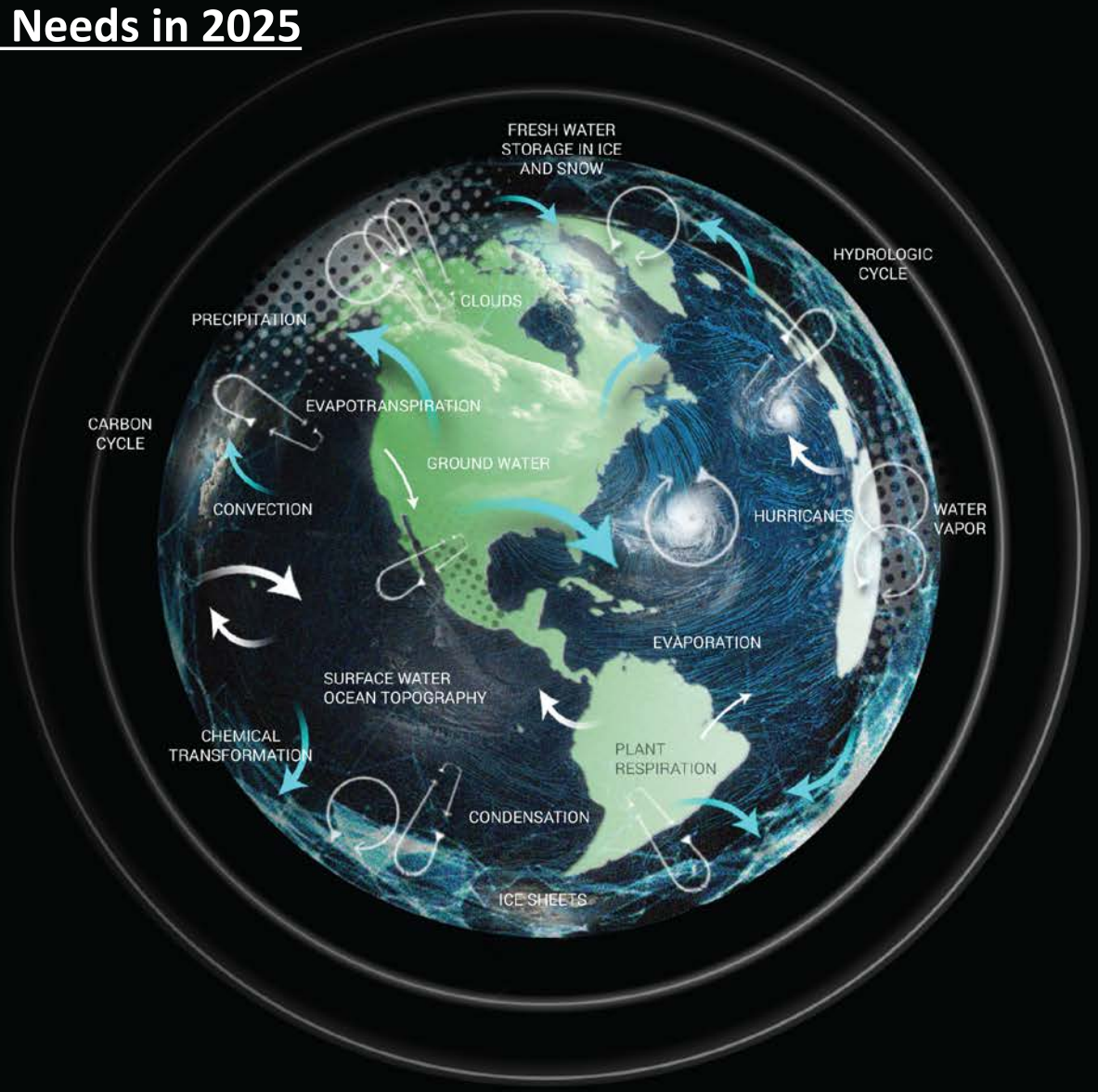
SC

Science and Commercial Space Condo

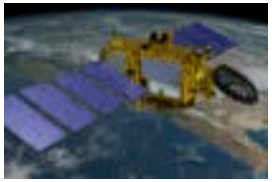
Jason Hyon/ Earth Science and Technology Directorate/ Jet Propulsion Lab/California Institute of Technology

Earth Science Needs in 2025

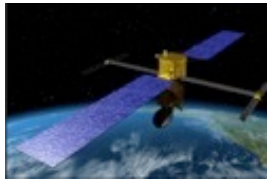


Earth Science

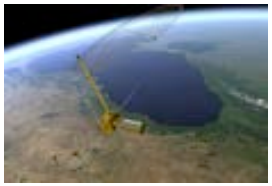
2016 - 2020 → Ongoing → > 2020



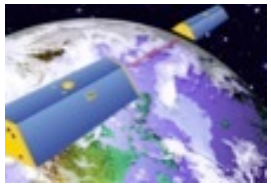
Sentinel 6
(Jason CS)



