National Aeronautics and Space Administration

NASA's Earth Observing Missions In Operation, Development and the Decadal Survey

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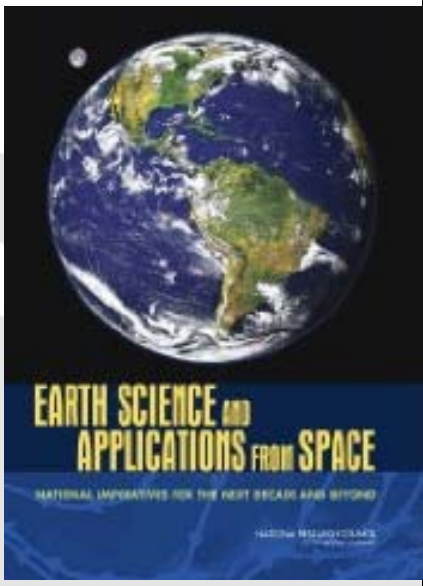
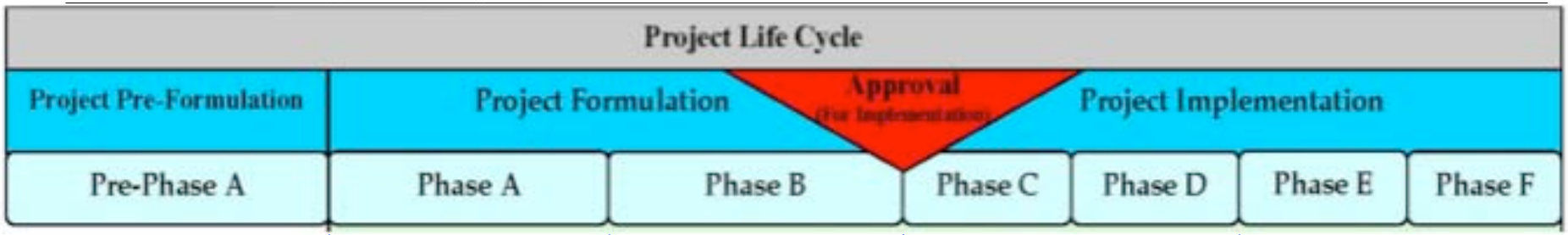
Why are we here?



- 2007 National Academy Study indicated that NASA needed to spend greater effort to enable the societal benefits that could be achieved from its orbiting observatories.
- We have initiated our first DS missions with a focus on renewed focus on applications
  - We have conducted Applications workshops for SMAP, HyspIRI, and DESDynI, with more planned for each mission as they mature.
- But we have not considered in a focused way how our other missions are successfully (or unsuccessfully) achieving their full potential for societal benefits
- We need to assess how the operating and foundational NASA missions are achieving their potential, and what we (NASA ***and*** partner Agencies) can do to ensure they do achieve that potential

Missions Distributed by NASA Flight Project Life Cycle



Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
NASA: DESDynI CLARREO SWOT ASCENDS ACE GEO-CAPE HyspIRI Reimbursable: QuikSCAT FO	NASA: ICESat-2 Venture EV-1 Reimbursable: Jason-3	NASA: SMAP Reimbursable: TSIS CERES FM6 Other: OCO-2 NPOESS?	NASA: NPP Glory Aquarius GPM LDCM Reimbursable: GOES-P GOES-R/S Other: SAGE III		NASA Prime: Aura OSTM NASA Extended: Aqua Terra TRMM Jason EO-1 ~~QuikSCAT~~ SORCE Acrimsat CALIPSO CloudSat GRACE ~~ICESat~~	

BLUE indicates Decadal Survey activities

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Phase E: Missions In Operation

NASA Operating Research Missions

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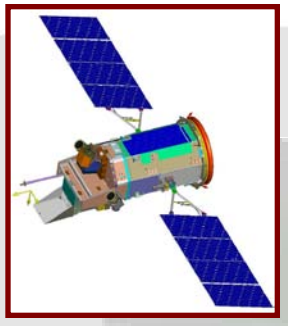
Phase C/D: Missions In Development

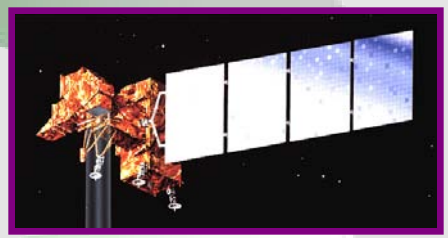
ESD Missions in Development & Formulation



