Committee on Operational Environmental Satellites

Meeting 2018-1

March 21, 2018

Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM)

Opening Remarks

COES Co-Chairs:

- Mr. David McCarren (DOD-USN)
- Mr. Ajay Mehta (NOAA-NWS)

COES Executive Secretary:

- Mr. Michael F. Bonadonna (OFCM)

Meeting is being recorded to help produce an accurate Record of Action (ROA)

Agenda

- Opening Remarks: …….COES Cochairs
- Action Item Review: ……Executive Secretary
- Radio Frequency Interference (RFI) Update: ……Al Wissman (NOAA)
- STIWG Update: ……..……. Lysanias Broyles (USACE)
- Earth Science and Applications From Space Decadal Survey:
  ……..William Gail, Chief Technology Officer, Global Weather Corporation
  ……...and Waleed Abdalati, University of Colorado Boulder
  Open Discussion: ……..COES Members
- Action Item Review / Next Meeting: …….Executive Secretary
- Adjourn: …….The meeting is expected to end by 11:00 AM EDT.

Action Item Review

AI #	Text	Responsible Office	Comment	Status	Due Date
2017-4.1	Schedule an agenda item for the next COES meeting to look at environment satellite data acquisition and communications architectures including needs, plans, and relevant deadlines.	ExecSec	3/19/18: Not accomplished. We'll try for next meeting	Open	02/15/18
2017-4.2	Obtain a list from NOAA STAR of research satellite missions that may be of interest to COES discussion in future meeting.	ExecSec	3/19/18: No response from STAR	Open	01/15/18
2017-4.3	Prepare Information briefing for the February ICMSSR meeting summarizing commercial data initiatives in NOAA, NASA, and USAF.	COES Members, D.McCarren lead	Item was discussed at the February ICMSSR meeting	Closed	01/31/18
2017-4.4	Schedule an agenda item for the Summer 2018 COES meeting to review NOAA, NASA, and DoD progress and plans to obtain and use commercial weather data.	ExecSec		Open	05/16/18

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Committee for Operational Environmental Satellites

Radio Frequency Spectrum

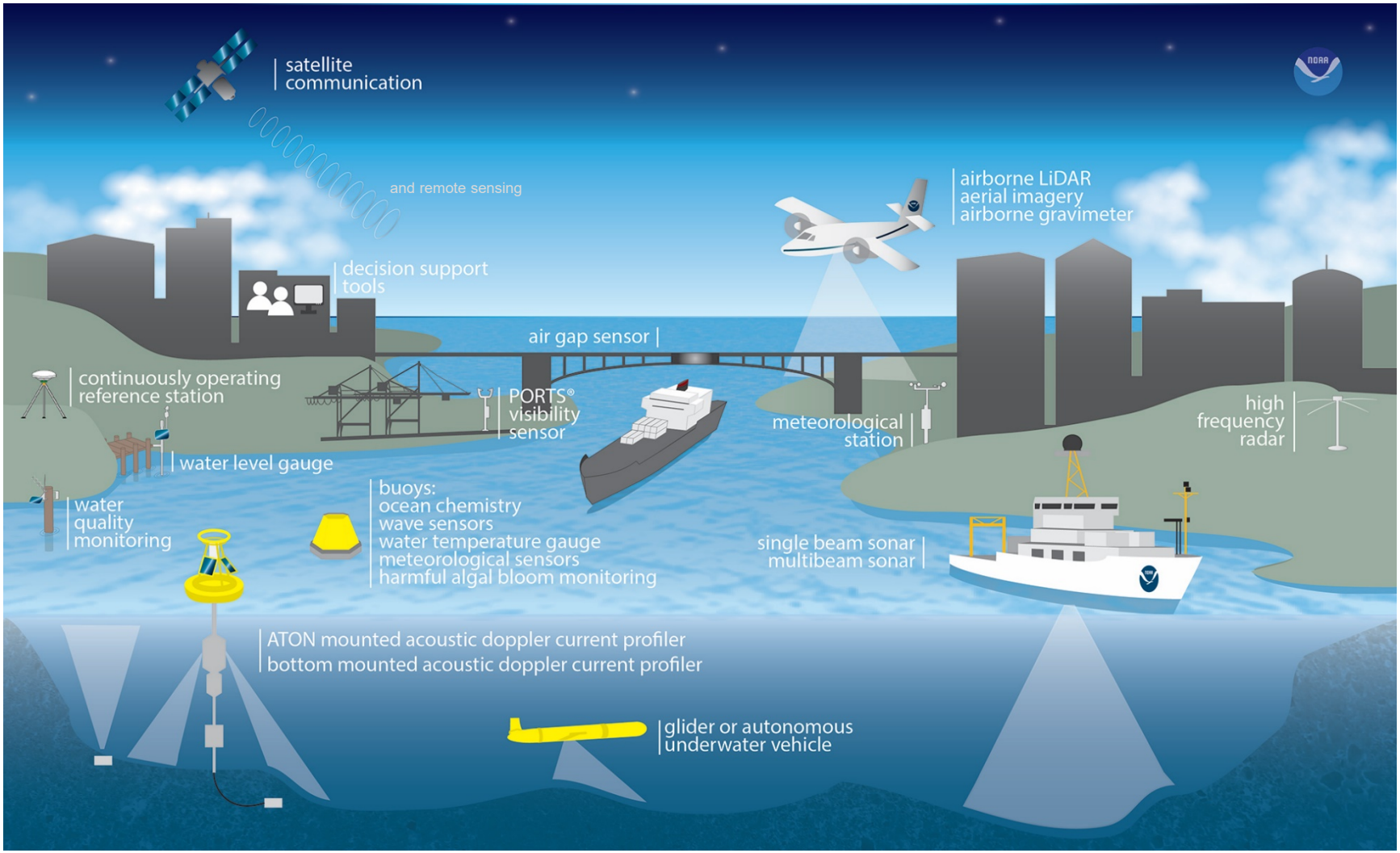
Al Wissman
NESDIS

March 21, 2018

Outline

- World Radio Conference 2019 agenda items
- Spectrum a Critical Resource to NOAA's Mission
- Spectrum Pipeline Relocation Engineering Study

Spectrum:
A Resource Critical to NOAA Missions



World Radio Conference 2019 Agenda Items

- Agenda 1.13 – Consideration of frequency bands for the future development of International Mobile Telecommunications (adjacent to 24.25 GHz and 86 GHz)

- Agenda item 1.7 – spectrum for telemetry, tracking and command in the space operation service for non-GSO satellites with short duration missions (150.05-174 MHz and 400.15-420 MHz)

- Agenda item 1.2 - in-band power limits in the frequency bands 401-403 MHz and 399.9-400.05 MHz

- Agenda item 1.3 - secondary allocation in the frequency band 460-470 MHz

World Radio Conference 2019 Agenda Items

- Agenda item 1.6 – Develop regulatory framework for passive bands operating in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHZ (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space),

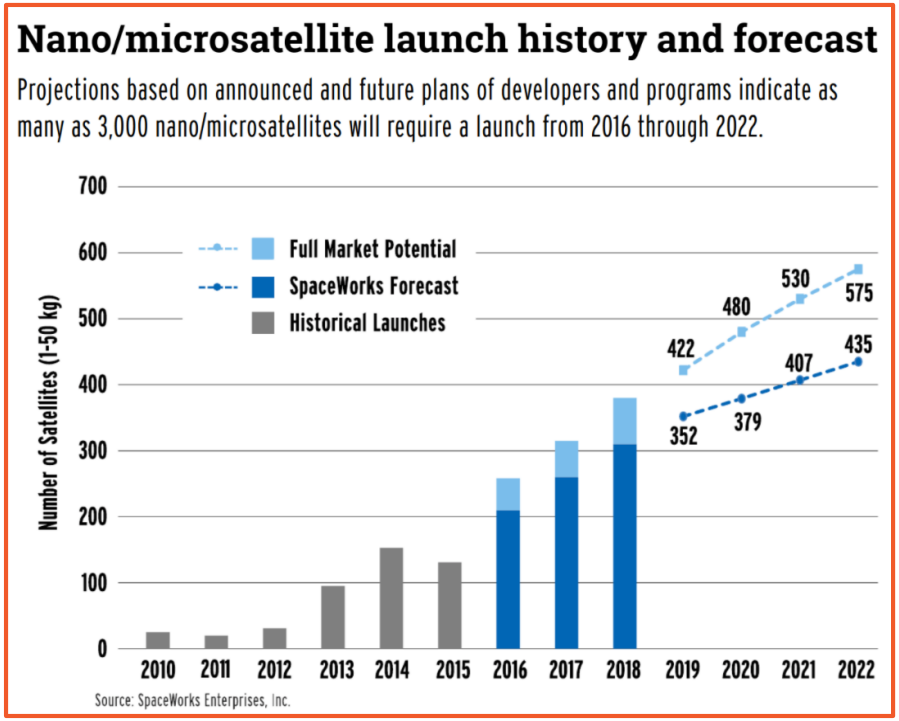
- Agenda 1.14 – Gateway and Fixed terminal links for High Altitude Platform Stations within existing fixed-service allocations. (21.4-22 GHz and 24.25- 27.5 GHz in Region 2, and 38-39.5 GHz globally)