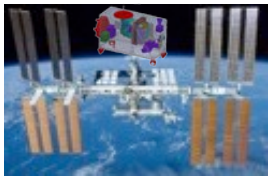
SWOT



NISAR



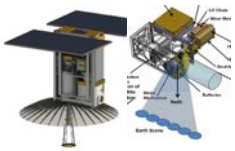
Grace Follow-On



OCO-3 on ISS

ECOSTRESS on ISS

MAIA



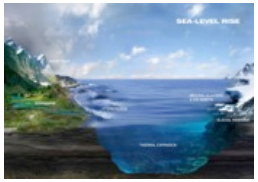
RainCube &
Tempest

Water Cycle:

How can we improve water resource management?

Natural Hazards:

How can we better prepare for extreme events (earthquakes, floods and hurricanes)?



Sea Level:

Will sea level continue to rise at the current rate?

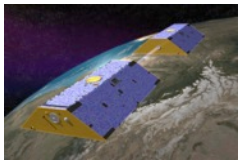
Carbon Cycle:

How are carbon storage and biodiversity changing?

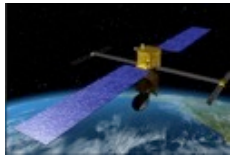
Extreme Weather:

Can we improve accuracy and lead times of extreme storms?

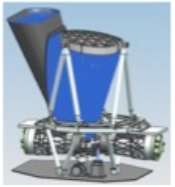
**2017
Decadal Survey
Aspirations**



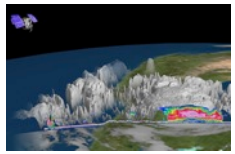
Grace-2



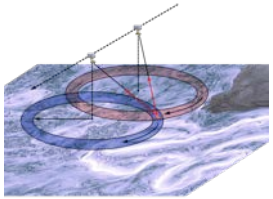
SWOT + PRISM



Imaging Spectrometer



3 Frequency,
Doppler Radar



Doppler
Scatterometer

Carbon
Observation
Architecture

Decadal Survey
Earth Science & Applications from Space

- Sponsors: NASA, NOAA, USGS
- For Earth Science, Environmental Monitoring & Applications Support
- Prioritize Science & Applications objectives NOT a list Missions

Timeline & Milestones

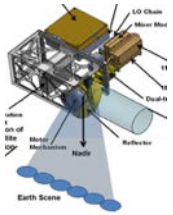
- Statement of Task Approved – May 2015
- Steering Committee Named, Nov 2015
- 1ST RFI– Submissions due Nov, 2015
  - 158 Responses, JPL 35 lead, 25 other
- Panel Structure Defined, Dec, 2015
- Panel Members Named, May 2015
- 2nd RFI – Submissions due May, 2015
  - 175 Responses, JPL 51 lead, 23 other
- 3rd RFI may focus on implementation approaches

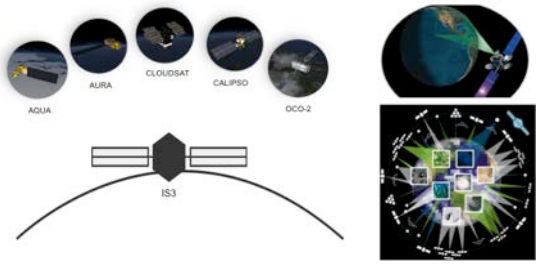
Steering Committee + 5 Panels

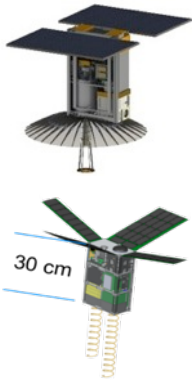
- Global Hydrological Cycles and Water Resources
- Weather and Air Quality: Minutes to Subseasonal
- Marine and Terrestrial Ecosystems and Natural Resource Management
- Climate Variability and Change: Seasonal to Centennial
- Earth Surface and Interior: Dynamics and Hazards

JPL's Contributions

- Science Leadership
- Sensor Development
- Observing Architectures







Earth Science Decadal Survey Challenge

With the given panel structure, how to evaluate and prioritize disciplinary and interdisciplinary science questions as well as measurement approaches that contribute to and across disciplines?

