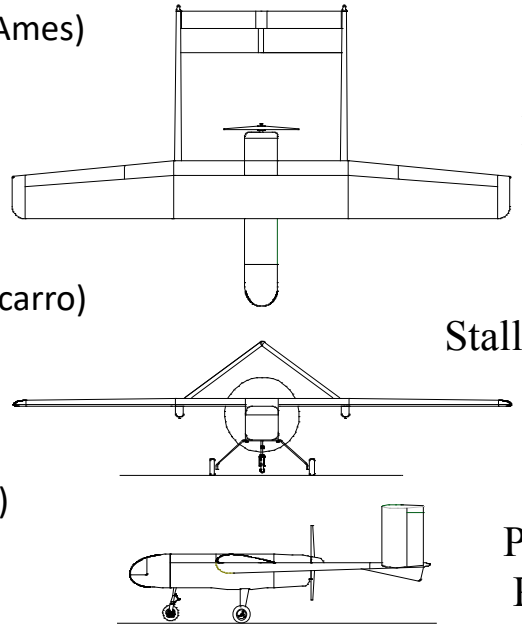
•SIERRA complements other UAVs in the NASA science fleet specializing in dangerous, low altitude missions that require larger payload capacity than typical small UAVs

• Airframe designed by NRL; systems development and integration at NASA Ames

• Ship 1 operated Oct 2008-Jul 2013

• Payloads flown include:

- VIS/NIR Hyperspectral Imager (NASA Ames)
- LIDAR Profilometer (CU-Boulder)
- Ocean Color suite (NASA GSFC)
- MMS (NASA Ames)
- CO2/CH4/H20 (Los Gatos Research/Picarro)
- C-Band SAR (Artemis/BYU)
- UHF/L-band SAR (Mirage Systems)
- Flux-gate Magnetometer (Geometrics)

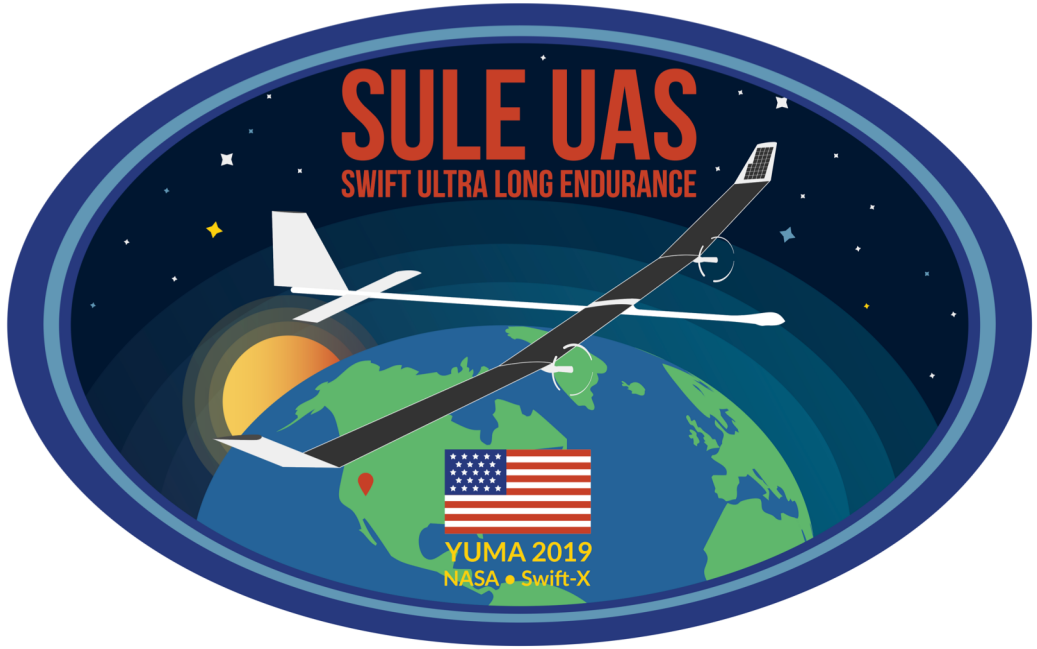


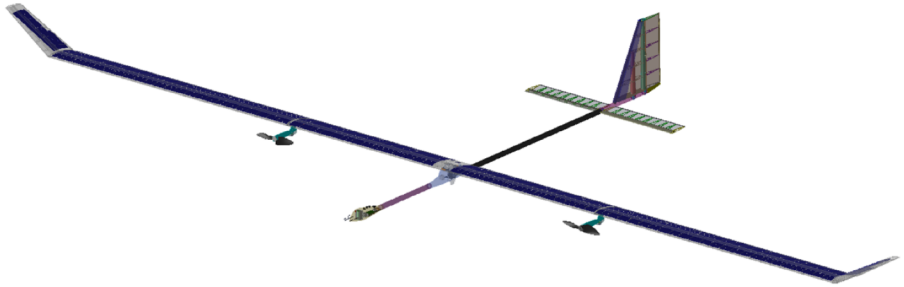
Wing Span	**20 ft.**
Length	**11.8 ft.**
Height	**4.6 ft.**
Wing Area	**42.4 sq. ft.**
Empty Weight	**215 lbs.**
Gross Weight	**375 lbs.**
Max Speed	**79 kts.**
Cruise Speed	**55 kts.**
Stall Speed (clean)	**30 kts.**
Aspect ratio	**9.43**
Rate of Climb	**545 ft./min.**
CG Position	**29-32% Chord**
Payload weight	**~100lbs**
Payload power	**28V DC**
Duration	**8-10 hrs**

Swift Engineering has SBIR Phase II funding to flight test a 30-day vehicle with 15lb payload at Yuma in Summer 2019 at Yuma Proving Grounds. ASP supports a Technical Monitor to the project and is providing a test payload to validate platform capabilities.

NASA SBIR PII – HALE UAV update

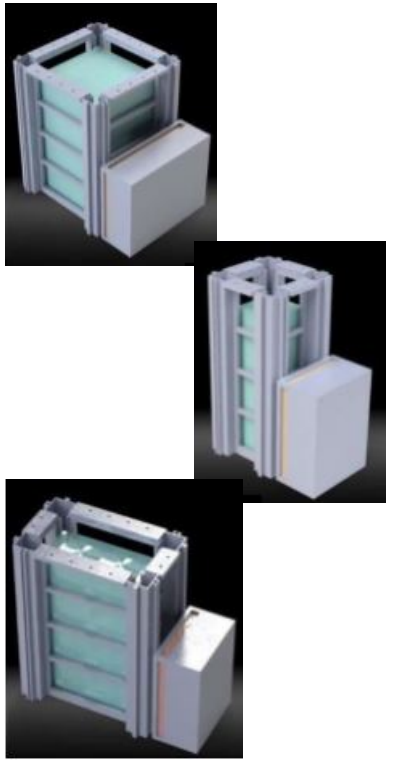
- NASA has been leading the development and science rationale for this new type of aircraft for 2 decades.
- Solar electric platform flying at 70kft for weeks to months with smaller payloads
- Provides observations similar to geostationary satellites; cubesat testbed
- Airbus Zephyr, Aeroenvironment+Softbank, Aurora Odysseus, and Prismatic are commercial programs in development
- NASA is funding Swift Engineering to test a prototype aircraft in summer 2019.
- Costa Rica is one location that is being investigated to support flight testing





- 30-day @ 70k ft
- 15lb payload in nose
- LiS battery

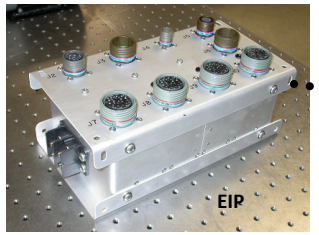
X-Cube: Towards a standard rack system for cubesat airborne testing



- Collaboration with the NASA Airborne Science Program and USRA
- Standard for integration of CubeSats into the NASA aircraft for suborbital flight testing
- A new means for instrument calibration and testing prior to integration into a spacecraft
- Creates more opportunities for new developers to collect valuable science data
- Deployment Switch Actuation to simulate spacecraft deployment
- Allows for data storage and ground communication
- 28 and 12 Volt DC available for each payload
- 30 Watts of power available per 1U payload volume

POC: APompeii@CalPoly.edu

NASA Global Hawk Real-Time Payload Communications & Control Systems



Instrument Power & Control

Ethernet

Interface Panels (8)

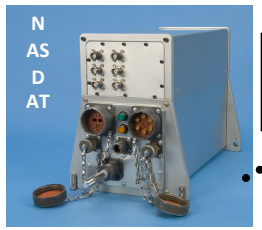
Payload Instruments

Master Payload Control System & PDU

Aircraft HW

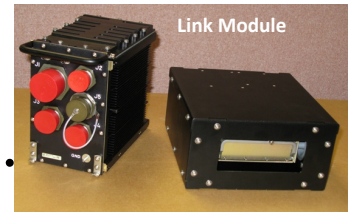
GHOC HW

PI Hardware



Network Server

Database & Ku Telemetry Controller



AIRCRAFT

GROUND

Iridium (4 ch)

Ku-Band Sat-Com

Iridium (2 ch)

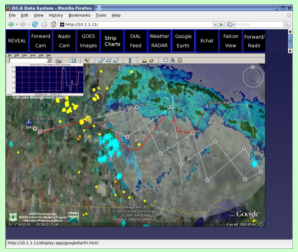
Web-Based Users

Science Network Data Servers

Global Hawk Ground Operations Center

Flight Deck

Payload Control GUI (Pilot / Mission Director)



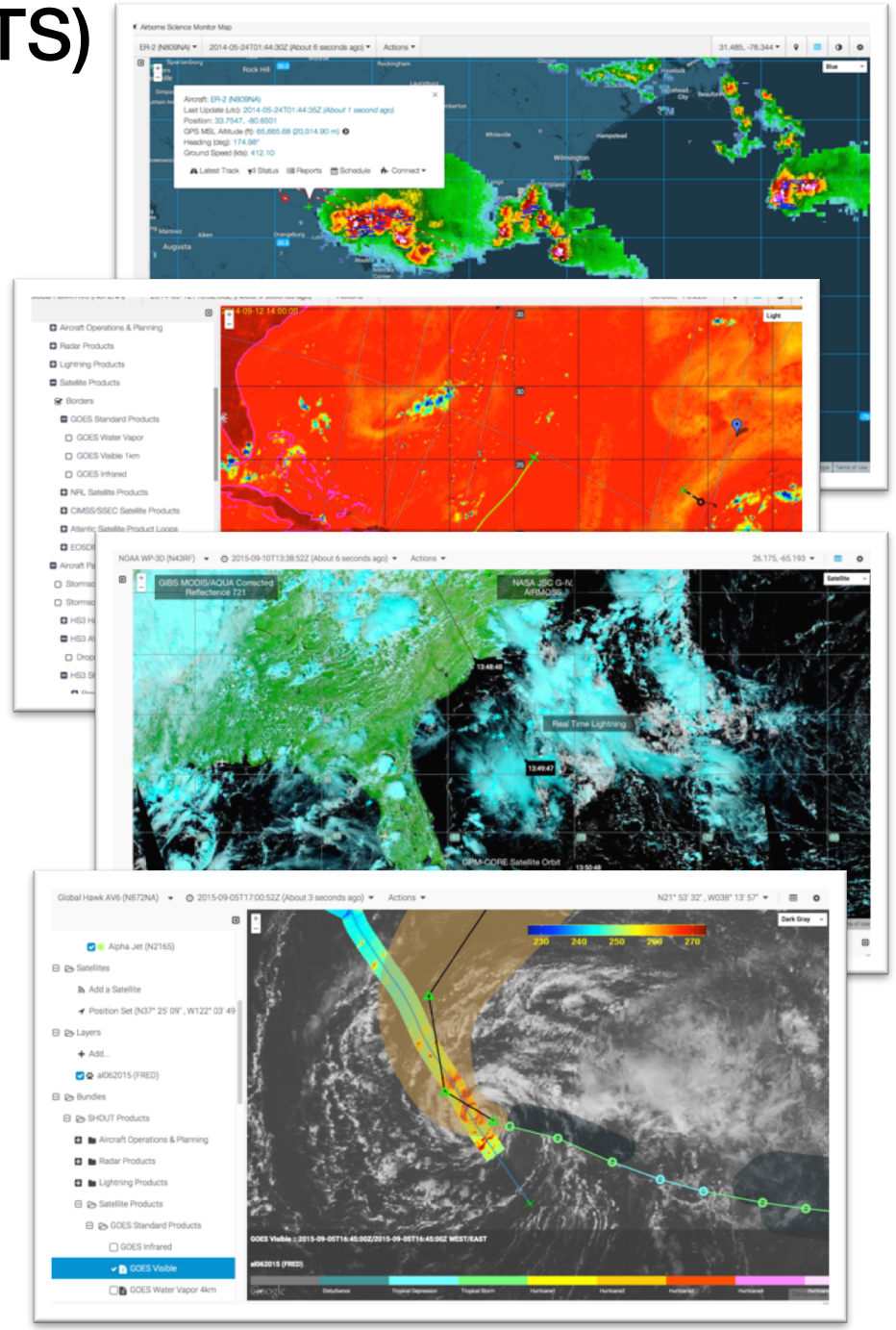
Experimenter Workstations

AMES UCSC ARC University Affiliated Research Center

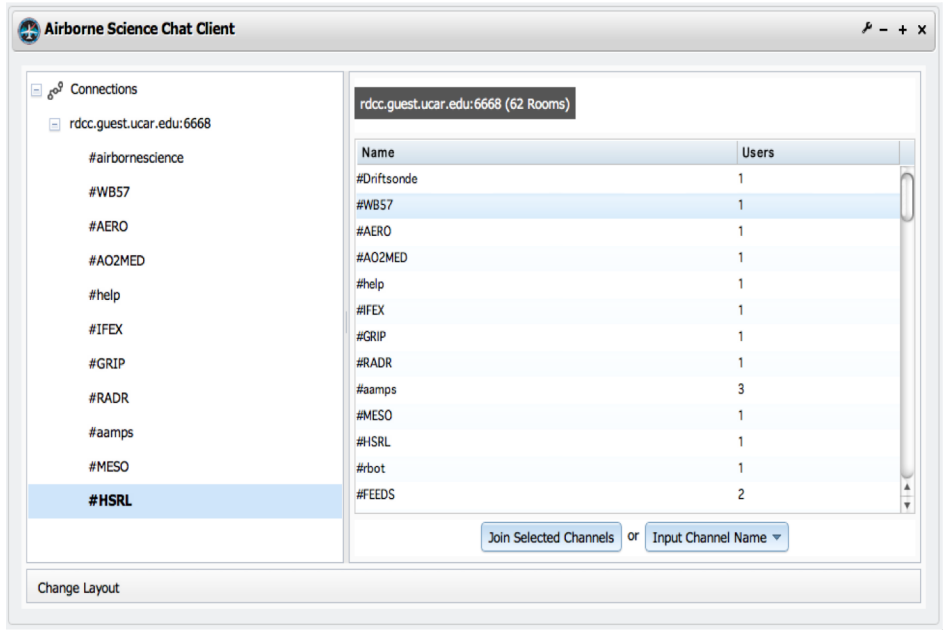
MISSION TOOLS SUITE (MTS)