- Agenda item 9.1.9 – Studies relating to spectrum needs and possible allocation of the frequency band 51.4-52.4 GHz to the fixed-satellite service (Earth-to-space)

- Agenda item 1.16 - Wireless access systems and radio local area networks (WAS/RLAN), in the frequency bands between 5.150 MHz and 5.925 MHz

Issue: Growing Demand for 400 MHz

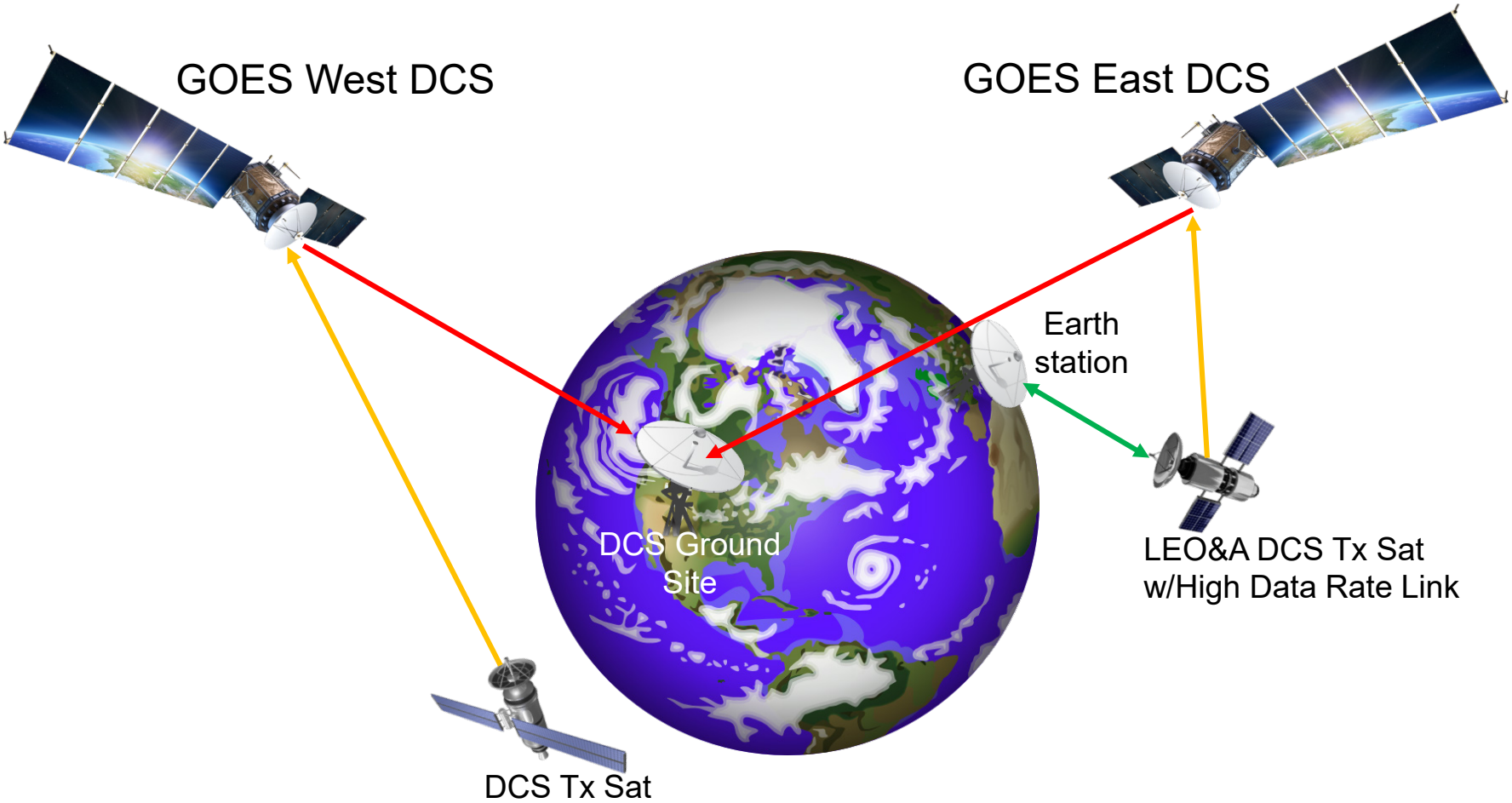
- DCS Transmitters, located throughout the United States & Protectorates (US&P) as well as many other countries, use the 401 MHz band to uplink to the DCPR on GOES (and others) satellites in geosynchronous and non-geosynchronous orbits.
- Satellites are also allocated to use this band (space-to-Earth) for space operations purposes.
  - Typically, these satellites transmit in all directions relatively equally and thus also radiate in direction of GOES and other DCS receiving satellites.
  - This energy, aggregated across multiples of these satellites (even multiples of constellations) is expected to become a significant source of RFI to the DCS system in time.



Concept: Use of DCS for Satellite Telemetry, Tracking and Small Data

- Concept of Satellite DCS Use is to enable satellites the ability and authorization to use DCS as a low-rate (300 & 1200 bps) interface for low data rate Launch, Early Orbit, and Anomaly (LEO&A) and/or payload communications and thereby make them a coordinated part of DCS and decrease the risk of RFI to the DCS.
  - The data flow will be from the satellite using DCS to the DCPR on GOES and then through the DCS information distribution process to the identified satellite mission operations center.
  - Should the satellite also require higher data rates, the satellite will use an alternate data link path and frequency.

Notional Architecture Concept

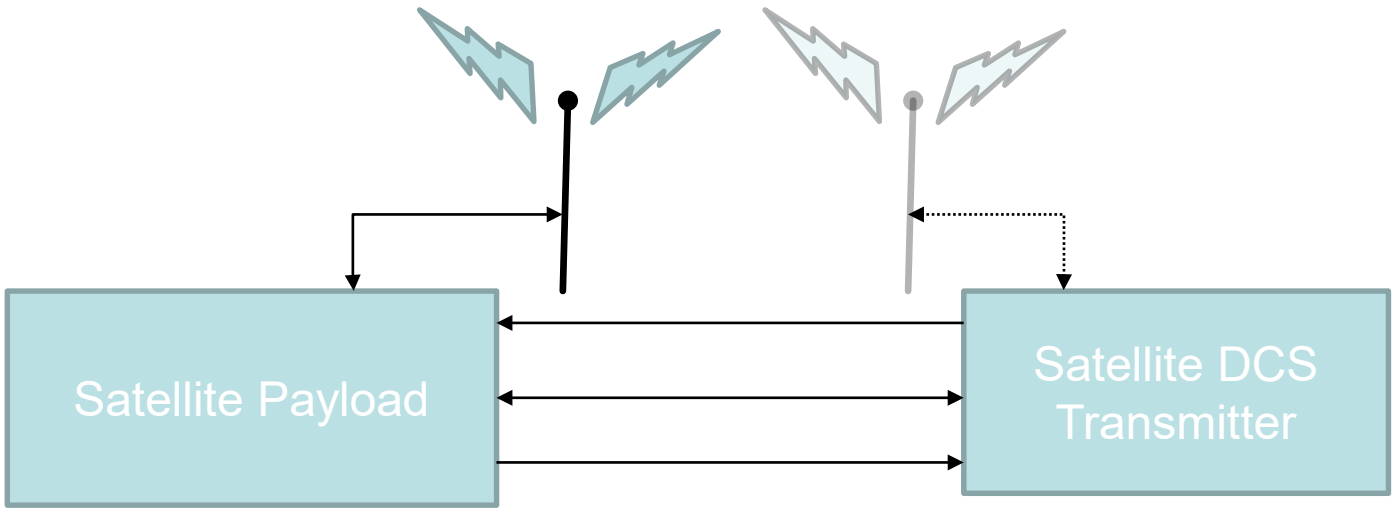


DCS Downlink

High Data Rate Link

DCS Uplink

Satellite Connectivity to DCS



- The DCS transmitter on board the S/C will use GPS from the S/C.
- System will turn on for the periods allocated by DCS system
- Analysis being done to account for possible doppler shift to other DCS receivers
- Interface definitions are being worked between the S/C host and the DCS board design team