Water Cycle & Resources

Ecosystems & Natural Resources

Climate Variations & Change

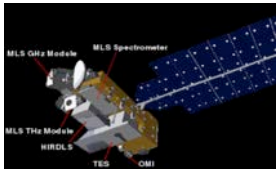
Weather & Air Quality

Earth Surface & Interior

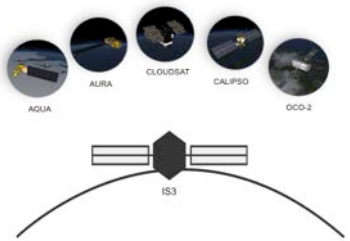
Observing Architectures

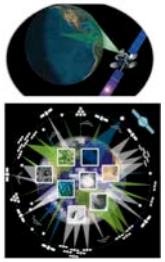
Multi-Purpose Sensors
e.g. HyspIRI

Multi-Sensor Platforms
e.g. Aura



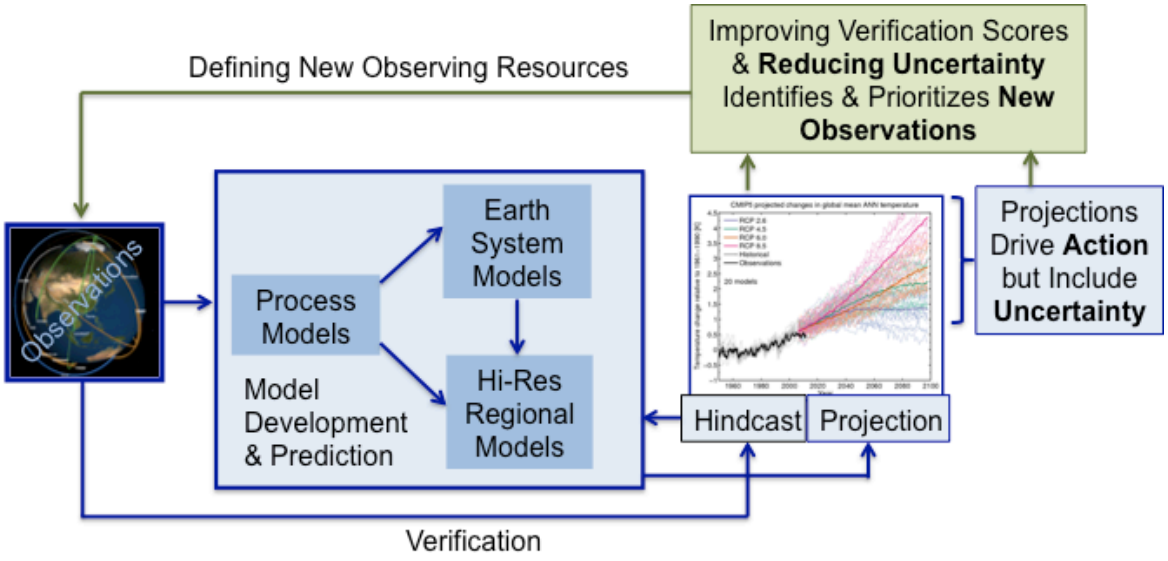
Distributed Platforms/Constellations e.g.
A-Train vs. Single Platform with servicing





