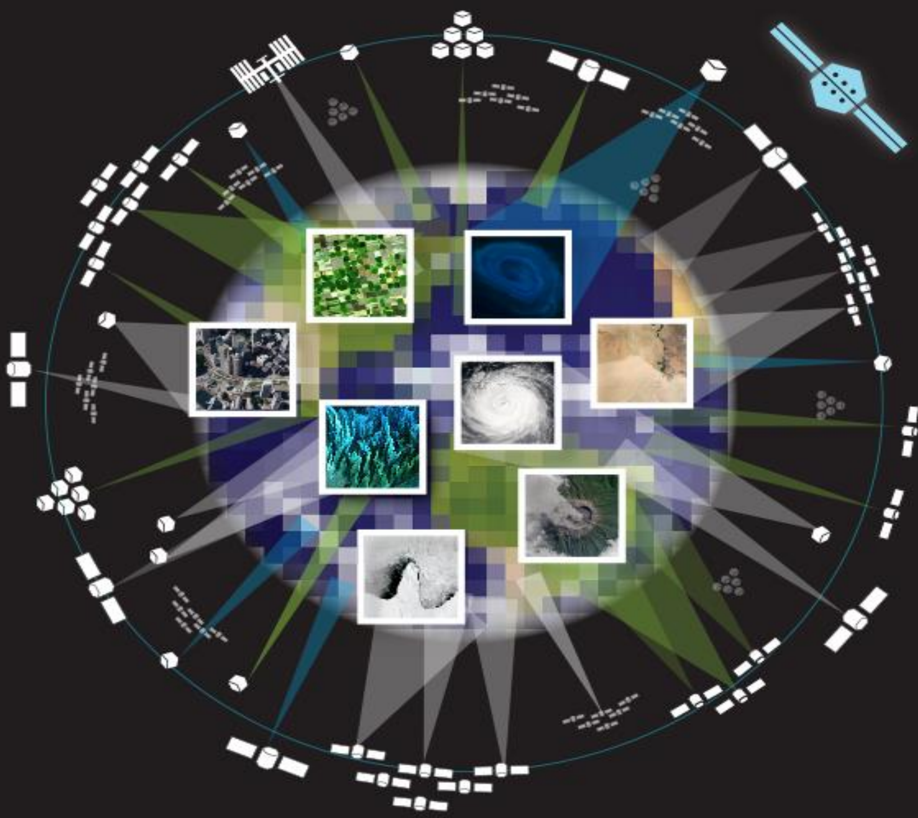
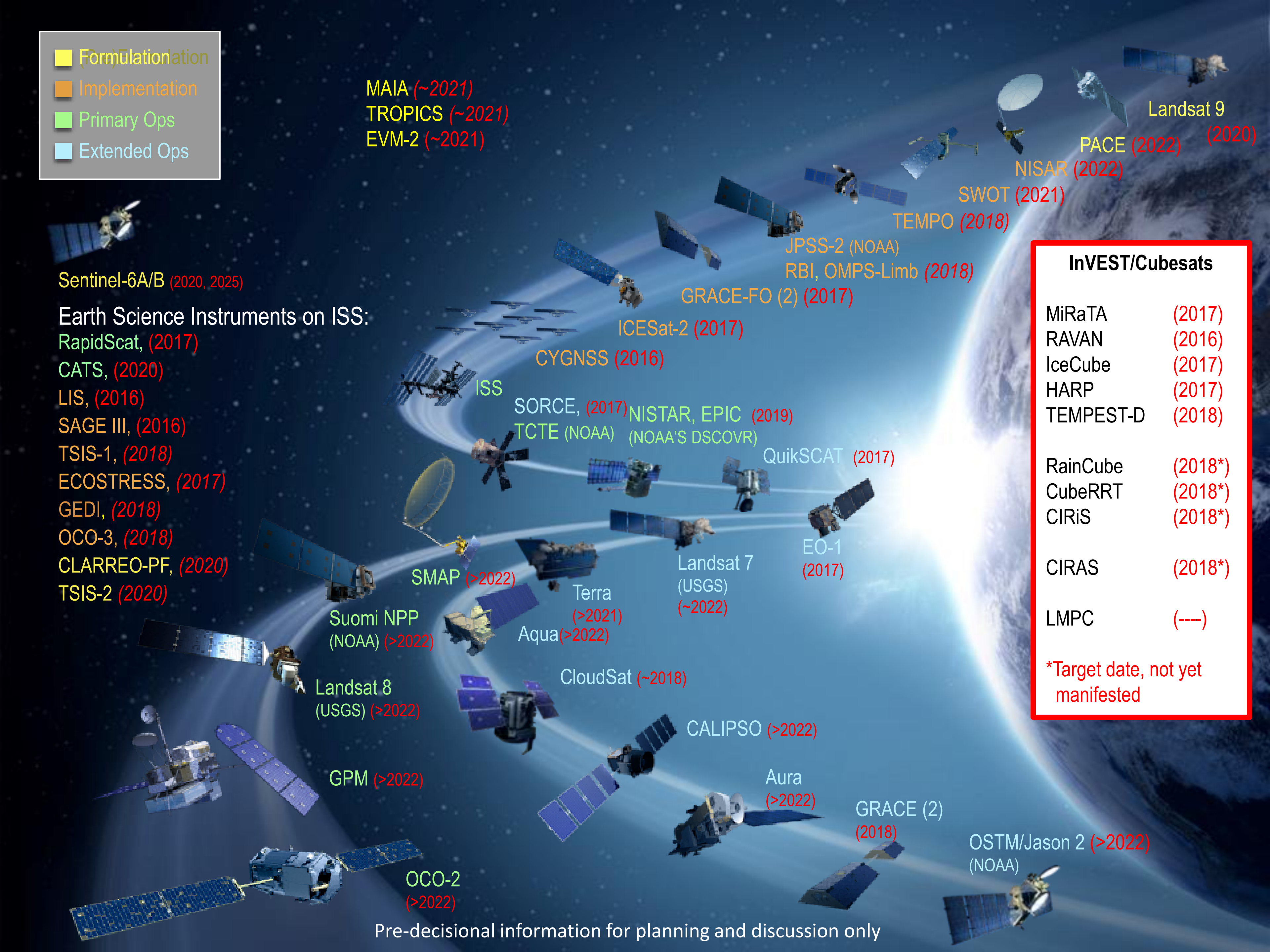
Enabling A Market Place For Science and Application