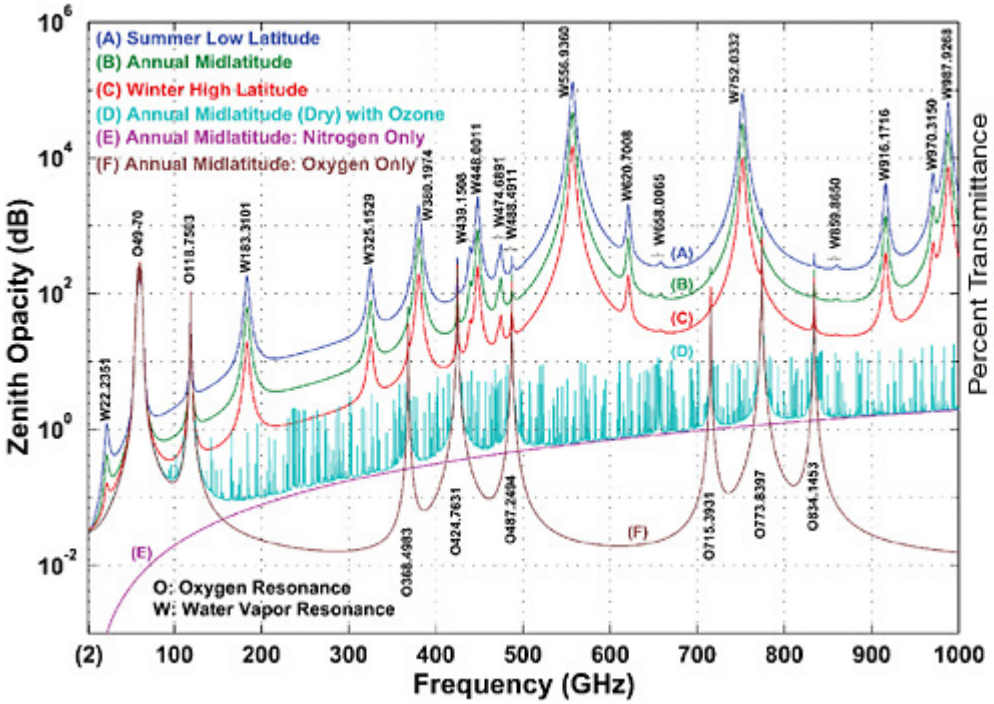
Tiger Team Review of Concept

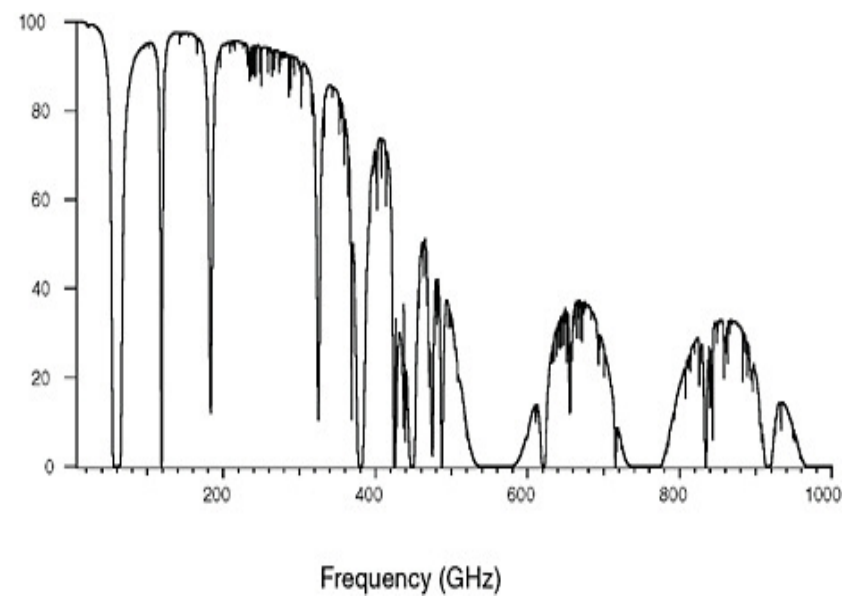
- Team met 11 times starting on September 21, 2017,
  - Several additional splinter meetings to work specific identified problems
- Overarching goal to identify any “show stopper” issues that negates further investigation of the satellite DCS use concept
- No issues were found to be “show stoppers”
- Some issues are either challenging or a significant change in DCS usage
- NOAA OGC is of the opinion that this activity demonstrates NOAA’s ongoing efforts to use spectrum efficiently and share where-ever possible

Remote Sensing Spectrum

There are no alternative frequencies for detecting natural properties

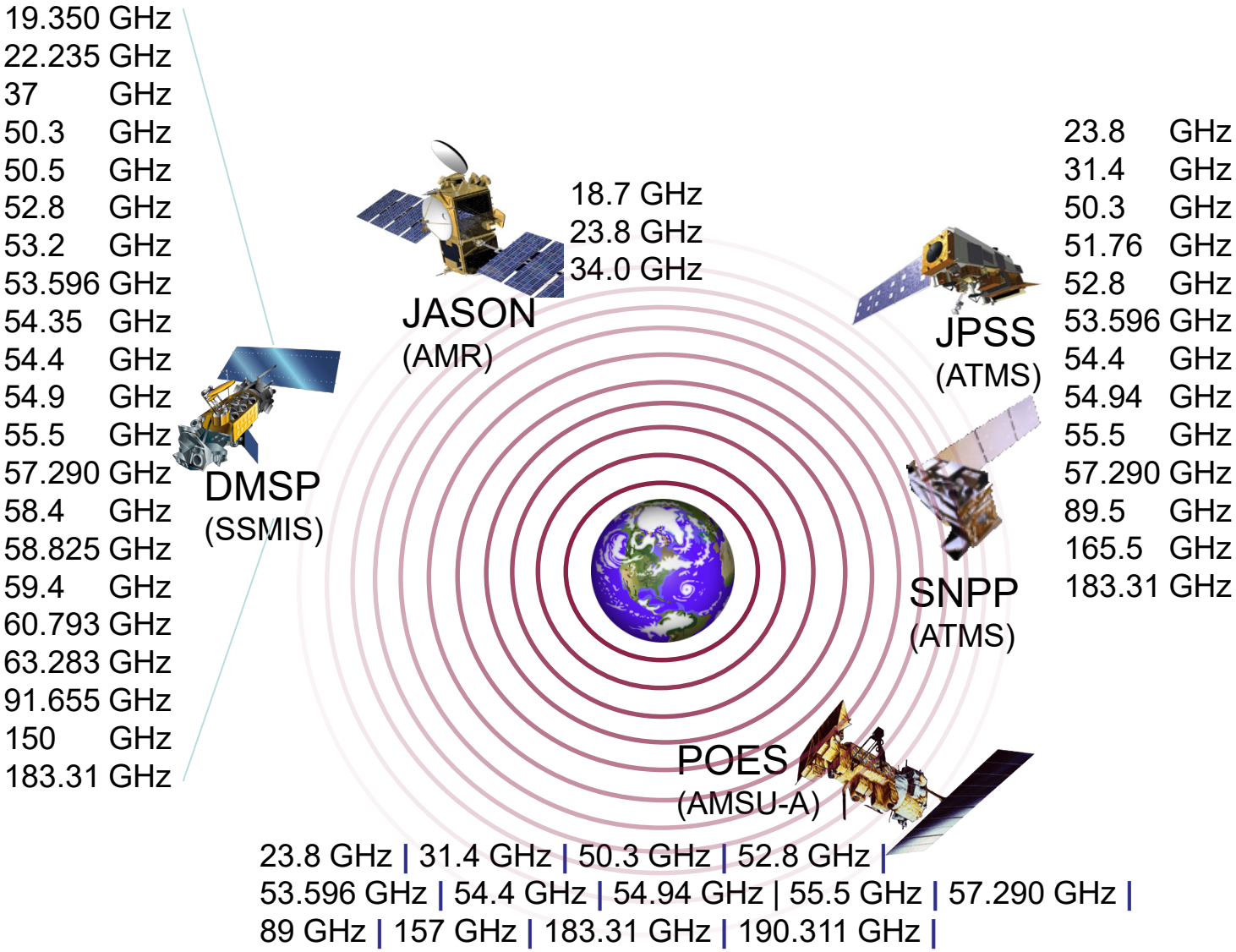
- The transmission spectrum of the atmosphere and the opacity of the atmosphere to particular frequencies allow the detection of weak natural radio frequency emissions
- “Line radiation spectra can be used to obtain temperature and humidity profiles in the atmosphere from the surface up into the mesosphere” (Source: NAP, 2010)
- Potential interference to these measurements from proposed commercial broadband wireless should be investigated for developing mitigation methods and implementation



