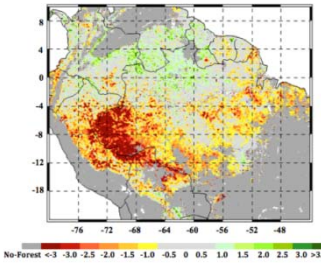
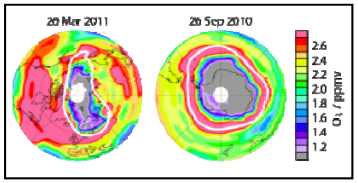
NASA Terrestrial Ecology Program
And
NASA's Carbon Cycle and Ecosystems Focus Area

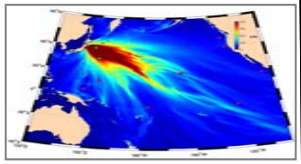
Hank Margolis
(presented by Josef Kellndorfer)

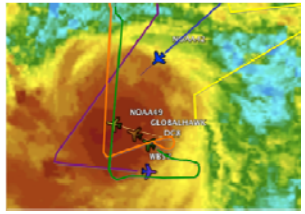
NASA's Earth Science Division

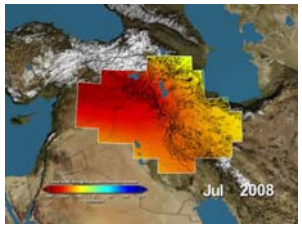
Research and Analysis

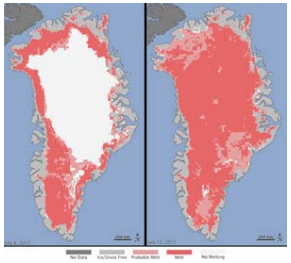




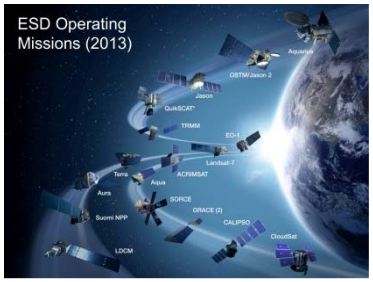


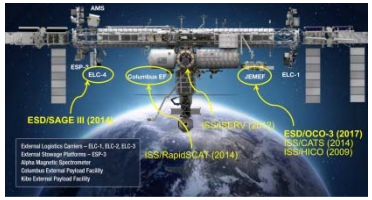




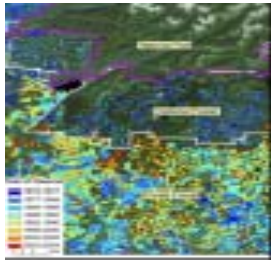


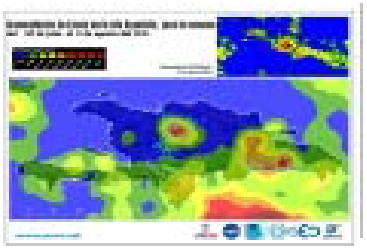
Flight

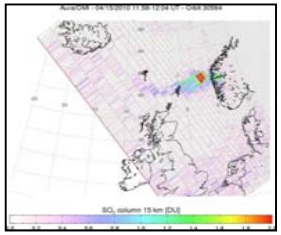


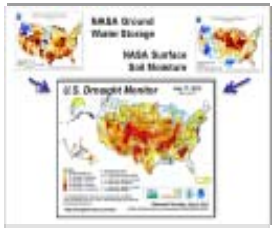


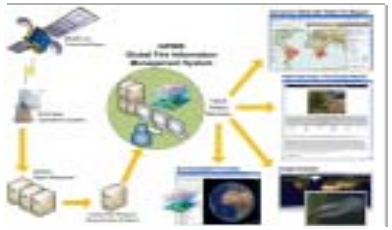
Applied Sciences

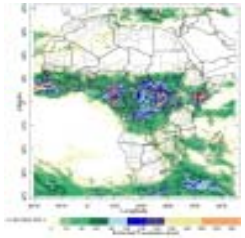




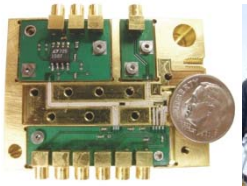


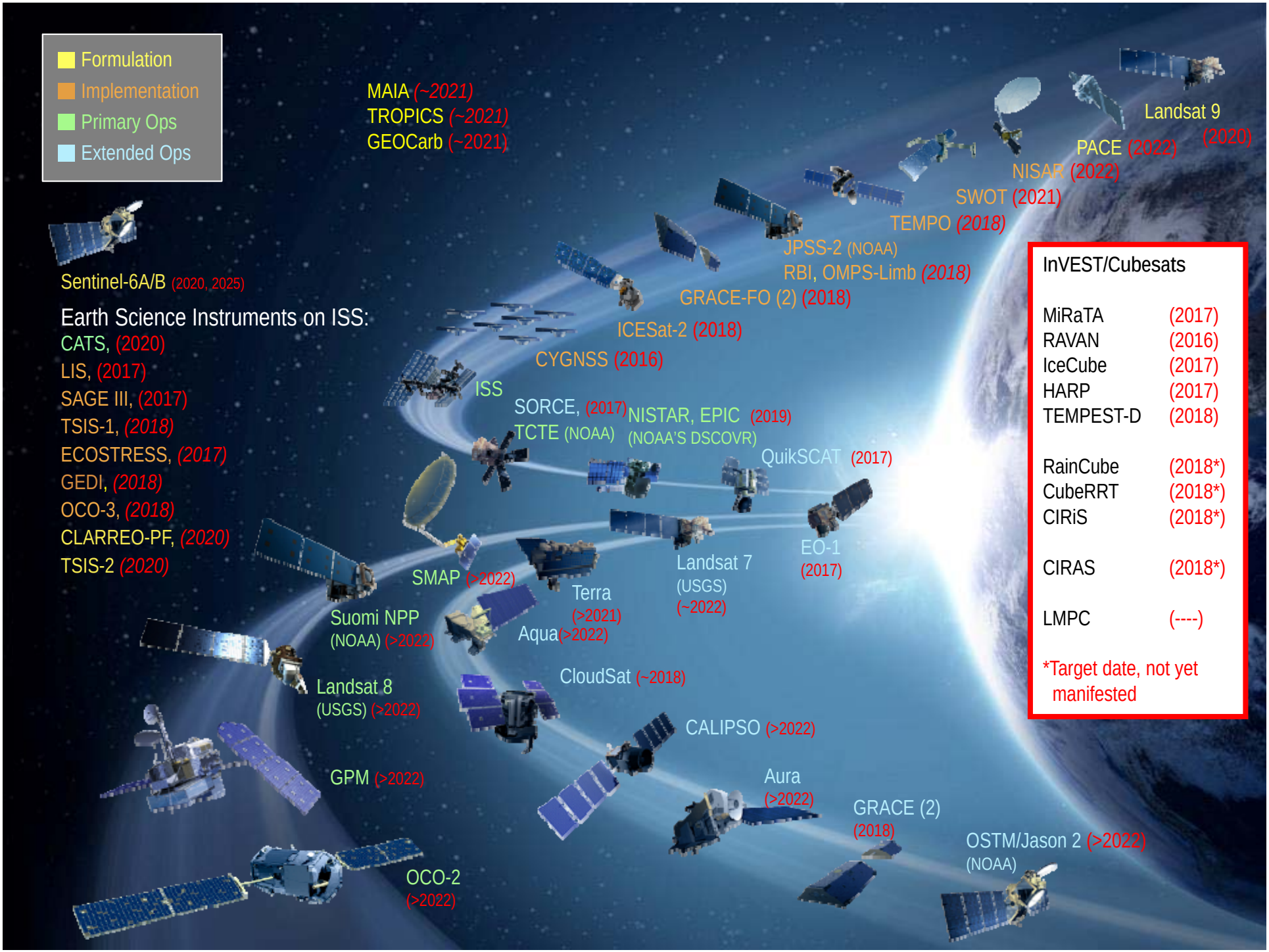






Technology




Formulation
Implementation
Primary Ops
Extended Ops
MAIA (~2021)
TROPICS (~2021)
GEOCarb (~2021)
Landsat 9 (2020)
PACE (2022)
NISAR (2022)
SWOT (2021)
TEMPO (2018)
JPSS-2 (NOAA)
RBI, OMPS-Limb (2018)
GRACE-FO (2) (2018)
ICESat-2 (2018)
