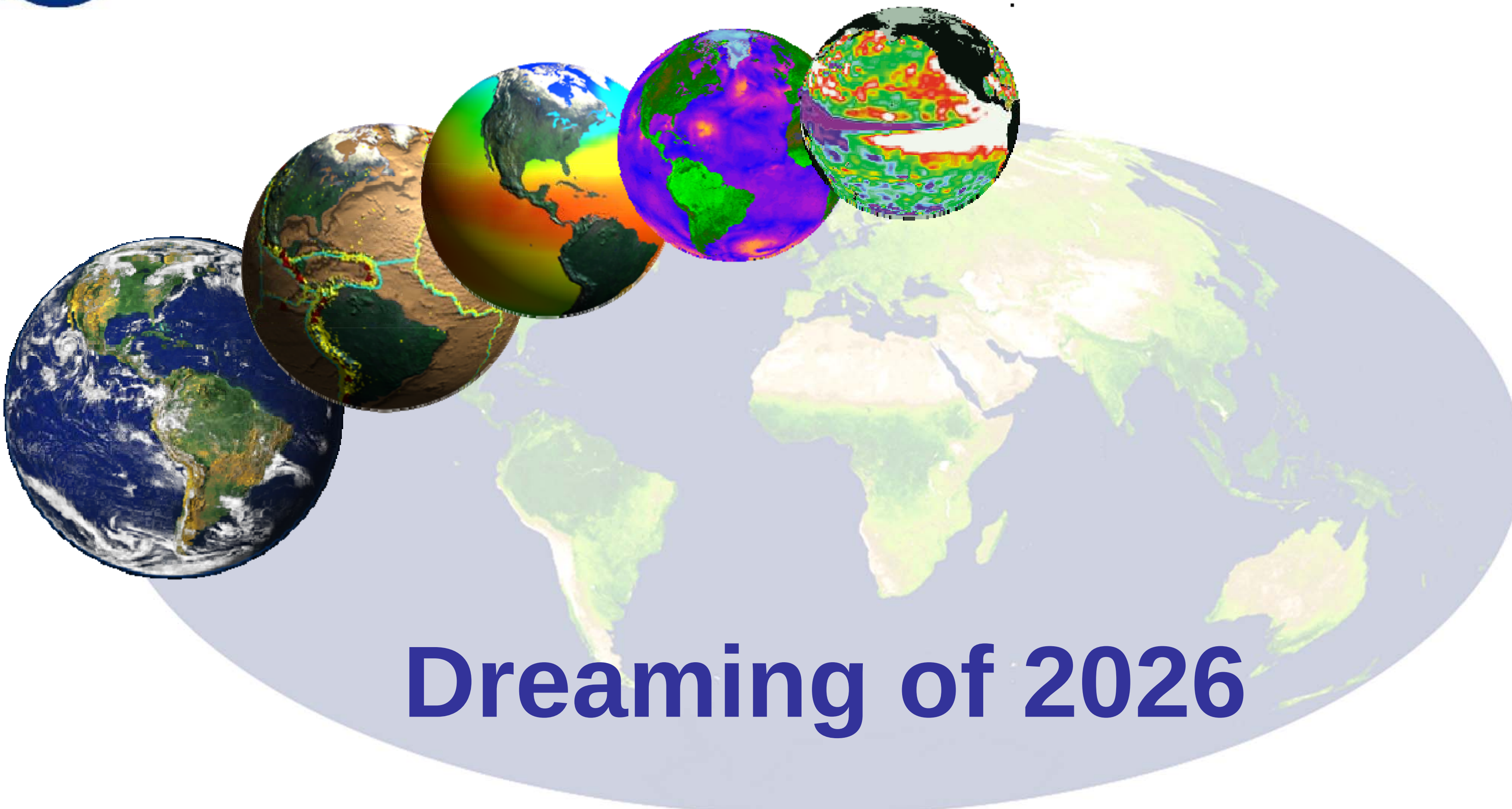
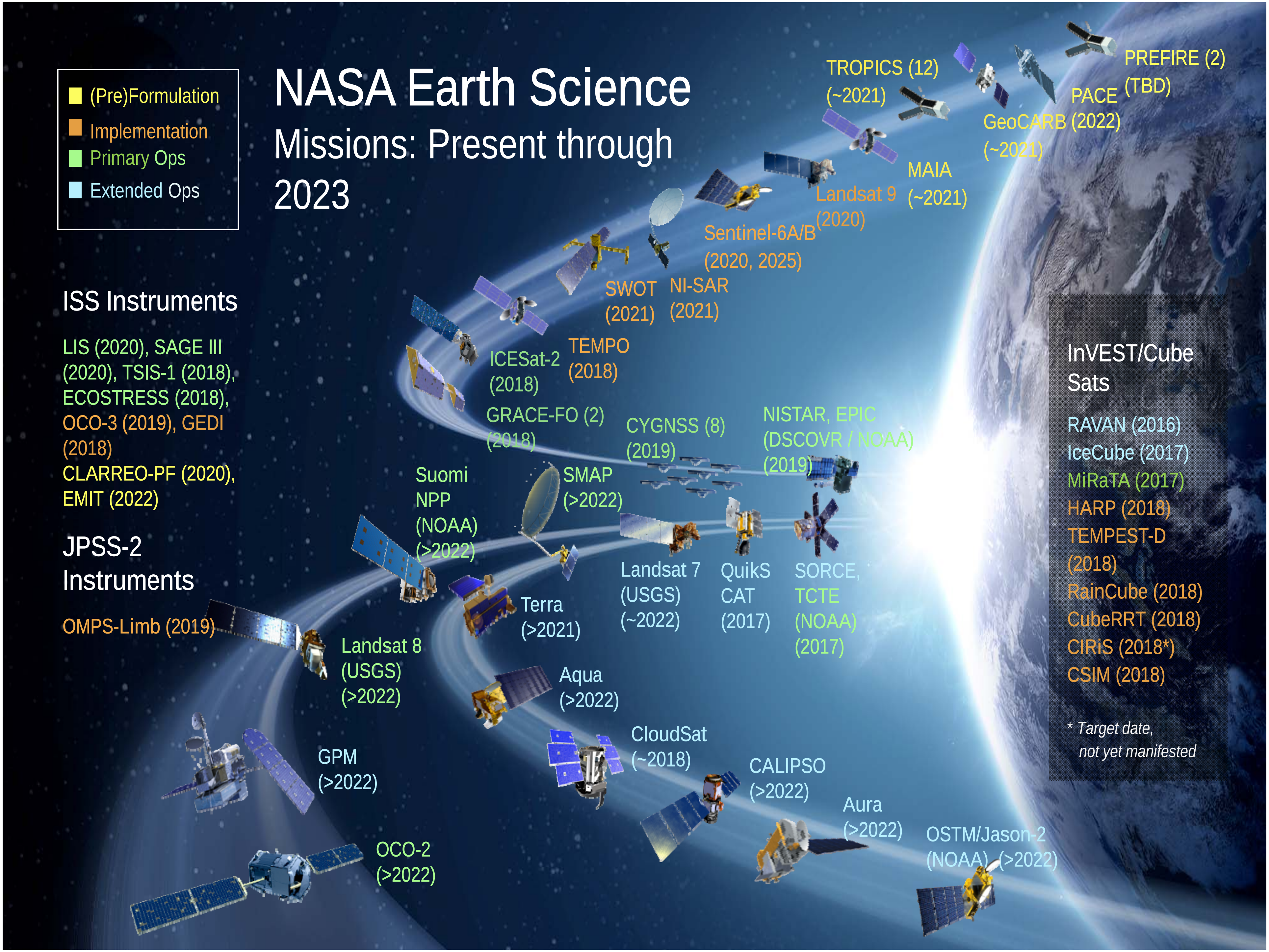
Unlocking a New Era in Biodiversity Science
Keck Institute for Space Studies, Pasadena, CA, October 1 - 5, 2018