System Engineering Approach to Earth Science – A Growing Need

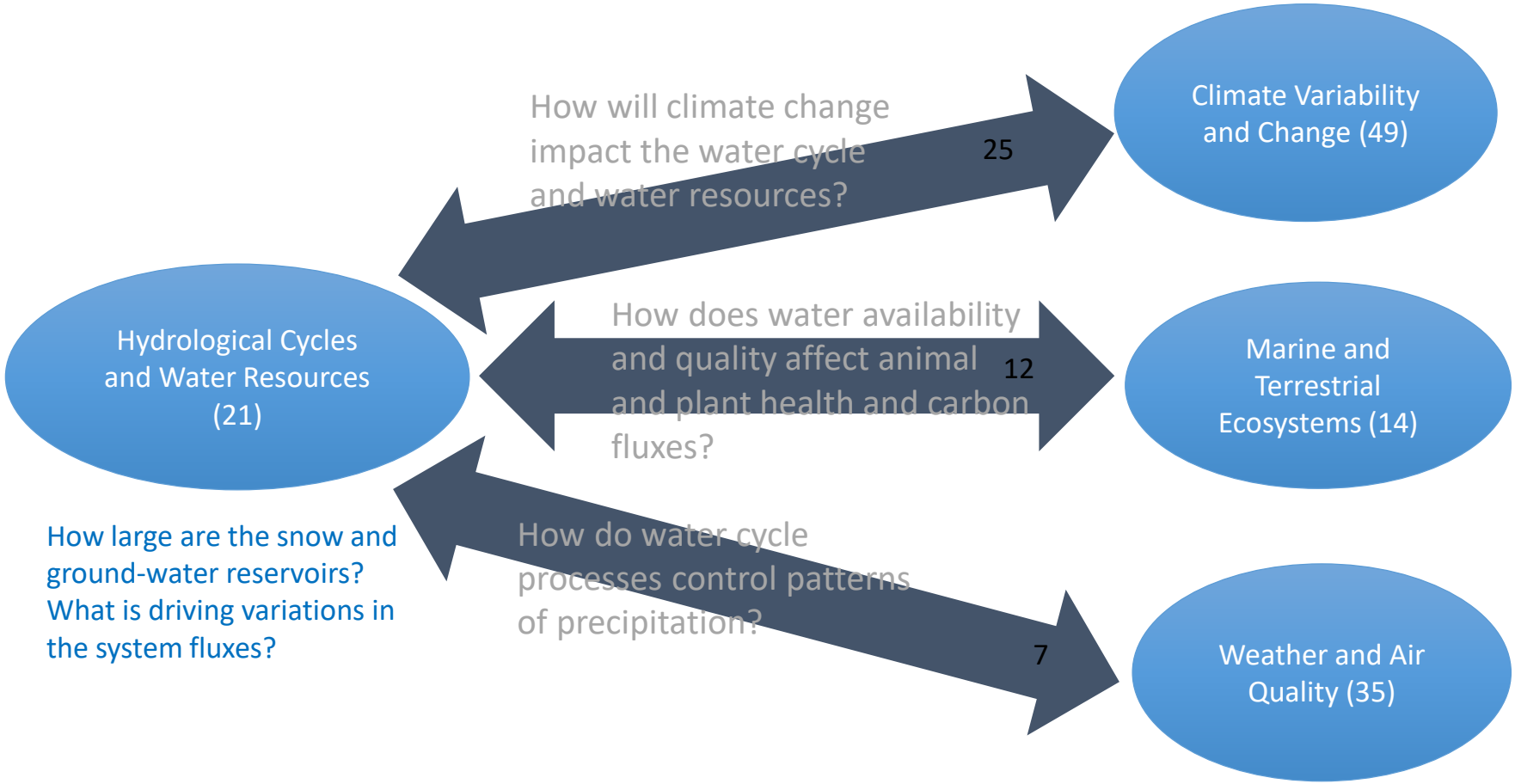
The complexity and maturity of Earth Science and the urgency of its applications necessitates a more formal approach to observation prioritization and life cycle, including formulation, implementation, analysis, information, and decision support.



- Prioritizing Earth System Science Questions Amidst a Range of Possibilities
- Identifying and Providing Actionable Information for Societal Needs
- Defining Observation Gaps for Reducing Uncertainty for Science & Applications