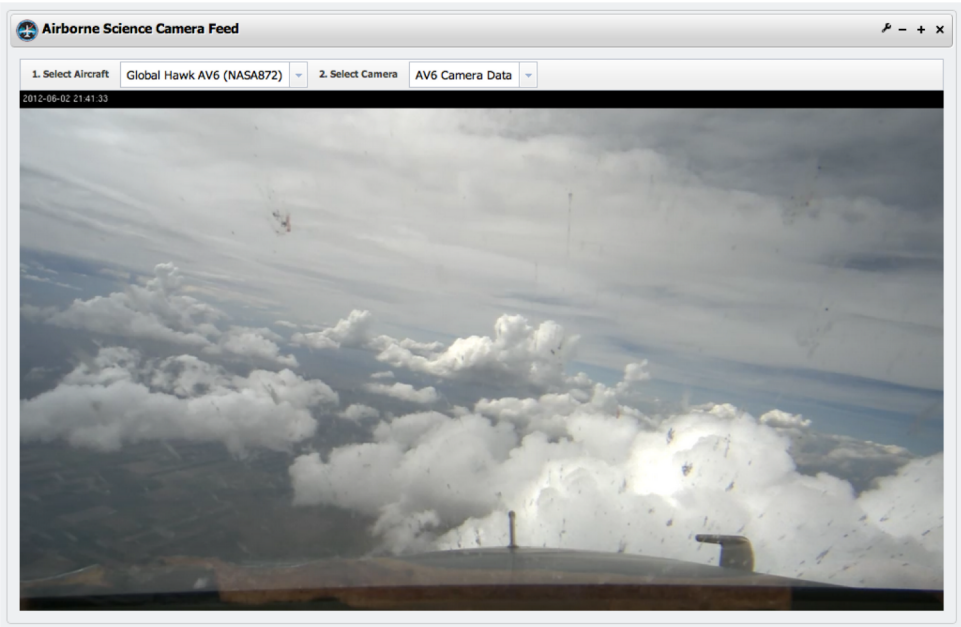
NASA AIRBORNE SCIENCE PROGRAM

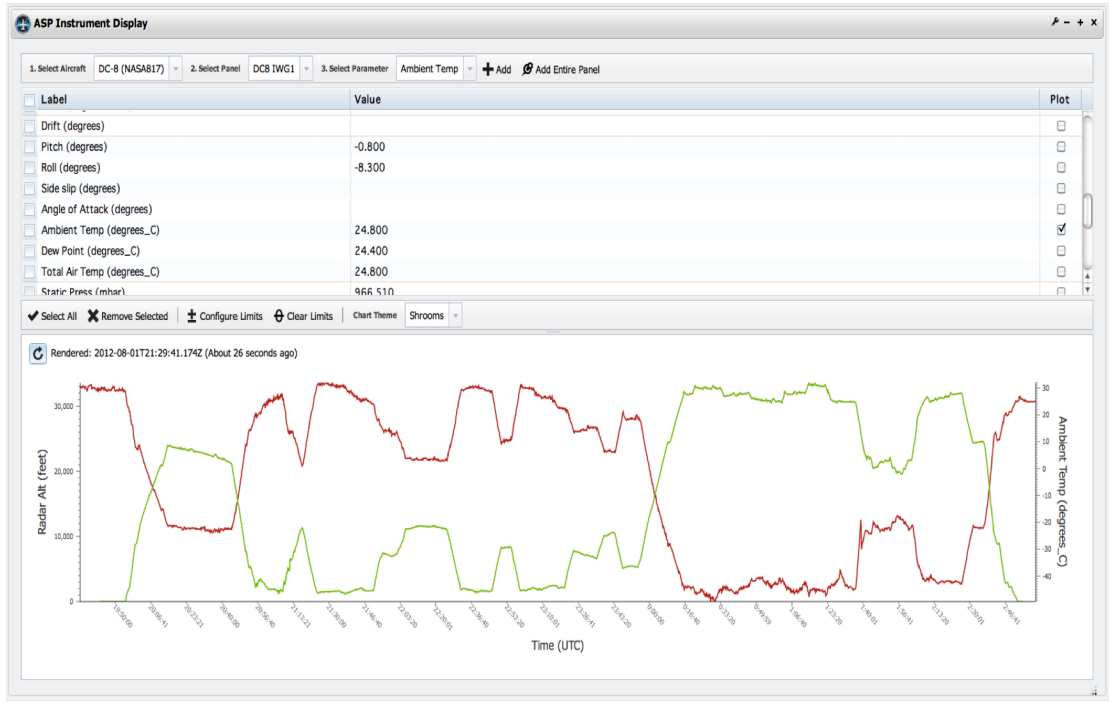
- Tactical decision-making and distributed team situational awareness
- Real time position and instrument telemetry ingest and visualization for single- and multi-asset campaigns
- Access to low latency satellite, radar, global lightning and other meteorological and mission products
- Communication and collaboration tools including document sharing and turn-key chat solutions
- Satellite pass prediction and swath visualization
- Mission operation and planning tools

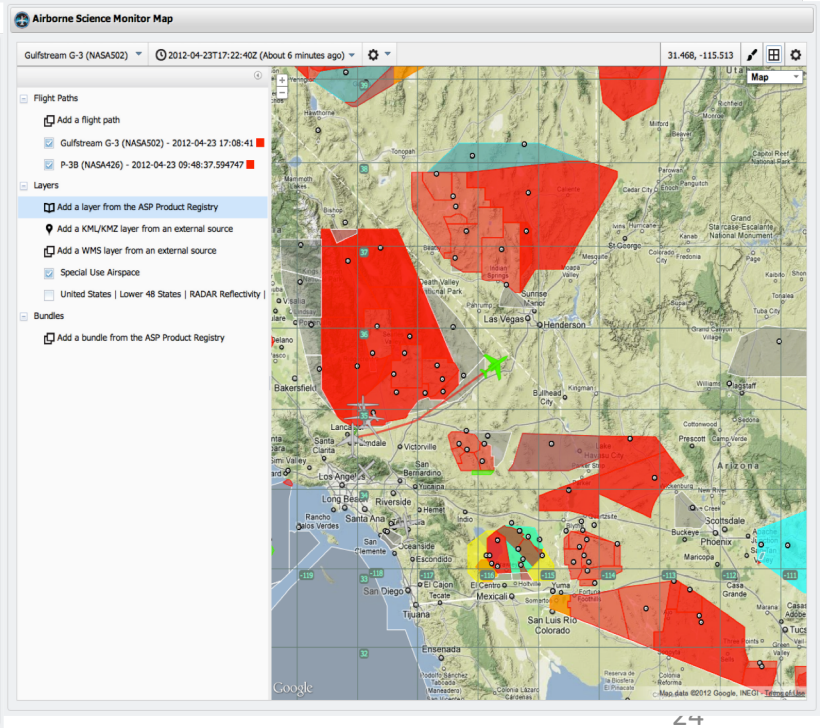


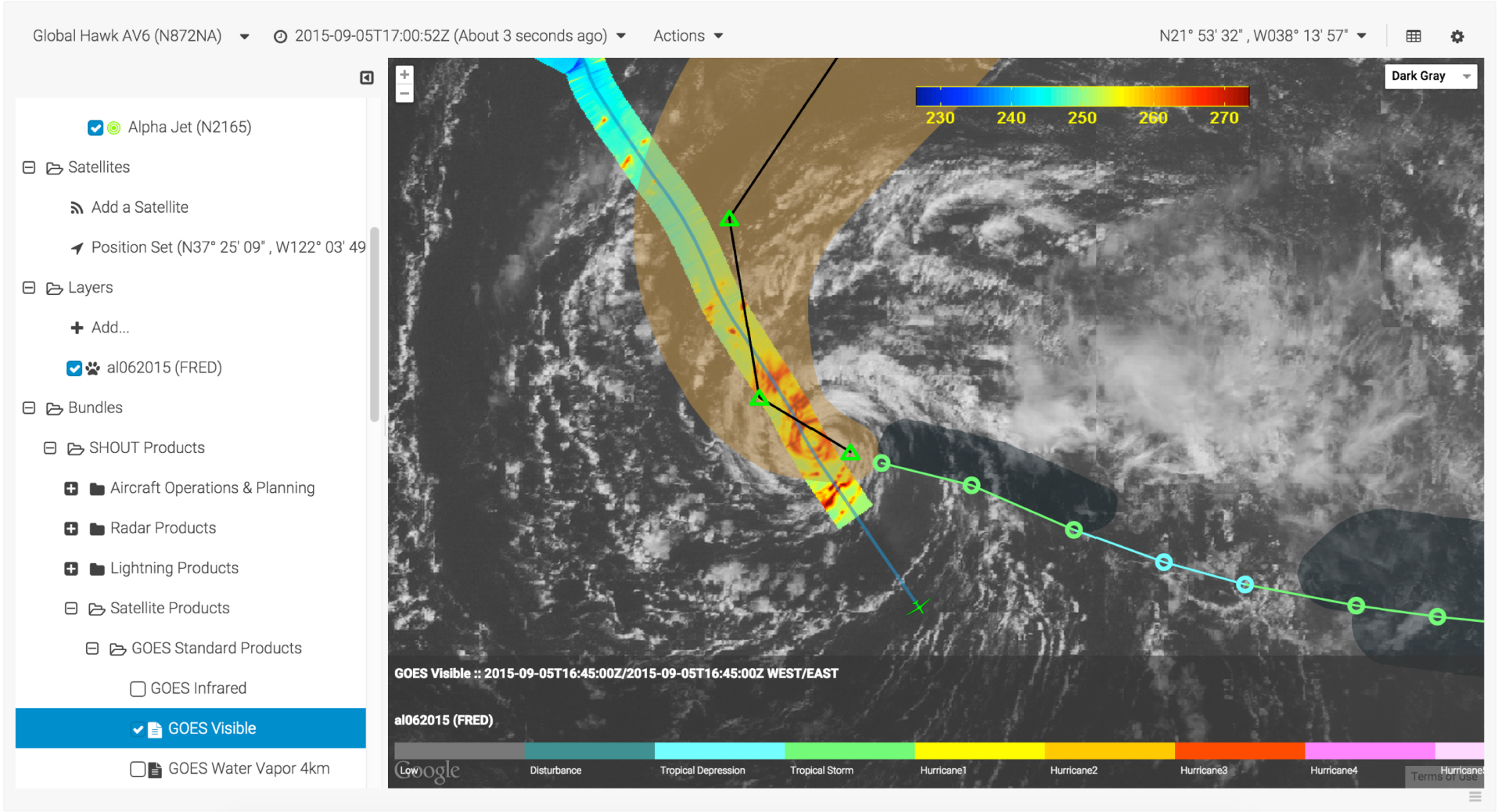
Project Lead: Aaron R. Duley, Ph.D.
NASA Airborne Science Program
Ames Research Center, Moffett Field, CA
For more information visit: https://mts.nasa.gov


Airborne Science Chat Client
Connections
rdcc.guest.ucar.edu:6668
#airbornescience
#WB57
#AERO
#AO2MED
#help
#IFEX
#GRIP
#RADR
#aamps
#MESO
#HSRL
rdcc.guest.ucar.edu:6668 (62 Rooms)
Name
Users
#Driftsonde 1
#WB57 1
#AERO 1
#AO2MED 1
#help 1
#IFEX 1
#GRIP 1
#RADR 1
#aamps 3
#MESO 1
#HSRL 1
#rbot 1
#FEEDS 2
Join Selected Channels
or
Input Channel Name
Change Layout


Airborne Science Camera Feed
1. Select Aircraft
Global Hawk AV6 (NASA872)
2. Select Camera
AV6 Camera Data
2012-06-02 21:41:33

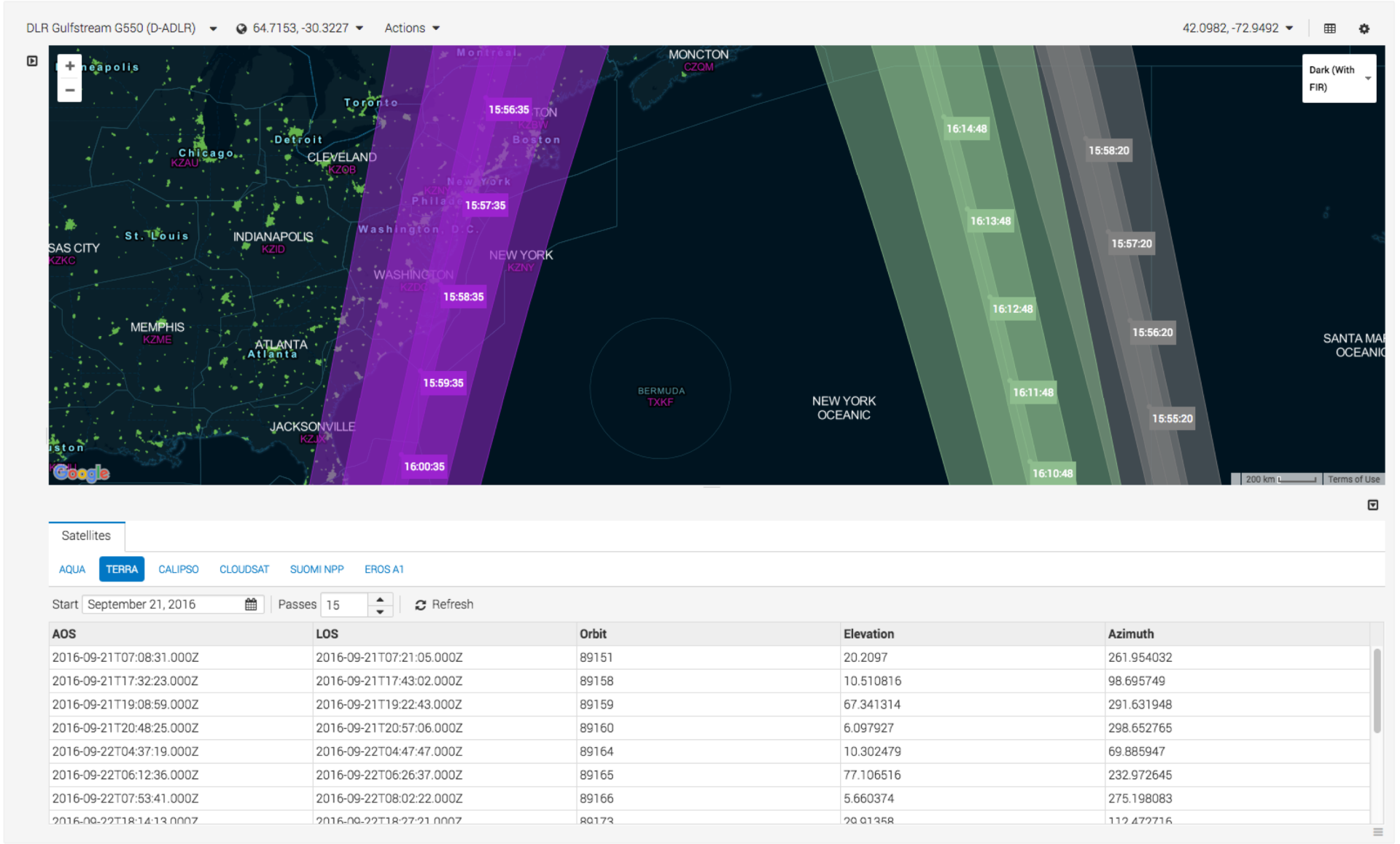

ASP Instrument Display
1. Select Aircraft
DC-8 (NASA817)
2. Select Panel
DC8 IWG1
3. Select Parameter
Ambient Temp
Add
Add Entire Panel
Label
Value
Plot
Drift (degrees)
Pitch (degrees) -0.800
Roll (degrees) -8.300
Side slip (degrees)
Angle of Attack (degrees)
Ambient Temp (degrees_C) 24.800
Dew Point (degrees_C) 24.400
Total Air Temp (degrees_C) 24.800
Static Press (mbar) 966.510
Select All
Remove Selected
Configure Limits
Clear Limits
Chart Theme
Shrooms
Rendered: 2012-08-01T21:29:41.174Z (About 26 seconds ago)
Radar Alt (feet)
Ambient Temp (degrees_C)
Time (UTC)