CYGNSS (2016)
Sentinel-6A/B (2020, 2025)
Earth Science Instruments on ISS:
CATS, (2020)
LIS, (2017)
SAGE III, (2017)
TSIS-1, (2018)
ECOSTRESS, (2017)
GEDI, (2018)
OCO-3, (2018)
CLARREO-PF, (2020)
TSIS-2 (2020)
ISS
SORCE, (2017)
TCTE (NOAA)
NISTAR, EPIC (2019)
(NOAA'S DSCOVR)
QuikSCAT (2017)
EO-1 (2017)
Landsat 7 (USGS) (~2022)
SMAP (>2022)
Terra (>2021)
Aqua(>2022)
Suomi NPP (NOAA) (>2022)
Landsat 8 (USGS) (>2022)
CloudSat (~2018)
CALIPSO (>2022)
GPM (>2022)
Aura (>2022)
GRACE (2) (2018)
OSTM/Jason 2 (>2022) (NOAA)
OCO-2 (>2022)
InVEST/Cubesats
MiRaTA (2017)
RAVAN (2016)
IceCube (2017)
HARP (2017)
TEMPEST-D (2018)
RainCube (2018*)
CubeRRT (2018*)
CIRiS (2018*)
CIRAS (2018*)
LMPC (----)
*Target date, not yet manifested

Research & Analysis

~15 Program Managers Covering Earth Sciences

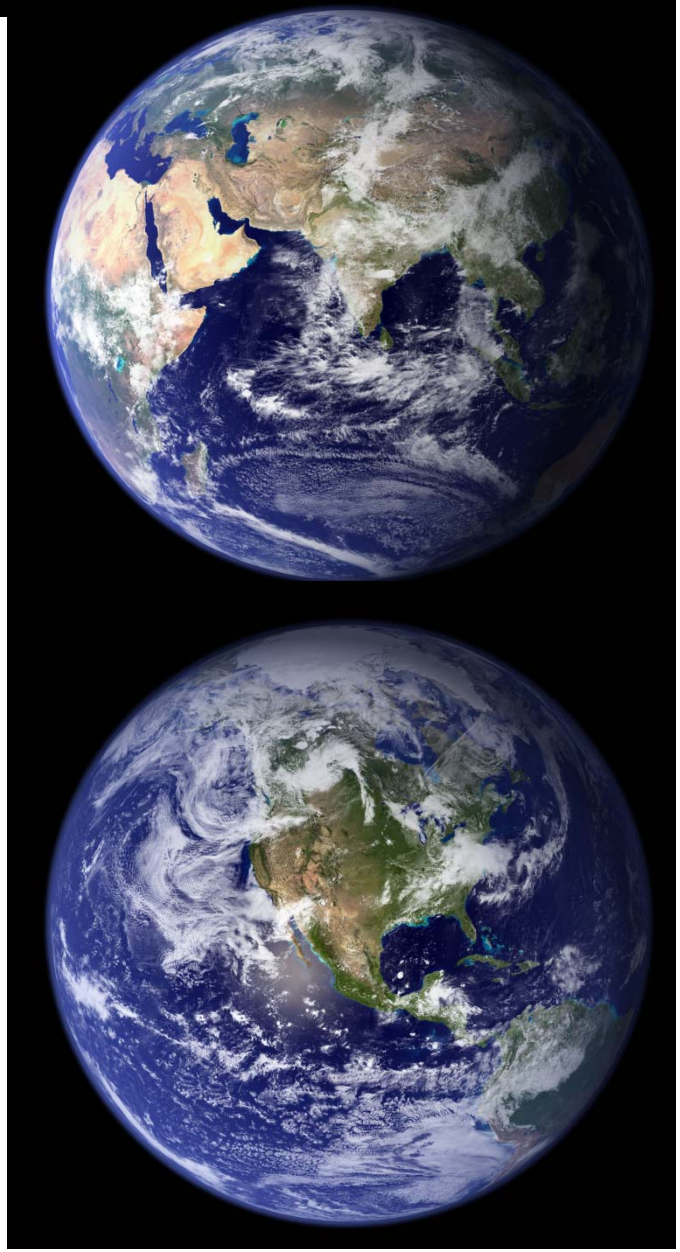
Carbon Cycle & Ecosystems Focus Area

Research and Analysis (R & A) Programs:

Biodiversity - Woody Turner
Land Cover and Land Use Change (LCLUC) - Garik Gutman
Ocean Biology and Biogeochemistry (OBB) - Paula Bontempi
Terrestrial Ecology (TE) – Hank Margolis, Kathy Hibbard, Eric Kasischke

Applied Sciences Programs:

Water Resources - Brad Doorn
Ecological Forecasting - Woody Turner



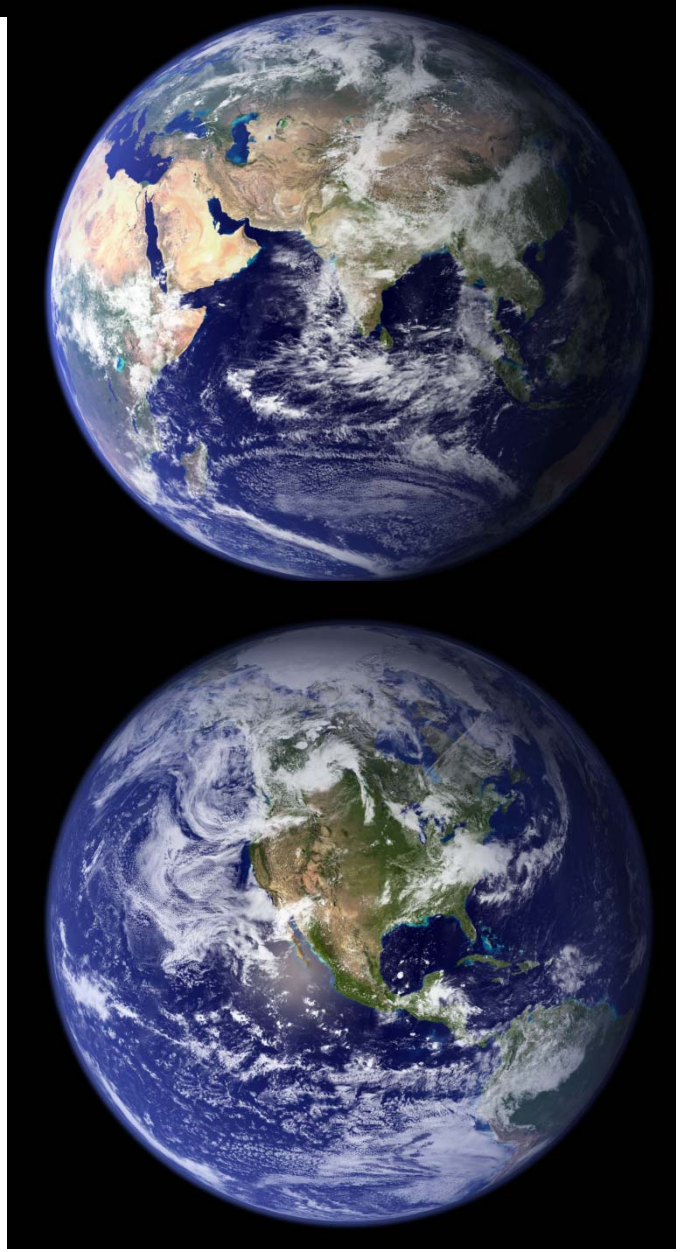
Carbon Cycle & Ecosystems Focus Area

How are ecosystems changing in response to environmental change and human actions?

How will they change in the future?

How do changes to ecosystems impact the other components of the Earth system?

How can carbon cycle and ecosystem science improve our capacity for mitigation and adaption to environmental change?



What Do We Do in the NASA Terrestrial Ecology (TE) Program?

- NASA Terrestrial Ecology Program, NASA Headquarters.
- TE Program Manager: Hank Margolis
- TE Program Scientists: Kathy Hibbard, Eric Kasischke
- Carbon Cycle and Ecosystems Focus Area

<u>Main Responsibilities</u>

- ABoVE: 2015-2025
- ORNL-DAAC
- GEDI (ISS), launch ~December 2018
- Support for:
  - ICESat-2: Autumn 2018 launch date
  - ASCENDS: Pre-formulation
  - Geo-Carb 2022 Launch
  - NISAR 2022 Launch

- Carbon Monitoring System
- Carbon Cycle Science
- Inter-Disciplinary Studies
- North American Carbon Program (NACP)
- AVIRIS airborne, EOS-Land, National Climate Science Assessment
- State of the Carbon Cycle Reports (SOCCR-2), CEOS Carbon Action Item.

NASA Terrestrial Ecology Approach to Research

TE Program's approach to investigating global ecosystems and the carbon cycle is broad-based, emphasizing NASA's unique capabilities and strengths. NASA Terrestrial Ecology research:

- Focuses on **utilizing existing satellite data and developing new capabilities for space-based global observations** of carbon stocks, primary productivity, vegetation composition, physiology, phenology, successional processes, biodiversity, and the biophysics of remote sensing these phenomena.
- Uses spatial information from **remote sensing data to scale up** site-based measurements to regional and global scales
- Analyzes **time series remote sensing data records to document and understand variability and changes** over time in ecosystems and carbon cycling
- Conducts calibration/validation of satellite data; algorithm development; **field campaigns**; process investigations; and data analysis/integration/assimilation
- Develops and exercises advanced, quantitative carbon and ecosystems **models**, data assimilation models, and coupled land-ocean-atmosphere models
- *Cooperates with NASA Applied Sciences to transition **innovative uses and practical benefits** of NASA Earth science data, scientific knowledge, and technology*
- *Cooperates with ESTO to advance the development and demonstration of **technologies** that enable improved future capability for the nation*