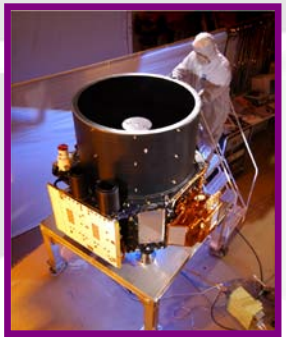
GLORY
Late 2010

AQUARIUS
Late 2010

NPP
Sep 2011

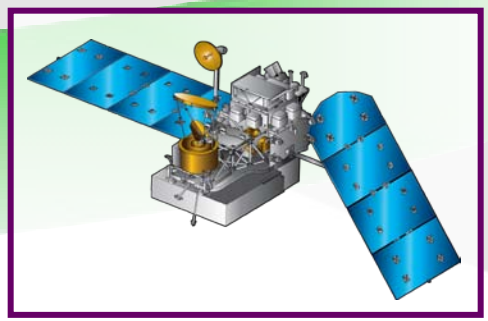


LDCM
Dec 2012



ICESat-2
Late 2015

SMAP
Nov 2014



GPM
Jul 2013
Nov 2014

Earth Science Missions in Development

NPOESS Preparatory Project[1] Strategic mission – Systematic measurement	Required for continuity of several key climate measurements between EOS and NPOESS
Glory Strategic mission – Initiate New Measurement and Continue Systematic Measurement	Addresses high priority objective of the US Climate Change Science Program and provide continuity for total solar irradiance
Aquarius[2] Competed mission – Earth System Science Pathfinder	First dedicated global measurement of sea surface salinity from space
LDCM[1] Strategic mission – Systematic measurement	Continues the 30+ year Landsat moderate resolution multispectral land imaging data record; includes new high sensitivity thermal instrument TIRS
Global Precipitation Measurement[2] Strategic Mission – Systematic measurement	Measure rain microphysical properties and vertical structure, Improve weather, climate, and hydrologic predictions and water resource management

[1] Represents Interagency Partnership

[2] Represents International Partnership

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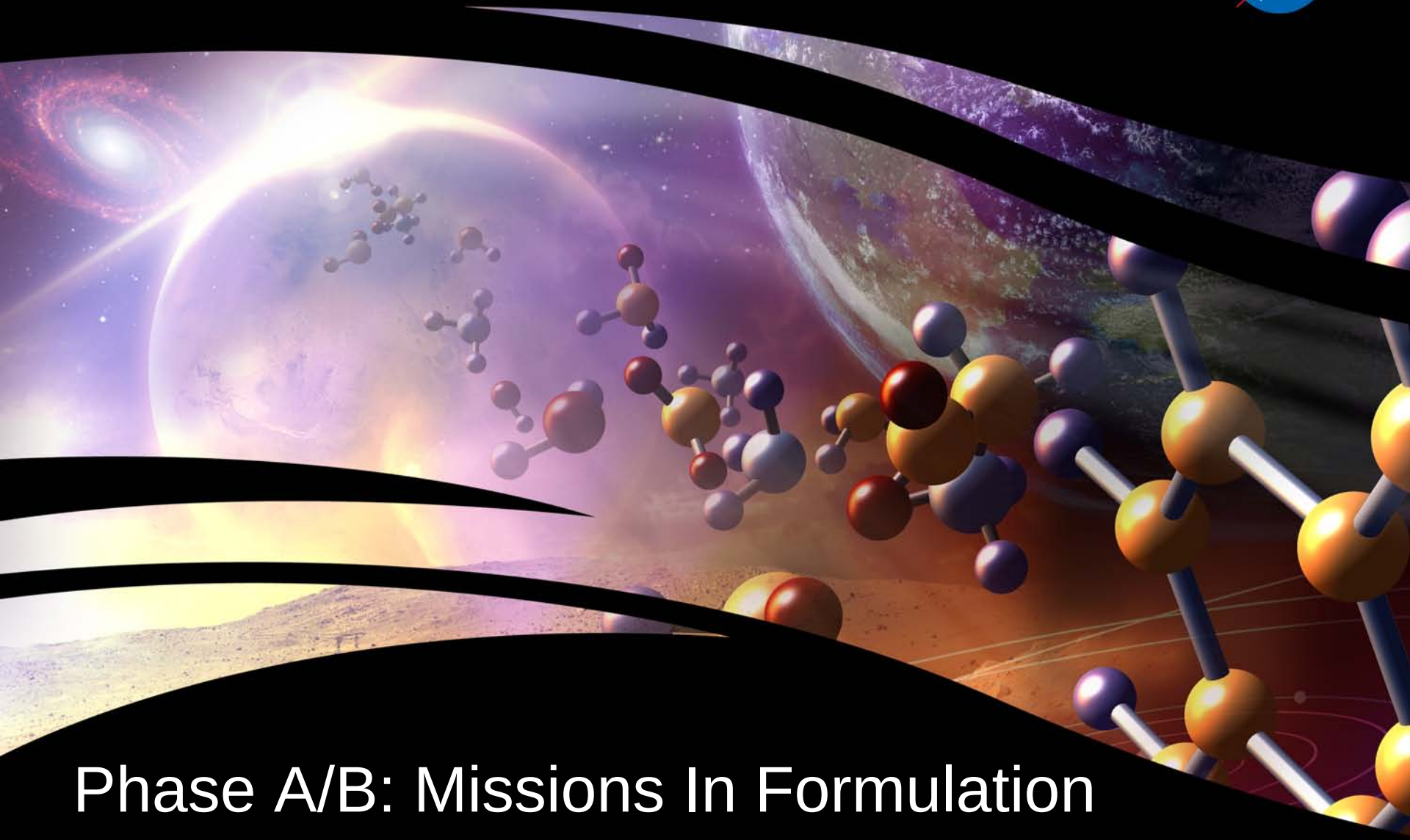