Airborne Science Monitor Map
Gulfstream G-3 (NASA502)
2012-04-23T17:22:40Z (About 6 minutes ago)
31.468, -115.513
Flight Paths
Add a flight path
Gulfstream G-3 (NASA502) - 2012-04-23 17:08:41
P-3B (NASA426) - 2012-04-23 09:48:37.594747
Layers
Add a layer from the ASP Product Registry
Add a KML/KMZ layer from an external source
Add a WMS layer from an external source
Special Use Airspace
United States | Lower 48 States | RADAR Reflectivity |
Bundles
Add a bundle from the ASP Product Registry
Map
Las Vegas
Henderson
Los Angeles
San Diego
Tijuana
Phoenix
Google



09/05/2015 – MTS screenshot of NASA Global Hawk (N872NA) above Tropical Storm Fred for the Sensing Hazards with Operational Unmanned Technology (SHOUT) mission. The aircraft just passed over the storm center at 59 kft, which is located about 2.5k nautical miles southeast of WFF.

The screenshot shows how MTS can be used to visualize satellite, instrument, aircraft and other overlays to improve mission situational awareness.



MTS includes satellite track prediction, track visualization, and access to ephemeris information.

https://products.mts.nasa.gov/v2-predict-service/details?id=52e2a7ff57ab33a325b35d6b

{ _id: "52e2a7ff57ab33a325b35d6b", meanmo: 14.5710927,
tle: "TERRA 1 25994U 99068A 16265.08908407 .00000162 00000-0 46036-4 0 9999 2 25994 98.2050 338.0093 0000992 91.0692 269.0591 14.57109273891489",
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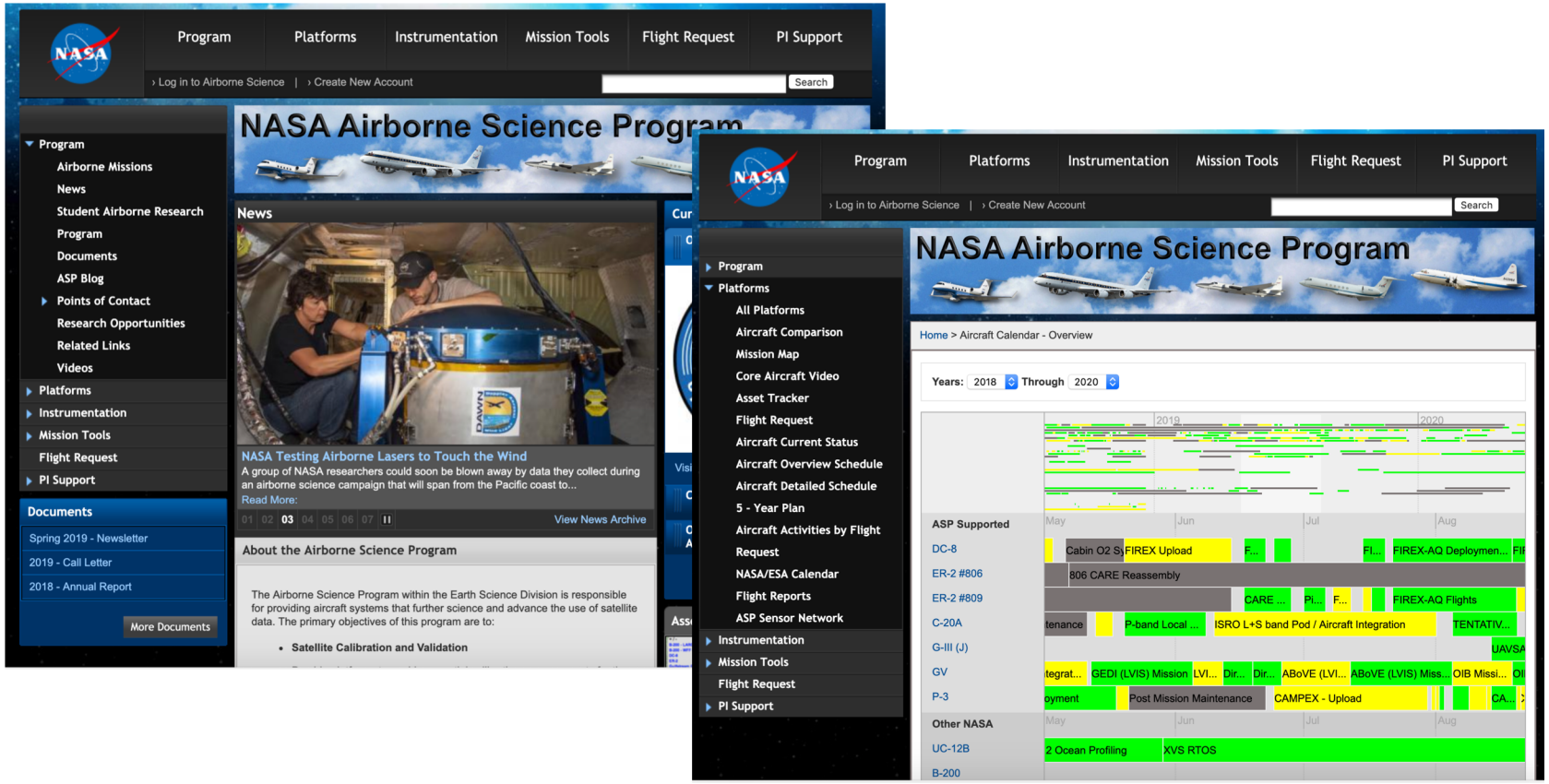
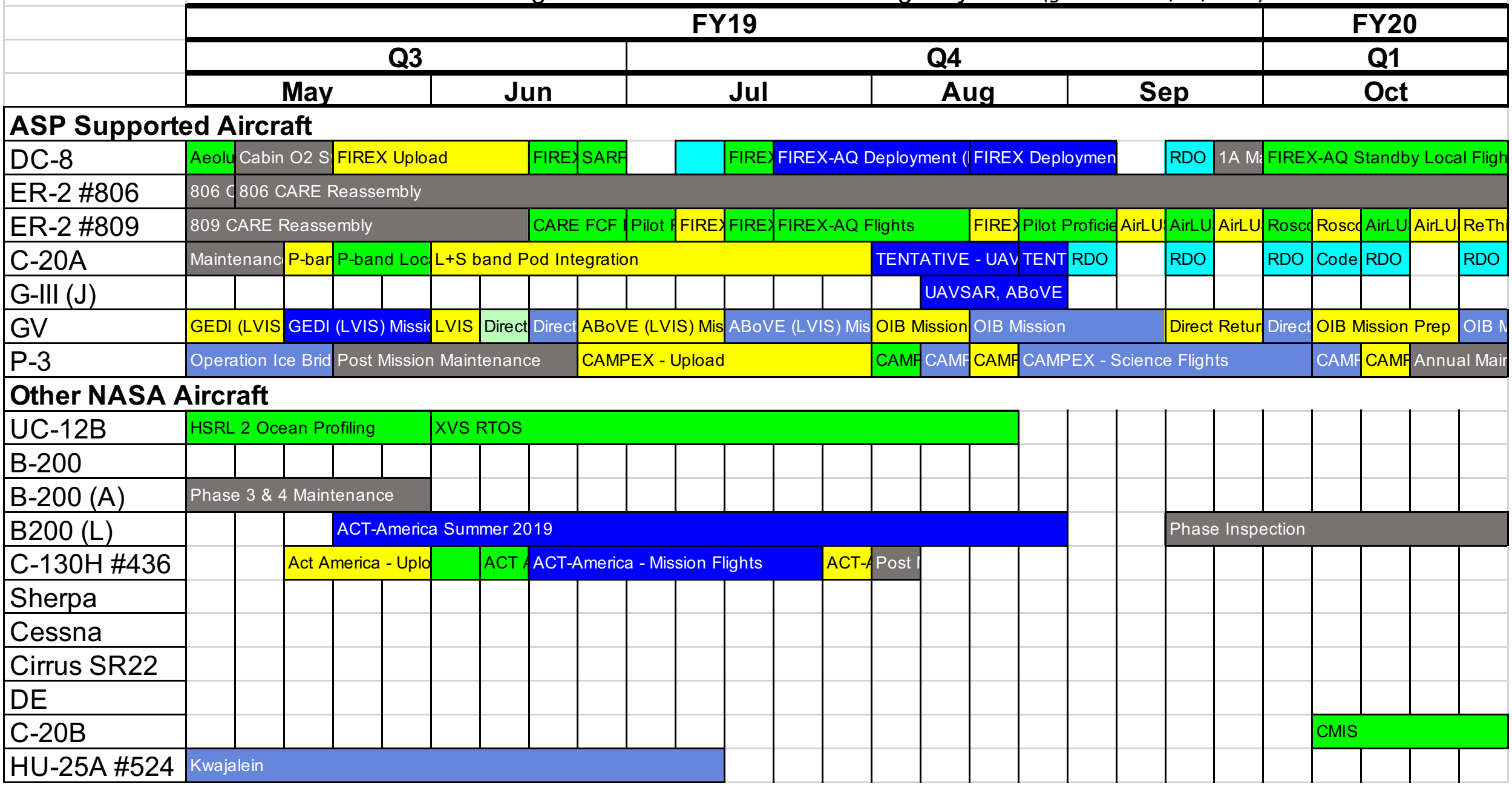
Airborne Science Program Online Resources



- Airborne Science asset details and schedules are available online at:
  - https://airbornescience.nasa.gov

- Aircraft cost estimates and flight hours can be requested using the online flight request system:
  - https://airbornescience.nasa.gov/sofrs/

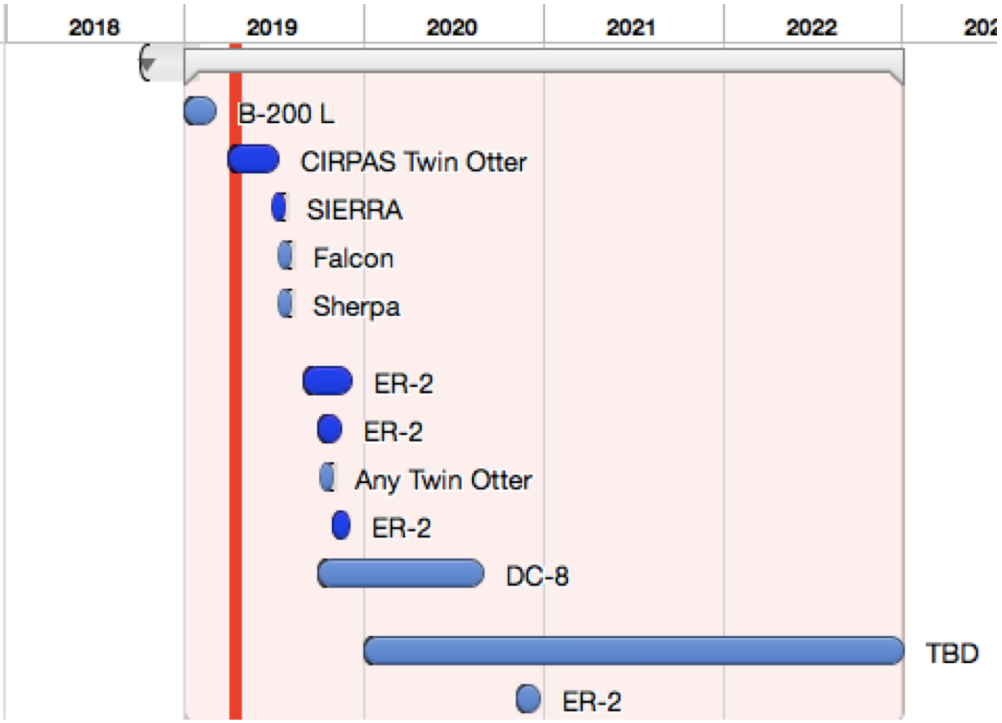
NASA Airborne Science Program 6-Month Schedule starting May 2019 *(generated 4/30/2019)*