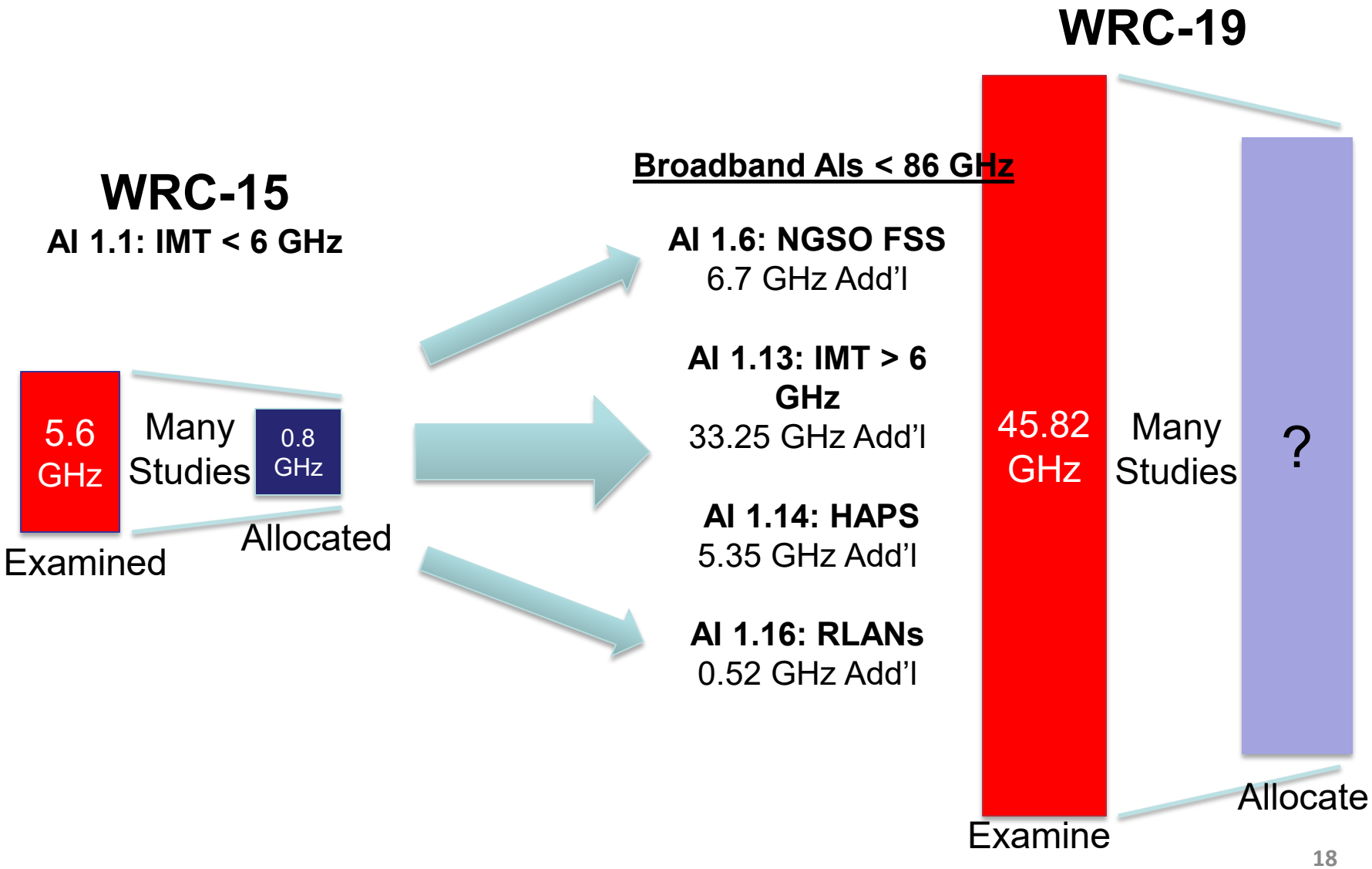


Source: http://www.nap.edu/read/12800/chapter/1

NOAA/NESDIS Passive Band Use



Broadband a Growing Concern



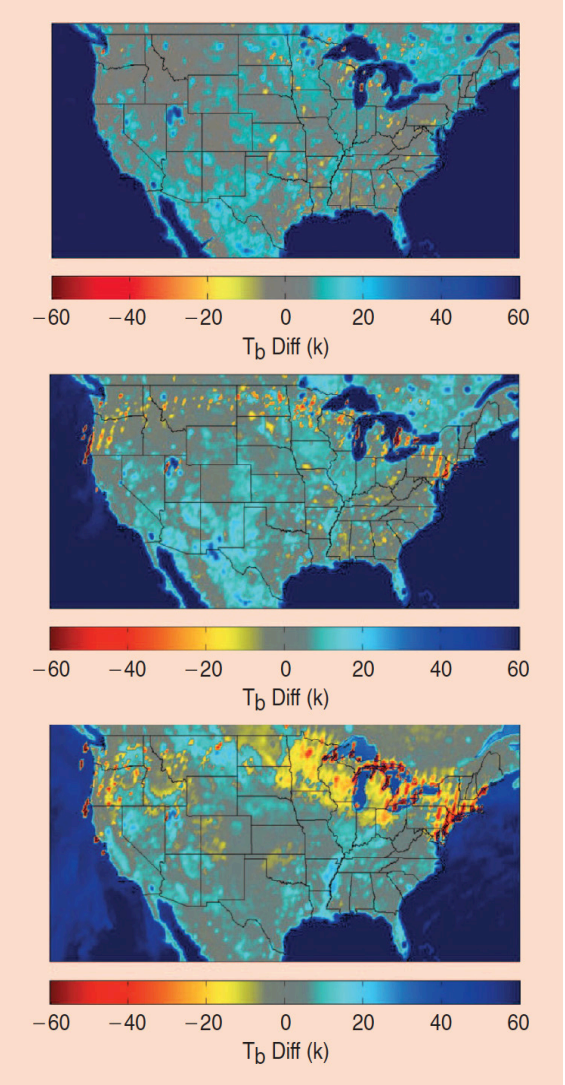
Passive Band Uses and Related RFI

Bands (GHz)	Scientific Observations	Space Borne Instruments	RFI Level and Sources
18.6–18.8	precipitation, cloud liquid water, snow cover, sea surface wind speed, sea ice	JASON AMR, AMSR-2, WindSat	**Moderate:** potentially from satellite TV service signals
22.21–22.5 23.6–24	atmospheric water vapor, sea surface wind speed, sea ice, precipitation, snow cover	SSMIS, JASON AMR, TMI, AMSR-2, GMI, AMSU-A, ATMS	**Moderate:** vehicle anti-collision radars
31.3–31.8 36–37	precipitation, cloud liquid water, snow cover, sea surface wind speed, sea ice	ATMS, AMSU-A, SSMIS, TMI, AMSR-2, JASON AMR, WindSat, GPM GMI	**Low:** new sources observed off oil platforms near the Indian subcontinent
50.2–50.4 51.4–59.3	atmospheric temperature profiling	ATMS, TOVS (MSU), SSM/T, AMSU-A, SSMIS	**Moderate:** potential for RFI due to spectrum sharing rules at 55–57

Sidharth Misra & Paolo de Matthaeis, "Passive Remote Sensing and Radio Frequency Interference (RFI): An Overview of Spectrum Allocations and RFI Management Algorithms," IEEE Geoscience and Remote Sensing Magazine, June 2014. Pages 68-73

RFI in Passive Remote Sensing

- Passive sensors are especially vulnerable to RFI because of the very low levels of the detected signal that carries information
- Even in protected and non-shared bands, RFI can still originate from sources emitting in adjacent bands
- A study done by McKague gives an example of increasing occurrence of RFI at K-band from 2005 to 2010
  - The graphic illustrates the temporal evolution of the spectral difference between the brightness temp (Tb) of the AMSR-E 18.7 and 23.8 GHz channels. Negative values of the Tb difference represents RFI in the 18.7 GHz channel
  - The bottom plot (Jan 2009) shows an “arc” of RFI observed over the northern regions of US. This broad arc is attributed to reflections of a Direct TV satellite signal, based on the relative position and incidence angles of the satellites



D. McKague, J. Puckett, and C. Ruf, “Characterization of K-band radio frequency interference from AMSR-E, WindSat and SSM/I,” in *Proc. Int. Geoscience Remote Sensing Symp.*, Honolulu, HI, July 25, 2010, pp. 2492–2494.