Phase A/B: Missions In Formulation

Note on Decadal Survey Mission Development

- NASA follows a well defined process for mission development, tailored to the specifics of the program
- All Decadal Survey missions are considered Strategic, and will be directed missions (as opposed to AO selected)
  - This means the mission management will be assigned to a Facility (almost always a NASA Center)
  - Venture Class and ESTO technology initiatives are competed
- Elements of the missions will be competed, with possible competed elements include but are not limited to Science Definition Teams and Instruments
  - ICESat-2 lidar recently went from an in-house build to a government-vendor partnership
- The developmental products, and to a degree the mission development schedule are largely defined by this established process.

Earth Science Decadal Survey Missions in Formulation

Soil Moisture Active/Passive Mission 1st Decadal Survey mission – Systematic measurement	Will use a combined radiometer and high-resolution radar to measure globally surface soil moisture and freeze-thaw state.
Earth Venture – 1 (EV-1) AO 1st Decadal Survey Venture class announcement	Complete suborbital, principal investigator-led investigations to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues
Ice Cloud and land Elevation Satellite – 2, ICESat-2 Systematic measurement and 2nd Decadal Survey mission	Will measure the dynamic state of the Earth's ice sheets, their seasonal and annual variations and volumetric change

[1] Represents Interagency Partnership

[2] Represents International Partnership

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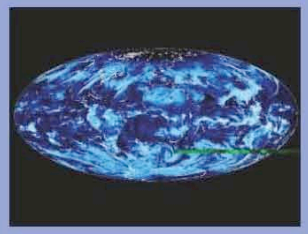
Mission Studies in Pre-Formulation

Missions in Pre-Formulation

Climate Absolute Radiance and Refractivity Observatory **(CLARREO)**



Soil Moisture Active Passive **(SMAP)**

Formulation

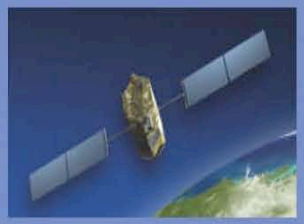
Ice, Cloud and land Elevation Satellite II **(ICESat-II)**

Formulation

Deformation, Ecosystem Structure and Dynamics of Ice **(DESDynI)**

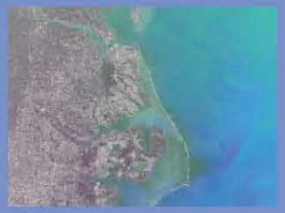
Hyperspectral Infrared Imager **(HYSPIRI)**

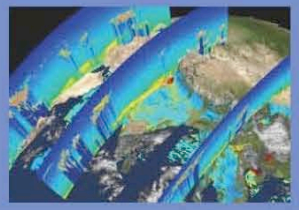
Active Sensing of CO2 Emissions **(ASCENDS)**