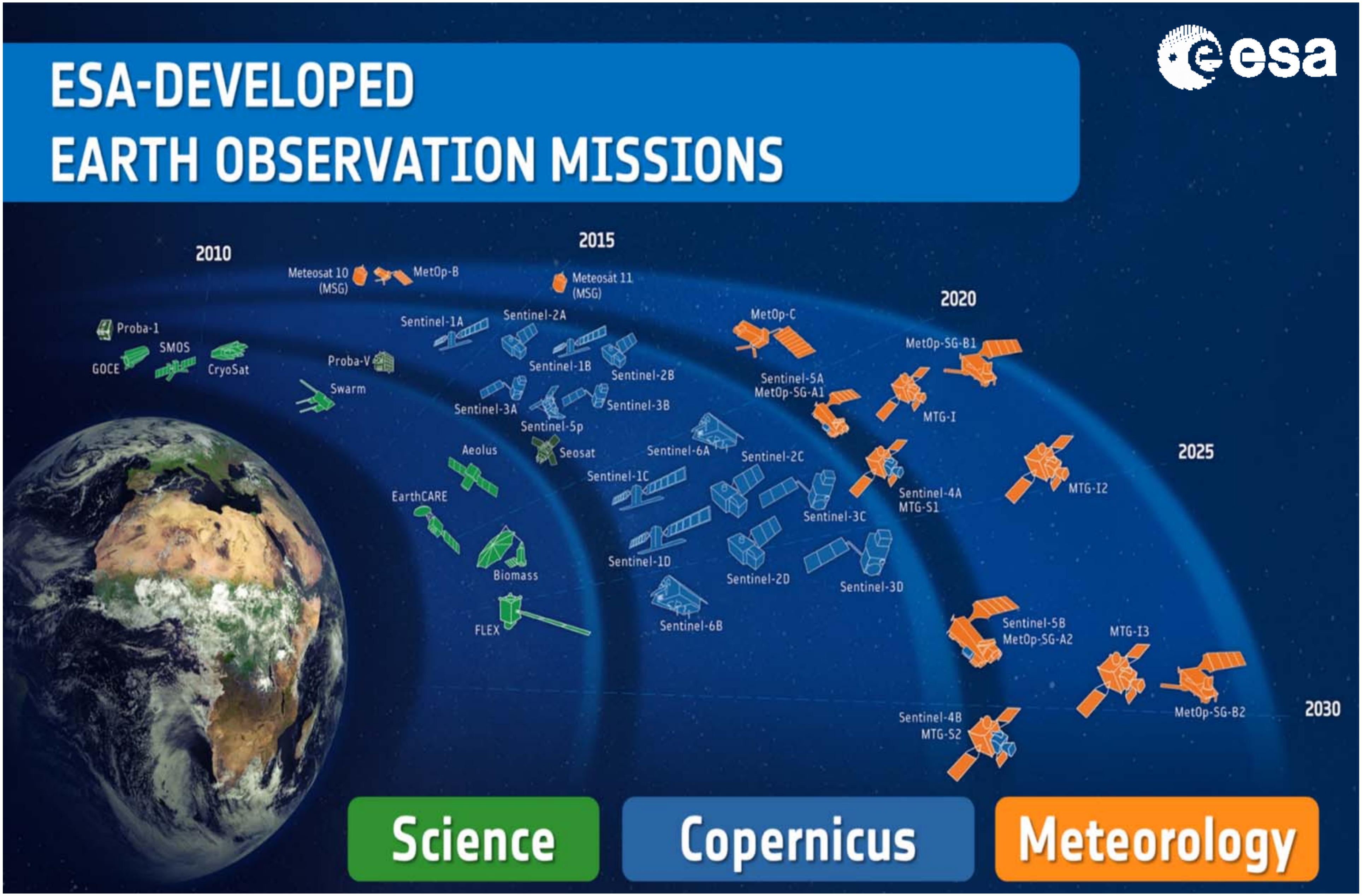
Dreaming of 2026

Woody Turner
Earth Science Division
NASA Headquarters

October 2, 2018


NASA Earth Science
Missions: Present through 2023
(Pre)Formulation
Implementation
Primary Ops
Extended Ops
ISS Instruments
LIS (2020), SAGE III (2020), TSIS-1 (2018), ECOSTRESS (2018), OCO-3 (2019), GEDI (2018)
CLARREO-PF (2020), EMIT (2022)
JPSS-2 Instruments
OMPS-Limb (2019)
TROPICS (12) (~2021)
PREFIRE (2) (TBD)
PACE
GeoCARB (2022) (~2021)
MAIA (~2021)
Landsat 9 (2020)
Sentinel-6A/B (2020, 2025)
SWOT (2021)
NI-SAR (2021)
TEMPO (2018)
ICESat-2 (2018)
GRACE-FO (2) (2018)
CYGNSS (8) (2019)
NISTAR, EPIC (DSCOVR / NOAA) (2019)
Suomi NPP (NOAA) (>2022)
SMAP (>2022)
Landsat 7 (USGS) (~2022)
QuikSCAT (2017)
SORCE, TCTE (NOAA) (2017)
Terra (>2021)
Landsat 8 (USGS) (>2022)
Aqua (>2022)
GPM (>2022)
CloudSat (~2018)
CALIPSO (>2022)
Aura (>2022)
OCO-2 (>2022)
OSTM/Jason-2 (NOAA) (>2022)
InVEST/Cube Sats
RAVAN (2016)
IceCube (2017)
MiRaTA (2017)
HARP (2018)
TEMPEST-D (2018)
RainCube (2018)
CubeRRT (2018)
CIRiS (2018*)
CSIM (2018)
* Target date, not yet manifested

And It's Not Just NASA



Need for Vigilance

INSIGHTS | *LETTERS*

Free satellite data key to conservation

Biodiversity is in crisis, with extinction rates orders of magnitude higher than background levels (*1*). Underfunded conservationists need to target their limited resources effectively. Over the past decade, satellite remote sensing has revolutionized our ability to monitor biodiversity globally, and is now used routinely, especially by nongovernmental organizations, to detect changes, set priorities, and target conservation action. The U.S. Geological Survey (USGS) unlocked high-resolution Landsat data in 2008 (*2*), making data available online (*3*), and the Copernicus program from the European Commission subsequently made their data available as well (*4*). These resources have been instrumental to biodiversity research. Assessments of environmental changes such as deforestation are now readily available. The current spatial and spectral resolution of Landsat data make them appropriate to many conservation applications, and although they are not always ideal, pragmatic researchers with limited resources use them regularly. Conservationists have already called for these data to remain free (*5*). Consequently, the news that USGS may charge for data (*6*) is deeply troubling.