Passive Band Summary

- NOAA's National Weather Service relies on accurate, timely and reliable satellite observations to provide better information to save lives and property -- as it builds a Weather-Ready Nation
- Reliable access to spectrum is a critical component for achieving NOAA's missions in support of the public
- Passive bands in the radio frequency spectrum are an essential aspect of the data necessary to protect the public, safe guard our economy and advance our scientific knowledge
- The RF spectrum has become a critical resource to many industries and sharing this resource reliably and safely is a technological challenge
- NOAA, along with the WMO, CGMS and others, is working to ensure adequate protection of the passive bands from disrupting incursions

Spectrum Pipeline Reallocation Engineering Study (SPRES) Overall Scope

- To assess the potential sharing of the 1675-1680 MHz frequency band and the adjacent 1680-1695 MHz frequency band among Department of Commerce (DOC), other federal Earth stations, and wireless carriers nationwide.
- Specifically, the study will establish a user/customer data flow and user needs baseline.
- Analysis will be performed to determine Interference Protection Criteria (IPC) for federal Earth stations as well as the need for protection zones around these downlink sites.
- Radio Frequency Interference (RFI) monitoring and mitigation techniques will be examined for suitability for this issue.
- Alternative architectures will also be examined for implementation on future space and ground based assets, e.g., GOES-Next.

Technical Concept, Justification, and Impact

- Technical Concept: The study will be done using engineering analysis including models and simulations

- Justification: With the possibility of another Advance Wireless Services (AWS) auction for the 1675 – 1680 MHz Frequency, Congress provided funds to study the impact, possible mitigations/alternative, and recommendations to facilitate successful spectrum sharing.

- Impact to NOAA/NESDIS mission if the SPRES Program is not started/continued in FY 19 or FY 20.
- The SPRES objective is to quantify the sharing challenges for federal Earth station users as well as identify techniques to facilitate successful spectrum sharing without causing harm to the integrity or access to DOC NOAA data.

Schedule

Projects	Duration	Milestones Activity
Project 1: Map the spacecraft-to-end user data flows and document user needs	6 months	Presentations at 1/3, 2/3 and 100% completion of Project Awarded: Next Phase Solutions and Services, Inc. Final Report delivered in June 2018
Project 2: Analysis of potential interference to users	9 months	Presentations at 1/3, 2/3 and100% completion of Project Estimated Award Date: 4/23/2018 Final Report delivered in November 2018
Project 3: Identification of alternative architectures	9 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 7/16/2018 Final Report delivered in February 2019
Project 4: Developing the cost of alternative architectures	8.5 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 4/19/19 Final Report delivered in October 2019
Project 5: Alternative communication techniques for satellite downlinks	6 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 4/19/19 Final Report delivered in August 2019

Schedule (Con't)

Projects	Duration	Milestones Activity
Project 6: Detailed survey of receiving equipment	11 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 5/2//2018 Final Report delivered in January 2019
Project 7: Determine the requirements and methods for protecting both the legacy GOES and GOES-R downlinks, i.e., SD, MDL, GRB	8 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 11/15/2018 Final Report delivered in September 2019
Project 8: Anomalous propagation interference to critical NOAA stations	7 months	Presentations at 1/3, 2/3 and 100% completion of Project Awarded: Shared Spectrum Company Final Report delivered in July 2018
Project 9: Interference thresholds for GOES-R receivers	11 months	Presentations at 1/3, 2/3 and 100% completion of Project Awarded: Next Phase Solutions and Services, Inc. Final Report delivered in November 2018
Project 10: Perform a radio frequency interference monitoring analysis for the 1675 – 1680 MHz band	10 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 10/29/2018 Final Report delivered in September 2019
Project 11: Perform LTE TDD Simulations, Passive Site Surveys, and Active testing	9 months	Presentations at 1/3, 2/3 and 100% completion of Project Estimated Award Date: 6/18/2018 Final Report delivered in March 2019

Implementation: Acquisition Strategy

Aerospace Corporation:
Contract # SP-133E-17-CQ-0020
Program Support
POP 1/1/2017 - 11/31/2020

Freedom Technologies Incorporated
Contract # SP-133E-18-CQ-0015
IDIQ Award
POP 2/6/2018 - 2/5/2020

Next Phase Solutions and Services, Inc.
Contract # SP-133E-18-CQ-0017
IDIQ Award, Project 1 & Project 9
POP 2/1/2018 - 1/31/2020

Shared Spectrum Company
Contract # SP-133E-18-CQ-0016
IDIQ Award & Project 8
POP 2/1/2018 - 1/31/2020

Implementation: Staffing Strategy

- Program Manger: Alpha Bailey
- Contracting Officer's Representative: Al Wissman
- Aerospace providing program office support (2 contractors, additional as needed)
- Other contractor staffing levels related to individual projects will vary base on the activities being conducted by Freedom Technologies Inc., Next Phase Solutions and Services Inc., and Shared Spectrum Company

Questions?

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2018 STIWG COES Report

Establishing Interagency Agreements for STIWG OpenDCS Platform Development and Support

LySanias Broyles

Rock Island District, USACE

STIWG Chair

STIWG

- The Satellite Telemetry Interagency Working Group (STIWG) exists under the Advisory Committee on Water Information (ACWI) and reports to the Committee for Environmental Services, Operations and Research Needs (C/ESORN) and the Subcommittee on Hydrology (SOH)
- STIWG is a user group for the Geostationary Operational Environmental Satellite Data Collection System (GOES DCS) and advises the National Environmental Satellite Data and Information Service (NESDIS) concerning satellite data relay requirments for hydrologic, meteorologic, oceanic, and other environmental data
- Promotes information exchange/sharing of data, research and development results
- Undertakes projects that benefit the GOES DCS Community

STIWG Agencies

- U.S. Forest Service
- NOAA (OCFM, OAR/ARL, NDBC, NESDIS, NOS and NWS)
- USACE
- Bureau of Land Management
- Bureau of Reclamation
- USGS (Water Mission Area)
- International Boundary and Water Commission
- CA Department of Water Resources

What is DCS

- DCS is a data relay capability on the GOES East and West satellites
- Data Collection Platforms (DCP's) deployed in the field collect readings and perform scheduled transmissions to one of the GOES spacecrafts (dependent upon geography) for relay back to Earth ground stations
  - Nearly ~8 million hydro-met observations are transmitted/day
  - Direct Read-out Ground Stations (DRGS) collect data directly from the initial GOES relay
  - L/HRIT DCS is GOES DCS data that is received by processing centers, repackaged and transmitted to GOES and relayed back to earth for L/HRIT ground stations with smaller dish antennas to receive
- GOES DCS is a primary system for many agencies supporting water resource management, navigation, flood control, agriculture, hydro-power, etc.

Working Groups

- DCS Preservation
  - Tasked with addressing issues pertaining to matters that impact the viability, availability and integrity of GOES DCS data from the GOES satellites.
- OpenDCS Standardization
  - Tasked with establishing an executable plan that will unify existing OpenDCS variants and capabilities into a single platform. The second objective is to establish a way to jointly plan and fund the new platform's development and support by the STIWG agencies.

STIWG OpenDCS

- Consolidate variants of OpenDCS
  - Cove baseline incorporating Sutron enhancements
    - Baseline selection determined by STIWG agencies' deployment rates
  - First release will incorporate Sutron developed National Ocean Service enhancements
  - The unified platform will be the official STIWG released and supported software

STIWG OpenDCS (cont'd.)

- Interagency Support Agreements
  - Existing MOA/MOU's allow USACE to establish SA's to receive funds from STIWG agencies in support of OpenDCS development through the RMA contract
    - 2018 Completed draft of agreement under existing 7600A between USACE and NOAA
      - Outlines the scope of work, expectations, requirements and funding

STIWG OpenDCS (cont'd.)

- Existing MOA's and MOU's with USACE provide fundamental structure
  - Department of Agriculture (USFS)
  - Department of Commerce (NOAA: NESDIS, NOS, NWS, NDBC, etc.)
  - Department of Interior (BLM, USBR and USGS)
  - Department of State (IBWC)
- Promote collaboration and improved scoping for future development
- Establishes End-to-End GOES Coordination between STIWG agencies
- Working with HEC to have all SA's in place by FY19

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Thriving on Our Changing Planet