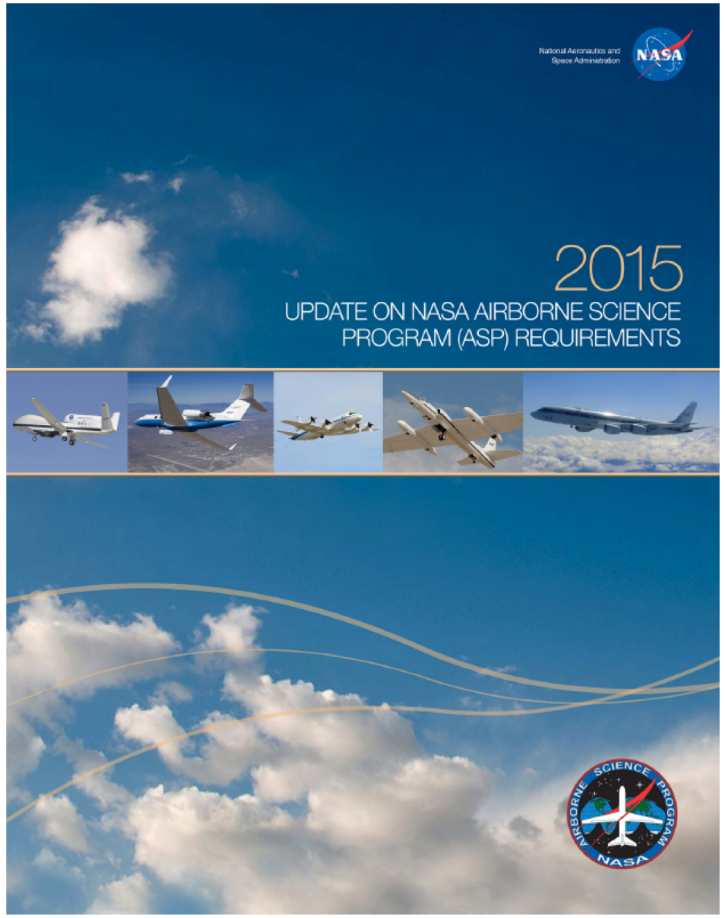
https://airbornescience.nasa.gov/aircraft_overview_cal

NASA Instrument test flights

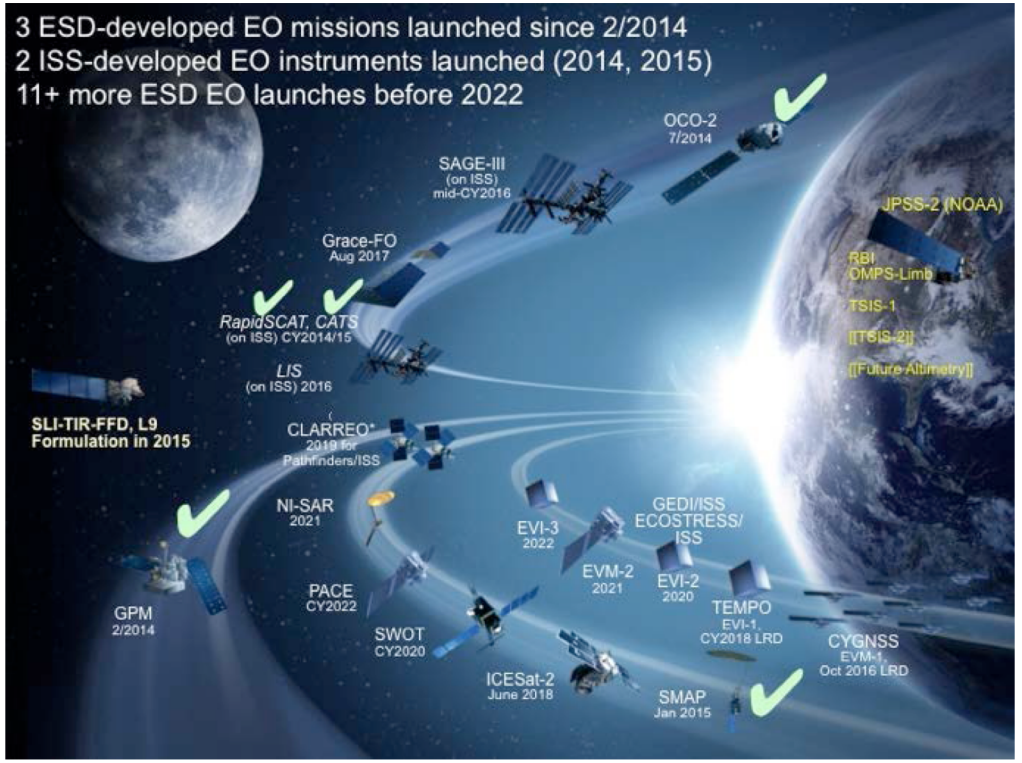
Title	Flt Hours	PS/PE/PM	Related Satellite/Sensor
8) New Techology			
8.1) IPDA Lidar	25	IIP16	
8.2) C-Harrier	40	AITT	Aqua, Terra, S-NPP
8.3) CIRES-IDD		IIP16	
8.4) Compact midwave imaging system		IIP16	
8.5) Airborne Differential Absorption Radar		IIP16	
8.6) AirMSPI-2	18	AITT	
8.7) Air-LUSI	18	AITT	S-NPP
8.8) SLI-T		ESTO	Landsat
8.9) Compact Limb Sounder / SHOW	12	IIP	
8.10) Multi Application Smallsat Tri-band Radar Air-MASTR		IIP16	
8.11) IIP/AITT 2019		IIP19	
8.12) Air-LUSI	18	AITT	S-NPP



2015 Requirements Report



- Input from Science Center survey process
- 5-year planning process
- Current flight requests
- Interviews with Program Scientists and science community
- Science team meetings, workshops and reports
- Considerations for 2017 Decadal Survey



Sources of data for requirements forecasting

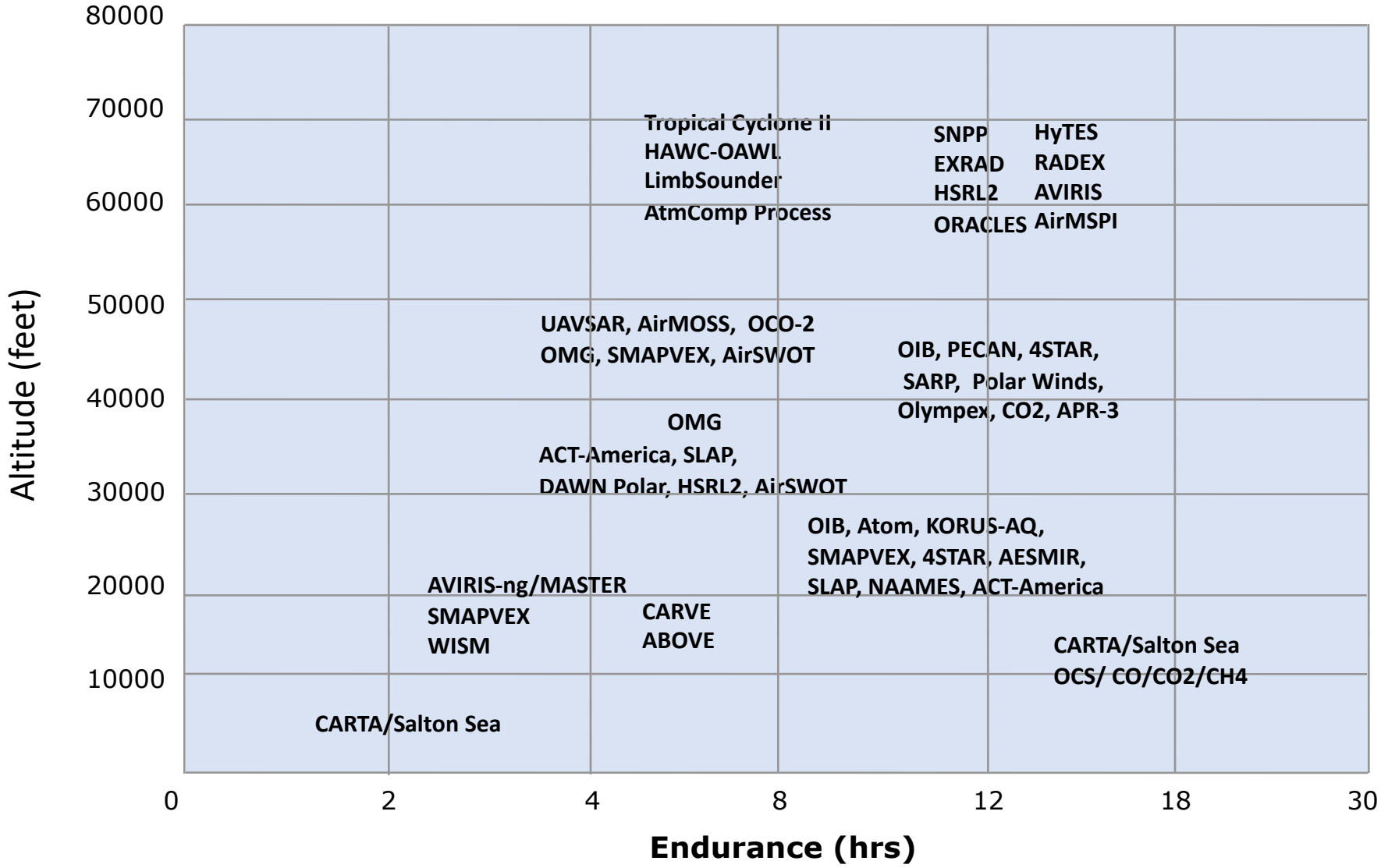
- **Flight request system** – all proposals and grant recipients are required to submit a flight request that describes their unique requirements as well as providing a process for funder and aircraft operator sign-off, as well as providing an accounting of flight hours flown against each request. Data from this system assists ASP in cataloguing and developing statistics on aircraft use and requirements.

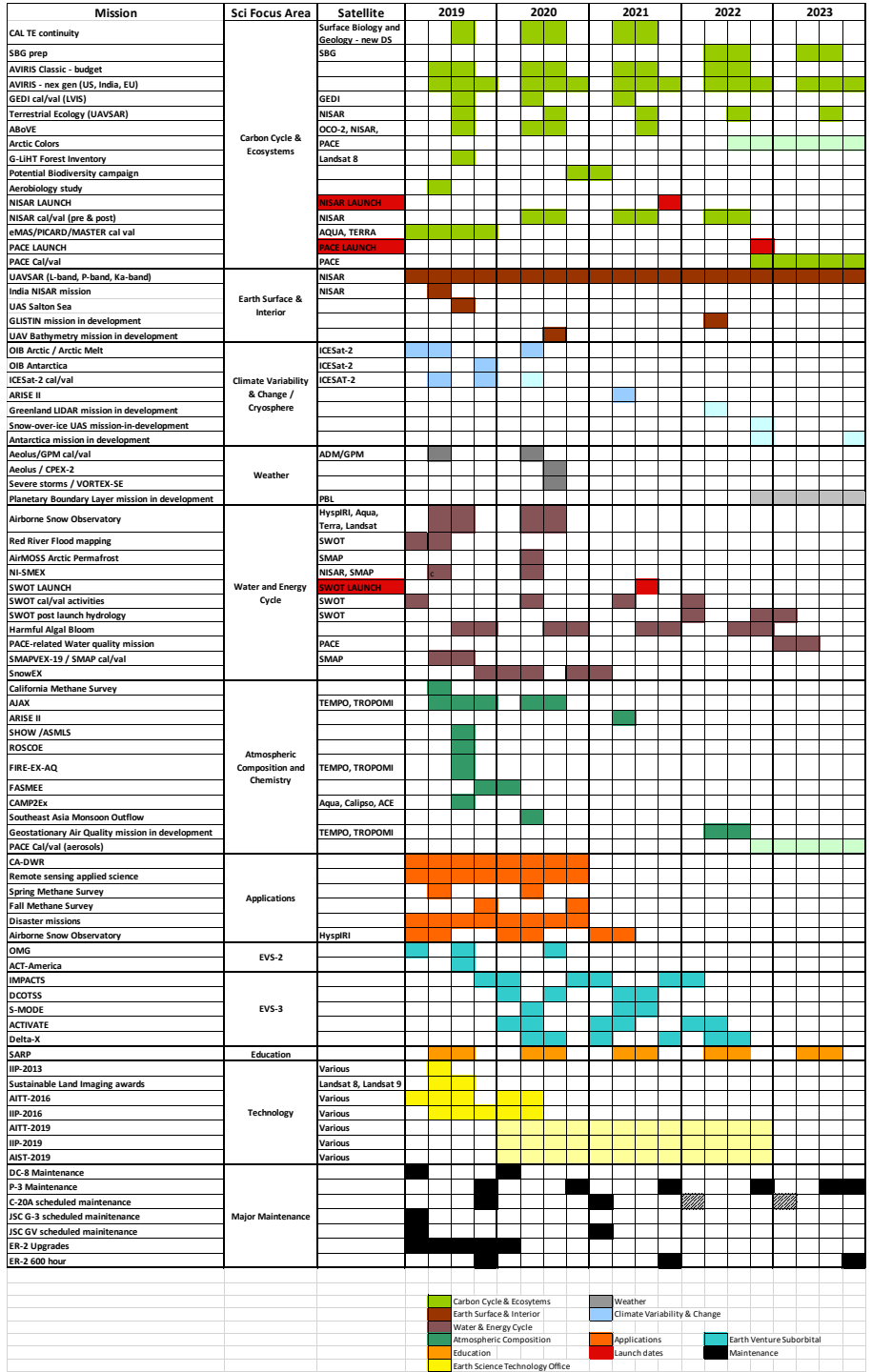
- **5-yr forecast** – Each year ASP meets with stakeholders in SMD R&A and ESTO to review current flight requests as well as to put schedule placeholders in the outyears so that the program can document and plan for missions and payloads in formulation

- **Community Interaction** – ASP staff attend science team meetings for major projects and for missions in formulation to understand requirements for instrument test flights and post-launch cal/val activities. Also accomplish site visits during missions to determine adequacy of capabilities and support.

- **Center Survey** – ASP initiated the Center ASP Survey to gather requirements from Science centers as another means for cataloguing future needs.