USGS has recently convened an advisory committee to determine whether users would be prepared to pay for increased spectral and spatial resolution images (*7*). Requiring users to pay would put these images beyond the reach of conservationists. It would halt time-series analyses that have been useful in monitoring the effects of climate change, land-cover change, and ocean surfaces, likely hindering the achievement of the Sustainable Development Goals (*8*). We urge the USGS to reconsider their position and continue to provide data from the Landsat program freely to all users.

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(*Science* 2018, 361:139-140)

→Users can provide inputs to the LAG and USGS at landsatdatapolicy@usgs.gov.

2018 NRC Decadal Survey Observing System Priorities

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	**CO_2 and methane fluxes and trends,** global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	**Global ice characterization** including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	**Coincident high-accuracy currents and vector winds** to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		X	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & Snow Water Equivalent	**Snow depth and snow water equivalent** including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	**3D structure of terrestrial ecosystem** including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		X	
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	**Diurnal 3D PBL thermodynamic properties and 2D PBL structure** to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	**High-resolution global topography** including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X

** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables

Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element	
Aquatic Biogeochemistry	**Radiance Intercalibration**
Magnetic Field Changes	**Sea Surface Salinity**
Ocean Ecosystem Structure	**Soil Moisture**

(National Academies of Sciences, Engineering, and Medicine. 2018. *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*. Washington, DC: The National Academies Press. https://doi.org.10.17226/24938.)

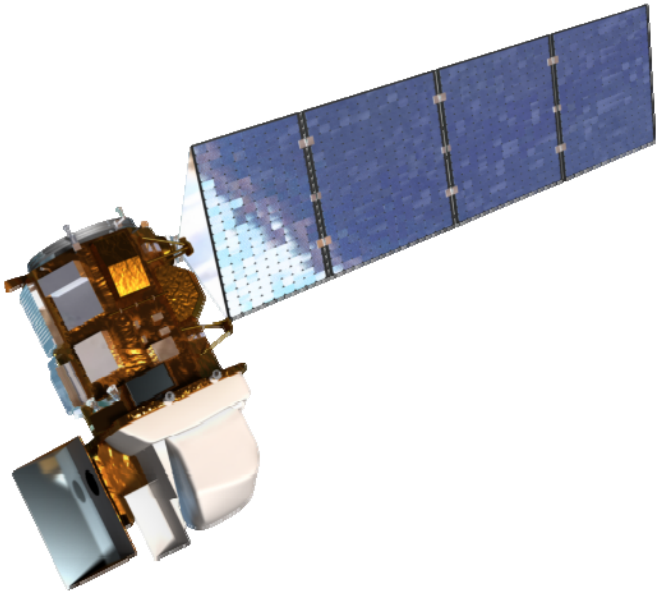
H4 Imaging (And Then Some)