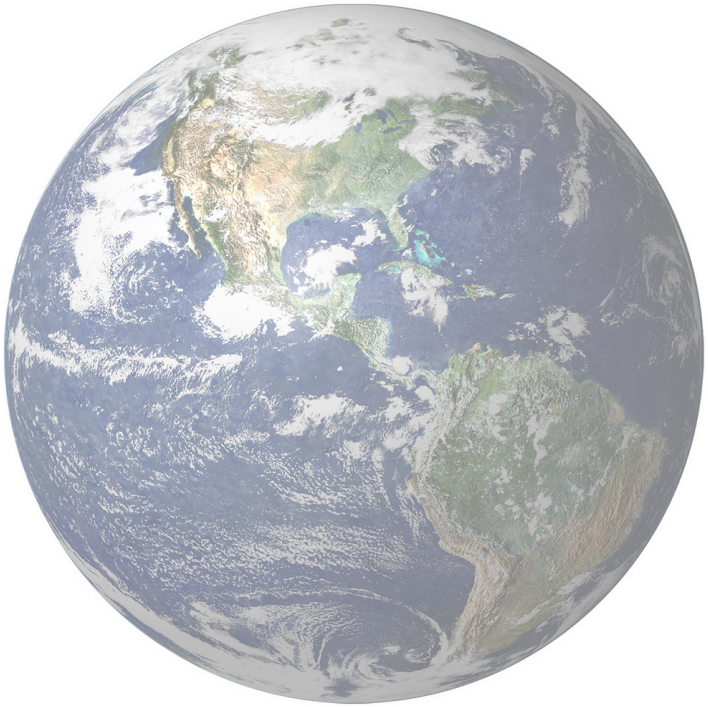
A Decadal Strategy for Earth Observation from Space

#EarthDecadal

The National Academies of SCIENCES ENGINEERING MEDICINE

Thriving on Our Changing Planet

A Decadal Strategy for Earth Observation from Space



A report of the
Decadal Survey for Earth Science and Applications from Space
Released: 5 January 2018

Report available at: http://www.nas.edu/esas2017

Quick Summary: Recommendations

1

VISION & STRATEGY

"Thriving on our Changing Planet"

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Those with objectives prioritized as most important fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among seven candidates
- Structure **new NASA mission program elements** to accomplish this
- Methods for new NASA capabilities to be **leveraged by NOAA and USGS**

4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS

What We Were Asked to Do

OVERARCHING TASKS

- Assess **progress from 2007**
- Develop a prioritized list of top-level **science and application objectives** for 2017-2027
- Identify gaps and opportunities in the **programs of record** at NASA, NOAA, and USGS
- Recommend approaches to facilitate the development of a robust, resilient, and appropriately balanced U.S. **program of Earth observations** from space

GENERAL & AGENCY-SPECIFIC TASKS

- **Cross-Agency**
  - Enabling activities
  - Partnerships & synergies
- **NASA**
  - Program balance and scope
  - Ventures flight element
  - Decision principles and measurement continuity
- **NOAA and USGS**
  - Non-traditional observation sources
  - On-ramp of scientific advances
  - Research-to-operations
  - Technology replacement/infusion

Steering Committee

WALEED ABDALATI, University of Colorado Boulder, *Co-Chair*
WILLIAM B. GAIL, Global Weather Corporation, *Co-Chair*

STEVEN J. BATTEL, Battel Engineering, Inc.
STACEY W. BOLAND, Jet Propulsion Laboratory
ROBERT D. BRAUN, University of Colorado
SHUYI S. CHEN, University of Washington
WILLIAM E. DIETRICH, University of California, Berkeley
SCOTT C. DONEY, University of Virginia
CHRISTOPHER B. FIELD, Stanford University
HELEN A. FRICKER, Scripps Institution of Oceanography
SARAH T. GILLE, Scripps Institution of Oceanography
DENNIS L. HARTMANN, University of Washington
DANIEL J. JACOB, Harvard University
ANTHONY C. JANETOS, Boston University
EVERETTE JOSEPH, University of Albany, SUNY
JOYCE E. PENNER, University of Michigan
SOROOSH SOROOSHIAN, University of California, Irvine
GRAEME L. STEPHENS, Jet Propulsion Laboratory/Caltech
BYRON D. TAPLEY, The University of Texas at Austin
W. STANLEY WILSON, National Oceanic and Atmospheric Administration (ret.)

ANTONIO J. BUSALACCHI JR., NAE (Original Co-Chair - resigned from committee, 8/19/2015 -- 5/5/2016) UCAR
MOLLY K. MACAULEY [Deceased], (Member, 12/1/2015 -- 7/8/2016) Resources for the Future

National Academies
- Space Studies Board (lead)
- Board on Atmospheric Sciences and Climate
- Board on Earth Sciences and Resource
- Ocean Studies Board
- Polar Research Board
- Water Sciences and Technology Board

Panels

Global Hydrological Cycles and Water Resources

Co-Chairs: Jeff Dozier, UC Santa Barbara and Ana Barros, Duke University

The movement, distribution, and availability of water and how these are changing over time

Weather and Air Quality: Minutes to Subseasonal

Co-Chairs: Steve Ackerman, University of Wisconsin and Nancy Baker, NRL

Atmospheric Dynamics, Thermodynamics, Chemistry, and their interactions at land and ocean interfaces

Marine and Terrestrial Ecosystems and Natural Resource Management

Co-Chairs: Compton (Jim) Tucker, NASA GSFC and Jim Yoder, WHOI

Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and factors that influence health and ecosystem services

Climate Variability and Change: Seasonal to Centennial

Co-Chairs: Carol Anne Clayson, WHOI and Venkatachalam (Ram) Ramaswamy, NOAA GFDL

Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

Earth Surface and Interior: Dynamics and Hazards

Co-Chairs: Dave Sandwell, Scripps and Doug Burbank, UC Santa Barbara

Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate

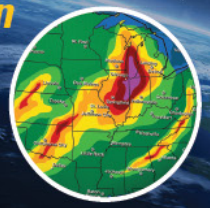
Earth Information is Increasingly Critical to *Thriving* on our Planet

THE IMPORTANCE OF EARTH INFORMATION

Earth-observing satellites provide critical information about our planet. This information supports a broad range of societal needs and enables the scientific discovery required to meet those needs, making us all healthier, safer, and more efficient.

Helping Plan Our Day

300 billion *weather forecasts used by Americans every year*



100+ million *American adults use internet-based mapping services*

Americans rely on sophisticated Earth information throughout their everyday lives, from weather forecasts to navigation applications in their cars. Satellites are the original sources of much of the data.

Protecting Our Health

6.5 million *premature deaths from air pollution around the world every year*

Earth-observing satellites track the concentration of harmful pollutants across the country, providing air quality data for rural areas without ground-based monitoring systems and measuring the effects of air quality regulations.

50% *of the world's population is at risk from malaria.*

Satellite observations of temperature, vegetation, and rainfall help predict the spread of mosquito-borne illnesses like malaria, Zika, and West Nile Virus.

Keeping Us Secure

The estimated value of NASA and NOAA information services to the U.S. Navy's operational effectiveness is **$2 billion** *per year.*

The U.S. Navy and other U.S. defense agencies partner with NASA and NOAA to use satellite data, to access operational services, and to leverage their scientific progress.

Mitigating Natural Disasters

Extreme weather and fires have cost the federal government more than **$350 billion** *over the past decade.*

Satellite measurements play a critical role in tracking the paths of hurricanes and wildfires so that we can warn populations at risk, assess the damages, and avoid future costs.

Ensuring Resource Availability

Advanced technology, including many types of Earth information, will unlock up to **$1.6 trillion** *in economic savings for energy generation and use by 2035.*

Satellite observations can also help ensure water availability, which is particularly important to the 20% of the world now living in areas of water scarcity.