ESD mission flight envelope requirements: FY15 and FY16





5-year Plan / Mission format

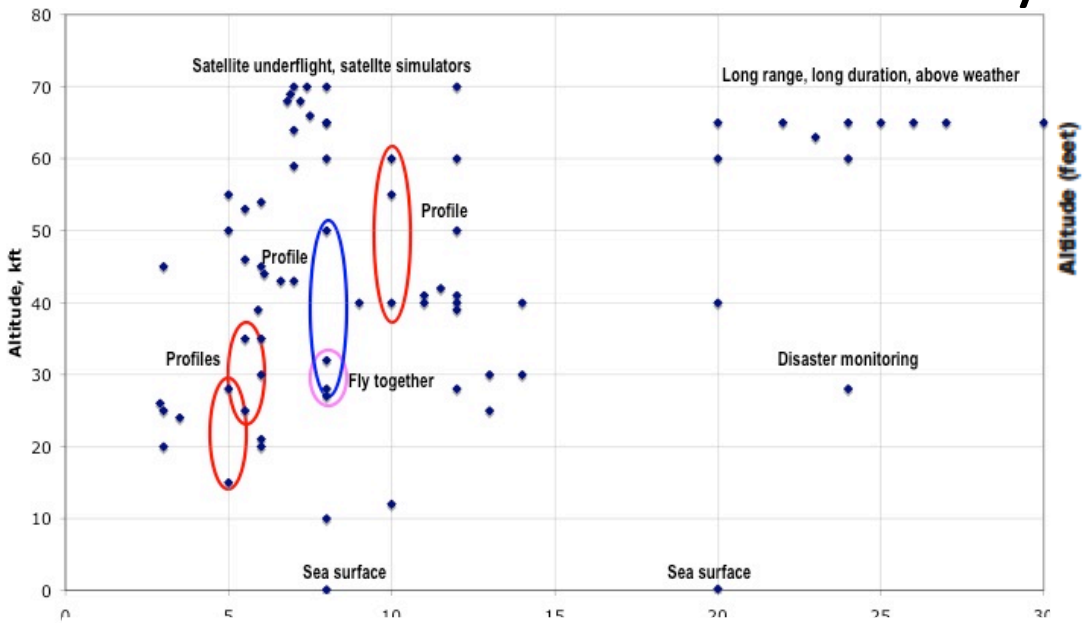
Mission	Sci Focus Area	Satellite	2019				2020				2021				2022				2023			
CAL TE continuity	Carbon Cycle & Ecosystems	Surface Biology and Geology - new DS																				
SBG prep		SBG																				
AVIRIS Classic - budget																						
AVIRIS - nex gen (US, India, EU)																						
GEDI cal/val (LVIS)		GEDI																				
Terrestrial Ecology (UAVSAR)		NISAR																				
ABoVE		OCO-2, NISAR,																				
Arctic Colors		PACE																				
G-LiHT Forest Inventory		Landsat 8																				
Potential Biodiversity campaign																						
Aerobiology study																						
NISAR LAUNCH		NISAR LAUNCH																				
NISAR cal/val (pre & post)		NISAR																				
eMAS/PICARD/MASTER cal val		AQUA, TERRA																				
PACE LAUNCH		PACE LAUNCH																				
PACE Cal/val		PACE																				
UAVSAR (L-band, P-band, Ka-band)	Earth Surface & Interior	NISAR																				
India NISAR mission		NISAR																				
UAS Salton Sea																						
GLISTIN mission in development																						
UAV Bathymetry mission in development																						
OIB Arctic / Arctic Melt	Climate Variability & Change / Cryosphere	ICESat-2																				
OIB Antarctica		ICESat-2																				
ICESat-2 cal/val		ICESAT-2																				
ARISE II																						
Greenland LIDAR mission in development																						
Snow-over-ice UAS mission-in-development																						
Antarctica mission in development																						
Aeolus/GPM cal/val	Weather	ADM/GPM																				
Aeolus / CPEX-2																						
Severe storms / VORTEX-SE																						

Planetary Boundary Layer mission in development		PBL
Airborne Snow Observatory	Water and Energy Cycle	HyspIRI, Aqua, Terra, Landsat
Red River Flood mapping		SWOT
AirMOSS Arctic Permafrost		SMAP
NI-SMEX		NISAR, SMAP
SWOT LAUNCH		SWOT LAUNCH
SWOT cal/val activities		SWOT
SWOT post launch hydrology		SWOT
Harmful Algal Bloom		
PACE-related Water quality mission		PACE
SMAPVEX-19 / SMAP cal/val		SMAP
SnowEX		
California Methane Survey	Atmospheric Composition and Chemistry	
AJAX		TEMPO, TROPOMI
ARISE II		
SHOW /ASMLS		
ROSCOE		
FIRE-EX-AQ		TEMPO, TROPOMI
FASMEE		
CAMP2Ex		Aqua, Calipso, ACE
Southeast Asia Monsoon Outflow		
Geostationary Air Quality mission in development		TEMPO, TROPOMI
PACE Cal/val (aerosols)		
CA-DWR	Applications	
Remote sensing applied science		
Spring Methane Survey		
Fall Methane Survey		
Disaster missions		
Airborne Snow Observatory		HyspIRI
OMG	EVS-2	
ACT-America		

Fall Methane Survey			
Disaster missions			
Airborne Snow Observatory		HyspIRI	
OMG	EVS-2		
ACT-America			
IMPACTS	EVS-3		
DCOTSS			
S-MODE			
ACTIVATE			
Delta-X			
SARP	Education		
IIP-2013	Technology	Various	
Sustainable Land Imaging awards		Landsat 8, Landsat 9	
AITT-2016		Various	
IIP-2016		Various	
AITT-2019		Various	
IIP-2019		Various	
AIST-2019		Various	
DC-8 Maintenance	Major Maintenance		
P-3 Maintenance			
C-20A scheduled maintenance			
JSC G-3 scheduled mainitenance			
JSC GV scheduled mainitenance			
ER-2 Upgrades			
ER-2 600 hour			

Carbon Cycle & Ecosytems
Earth Surface & Interior
Water & Energy Cycle
Atmospheric Composition
Education
Earth Science Technology Office
Weather
Climate Variability & Change
Applications
Launch dates
Earth Venture Suborbital
Maintenance

From Center Survey



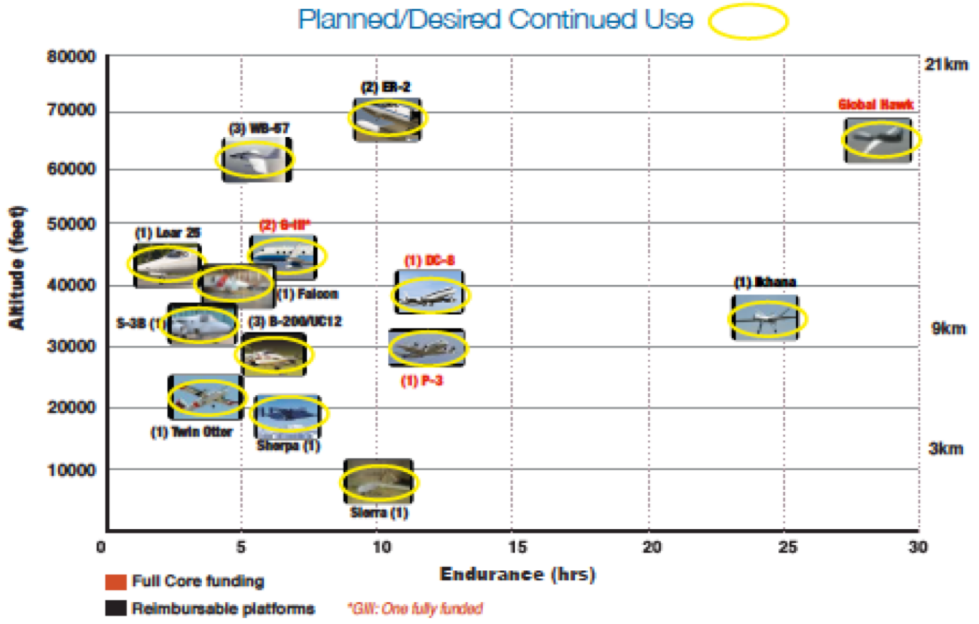


Figure 19. *Specific requirements for continued use of NASA aircraft indicated in Center survey results.*

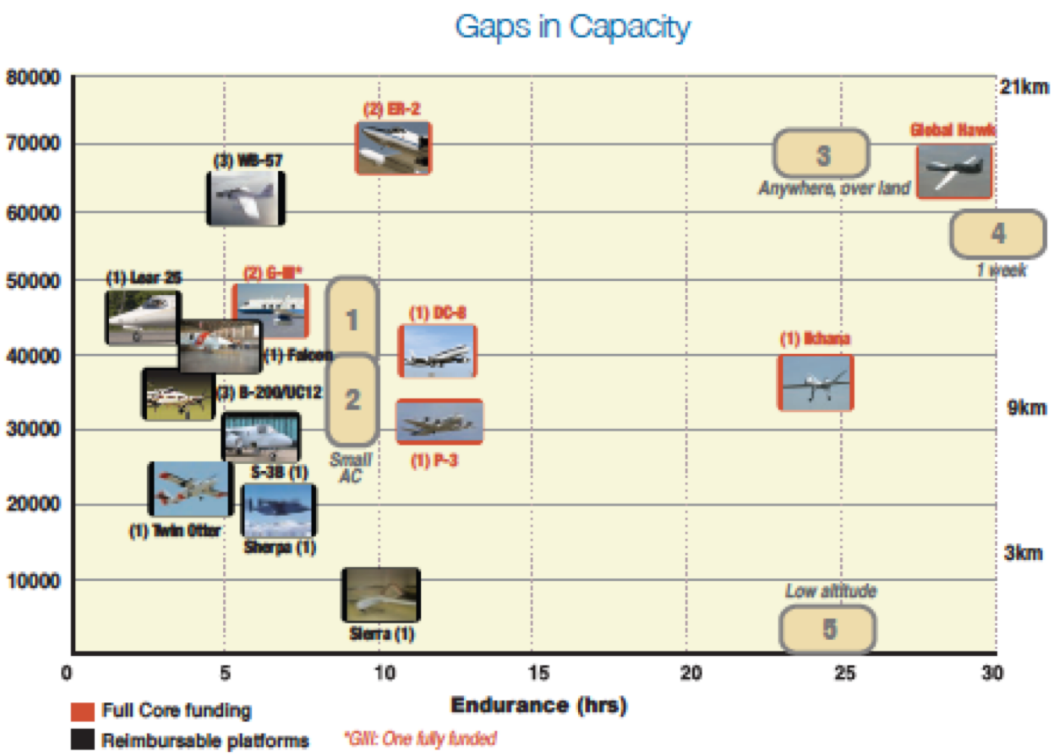


Figure ES-3 *Summary of aircraft gaps as identified by NASA Science Center Survey.*

Table ES-1 Explanation of gaps indicated in Figure ES-3

	Gap	Performance Need	Science Rationale	Possible Solution
1	Flight altitude to 50kft, 8 hr duration, moderate payload	Similar to DC-8 flight regime, including nadir ports, but something smaller and less expensive	Lidar systems for weather and terrain mapping, but not full size laboratory	Gulfstream V
2	Flight altitude 25 to 35 kft, 8 hr duration, small to moderate payload	Similar to King Air (B-200), but with longer duration	In situ sampling and ocean color both want 8 hrs, but flight characteristics and cost of B-200	King Air B-350; possible business jet
3	Very high altitude (65+kft), long duration (24 hrs), fly anywhere	Similar flight regime as Global Hawk, ideally higher, not constrained to over ocean	Ability to see the evolution of atmospheric transport processes during a 24-hour period	Continue UAS in the NAS work; possible new aircraft
4	Very long endurance (~week)	Above weather and traffic with ability to follow event	Ability to monitor or track fire or pollutant plume, storm development	Aerial refueling, airship or balloon; new aircraft
5	Low altitude, long duration (or long range to target), where the target is remote or there are basing constraints	100 – 200 ft over water, stable flight; over land with auto pilot	Radiation science over the ocean; carbon flux measurement; coral or ocean color imaging	Long duration, low altitude UAS (OR ship launch)

Gap analysis from 2015 Center Survey

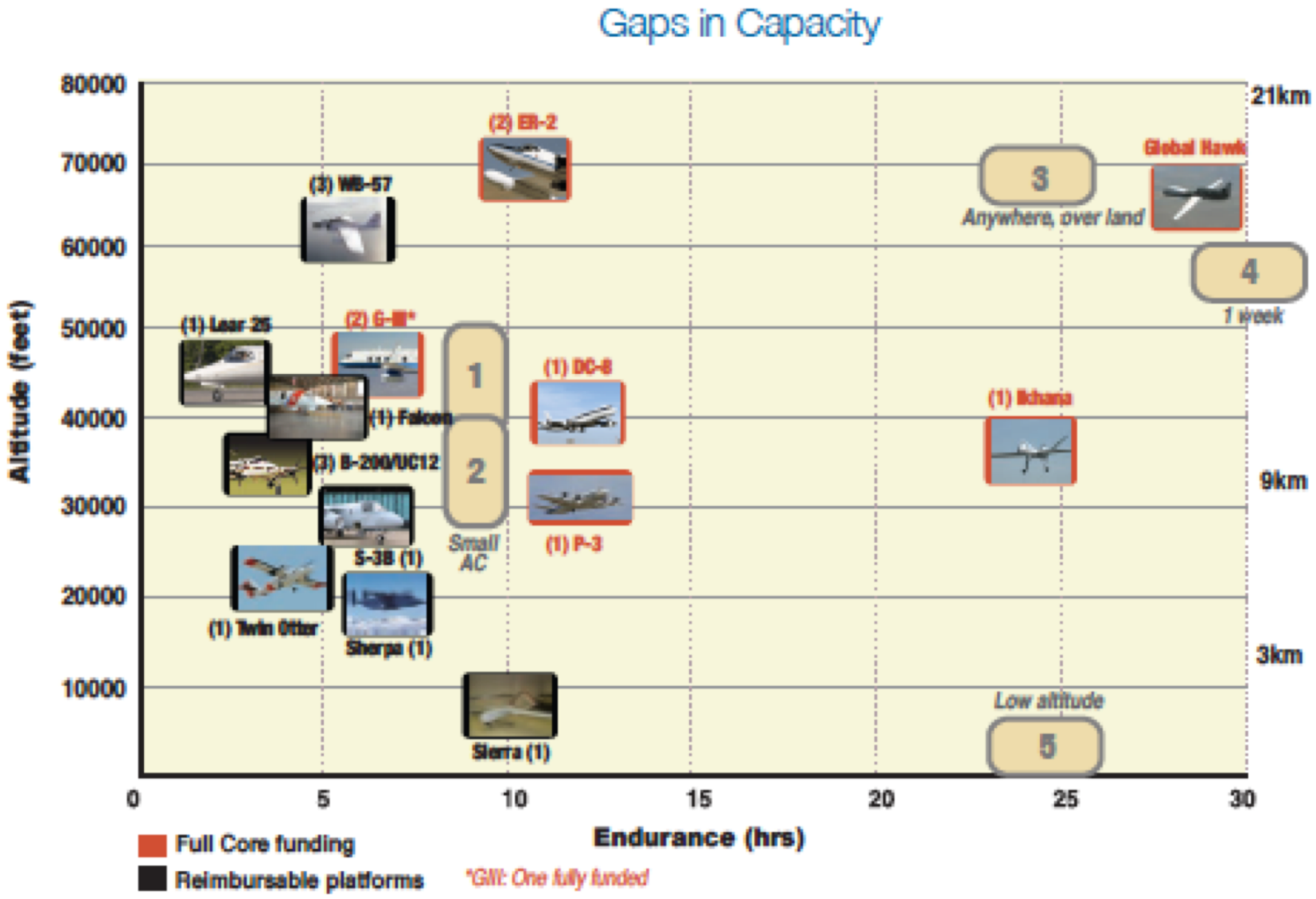


Figure ES-3 *Summary of aircraft gaps as identified by NASA Science Center Survey.*