EBV class	EBV	Habitat type							
		Wetland vegetation	Benthic communities			Pelagic organisms			
		Mangrove/ salt marsh	Seagrass	Macroalgae	Coral	Phytoplankton	HAB	Fish, Zoo-plankton	Apex predator
Genetic composition	Population genetic diversity	Unproven	Unproven	Unproven	Unproven	Unproven	Unproven	Unproven	Unproven
Species populations	Distribution	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Habitat model required	Habitat model required
	Abundance	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Habitat model required	Habitat model required
	Size/vertical distribution	Demonstrated limited cases	Unproven	Demonstrated limited cases	Unproven	Demonstrated limited cases	Unproven	Unproven	Unproven
Species traits	Pigments	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Unproven	Demonstrated limited cases	Demonstrated limited cases	NA	NA
	Phenology	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Unproven	Demonstrated limited cases	Demonstrated limited cases	Habitat model required	Habitat model required
Community composition	Taxonomic diversity	Unproven	Unproven	Unproven	Unproven	Demonstrated limited cases	Demonstrated limited cases	Unproven	Unproven
Ecosystem structure	Functional type	Demonstrated limited cases	Unproven	Unproven	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Unproven	Unproven
	Fragmentation/ heterogeneity	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Demonstrated limited cases	Routine use for open ocean	Demonstrated limited cases	Habitat model required	Habitat model required
Ecosystem function	Net primary production	Habitat model required	Habitat model required	Habitat model required	Unproven	Routine use for open ocean	Unproven	NA	NA
	Net ecosystem production	Habitat model required	Unproven	Unproven	Unproven	Demonstrated limited cases	NA	NA	NA

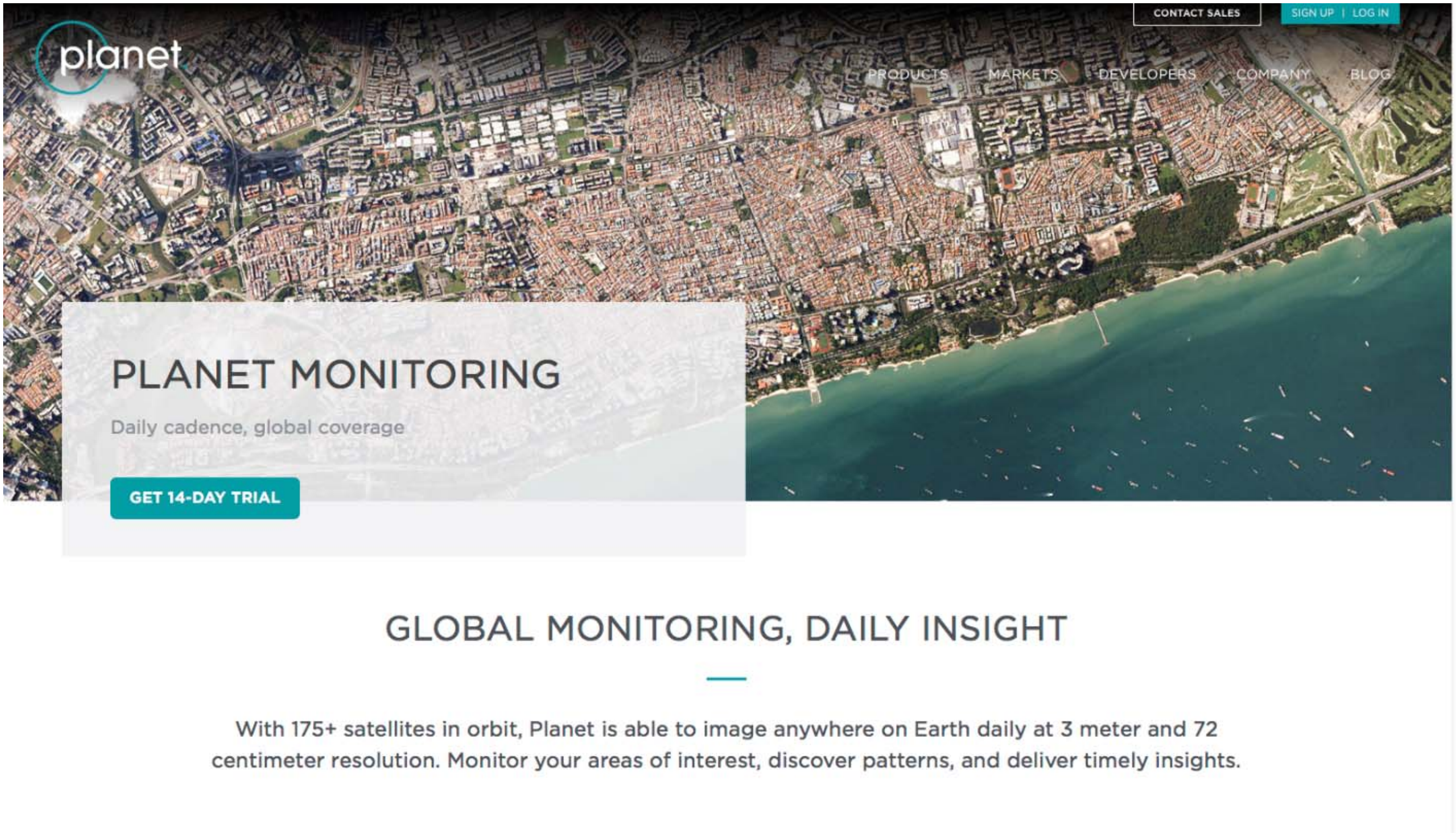
Legend
Unproven
Demonstrated limited cases
Routine use
Habitat model required

(F. Muller-Karger et al. *Ecological Applications* 2018)