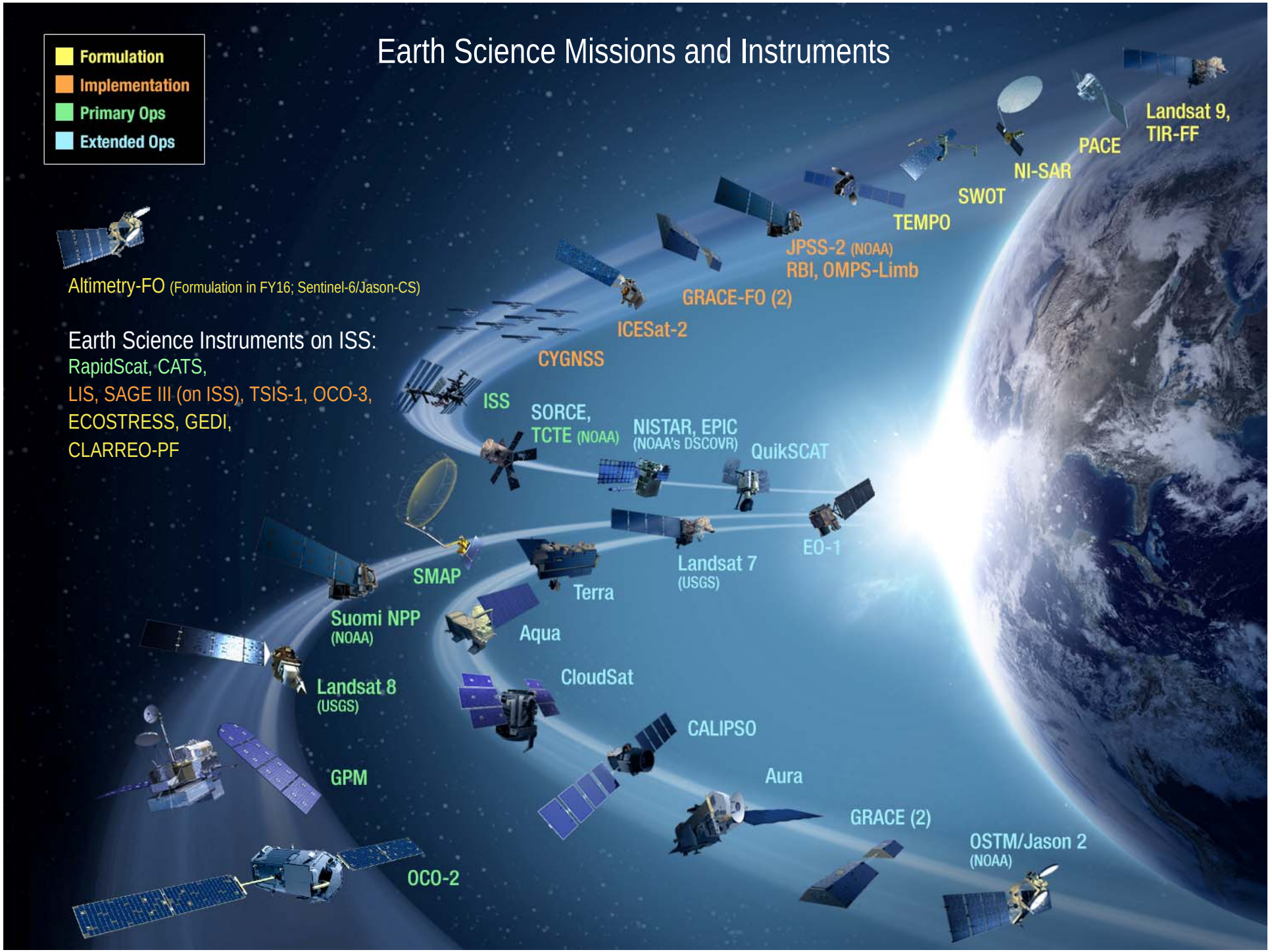
NASA Terrestrial Ecology Approach to Research

Terrestrial Ecology Elements:

- ❑ *Phenology*
- ❑ *Vegetation structure*
- ❑ *Ecosystem services*
- ❑ *Nutrient and biogeochemical cycling*
- ❑ *Productivity*
- ❑ *Stress*
- ❑ *Disturbance and extreme events*
- ❑ *Drought impacts and feedbacks*
- ❑ *Permafrost dynamics*
- ❑ *Disease outbreaks*
- ❑ *Ecosystem physiology*
- ❑ *Mapping ecosystem properties*
- ❑ *Modeling and data assimilation*

TE Budget (2016) = ~$15 M / yr

Portfolio (2016) = ~$26 M / yr

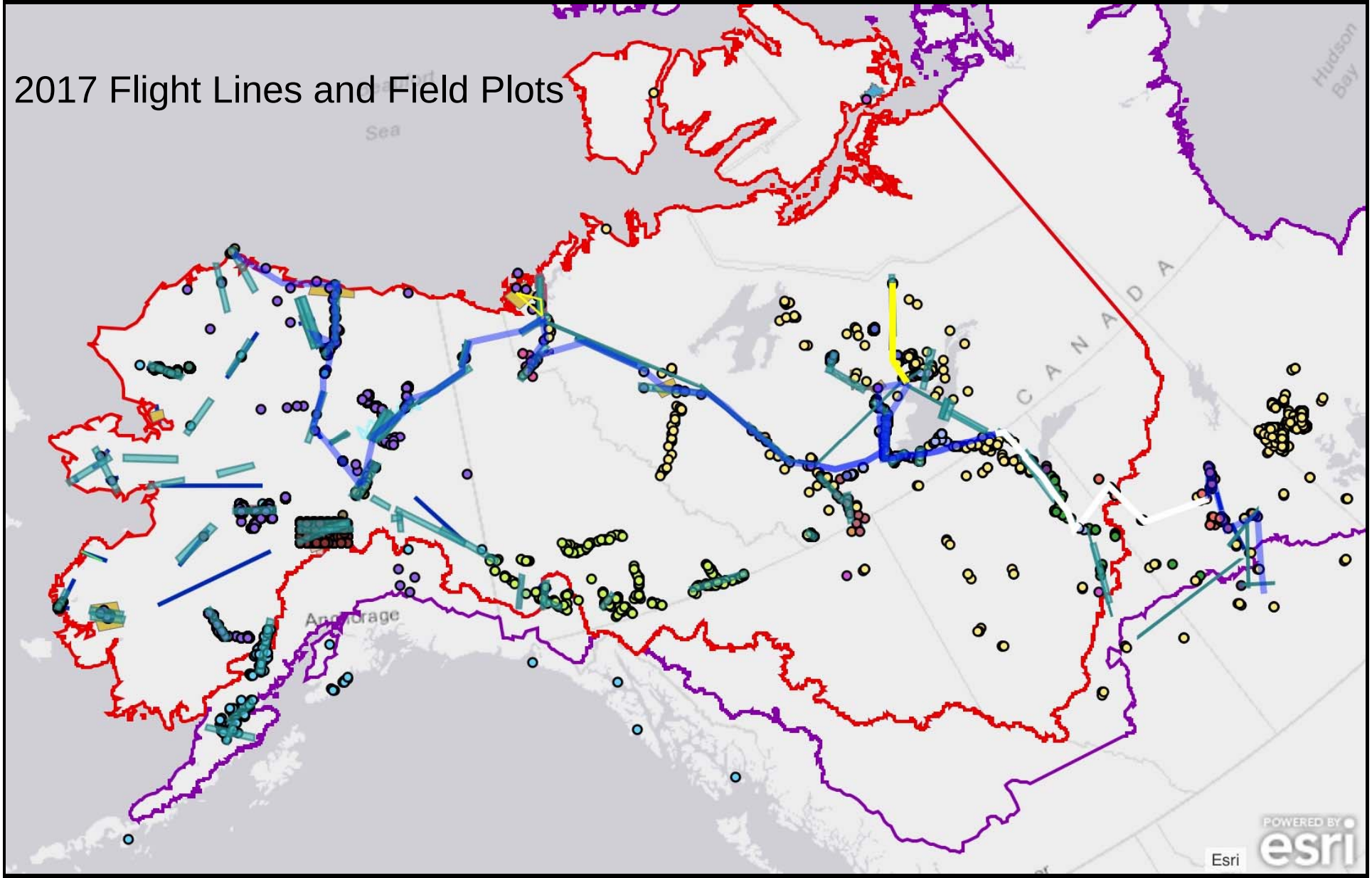

Earth Science Missions and Instruments
Formulation
Implementation
Primary Ops
Extended Ops
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