Surface Water and Ocean Topography **(SWOT)**

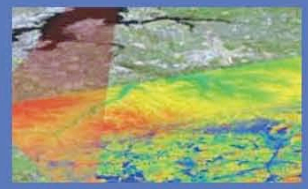
Geostationary Coastal and Air Pollution Events **(GEO-CAPE)**





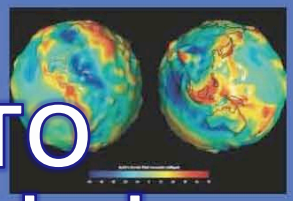
Aerosol - Cloud - Ecosystems **(ACE)**

LIDAR Surface Topography **(LIST)**



Precipitation and All-Weather Temperature and Humidity **(PATH)**

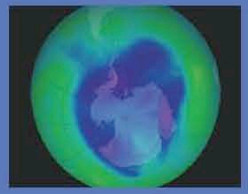
Gravity Recovery and Climate Experiment **(GRACE-II)**



ESTO Funded

Snow and Cold Land Processes **(SCLP)**

Three-Dimensional Winds from Space Lidar **(3D-Winds)**



Global Atmospheric Composition Mission **(GACM)**

Tier I

Tier II

Tier III

NASA Near-Term Missions (4/15 total)

Mission	Mission Description	Orbit	Instruments
CLARREO (NASA portion)	Solar and Earth radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer
ICESat-2	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter

NASA Mid-Term Missions (5/15 total)

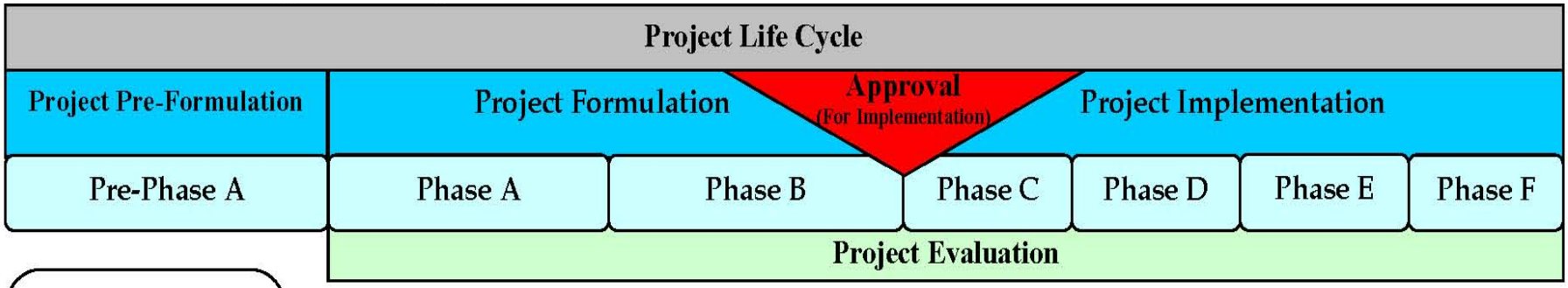
Mission	Mission Description	Orbit	Instruments
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar

NASA Late-Term Missions (6/15 total)

Mission	Mission Description	Orbit	Instruments
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST*	GEO	MW array spectrometer
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar

*Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high-accuracy SST measurement

Flight Project Life Cycle



Program establishes team to conduct broad range of concept studies that meet Agency NGOs & program requirements; defines management & technical approaches, & selects acceptable alternatives
Pre-Project Team conducts Mission Concept Review (MCR)
AA/MDAA conduct Project Acq. Strategy Planning Meeting (ASP)

Decision Authority (DA) conducts KDP A
MDAA approves FAD
DA approves entry to Phase A

DESDynI, CLARREO & Tier 2

MD/Program establish Project Office and conduct Acq. Strategy Meeting (ASM)
Project develops concept, management and technical approaches, requirements, etc.; conducts SRR & refines technical approach
Project conducts SDR or MDR, & develops preliminary Project Plan

DA conducts KDP B & approves entry to Phase B

ICESat-2 Venture EV-1

Project develops baseline design to meet requirements with acceptable risk within cost & schedule constraints; completes technology development; conducts PDR & completes baseline Project Plan

DA conducts KDP C & approves entry to Phase C
MDAA approves Project Plan

SMAP

Project implements in accordance with Project Plan and Project Lifecycle
- Update project approach, PCA, Program Plan, Project Plan, & budget when major budget or content issues require such changes
- Conduct project reviews
- Support special reviews and KDPs as required

These activities are what NASA does very well. But the same process that produces successful missions does not encourage outreach to organizations outside the focused mission science requirements.