H4 High Spatial and Temporal:
Landsat and Sentinel-2

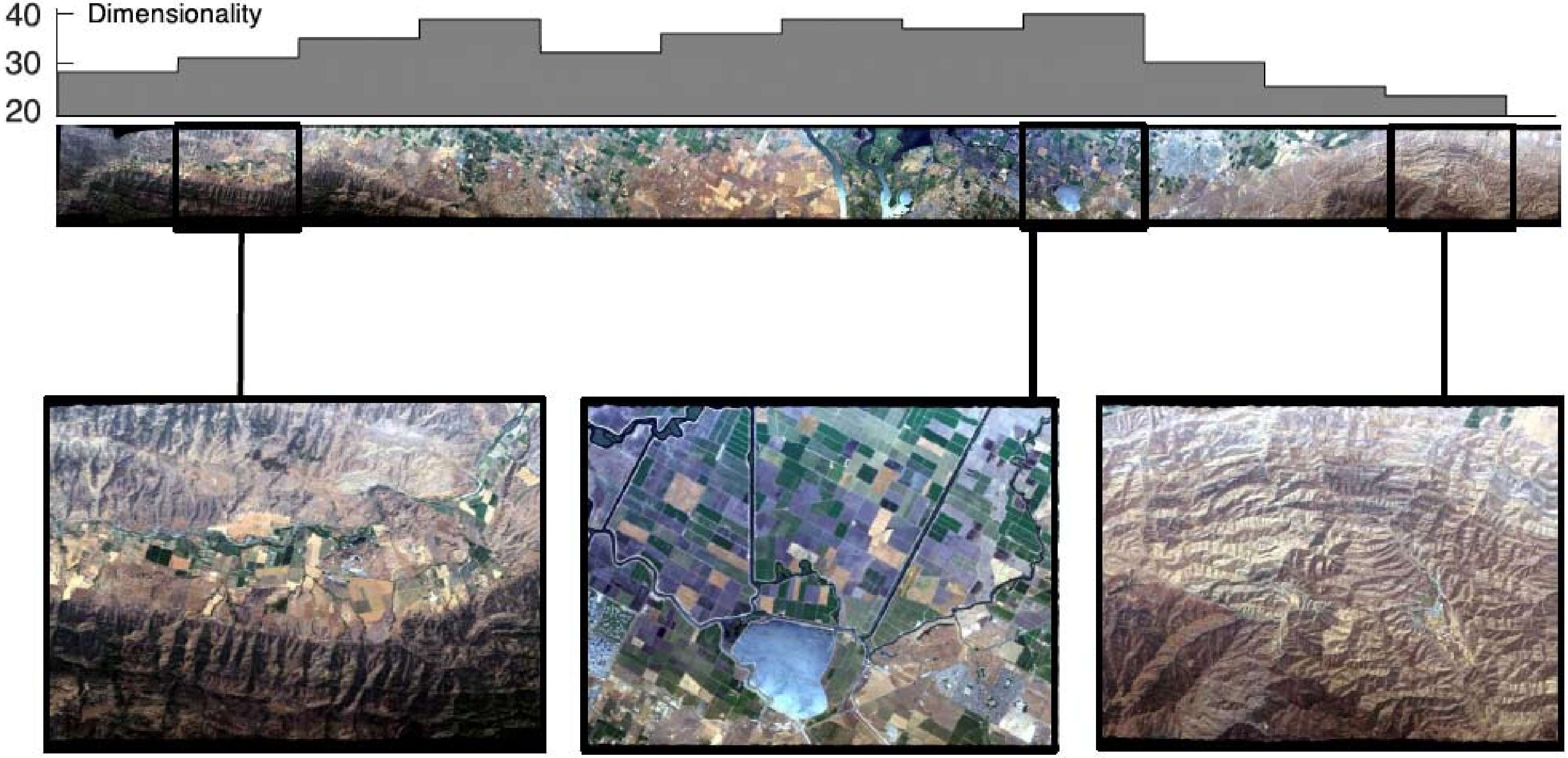


H4 High Spatial and Temporal:
Planet and Other Commercials

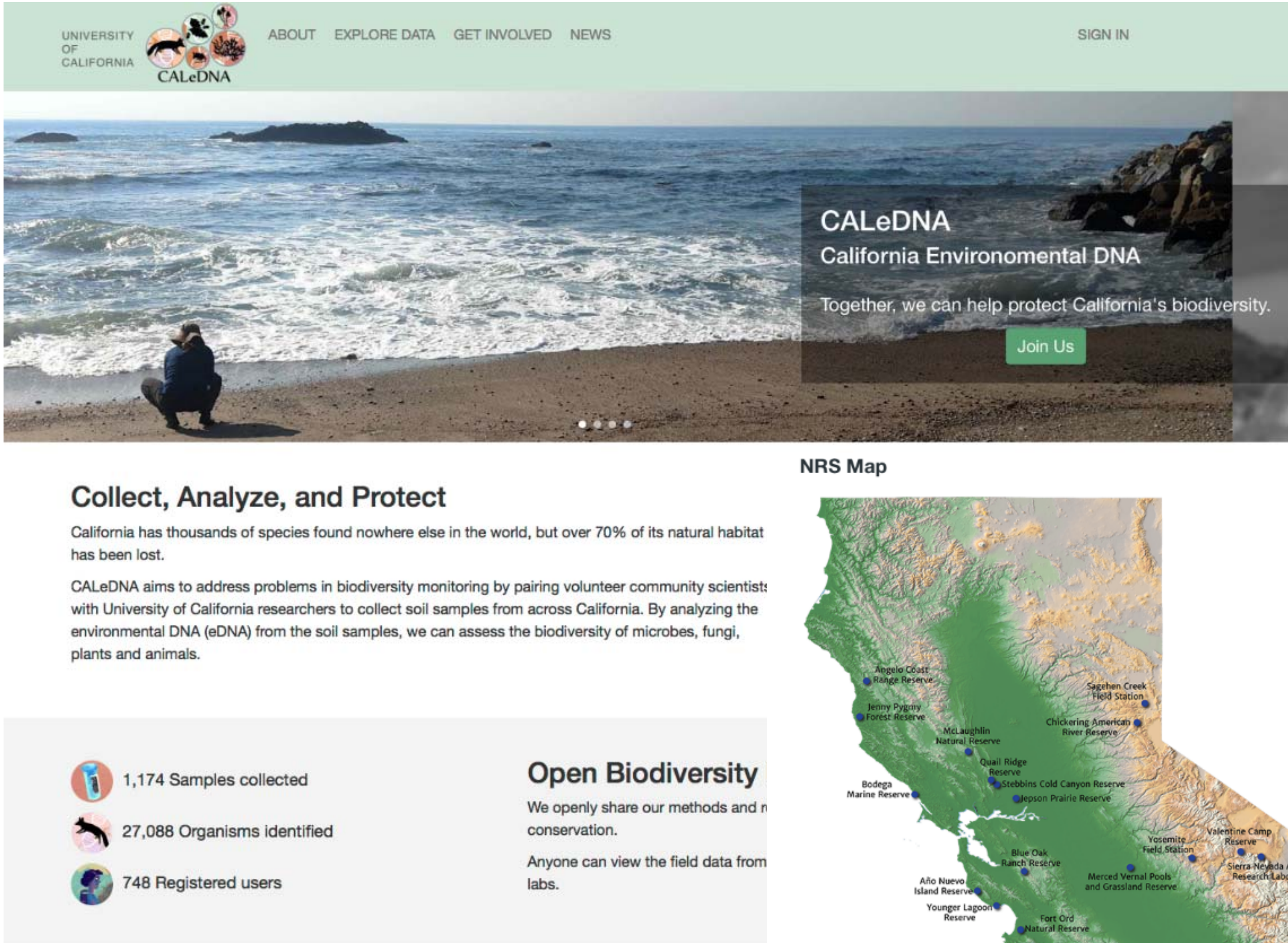


(https://www.planet.com/products/monitoring/)

Flightline Segments