NASA Terrestrial Ecology Approach to Research

Terrestrial Ecology Recent Research Calls:

- ❑ Arctic-Boreal Vulnerability Experiment (ABoVE-2 Airborne Campaign)
- ❑ Interagency Carbon Cycle Science
- ❑ Carbon Monitoring System (CMS)
- ❑ Inter-Disciplinary Sciences (IDS):
  - Understanding the Global Sources and Sinks of Methane
  - Ecology at Land/Water Interfaces – Human and Environmental Interfaces
  - Partitioning of Carbon Between the Atmosphere and Biosphere

Arctic-Boreal Vulnerability Experiment (ABoVE)



2017 ABoVE Airborne Campaign Timeline

Foundational Flights

Jun 2017 Campaign 1A – Spring ALT (UAVSAR, AirMOSS)

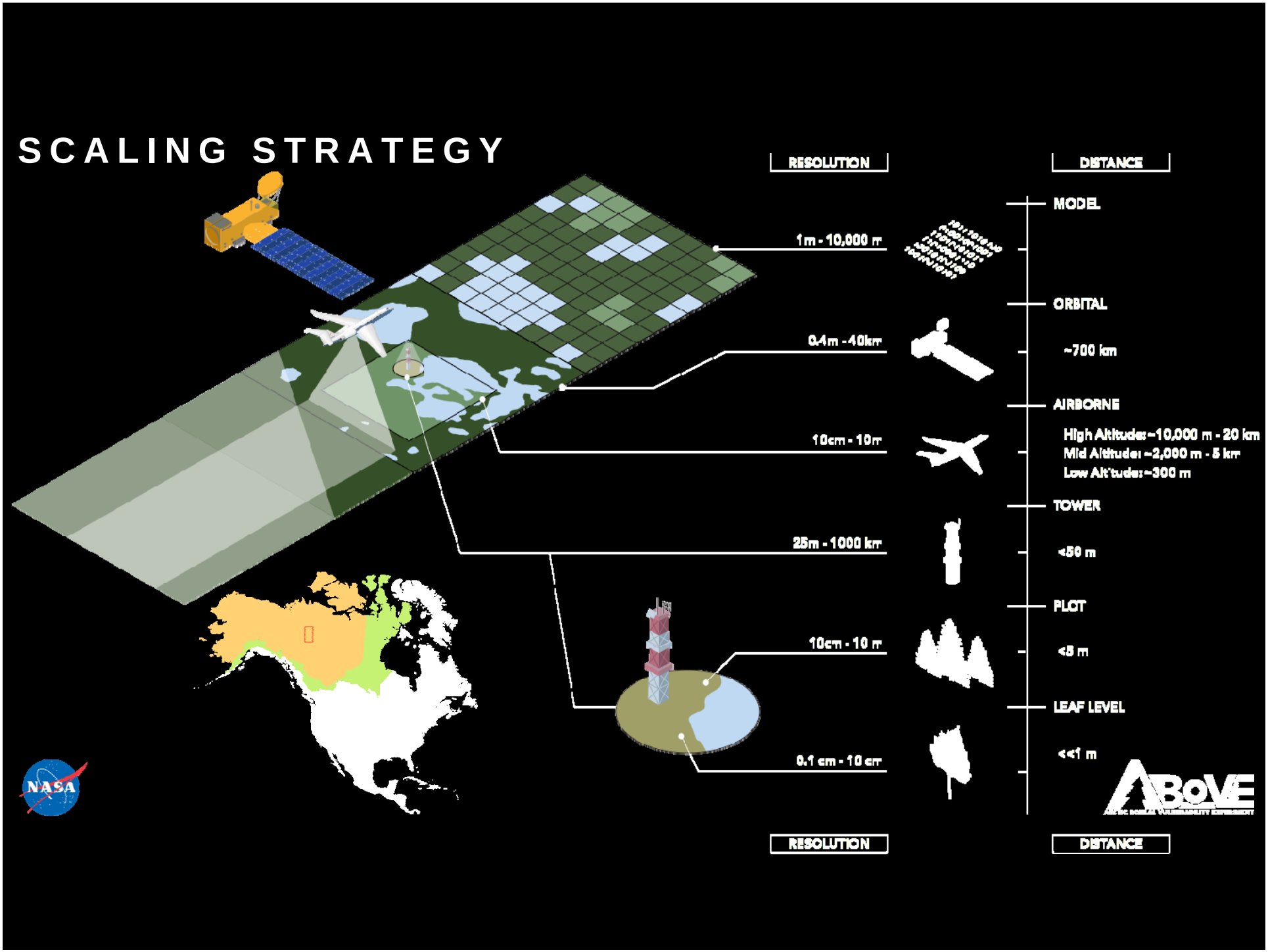
Jul 2017 Campaign 1B – Mid-summer Veg Peak (LVIS, AVIRIS, ASCENDS)