Mission Requirements for Pre-Phase A

Scope of Major Pre-Phase A Activities:

Headquarters

- Approve a Formulation Authorization Document
- **Develop DRAFT Level 1 Requirements**
- Conduct Acquisition Strategy Planning Meeting

Technical Activities:

- Develop and document preliminary mission concepts
- Conduct internal Reviews
- Conduct Mission Concept Review Project Planning, Costing and Scheduling
- Develop and document a DRAFT Integrated Baseline, including:
  - High level WBS
  - Assessment of Technology Readiness Levels
  - Assessment of Infrastructure and Workforce needs
  - Identification of potential partnerships
  - Identification of conceptual acquisition strategies for proposed major procurements

KDP Readiness

- Obtain KDP A Readiness products
- Approval through the governing PMC

Areas for Mission Science Team

- **Development of Level 1 Science Requirements**
- Support development of preliminary mission concepts
- Support the assessment of Technical Readiness Levels
- Identify potential partnerships

Areas for Applied Science Community

- Initiate assessments of potential applied science returns
- Caucus community and partner input
- Support cost benefit analyses for possible requirements modifications to enable critical applications

Mission Requirements for Phase A

Scope of Major Phase A Activities:

Headquarters
- Establish Baseline Level 1 Requirements
- Conduct Acquisition Strategy Meeting
- Initiate Interagency and International Agreements

Technical Activities:
- Develop preliminary system level requirements
- Develop/document Baseline Mission Concept
- Develop preliminary mission operations concept
- Initiate technology developments
- Develop initial orbital debris assessment
- Conduct System Requirements Review
- Conduct Mission Definition Review

Project Planning, Costing and Scheduling:
- Prepare a preliminary Project Plan
- Conduct required Integrated Baseline Reviews
- Develop/document preliminary Integrated Baseline
- Identify Export Controlled technical data

KDP Readiness:
- Obtain KDP B Readiness products
- Approval through the governing PMC

Areas for the Mission Science Team:

- Concur with Level 1 Science Requirements
- Support development of preliminary system-level requirements
- Support development of mission baseline concept
- Support Development of preliminary mission operation concept

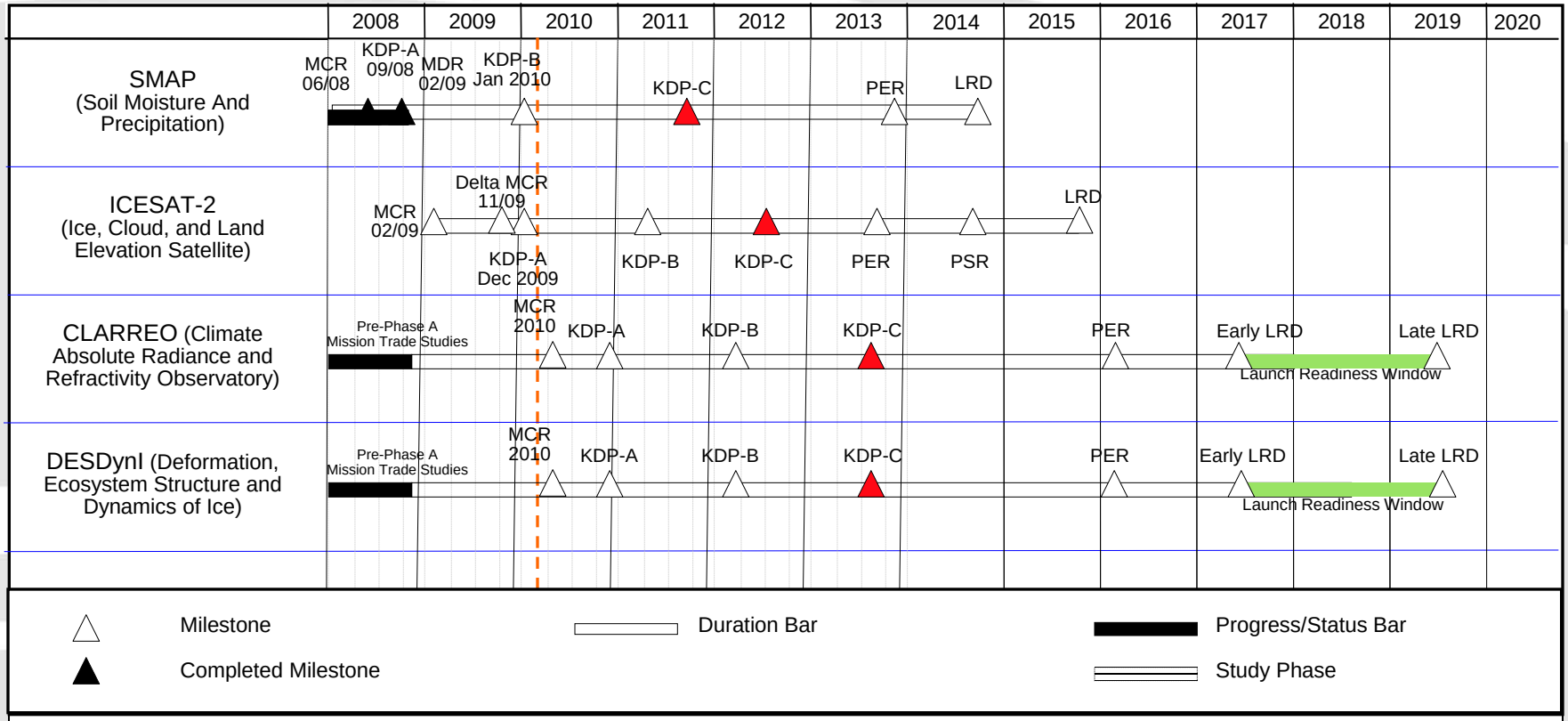
Areas for Applied Science Community:

- Refine applications feasibility studies
- Participate in science team analysis of refined level 1 requirements
- Support focused applications workshop

TBD

Tier 1 Mission Readiness

As of 10/14/2008



These schedules are driven by technical readiness and by available resources
*Readiness Window depends on resources **and** total mission cost.*

System Design Decisions will be made within the next year (for SMAP & ICESat-2) or the next 2-3 years (CLARREO & DESDynI)

▲ **Requirements set at KDP-C**

Earth Science Observations are more than Satellites

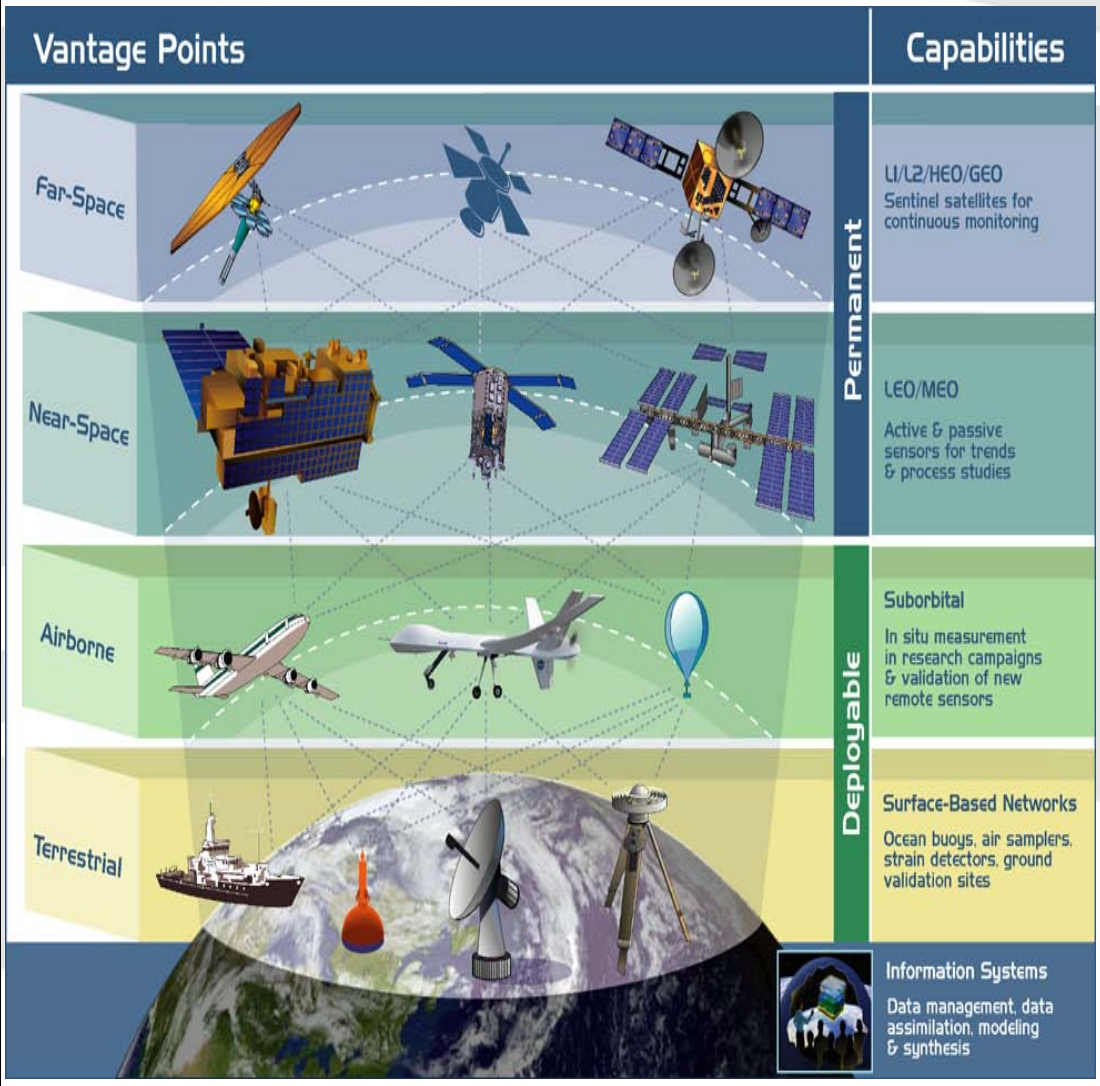
- Airborne, for observations, instruments, and simulators
- Advanced instrument and technology investments for future satellite hardware
- Ground calibration of instruments for better absolute accuracy
- Airborne and ground sites for flight validation