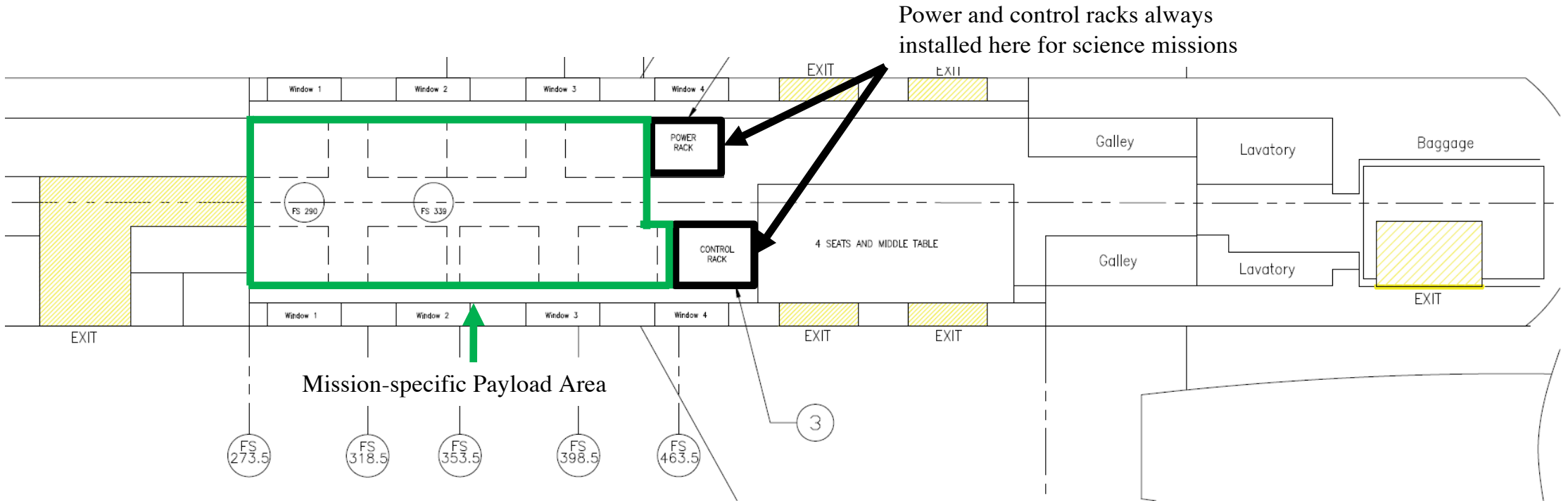
NASA Airborne Science Program

- Provides airborne capability to meet Earth Science requirements utilizing NASA, OGA, and commercial platforms
  - Capability maintained/added/removed based upon budgets and requirements
  - Requirements vetted yearly
  - Actively looking for options
  - https://airbornescience.nasa.gov/

- Responsive to Earth Science airborne platform requirements
  - Over 300 airborne instruments and counting….
  - Over 3100 Earth Science flight hours in FY18

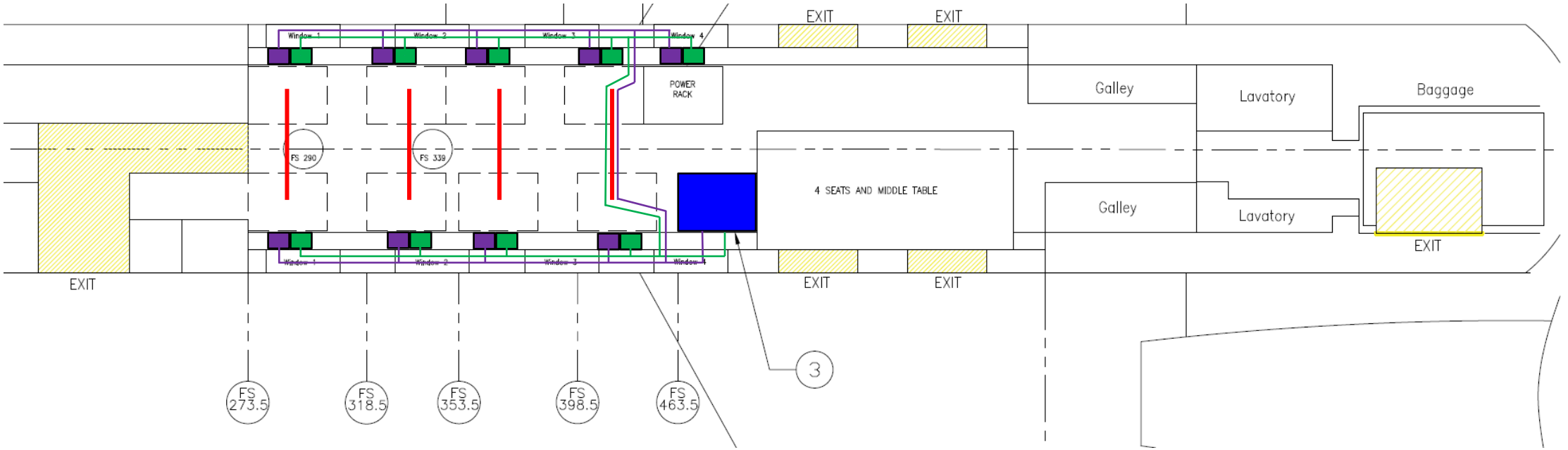
BACKUPS

- Cabin Layout
  - Control Rack – houses all network and computer equipment for payload support and left side power equipment
  - Power Distribution Rack – houses right side power conversion and circuit protection equipment
  - Up to 8 rack/seat locations maximum in cabin
    - Excluding existing 4-seat conference table in aft cabin
  - Full restraint seats available so experiments can be monitored at rack for takeoff and landing.
  - Seat track available through entire rack area



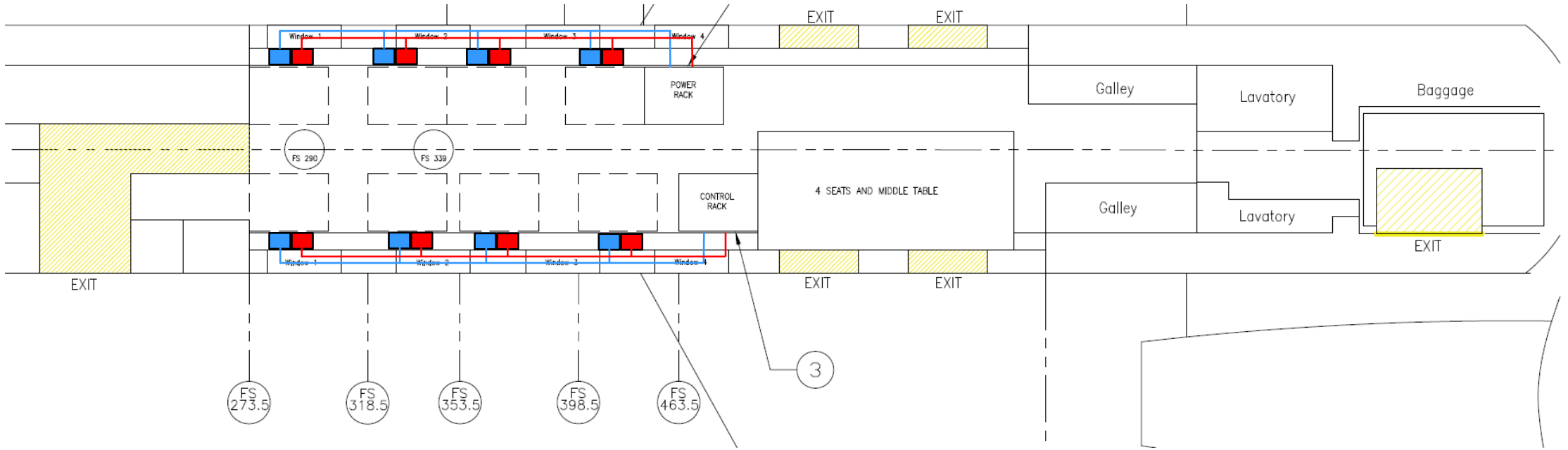
RF/Data Distribution

- 2x Cat 6A Network Receptacle (8P8C) and cabling
- 1x Coaxial Cabling TNC Receptacle and cabling
- Fiber optic cable pair (OM1/OM3) and Cat 6A run through **overhead conduit (x4)**
- Control Rack



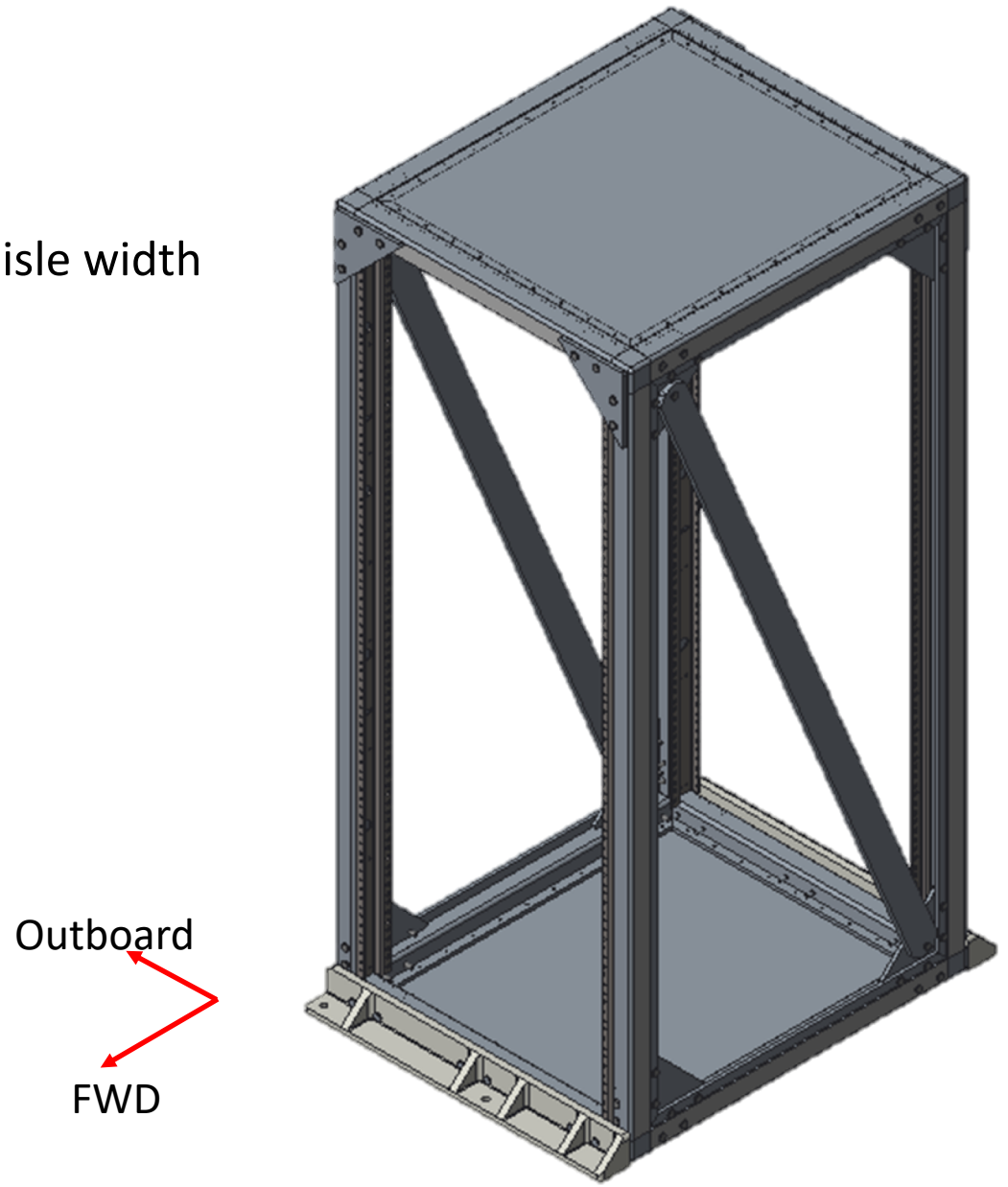
Power Distribution

- Electrical Power Distribution
  - Overall max load: 40kVA



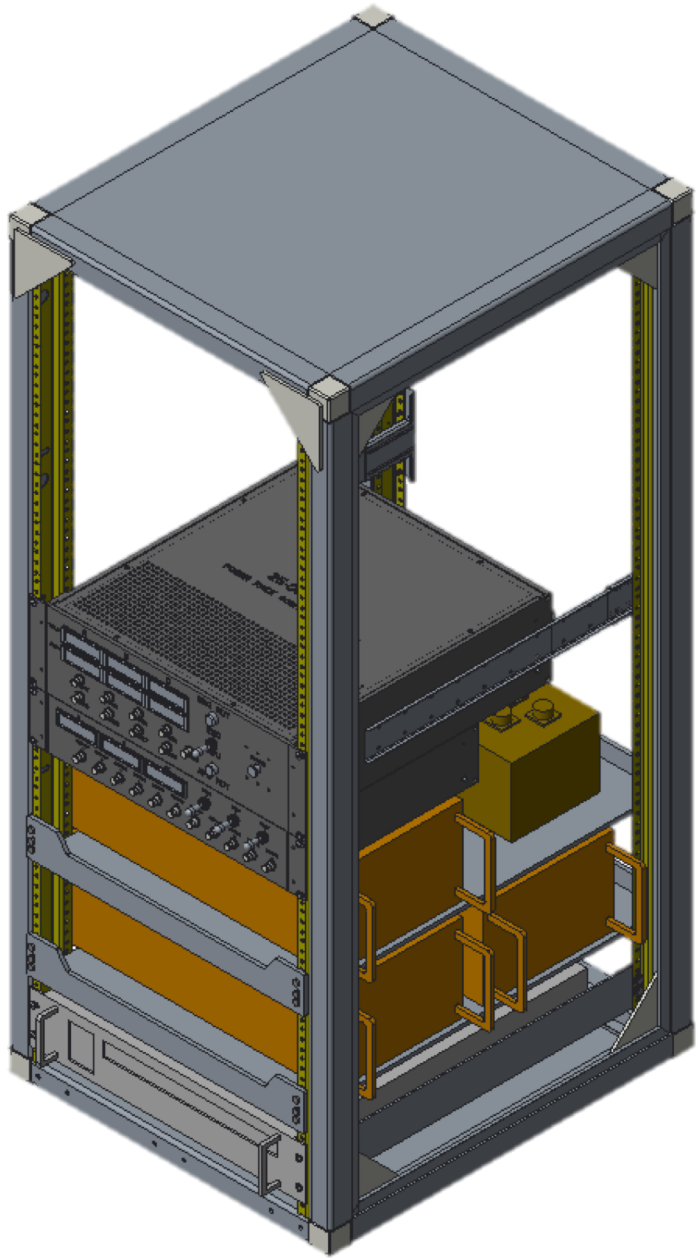
Racks

- Experimenter Racks
  - 22”W x 25”D x 51”H
    - Biggest racks that can fit in GV while maintaining aisle width
  - 25U available space (1U = 1.75”)
  - Maximum weight: 340lbs
  - Empty weight: ~50lbs
  - Maximum overturning moment: 6225 in-lbs