River Valley, Dimensionality 31 | Cropland/Urban, Dimensionality 40 | Barren, Dimensionality 23

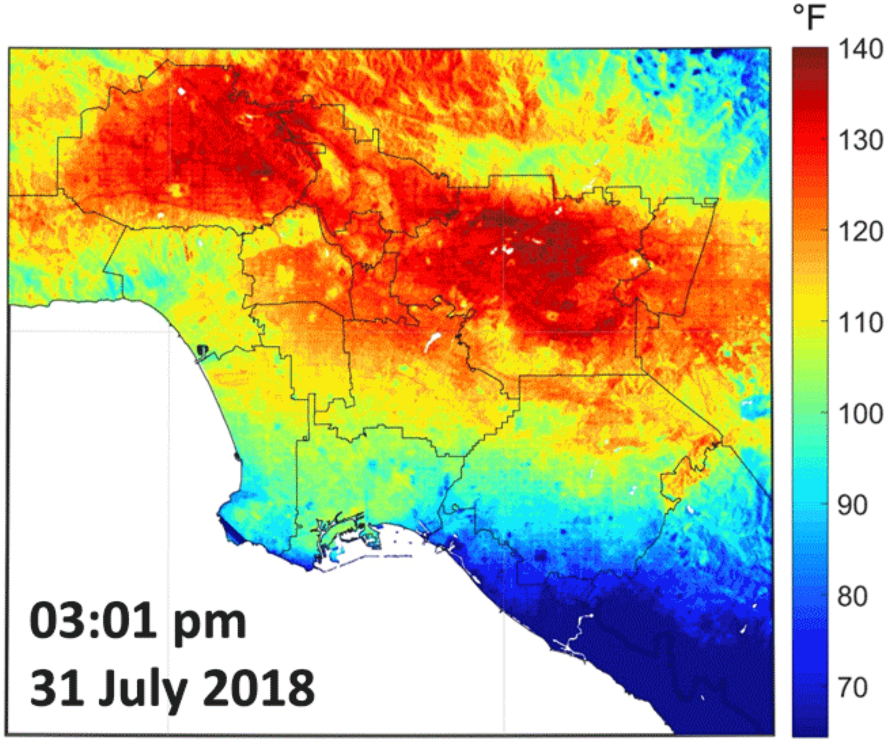


(http://www.ucedna.com)

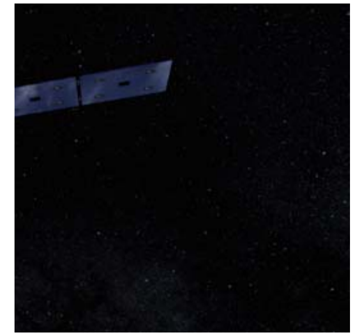
NRS Map

(https://ucnrs.org/find-a-reserve/)

Thermal!