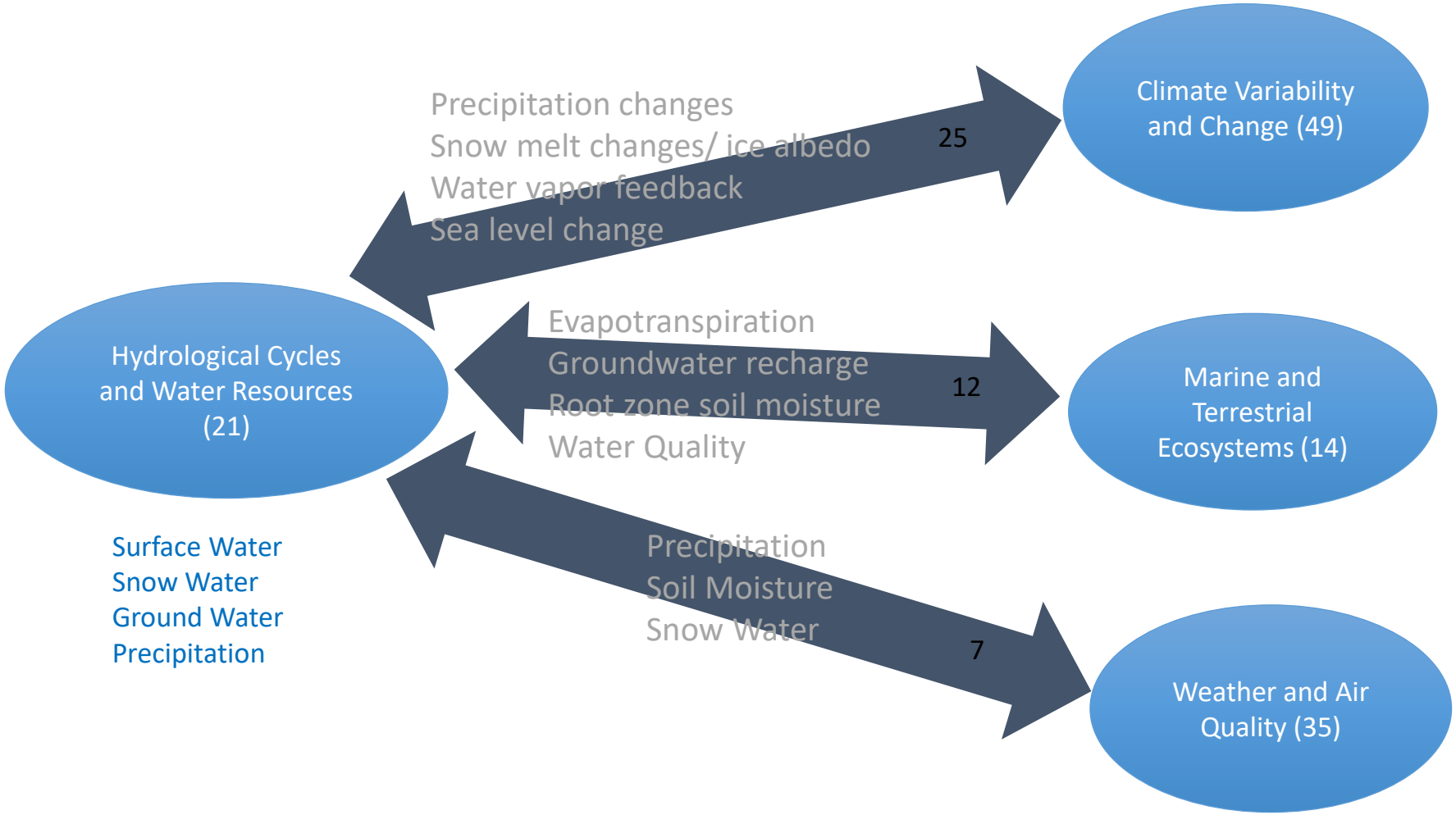
DS Input Highlights Research Objectives

Strong coupling between Water-related issues and other themes



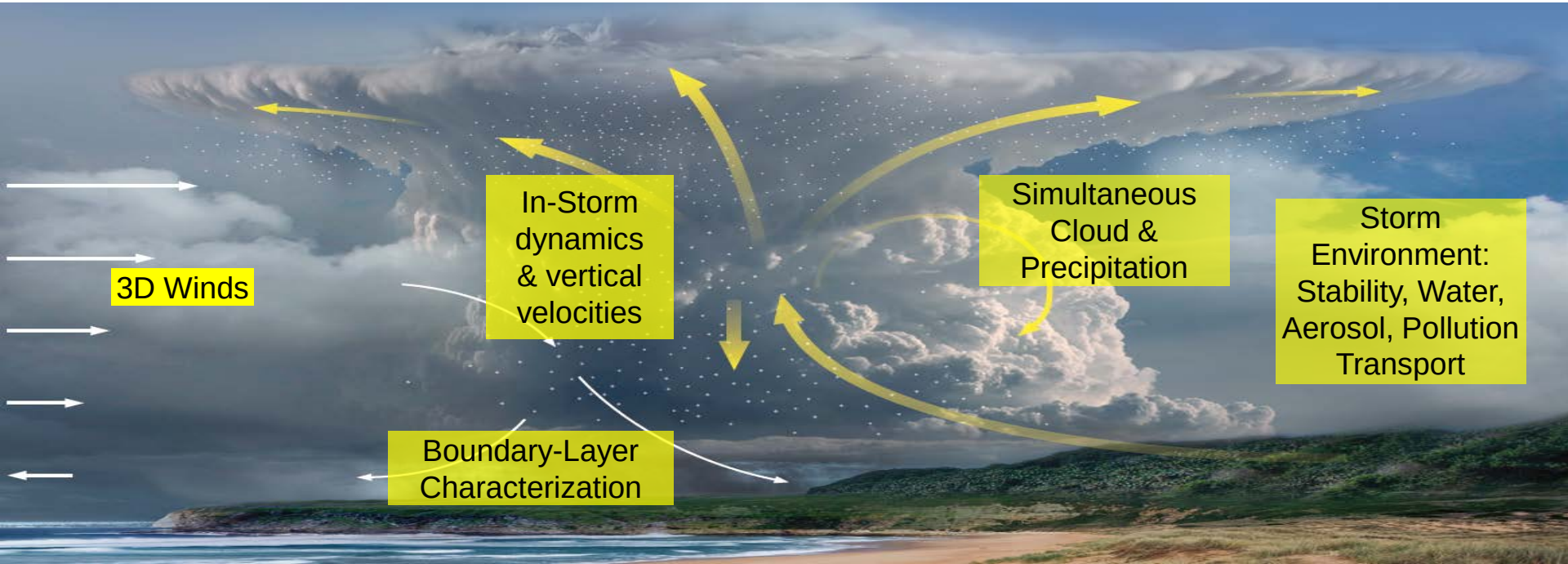
DS Input Reveals Measurement Links - Need for Concurrent Measurements