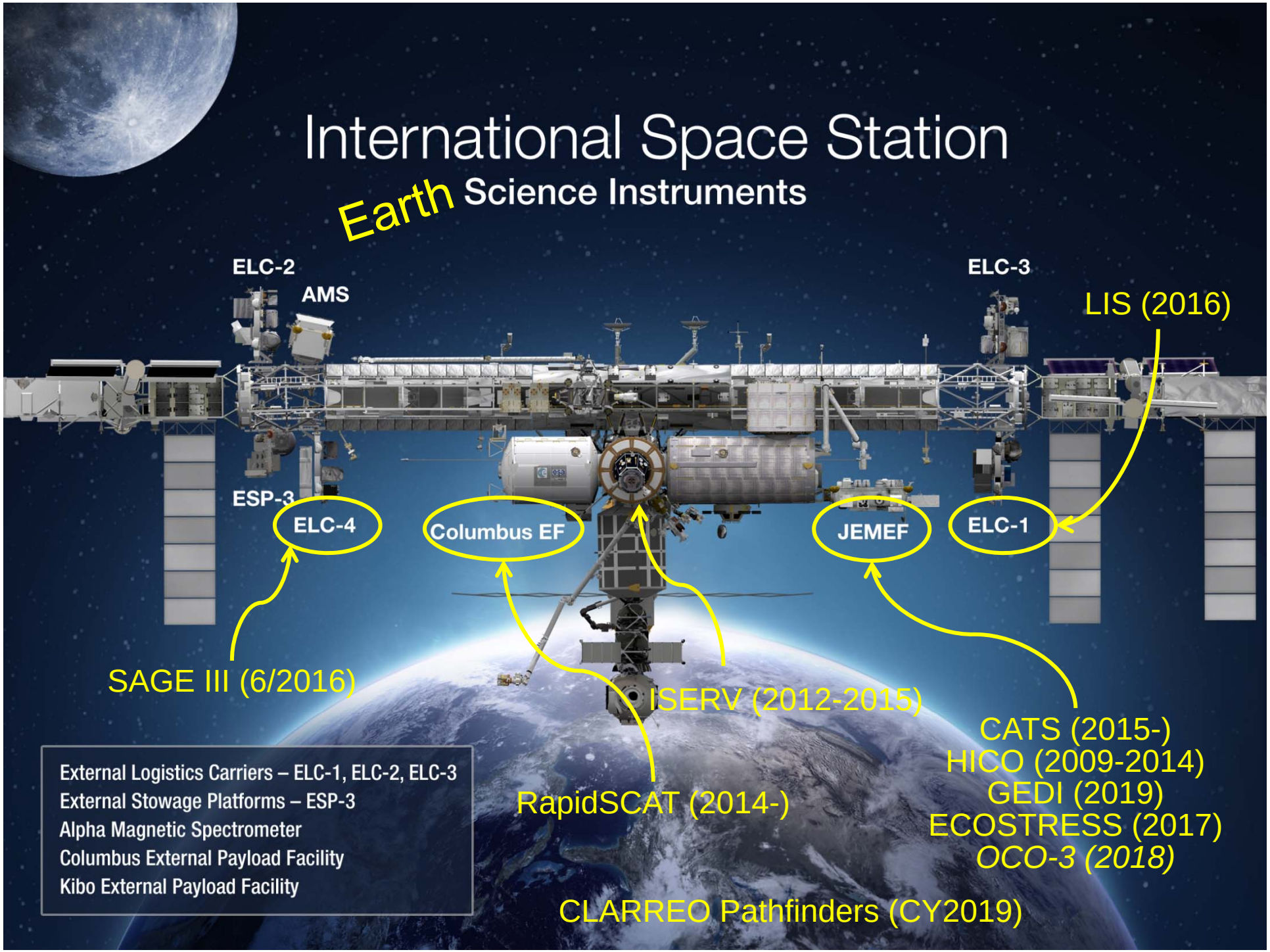
Sept 2017 Campaign 1C – Late Summer ALT (UAVSAR, AirMOSS)

PI-led Flights

Apr – Oct 2017	Carbon Flux Campaigns (Sweeney)
Jun – Sep 2017	CFIS Chlorophyll Fluorescence campaigns (Drewry)
Jun, Aug 2017	AirSWOT campaigns (Smith)
Oct 2017	Early Cold Season ALT (UAVSAR, AirMOSS) (Moghaddam)

SCALING STRATEGY




International Space Station
Earth Science Instruments
ELC-2
AMS
ELC-3
LIS (2016)
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
SAGE III (6/2016)
ISERV (2012-2015)
CATS (2015-)
HICO (2009-2014)
GEDI (2019)
ECOSTRESS (2017)
OCO-3 (2018)
RapidSCAT (2014-)
CLARREO Pathfinders (CY2019)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION (GEDI)

Forest height and vertical structure; habitat quality & biodiversity; Forest carbon sinks & source areas; loss of carbon from extreme events such as fires and hurricanes; parameterization of ecosystem models	Forest Management & Carbon Cycling
Canopy 3D structure that influences snowmelt, evapotranspiration, canopy interception of precipitation. Glacier surface elevation change; lake & river stage; snowpack elevation; coastal tides.	Water Resources
Improved canopy aerodynamic profiles to parameterize weather prediction models. Canopy and biomass products that initialize and constrain climate models; impacts of land use change on climate	Weather Prediction
Accurate bare earth and under canopy topographic elevations for improved digital elevation models from radar. Calibration of satellite based observations of surface deformation and earthquakes	Topography & Surface Deformation

Key Global Ecosystem Dynamics Investigation Lidar Facts

Mission/Portal Page:	http://science.nasa.gov/missions/gedi/
Altitude:	420km
Inclination:	51.65°
Origination:	NASA
Instruments:	LIDAR
Principle Investigator(s):	Ralph Dubayah, University of Maryland
Other Key Personnel:	Jim Pontius Todd Denkins

Launch: Late 2018

- Geodetic-class, light detection and ranging (lidar) laser system
- 3 lasers, 10 parallel tracks of observations.
- lasers fire 242 times/second
- 25-m spot (a footprint). separated by 25 m along track
- Across-track distance of about 600 m between each of the 10 tracks.
- Expected to produce about 15 billion cloud-free observations during its nominal 24-month mission length