Active Remote Sensing for 3D and Night Vision



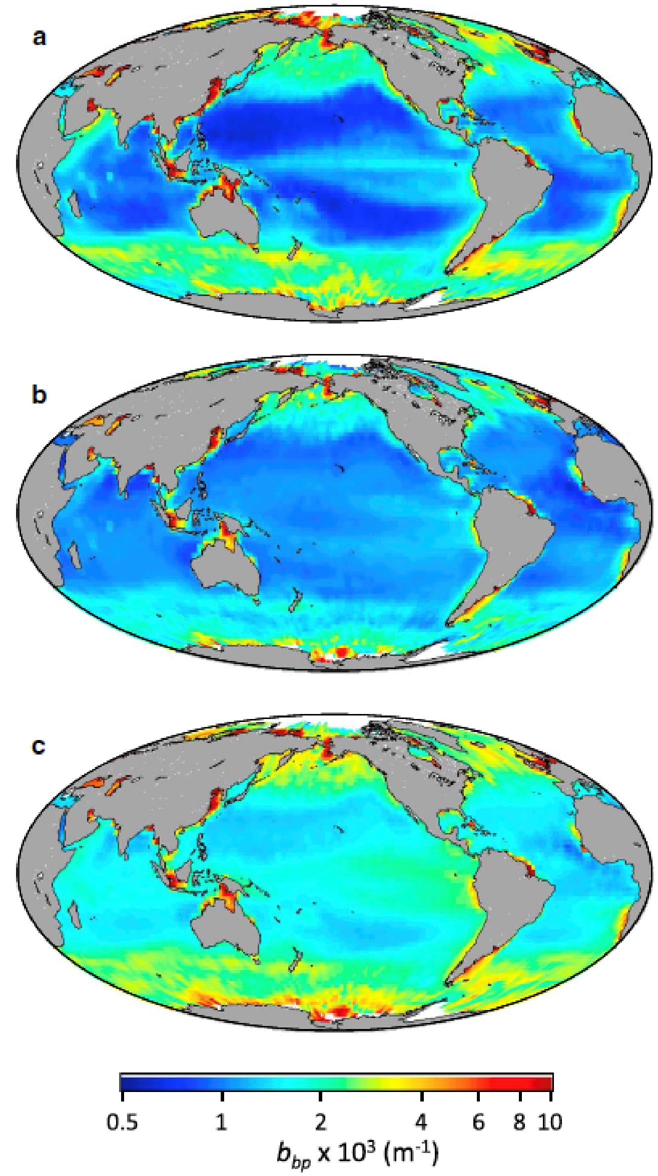


Figure 2. Global distributions of surface particulate backscattering coefficients (b_{bp}). (a) CALIOP-based b_{bp}. (b) MODIS-based b_{bp} from the GSM algorithm. (c) MODIS-based b_{bp} from the QAA algorithm. Data in each panel are climatological annual averages for the 2006–2012 period. All data have been standardized to 2° latitude × 2° longitude pixels.

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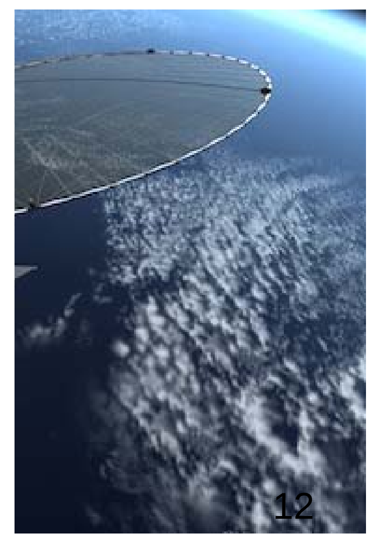
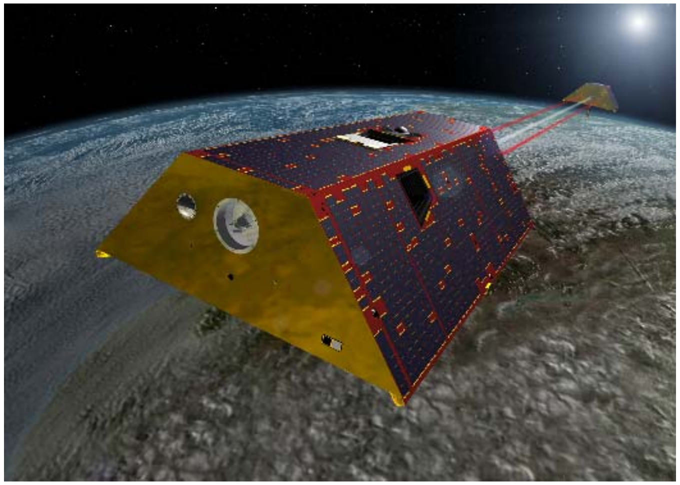


(M.J. Behrenfeld et al. *GRL* 40:4355-4360, 2013)

Following the Water
Actively—and Passively


Global Precipitation Mission


Soil Moisture Active Passive


Gravity Recovery and Climate Experiment Follow On


Surface Water and Ocean Topography (2021 launch)

Remotely Sensing People

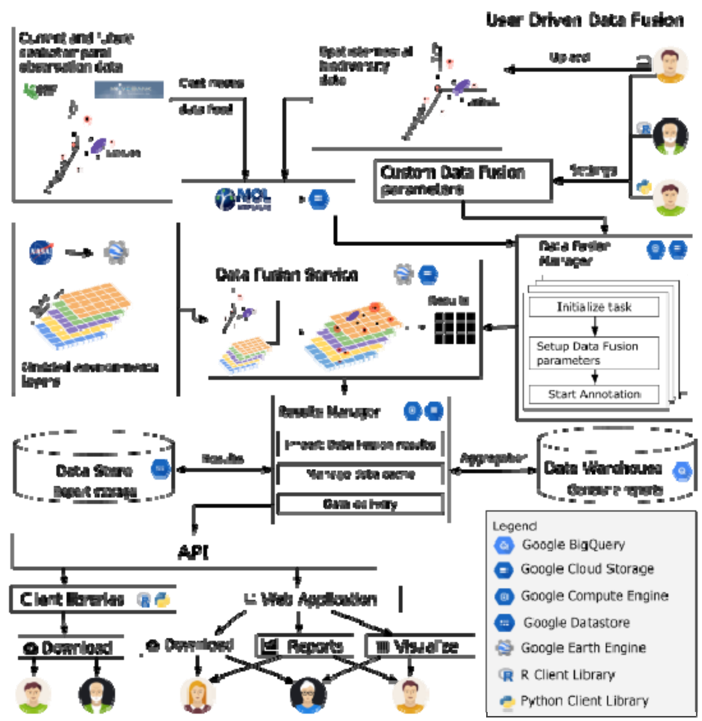
In Situ Integration Imperative

YaleNews EXPLORE TOPICS ▼

Space-based tracker to give scientists a beyond-bird's-eye-view of wildlife

By Kendall Teare | AUGUST 14, 2018

Data Fusion with Map of Life



(Source: W. Jetz, R. Guralnick, A. Wilson AIST-16-0092 1st Annual Review 8/10/2018)

Lidar!