A Paradigm and a Challenge

Earth Science and Applications Paradigm for the Coming Decade

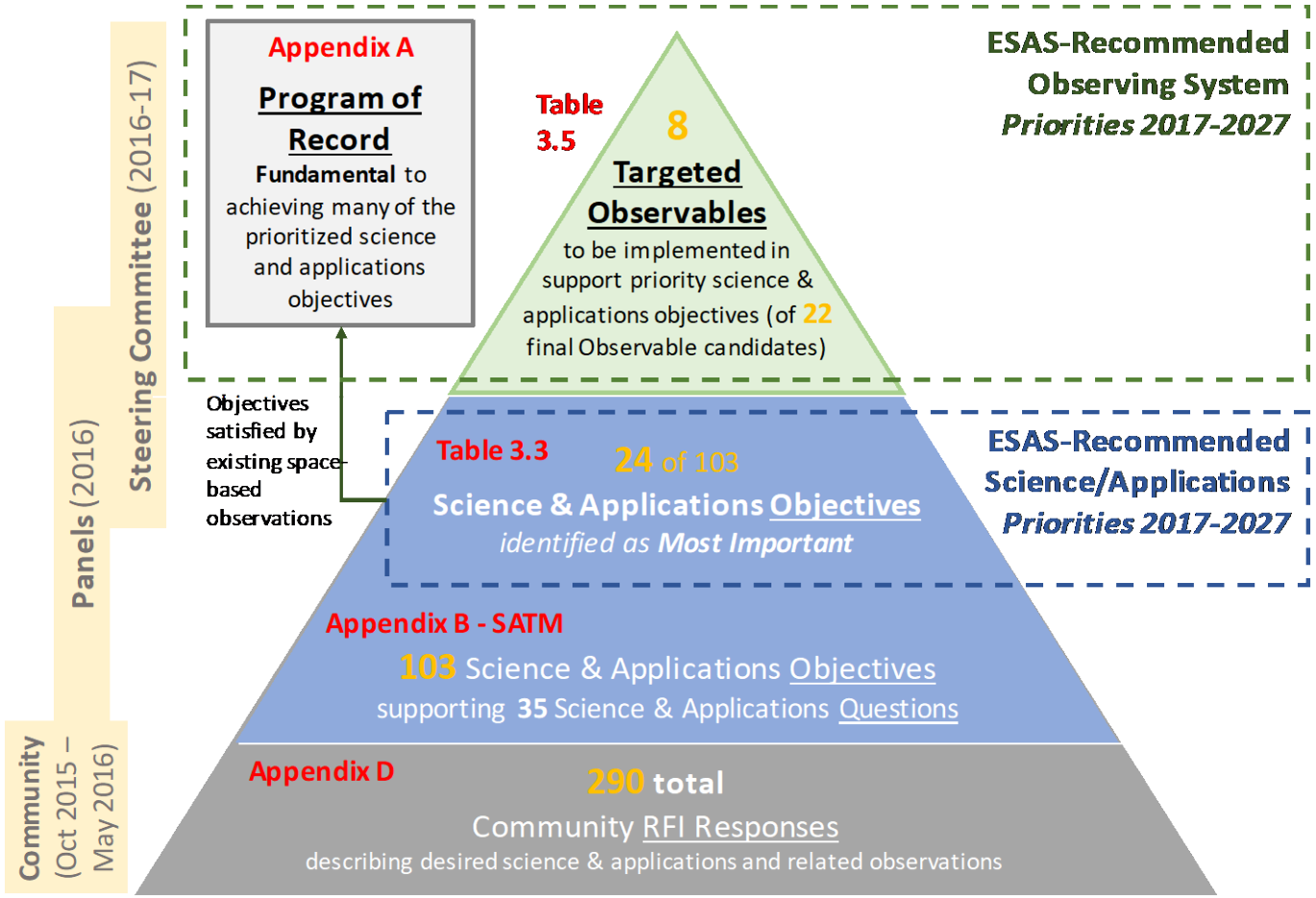
Earth science and derived Earth information have become an integral component of our daily lives, our business successes, and society's capacity to thrive. Extending this societal progress requires that we focus on understanding and reliably predicting the many ways our planet is changing.

Decadal Community Challenge

Pursue increasingly ambitious objectives and innovative solutions that enhance and accelerate the science/applications value of space-based Earth observation and analysis to the nation and to the world in a way that delivers great value, even when resources are constrained, and ensures that further investment will pay substantial dividends.

Path from Science & Applications to Observational Priorities

Blue: Science & Applications; Green: Observables



Recommended NASA Flight Program Elements

Program of Record.
The series of existing or previously planned observations, which **should be completed as planned**. Execution of the ESAS 2017 recommendation requires that the total cost to NASA of the Program of Record *flight missions from FY18-FY27 be capped at $3.6B.*

- ***Designated.*** A new program element for ESAS-designated cost-capped medium- and large-size missions to address ***observables essential to the overall program*** and that are outside the scope of other opportunities in many cases. Can be competed, at NASA discretion.
- ***Earth System Explorer.*** A new program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Incubation.*** A new program element, focused on investment for priority observation opportunities needing advancement prior to cost-effective implementation, including an Innovation Fund to respond to emerging needs. ***Investment in innovation for the future***.
- ***Venture.*** Earth Venture program element, as recommended in ESAS 2007 with the addition of a new Venture-Continuity component to provide ***opportunity for low-cost sustained observations***.

Summary of Top Science & Applications Priorities*

* Complete set of Questions and Objectives in Table 3.3

Science & Applications Topic	Science & Applications Questions addressed by **MOST IMPORTANT** Objectives
Coupling of the Water and Energy Cycles	**(H-1)** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods? **(H-2)** How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	**(E-1)** What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? **(E-2)** What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? **(E-3)** What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?
Extending & Improving Weather and Air Quality Forecasts	**(W-1)** What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations? **(W-2)** How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months? **(W-4)** Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? **(W-5)** What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty & Informing Societal Response	**(C-2)** How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	**(C-1)** How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage? **(S-3)** How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics, Geological Hazards	**(S-1)** How can large-scale geological hazards be accurately forecasted and eventually predicted in a socially relevant timeframe?

Recommended NASA Priorities: Designated

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		

Recommended NASA Priorities: Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
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

Recommended NASA Priorities: Incubation/Other

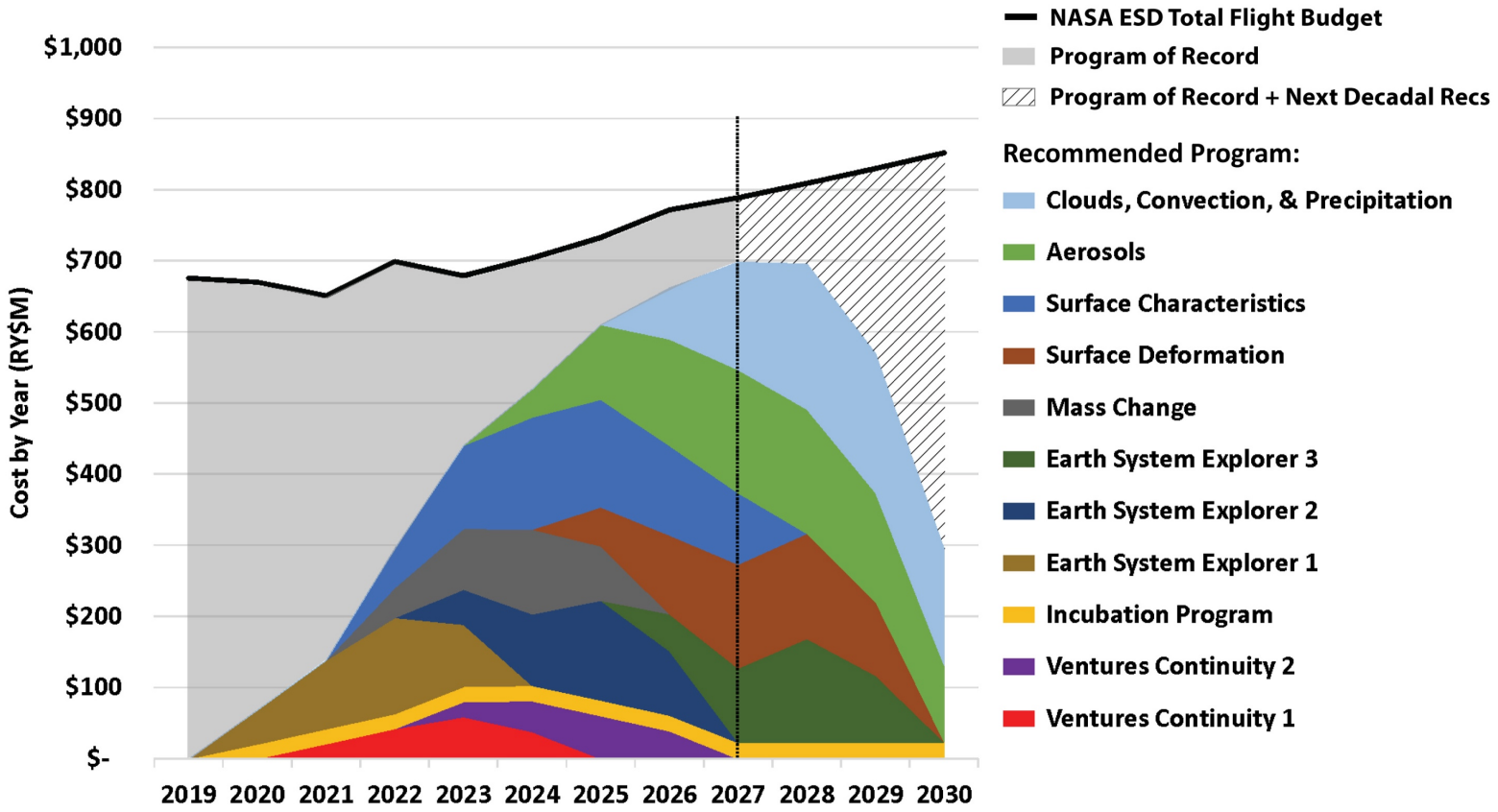
TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (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**

NASA Budget Compliance



- Liens from last decade into this one are substantial
- Very little flexibility to absorb funding challenges until mid decade
- Committee sought to keep liens lower on next decade
  - Allows more flexibility for next decadal survey
  - Some carry over of programs into subsequent decade is required