Water-related measurements support many other themes

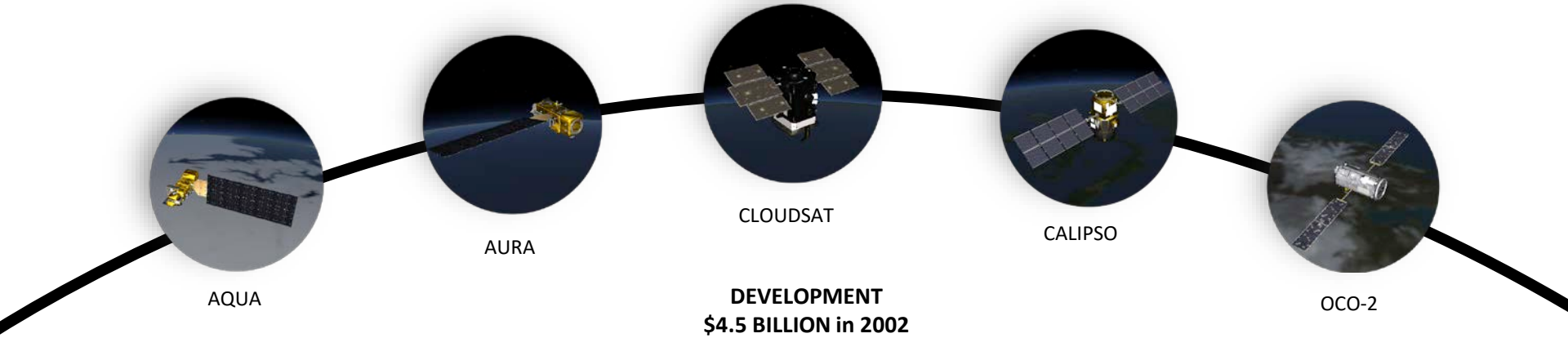


Example: Understanding Weather Science

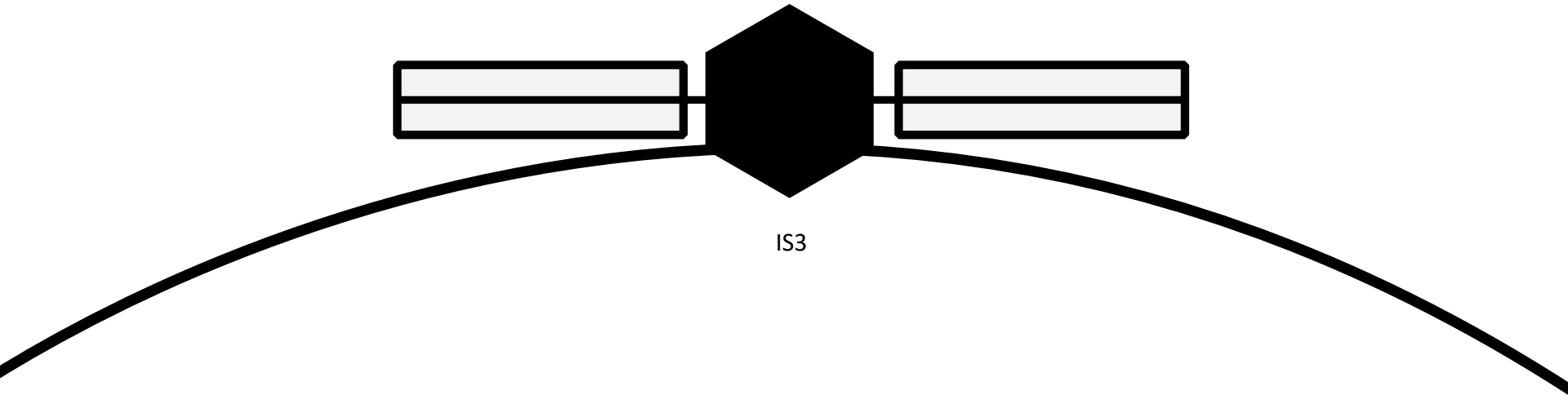
- Constellations or GEO to monitor **storm evolution**
- Higher spatial resolutions to capture **mesoscale structure**
- Capture **microphysical processes** key to precipitation growth
- Advancing technology to characterize the atmospheric **boundary-layer**
- Improved atmospheric profiling to characterize the **storm environment**
- Characterizing storm dynamics and extremes with **Doppler radar**
- **Miniaturization** of sensors for **cubesats**, constellations and lower costs



A-TRAIN BEFORE



A-TRAIN AFTER



JPL's Miniaturized Weather Instruments

What are optimal configurations/constellations?