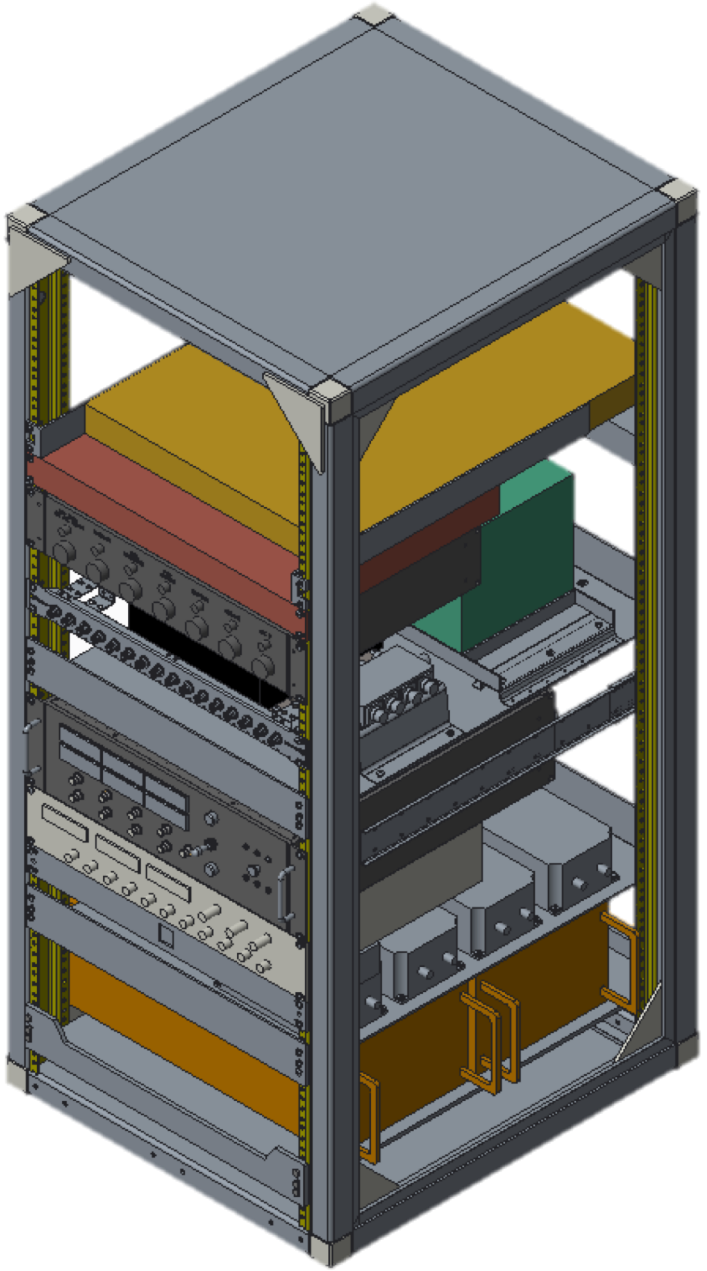
Power Rack

- Power Rack
  - Contains power conversion and circuit protection equipment for right side of aircraft
    - Control Rack houses left side equipment
  - 20kVA overall power per side
    - 120V 400Hz 3-phase available
    - 10.5kVA 120V 60Hz per side of aircraft
    - 400A 28VDC available (more capacity available on request)
  - Contains SLA UPS for control rack components
  - Interfaces with L Main, R Main, and APU AC busses
    - Allows for APU use in flight
  - Provides V and A readouts for each phase of 400Hz
  - Provides V, A, and Hz readouts for 60Hz power
  - Aircraft provides no-interruption switching between power sources



Control Rack

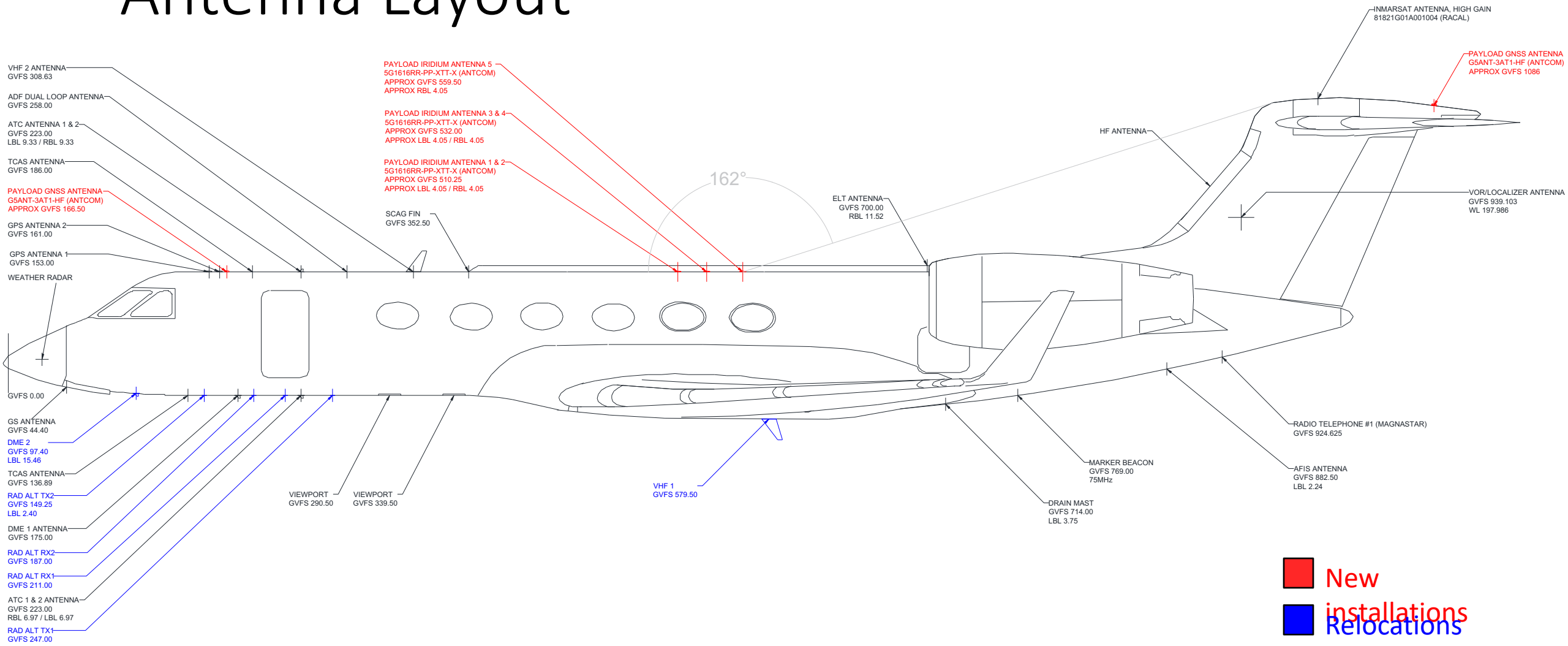
- Control Rack
  - Houses all network and computer equipment for payload support
  - Capabilities based on existing ASP aircraft and experimenter questionnaires
- GPS Signal Distribution
  - GPS Source MS18 - 1x8 0dB gain splitter
  - Notch filter to minimize SATCOM interference
  - System meets AS6129 platform requirements
- NASDAT
  - 4 ARINC 429 Interfaces – FMS, IRS, ADC, GPS
  - 4-channel Iridium modem
    - Additional Iridium bandpass filtering
- Other planned systems:
  - Adlink MXC-6300
  - GMS II Goldeneyes
  - Ballard AB3000 series



Control Rack, cont.

- Ethernet Switching / Routing
  - Cisco Nexus 3100-V
    - 48 port 10Gbe Switch
    - 6x QFSP+ Ports – 100Gbps
  - IEEE 1588-2008 (PTP) Compliant
  - Cisco IR829 Industrial Integrated Services Router
    - Interfaces with onboard Inmarsat network
    - Provides partitioned payload Wi-Fi
    - LTE Capable
- Precision Timing
  - Spectracom SecureSync
  - PTP Grandmaster Clock
  - Provides other timing signals (IRIG, STANAG, 1PPS, etc.)
- Signal Routing
  - BNC and Ethernet patch panels allow flexibility with signal distribution

Antenna Layout



New installations

Relocations

Payload Antennas

- GNSS Antennas
  - Antcom G5Ant-3AT1-HF
  - GPS/GLONASS L1/L2
  - Forward GNSS Antenna
    - >28 ft. separation from Iridium Farm
  - Tailcap GNSS Antenna
    - Shaded from Iridium Farm by the tail
    - Close (~7ft) to Inmarsat HGA

- Iridium Farm
  - Antcom 5G1616RR-PP-XTT-X
  - 5 Dual-Element Iridium Antennas
    - 4 for NASDAT
    - 1 for ASP Handset (Iridium Extreme 957)
  - Installed Mid-cabin

Antenna Filtering

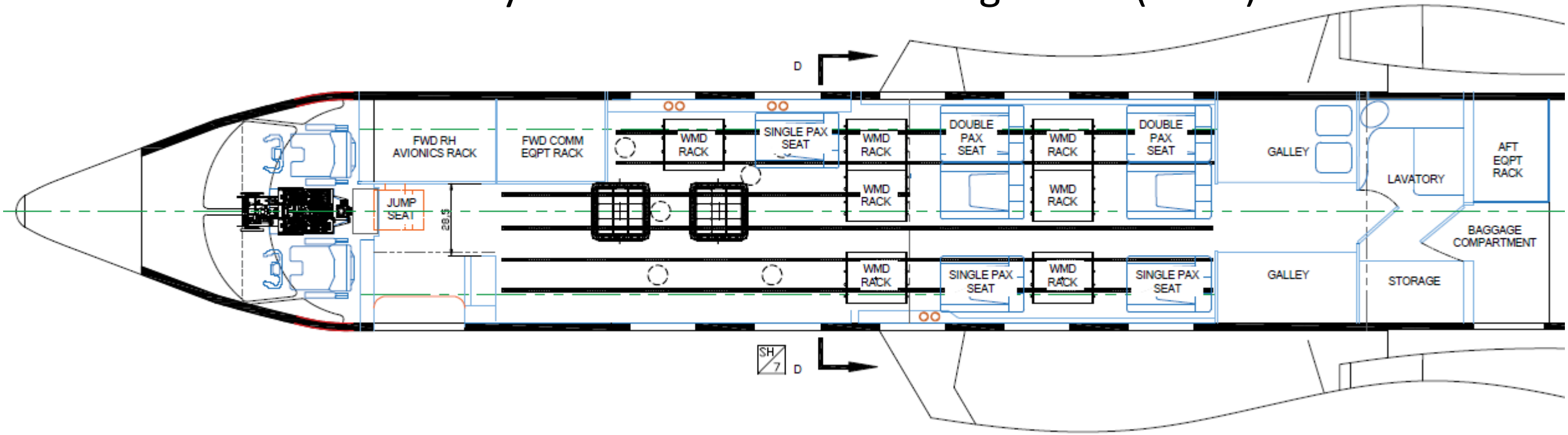
- Total Iridium/Inmarsat Rejection in GPS chain (relative to unfiltered GPS ant and unfiltered Iridium)
  - Iridium to GPS: At 1616 MHz (Iridium edge) → 20 dB K&L Iridium bandpass + 22 dB antenna rejection filter + 41 dB Reactel filter => **83 dB** rejection compared to unfiltered condition
  - Inmarsat to GPS: At 1630 MHz (Iridium/Inmarsat uplink edge) → 34 dB antenna rejection filter + 50 dB Reactel Notch filter => **84 dB** rejection compared to unfiltered condition

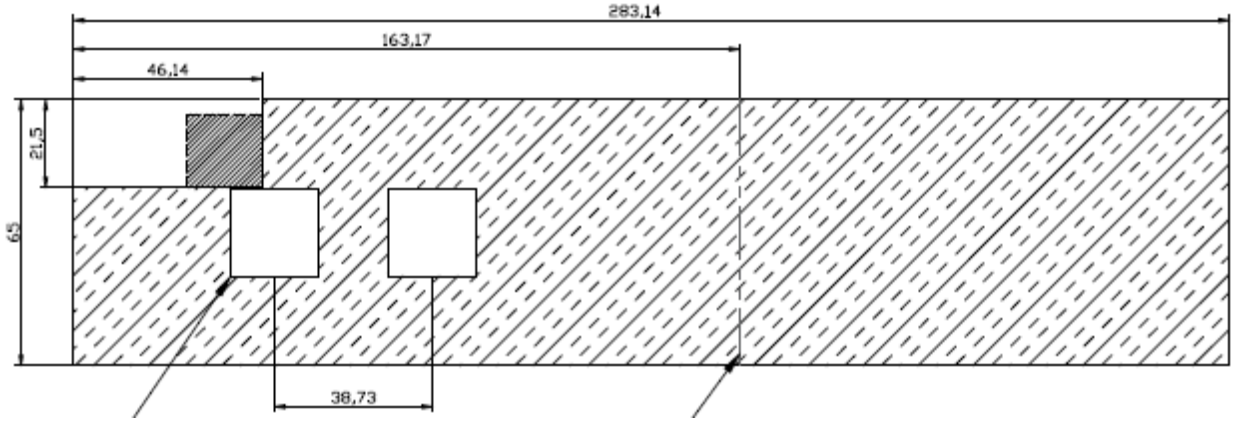
- Total Inmarsat Rejection seen by Iridium modems (relative to unfiltered Iridium modems)
  - Inmarsat to Iridium: At 1630 MHz (Iridium/Inmarsat uplink edge) → 50 dB Reactel K&L bandpass filter => **50 dB** rejection compared to unfiltered condition