NOAA Observation System Opportunities

EXPECTED NOAA "UNSATISFIED PRIORITIES"	EXPECTED NOAA PRIORITY AND RATIONALE	RELATED ESAS 2017 PROGRAMS OR TARGETED OBSERVABLES
Instrument Cost Reduction	HIGH – Reducing cost of any system element enables greater system capability. NOAA has limited capacity to invest in development activities that eventually reduce production cost.	Incubation program element NASA ESTO
3D Winds in Troposphere and Lower Stratosphere	HIGH – High cost and low technology readiness impede inclusion in NOAA operational system.	*Atmospheric Winds*
Global Precipitation Rate	HIGH – High cost and low technology readiness impede inclusion in NOAA operational system.	*Clouds, Convection, & Precipitation*
Seasonal Forecasting	MEDIUM – Multiple new and often difficult observations needed, notably upper ocean and ocean-atmosphere coupling, along with assurance of continuity and ongoing cost reduction for existing observations.	Many ESAS 2017 Targeted Observables
Ocean Surface Vector Winds	MEDIUM – Coverage is likely to be less than desired, with high-volume coverage presently costly.	*Ocean Surface Winds & Currents*
Global Atmospheric Soundings	MEDIUM – Expect future systems to have more soundings of at least moderate precision/accuracy levels as compared to today, but high precision/accuracy IR and microwave soundings may be lacking.	*Planetary Boundary Layer*
GEO-based Regional IR and Microwave Sounding	LOW to MEDIUM – Useful for forecaster nowcasting, but generally considered less valuable than global sounding.	*Planetary Boundary Layer*

NASA Portfolio Balance

- Earth Science research and analysis: *maintain* at approximately 24% of the ESD budget (22-26%)
  - Includes 18% for openly competed research and analysis
  - Includes approximately 3% each for computing and administration
- Flight program (including Venture): *maintain* at 50-60% of the ESD budget
- Mission operations: *maintain* at 8-12% of the ESD budget
- Technology program: *increase* from current 3% to about 5% of the ESD budget
- Applications program: *maintain* at 2-3% of the ESD budget

Programmatics - NASA

Rec 4.6 Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)

Rec 4.7 Small scope changes to **applications & technology programs**

Rec 4.8 Reevaluate **Ventures structure** at mid-term

Rec 3.3 **Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

Programmatics - NOAA

Rec 4.9 Make it easier to extend use of NOAA **satellite data for other NOAA uses** beyond weather

Rec 4.10 Further leverage US and international government **partner observations**

Rec 4.11 Be a leader in exploiting **commercial observations**

Rec 4.12 Establish with NASA a flexible framework to **co-develop technology** that will be used by NOAA

Programmatics - USGS

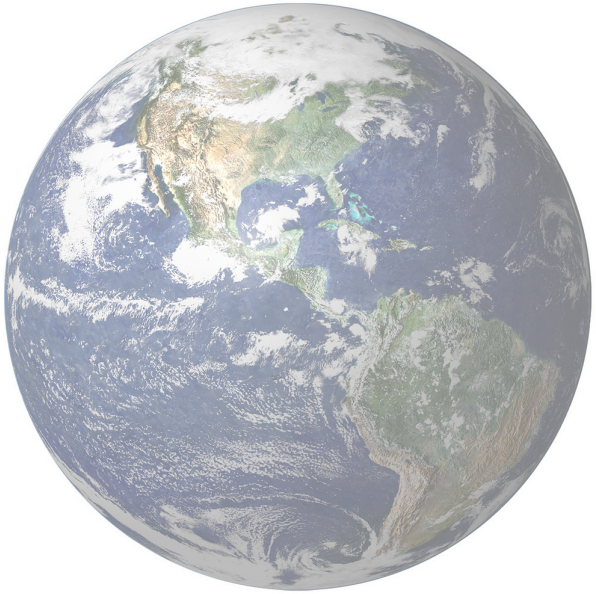
Rec 4.13 Ensure Landsat **user needs** continue to be understood and addressed

Rec 4.14 Constrain and reduce **Landsat development cost**

Rec 4.15 Leverage **Landsat-related partnerships**, including international complements

The Decade Ahead

Thriving on our Changing Planet



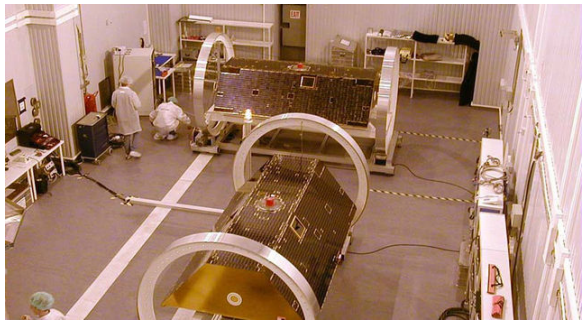
A decade in which we find growing community and public recognition of:

- Society's broad reliance on Earth information to **thrive**
- The growing challenge of understanding and predicting a moving target, as Earth **change** happens around us through natural and human influence

Anticipated Programmatic Progress

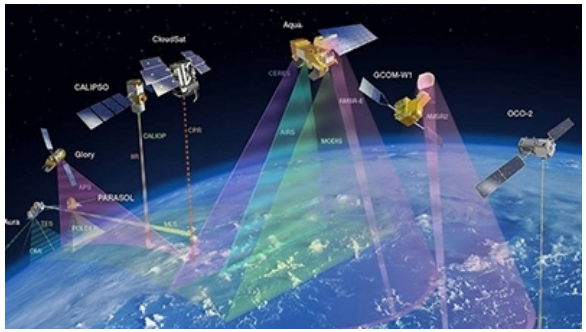
Programmatic implementation within the agencies will be made more efficient by:

- *Increasing program cost-effectiveness*
- *Institutionalizing sustained science continuity*
- *Enabling untapped interagency synergies*



Improved observations will enable exciting **new science and applications** by:

- *Initiating or deploying more than eight new priority observations of our planet*
- *Achieving breakthroughs on key scientific questions*

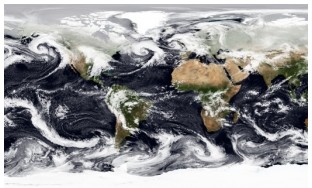


Enhanced societal value will be provided to businesses and individuals from scientific advances and improved Earth information, such as:

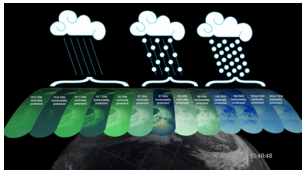
- *Increased benefits to operational system end-users*
- *Accelerated public benefits of science*
- *New enabling data for innovative commercial uses*

Anticipated Science/Applications Accomplishments

DESIGNATED Program Element



Make-up and distribution of **aerosols and clouds**

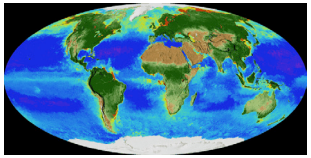


Impacts of **changing cloud cover and precipitation**

Growth or shrinkage of **glaciers and ice sheets**

Trends in **water stored on land**

Alterations to **surface characteristics and landscapes**



Evolving characteristics and health of **terrestrial vegetation and aquatic ecosystems**

Movement of **land and ice surfaces**

Candidate EXPLORER Program Element

- Sources and sinks of **CO2 and methane**
- Contributions of glaciers and ice sheets to **sea level rise**
- Impacts of **ocean circulation and exchange with atmosphere** on weather and climate
- Changes in **ozone and other gases** and impacts on health and climate
- **Snow amounts and melt rates** and implications for water resources
- Impact of changes in **land cover and related carbon uptake** on resource management
- Transport of **pollutants** and energy between land, ocean, and atmosphere

THANK YOU!

#EarthDecadal

The National Academies of SCIENCES ENGINEERING MEDICINE

Agenda

- Opening Remarks: …….COES Cochairs
- Action Item Review: ……Executive Secretary
- STIWG Update: ……..……. Lysanias Broyles (USACE)
- Radio Frequency Interference (RFI) Update: ……Al Wissman (NOAA)
- Earth Science and Applications From Space Decadal Survey:
  ……..William Gail, Chief Technology Officer, Global Weather Corporation
  ……...and Waleed Abdalati, University of Colorado Boulder
  Open Discussion: ……..COES Members
- Action Item Review / Next Meeting: …….Executive Secretary
- Adjourn: …….The meeting is expected to end by 11:00 AM EDT.

Action Item Review / Next Meeting

- **The Executive Secretary will document any action items taken during the meeting**
- **The Executive Secretary will coordinate with the cochairs and schedule the next meeting.**
  - **Our goal is to conduct 4 COES meetings in 2018 (March, June, September, and December)**
    - Mar 21, 2018
    - Jun 22, 2018
    - Sep 21, 2018
    - Dec 14, 2018

BACK-UP