Visible | *Infrared* | *Microwave* | *Radar* | *Gravity*

Miniature Dyson spectrometer

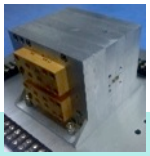
JPL IR&D Wide-Field Grating Spectrometer (WFGS)

Dual-Frequency Feedhorn

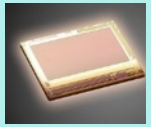
MMIC Receiver including Detector

Radiometer Backend and Power Conditioning

SSPA & Power Combiner

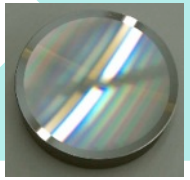


JPL BIRD MWIR Detectors



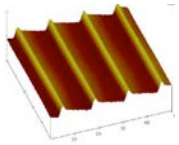
Motor and Drive Electronics

Up/Down Converter



JPL e-beam grating

Reflector



JPL Qualified Thales Cooler

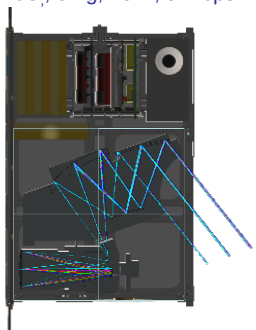
Command and Data Handling: Onboard FPGA

Processing (Pulse Compression and Modulation)

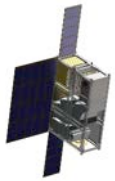
MASC

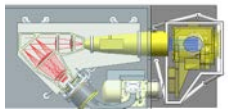
MicroGRACE Gravity Measurement
Spatial: 5 km (Horiz) x 250m (Vert)
Spectral: 35.6 GHz
SWAP: 6U, 20 kg, 30 W, <1 Mbps

Snow and Water Imaging Spectrometer
Spatial: ±5°, 0.28 km
Spectral: 228 Bands, 350 nm – 1.65 µm
SWAP: 6U, 9 kg, 15W, 5 Mbps

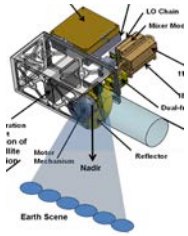


CubeSat Infrared Atmospheric Sounder (CIRAS)
Spatial: ±48.3°, 13.5 km
Spectral: 1000 Channels, 4.1-5.4 µm
SWAP: 6U, 20 kg, 30 W, 1 Mbps

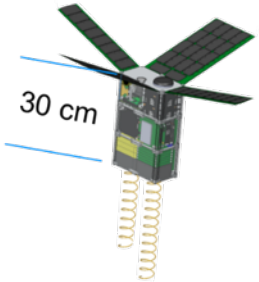




Microwave Atmospheric Sounder on CubeSat (MASC)
Spatial: ±45°, 15 km (183) – 20 km (118)
Spectral: 8 Channels: 118-183 GHz
SWAP: <0.01 m³, 3 kg, 7 W, 10 kbps