May 24 2016

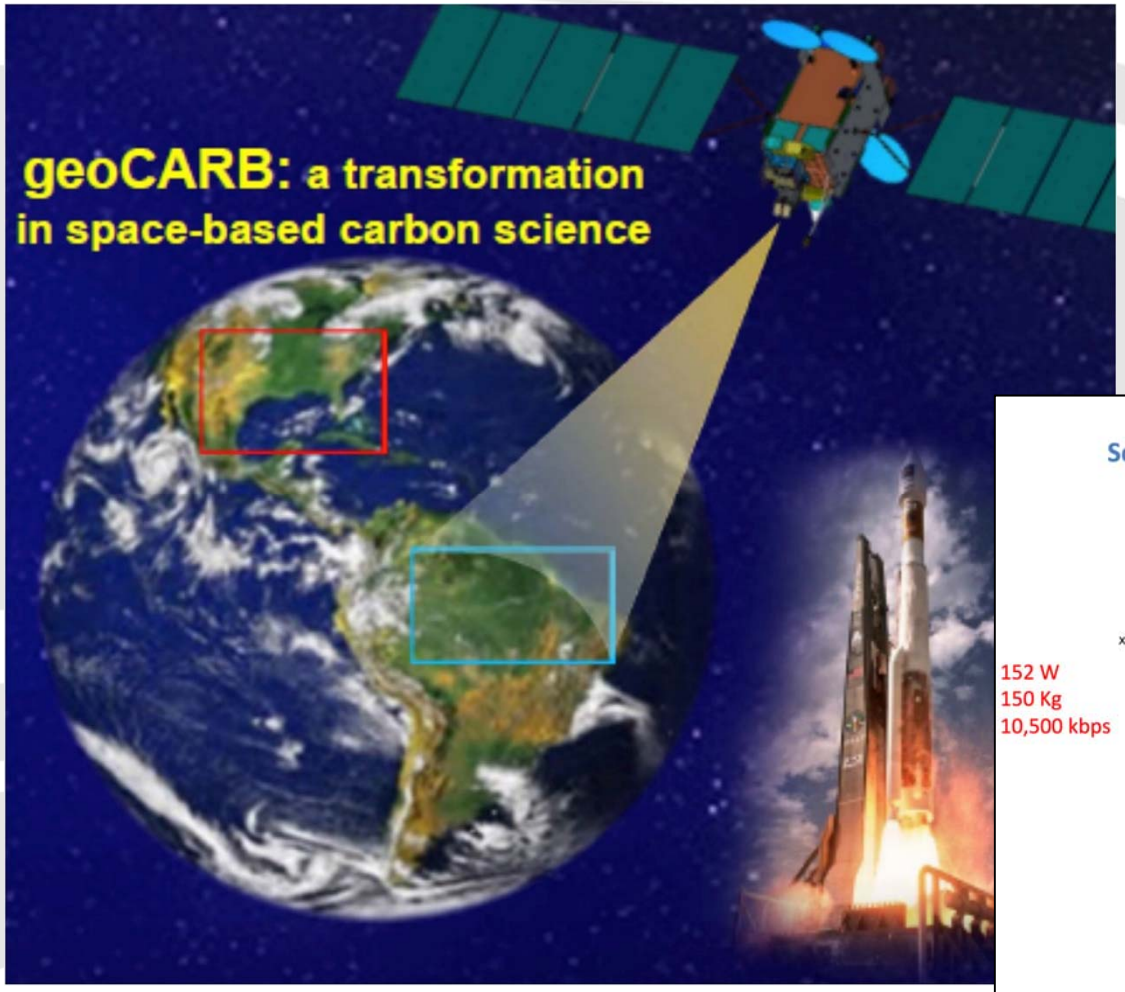
MISSION SCIENCE OVERVIEW

CRAIG DOBSON, NISAR PROGRAM SCIENTIST
HANK MARGOLIS, TE&C LEAD

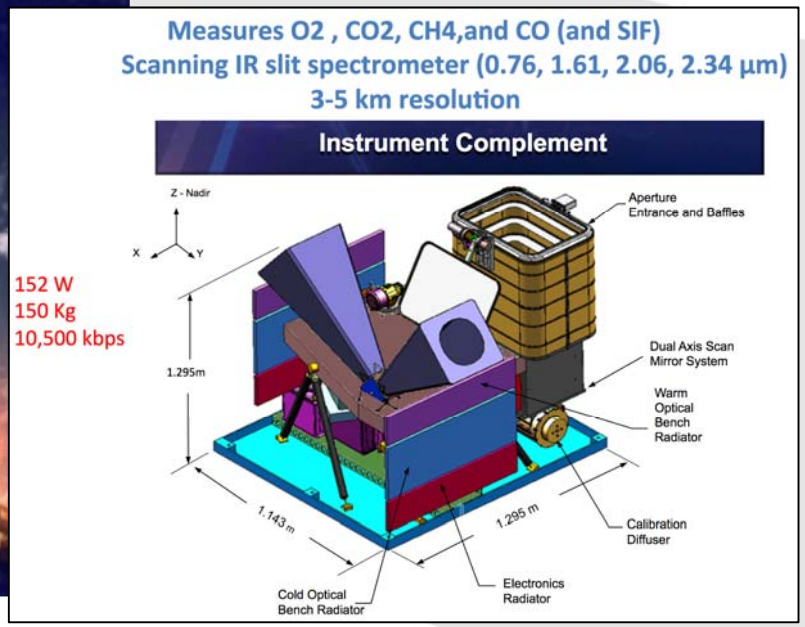
NISAR is a joint program by NASA and the Indian Space Research Organization (ISRO)

- Overall focus is on Earth surface dynamics (solid Earth, ecosystems, cryosphere)
- NASA provides L-band SAR/InSAR, antenna/boom, feed structure, GPS, telecom
- ISRO provides S-band SAR/InSAR, spacecraft, launch
- Expected launch late 2020 or 2021
- 3-yr mission with consumables for 5+
- 12-day repeat, sun-sync, dawn dusk orbit
- All land and ice covered areas imaged at least 2 every 12 days
- 24Tb/day downlink, ASF-DAAC for low level products
- Open data policy