SATCOM Provisions

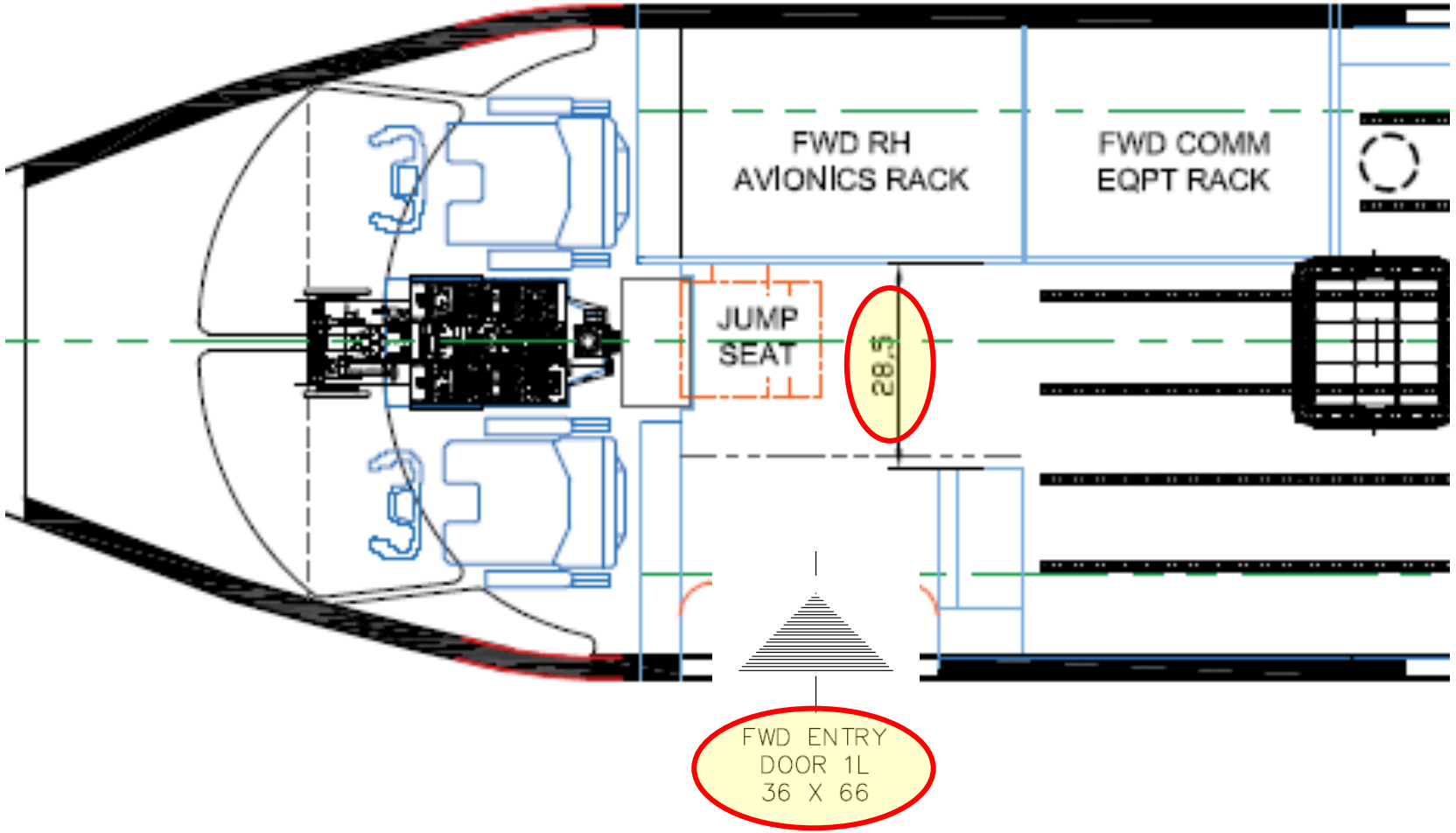
- Iridium
  - 5 dual-element Iridium Antennas installed
    - 5/10 elements used
  - 1 ASP-Provided handset (voice + data)
    - Iridium Extreme 9575
  - 4-channel modem on NASDAT
    - 9600bps max
  - Bandpass Filtering on all iridium connections
- Inmarsat
  - Included with aircraft
  - High Gain Antenna capable of 432kbps

Gulfstream III (NASA 520)
Notional Layout and Personnel Arrangement (LOPA)





Gulfstream III (NASA 520)
Aircraft Access

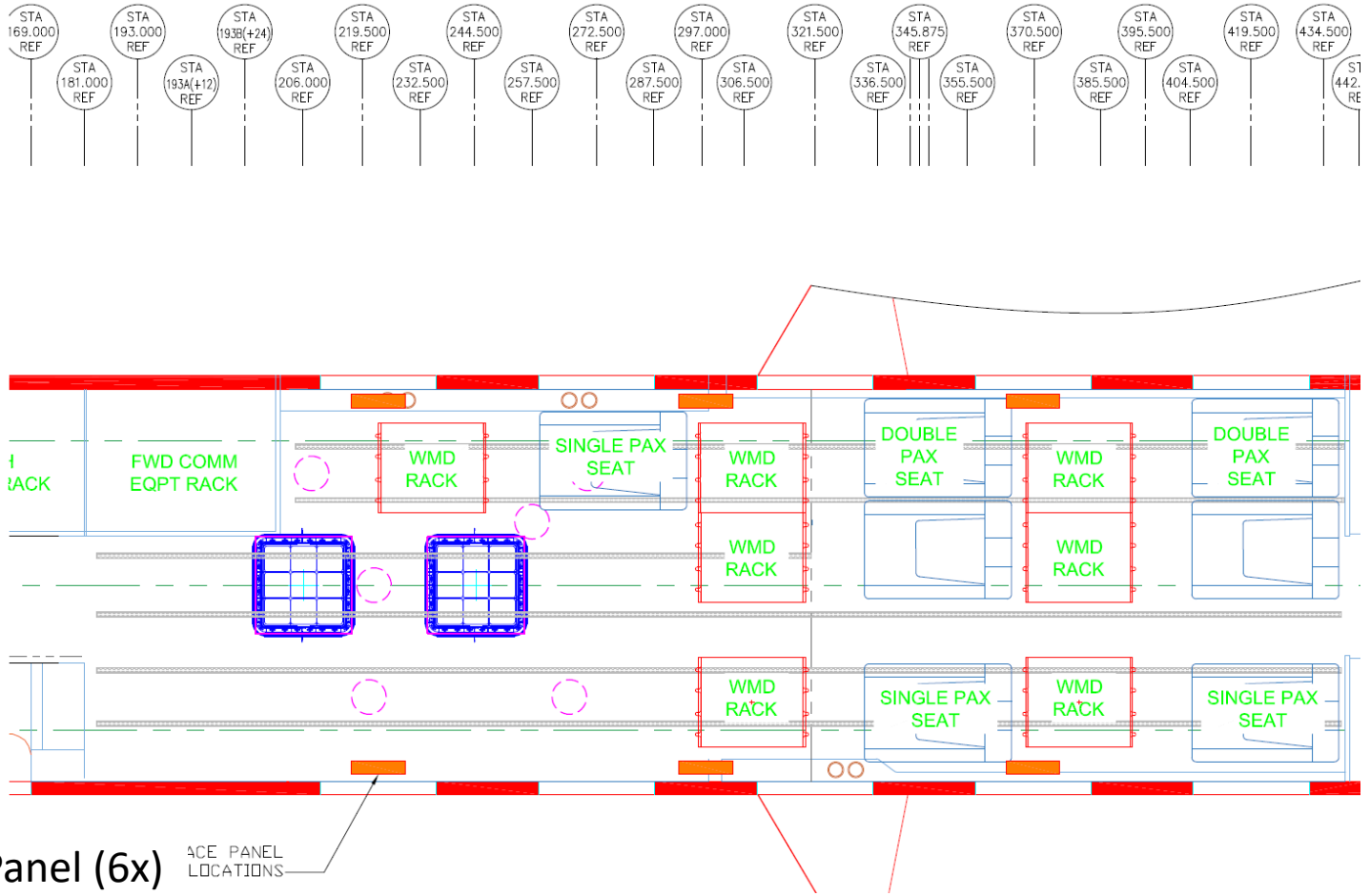


Gulfstream III (NASA 520)
Notional LOPA Description

- Example shows accommodations for seven researchers and seven racks; specific LOPA depends on mission requirements
- Personnel limit in passenger cabin will be 10
- Two identical square nadir portals located in passenger cabin aft of nose gear and forward of wing-to-body fairing
  - 18.16-in. x 18.16-in. opening
  - Distance between centers of portals is 38.7 in.
- Forward entry door is 36 in. wide x 66 in. high
- Aisle width aft of passenger door is 28.5 in.
- Six Researcher Interface Panels located in passenger cabin, three per side

Gulfstream III (NASA 520)
Research Power & Data Distribution

Six Researcher Interface Panels will be provisioned at six cabin locations as shown below



Research Interface Panel (6x)

Gulfstream III (NASA 520)
Research Power

- Research Power Distribution System will present adequate power of various denominations to six cabin research stations.

- Total Research Power Capacity
  - 80 A of 120 VAC/60 Hz power
  - 300 A or 28 VDC power
  - 15 A of 14 VDC
  - 20 A of 5 VDC

- UPS Override system will be located at each research station and controlled from the Cockpit.

Gulfstream III (NASA 520)
Researcher Interface Panel

HEADSET CONNECTORS CABIN INTERPHONE AND MONITORING OF THE AIRCRAFT RADIOS

RESEARCH POWER STATUS INDICATORS

COAXIAL INTERFACE TO THE RESEARCH PATCH PANEL WHERE JUMPERS WILL CONNECT THE RIP TO GPS OR IRIDIUM RF AS NEEDED.

AC BUS–1A AND AC BUS–1B, BOTH PROTECTED VIA 10A CIRCUIT BREAKERS. THE HUBBELL NEMA 5–15 RECEPTACLES ARE IN PARALLEL WITH THE MS3112F12–3S RECEPTACLES TO PROVIDE RESEARCHER 60Hz POWER.

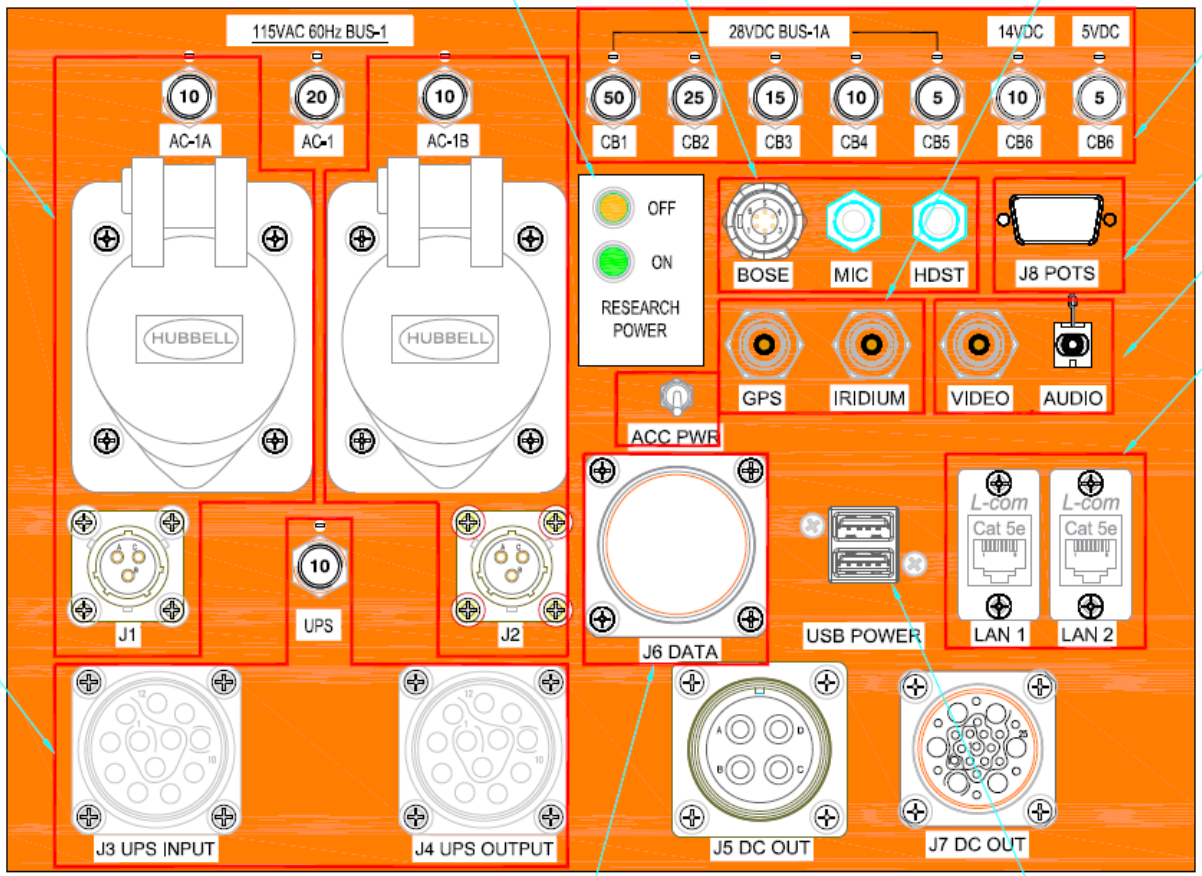
50A OF 28VDC IS AVAILABLE TO THE RESEARCHER WITH THE 50 AND 25A BUSSES PRESENTING ON J5 VIA THE MS3452W22–22S RECEPTACLE WHILE THE REMAINING DENOMINATIONS ARE AT THE J7 RECEPTACLE, P/N – MS24264R20B25SN. ALL CIRCUITS ARE LOCALLY PROTECTED BY THE ASSOCIATED CIRCUIT BREAKERS.

D–SUB INTERFACE FOR TIP AND RING FOR CONNECTING A HANDSET TO THE SATCOM SBU FOR VOICE CALLS OVER THE INMARSAT NETWORK.

INTERFACE TO THE RESEARCH PATCH PANEL TO DISTRIBUTE PROJECT A/V AS REQUIRED.

INTERFACE TO THE RESEARCH PATCH PANEL TO INTERFACE THE RIP TO ANY CONNECTED NETWORK OR SERVER INCLUDING INMARSAT SATCOM. OUR DATA RECORDING SYSTEM IS CAPABLE OF BEING NETWORKED TO ANY OF THE SIX STATIONS FOR DATA MONITORING AND EXTRACTION.

AN INTERNAL THREE–POLE RELAY, PROTECTED BY A 10A CIRCUIT BREAKER WILL PROVIDE THE FLIGHT CREW THE ABILITY TO REMOVE POWER TO A PROJECT EQUIPMENT THAT IS CONNECTED TO A UPS MOUNTED AT A GIVEN PALLET. THE RELAY RESPONDS TO SWITCH COMMANDS FROM THE FLIGHT CREW. RSIB WILL PROVIDE INTERFACE CABLES TO EXECUTE THIS PROCESS. WE WILL BRING POWER INTO THE RIP ON J3, IT WILL PASS THRU THE RELAY AND EXIT TO THE EQUIPMENT ON J4.



J6 WILL PROVIDE THE AIRCRAFT DATA BUSSES FOR PROJECT USE. THE ACC POWER SWITCH PROVIDES 28VDC TO SOCKET 60 OF J6 TO ENABLE LOCAL RECORDING OR SWITCHING AS NEEDED. THIS IS PARTICULARY USEFUL FOR BALLARD TYPE ISOLATION/RECORDING DEVICES.

BOTH PORTS PROVIDE 5VDC @2.1A FOR CHARGING DEVICES AS NEEDED. THESE ARE POWERED FROM THE AIRCRAFT 28VDC BUS.