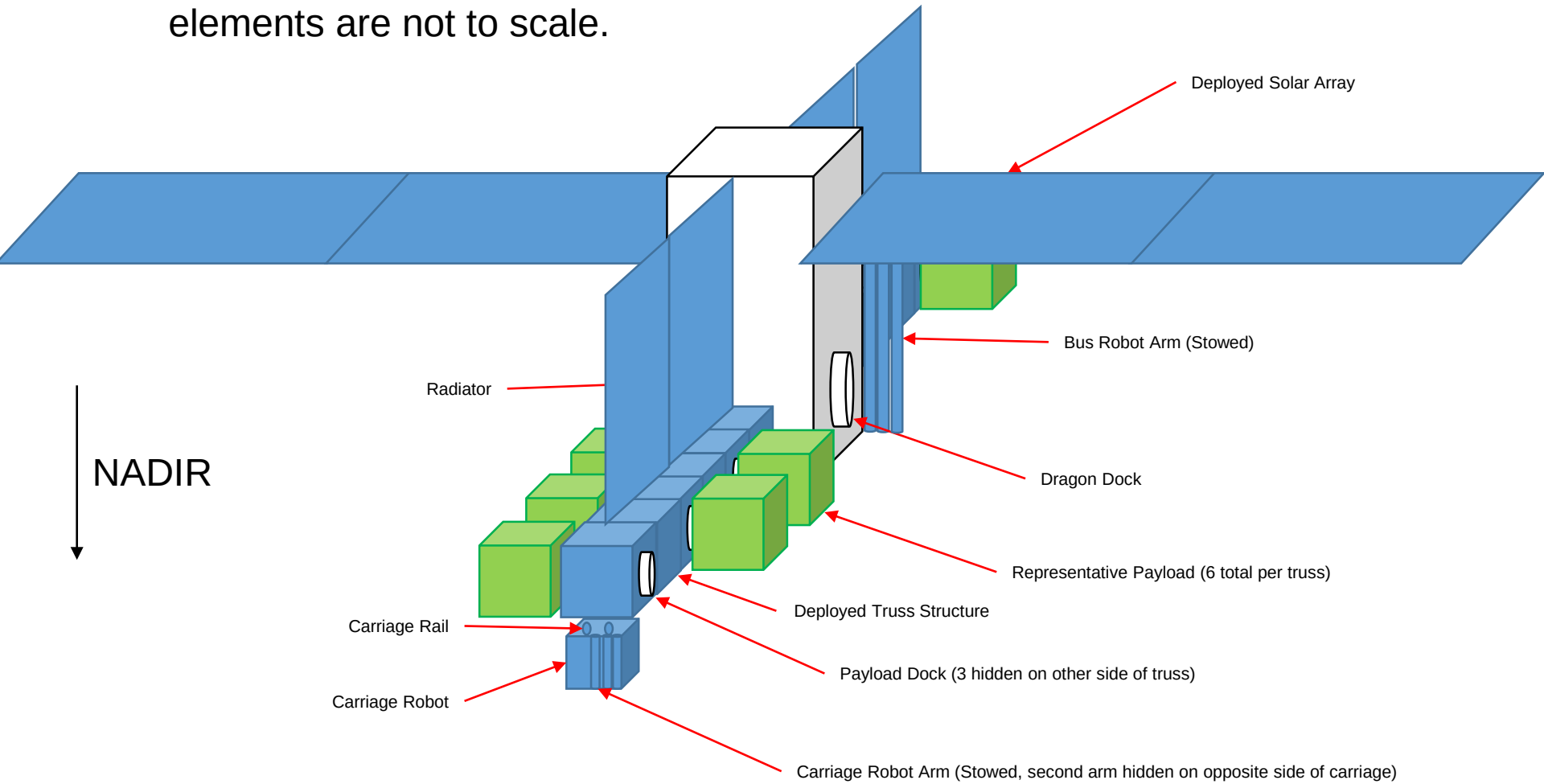
RainCube: Precipitation Profiler
Spatial: 5 km (Horiz) x 250m (Vert)
Spectral: 35.6 GHz
SWAP: 6U, 20 kg, 30 W, <1 Mbps



Total Identified Here: 72kg, 112W, 8 Mbps

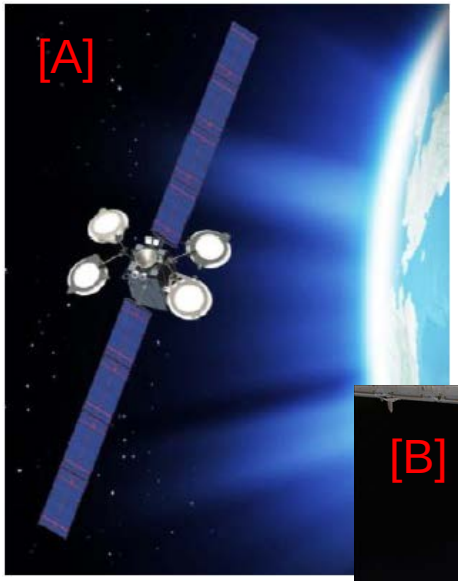
New Observatory Consideration

The below image defines the general configuration, however individual elements are not to scale.



Mission Architecture and Assumptions

- Mission Architecture
  - "GEO Bird" (Boeing 702 Equivalent) "Central Bus" [A]
    - Solar Panels oriented Port & Starboard
  - CanadaArm2 equivalent "docking arm" [B]
    - Falcon 9 Dragon capsules dock on nadir deck of "Central Bus"
  - 2 Instrument mounting trusses oriented in Ram and Wake directions of "central bus", with 6 Payload Interface Unit mounting locations each (functionally equivalent to Japanese Experiment Module (JEM) Exposed Facility (EF) [C]
  - 2 Remote Manipulator Systems (1 per Truss extension) for installation and removal of Instruments (each equivalent to Japanese Experiment Module Remote Manipulator System (JEMRMS)) [D]
- Assumptions
  - Each instrument is EOS/Landsat Class
    - ~175 kg, 250 W, 30 Mbps each instrument
    - >1X1X1m in volume
  - Falcon 9 launches at ~1/10 current cost



SpaceX

Jet Propulsion Laboratory
California Institute of Technology