- Effective interagency partnerships have been utilized in each of these areas

Earth Venture – 1 (EV-1) Investigations

- The first set of Venture-class investigations, or Earth Venture-1 (EV-1), solicited proposals for complete suborbital, principal investigator-led investigations to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues
  - **Sustained, science-based data acquisition —** The investigations must advance Earth system science objectives through temporally sustained regional- or larger-scale measurements sufficient and necessary to prove/disprove a scientific hypothesis or address scientific questions.
  - **Mature technology —** The investigations must use mature system technology where, at a minimum, there has been a system/sub-system model or prototype demonstration in a relevant environment (Technology Readiness Level (TRL) of 6 or greater).
  - **Competitive selection —** The investigations will be selected in an open competition, to ensure broad community involvement and encourage innovative approaches.
  - **Cost and schedule constraints —** Each suborbital Venture-class investigation must have a life cycle of less than or equal to 5 years and total investigation cost not to exceed $30 million.

Airborne and Ground-Based Measurement Programs



- Airborne science assets are actively engaged in the mission definition and development activities
  - Instrument development flights supporting mission definition (DESDynI and ASCENDS)
  - Data gathering as gap fillers (ICESat-2)
  - Test beds for IIP missions

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Flight Program Summary

Conclusion

- The NASA flight program invests $1.1B – 1.2B/year in its flight missions
  - Satellite development, operation of missions, EOSDIS and other DACs, competed mission science teams
- But our missions will always be focused on primary science, but are capable of returning so much more
- It becomes a question of

Requirements vs. Capabilities

- We need to see if there are subtle ways to redirect or refocus some small part of these activities to ensure we will retain as much capability as we can, knowing what the communities want
- We also need to see investment and involvement from the partners to realize the capabilities

How should we follow through?

- One approach employs parallel interactions at the mission level and the Program level
  - Individual missions are holding their focused missions applications studies
  - This meeting as a starting point for the Program Discussions
- At the program level we should consider follow-up meetings to this workshop, to encourage cross fertilization between missions and measurements
  - At IGARSS 2010 in Honolulu we will have 3 running sessions on applications enabled from or planned from NASA's earth observing satellites
- The Workshop report is
  - First to the Earth Science Division so we can best target our resources
  - Second to NASA to highlight the returns from our missions
  - Third to partner Agencies and the Administration on how we can/should work in collaboration
- **We want your best ideas on how to proceed!**