WHAT ARE THE OPPORTUNITIES?
WHAT ARE THE CHALLENGES?

Jason Hyon
November 9, 2017

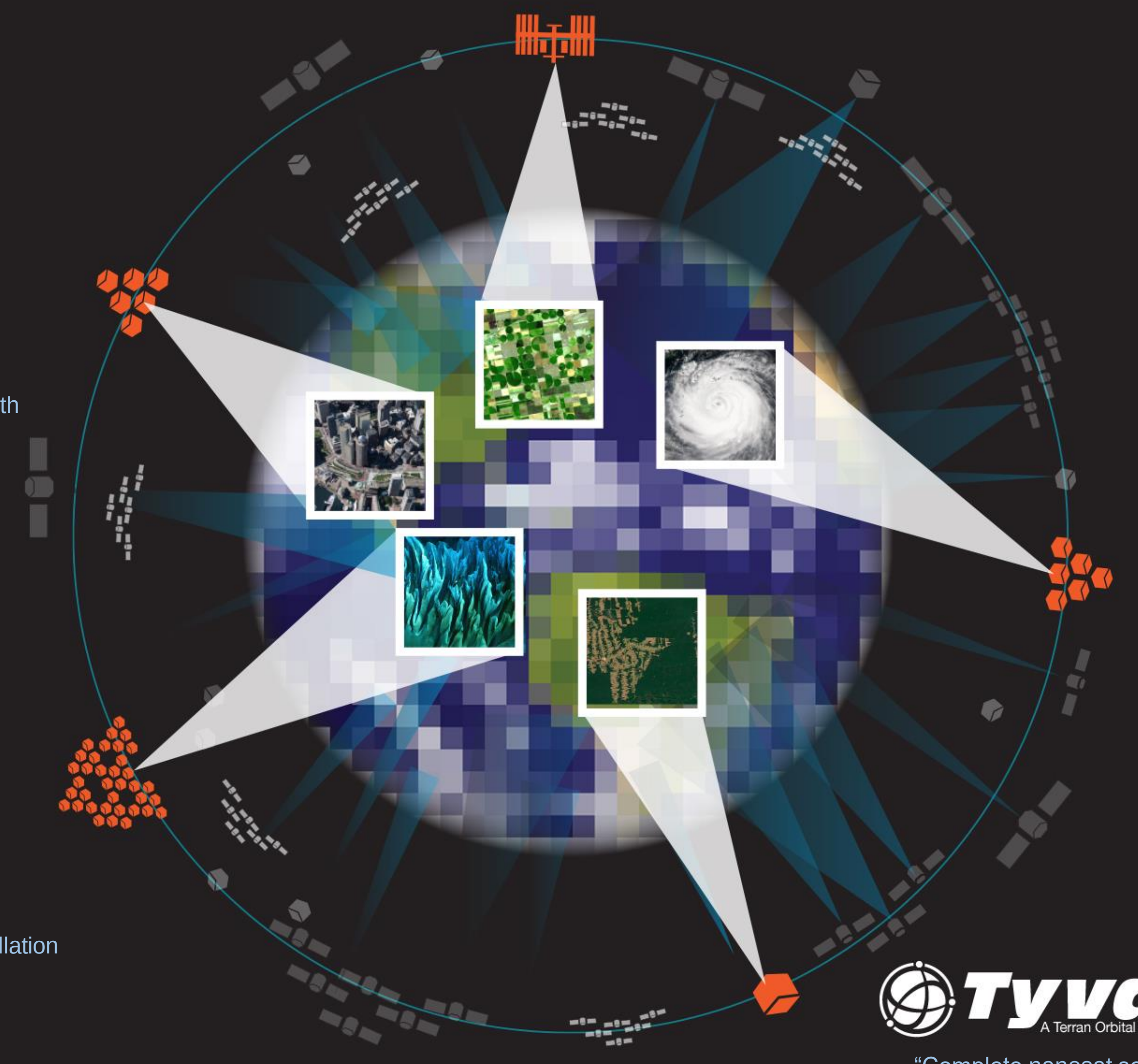
Chief Technologist, ESTD
Jet Propulsion Laboratory
California Institute of Technology


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

WHO IS JOINING THE FIELD?

TELEDYNE BROWN ENGINEERING, INC
A Teledyne Technologies Company

Camera platform on ISS for up to four digital-imaging instruments



Skybox Imaging

24-satellite constellation with high spatial and temporal resolution (including HD video)

GeoOptics

24 - satellite constellation for weather forecasting

PLANET LABS

100-satellite constellation for imaging

Tyvak A Terran Orbital Corporation

“Complete nanosat solution” (e.g. NASA-funded satellite rendezvous and docking)

Buzz Words Among Startups and Venture Capitalists (Not NASA)