geoCARB Selected for EVM-2

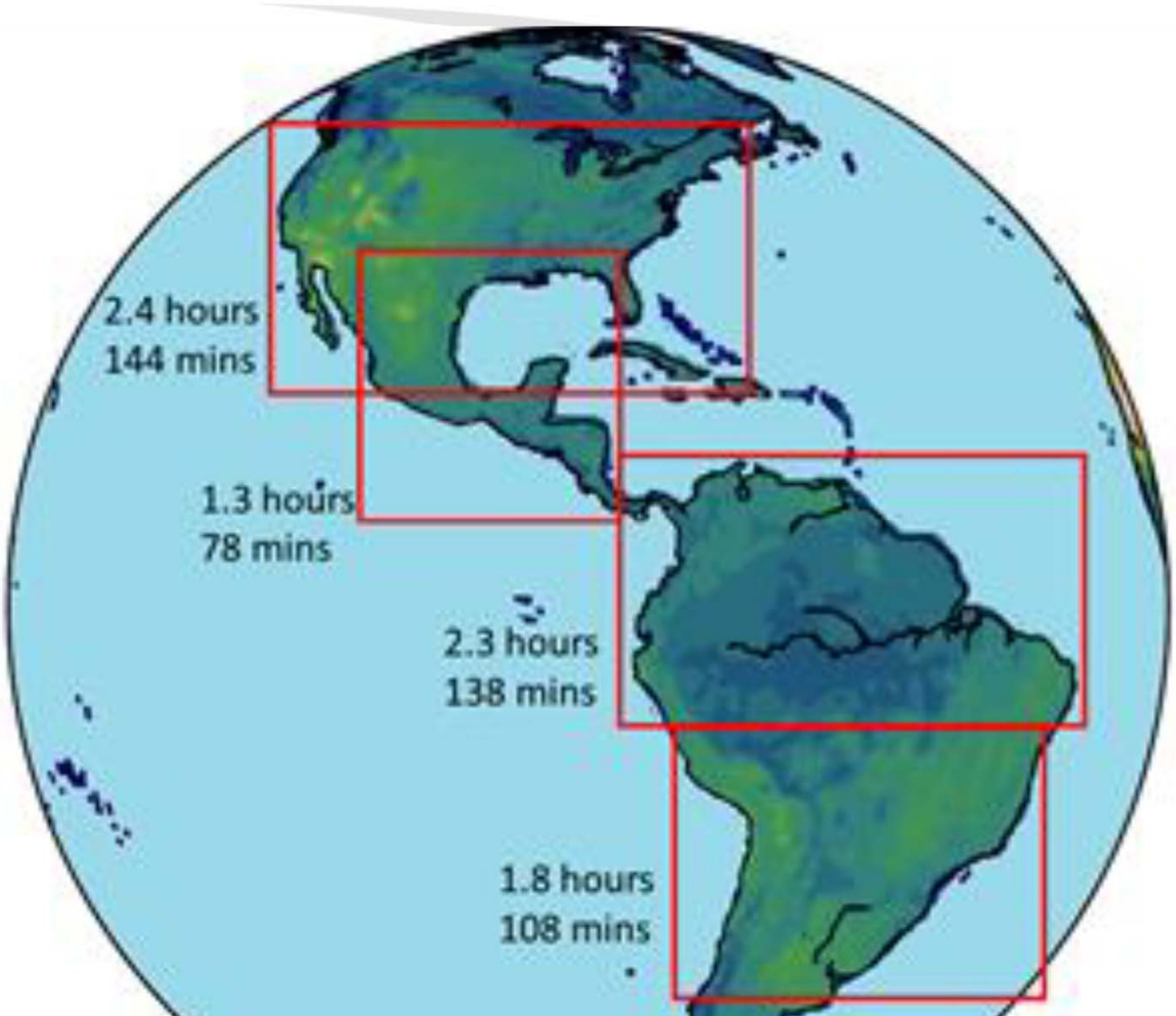


Berrien Moore, PI
University of Oklahoma



- First geostationary measurements of CO_2, CO, CH_4, and Solar Induced Fluorescence; 5-10 km resolution
- Hosted payload on an SES commercial communication satellite (PI-arranged hosting)
- Lockheed Martin Advanced Technology Center (Palo Alto);
  Colorado State University (Fort Collins); ARC; GSFC; JPL

Scan Blocks at 85 deg West)rbital Slot



CMS: Congressional Direction (Summary)

Congressional Direction in 2010:

Also included within the funds provided for other mission and data analysis, the conference agreement provides $6,000,000 for pre-phase A and pilot initiatives for the development of a carbon monitoring system. Any pilot developed shall replicate state and national carbon and biomass inventory processes that provide statistical precision and accuracy with geospatially explicit ass
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protocols. The Committee is concerned that NASA has not established a program of record around the development of MRV system, and therefore expects a plan from NASA not later than 90 days after enactment of this act incorporating such a system into its operating plan and long-term budget projection. The Committee recognizes that the current orbital and suborbital platforms are insufficient to meet these objectives. Therefore, the use of commercial off-the-shelf technologies is recommended as these products could provide robust calibration validation datasets for future NASA missions.

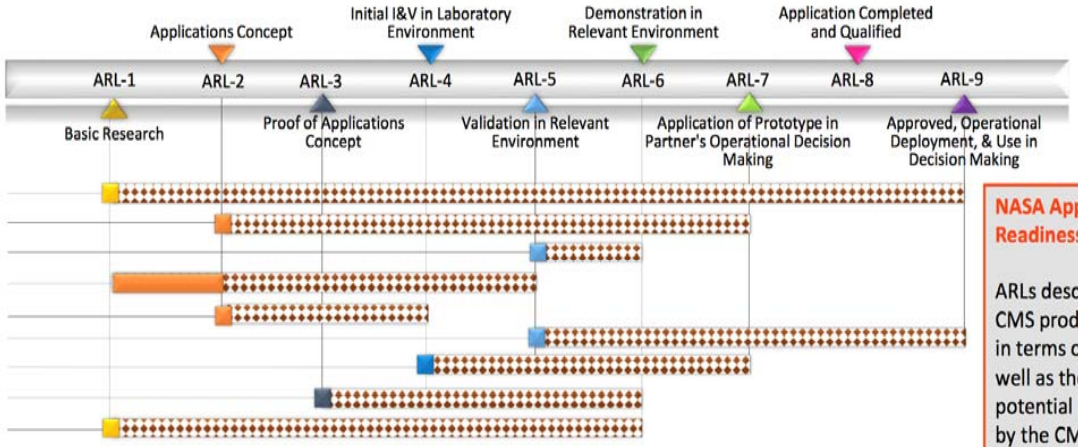
…"pilot initiatives for the development of a carbon monitoring system…"

..."replicate state and national carbon and biomass inventory processes that provide statistical precision and accuracy with geospatially explicit associated attribute data…"

…"development of a prototype Monitoring Reporting and Verification (MRV) system which can provide transparent data products achieving levels of precision and accuracy required by current carbon trading protocols…."

..."[development of] a plan…incorporating such a [MRV] system into its operating plan and long-term budget projection…"

CMS Application Readiness Levels (ARLs)



SY 2014 Projects

Andrews-03
Baker-01
Bowman-02
Ganguly-01
Greenberg-01
Hurtt-03
Lohrenz-05
Morton-01
Windham-Myers-01

Fatoyinbo-01
Hudak-01
Jacob-02
Ott-01
Walker-W-01
Williams-C-01

Different ARLs are provided for the products in these projects. Refer to individual corresponding charts describing the product ARLs.

Project ID
PI-Project # (Andrews-02)-Each CMS Project is represented by its color and identified by the PI on the project

Solid color: each solid bar is indicative of where the PI feels their project is NOW in terms of application readiness.

Pattern fill: indicates the level each PI is striving for and the application readiness level they feel their project can ultimately satisfy.

NASA Application Readiness Levels (ARLs)

ARLs describe where the CMS product is currently in terms of readiness, as well as the desired and potential level as defined by the CMS Product Scientist.

The ARLs were provided by the CMS Product Scientist and represent the most accurate representation of the state of each product.

Products can start at any level. It is not expected they will start at ARL1 and end at ARL9.

DSCOVR – EPIC (Lunar Transit movie)

DSCOVR – EPIC (Solar Eclipse, 21-08-2017)