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Engaging Space Agencies for Biodiversity

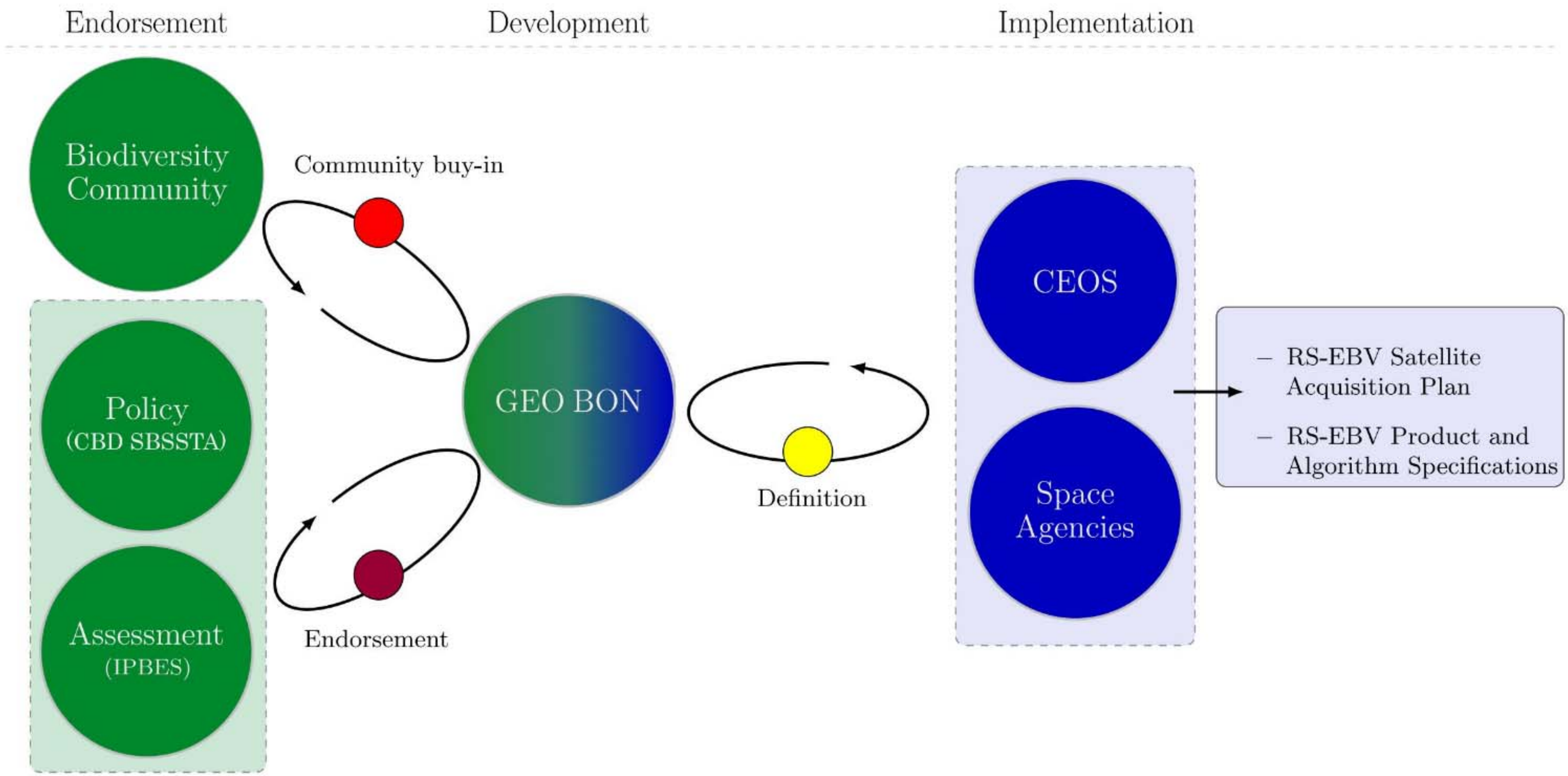

Figure 1. Outline of the overall process by which remotely sensed Essential Biodiversity Variables should be developed and matured.

(Paganini et al. 2016, *Remote Sensing in Ecology and Conservation*)

Goals and Next Steps

- Goal 3 for this KISS Study Program:
  - “Develop an implementation plan/roadmap for an observing system architecture that integrates across multiple satellite remote sensing and *in situ* datasets to provide crucially-needed biodiversity information for both plants and animals.”
- Need plan to engage this wealth of information, including:
  - Targeting specific—by name—mission science teams for proposals and membership
  - Considering Earth Venture (Suborbital, Instrument, and Mission) proposal opportunities
    - NASA scoping studies are wrapping up
  - Suggesting how NASA and NSF could jointly promote this goal
  - Promoting interdisciplinary lidar study(-ies)
  - Strengthening ties to GEO BON through Essential Biodiversity Variable (EBV) development and assembling BON in a Box tools
    - Build upon GEO BON, Don’t reinvent it
  - Translating satellite needs for biodiversity observations into requirements for space agencies to address through CEOS
- Keep phylogeny central to any effort = Speak to biologists and ecologists in the language of evolution so they understand us
- Study how life scales
- Bring the diversity of life through the 21st century intact

Thank You