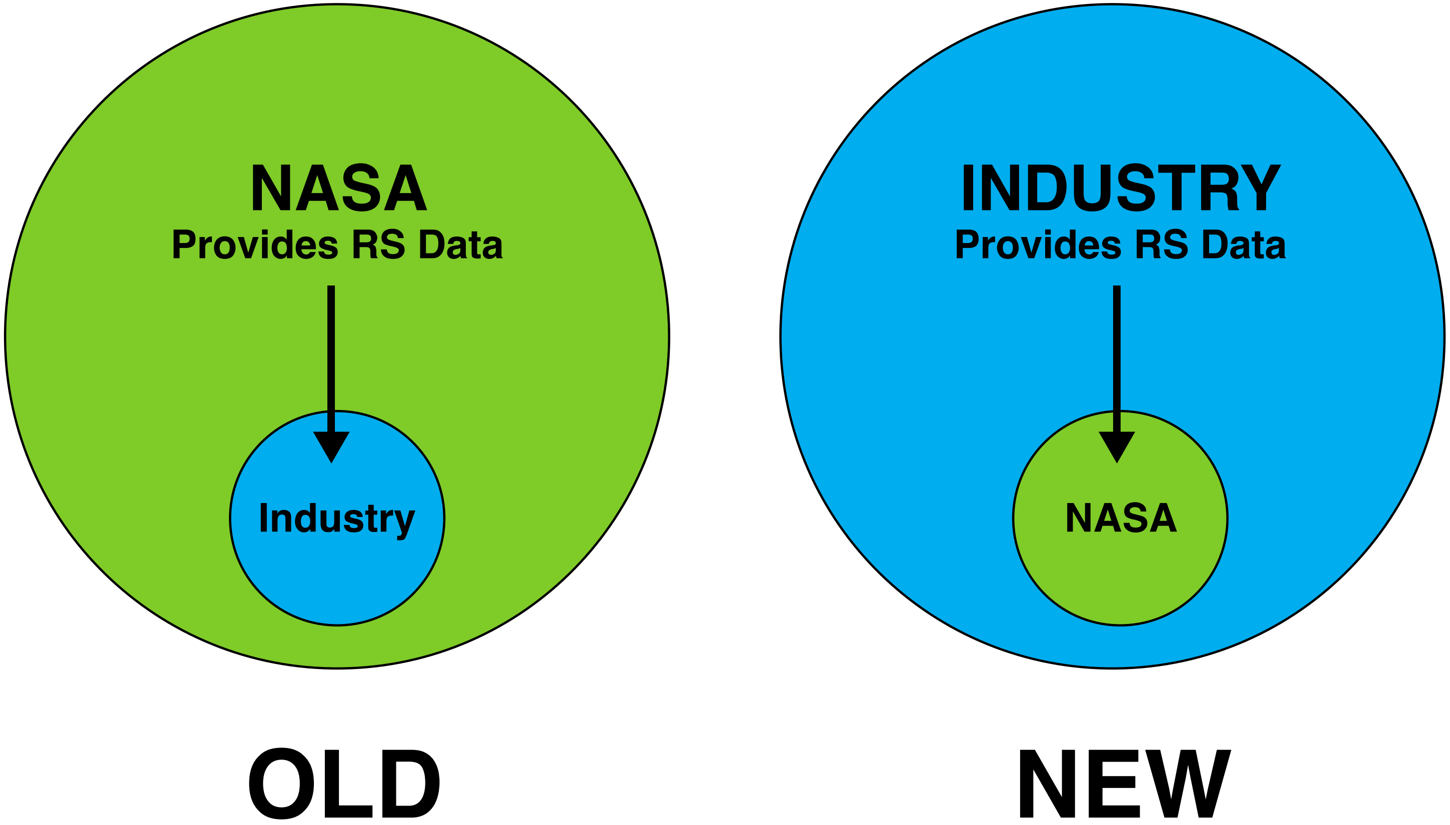
WHAT ARE THE TOP WAYS REMOTE SENSING IS BEING USED NOW?

1. Determining soil moisture content using active and passive sensors from space
2. Mapping with laser precision using Light Detection and Ranging technology
3. Catching tax-evaders red-handed by locating new construction and building alterations
4. Spinning the globe with mapping services like Google Earth, Bing Maps and OpenStreetMaps
5. Predicting retail earnings and market share by counting cars in parking lot
6. Snapping aerial photos for military surveillance using messenger pigeons in World War II
7. Charging higher insurance premiums in flood-prone areas using radar
8. Doing the detective work for fraudulent crop insurance claims
9. Searching for aircrafts and saving lives after fatal crashes
10. Detecting oil spills for marine life and environmental preservation

SOURCE: 100 EARTH SHATTERING REMOTE SENSING APPLICATIONS & USES
(http://gisgeography.com/100-earth-remote-sensing-applications-uses/)

REMOTE SENSING FOR NON TRADITIONAL INDUSTRY

Monsato, Land O' Lakes, Home Depot, Etc.`



Motivation

In the next decades, we must learn to

Better manage natural resources,

Improve agricultural productivity,

Increase the availability of clean drinking water,

Mitigate the effects of urbanization,

Conserve habitats and biodiversity.

In addition to serving the science community, to do so requires better understanding of how human use impacts the land and the natural ‘ecosystem services’ we need.

Information provided by people will open new science possibilities

For commercial use and citizen science, one can imagine that it can tie events with local businesses based on GIS data

Users will earn money based on their contribution

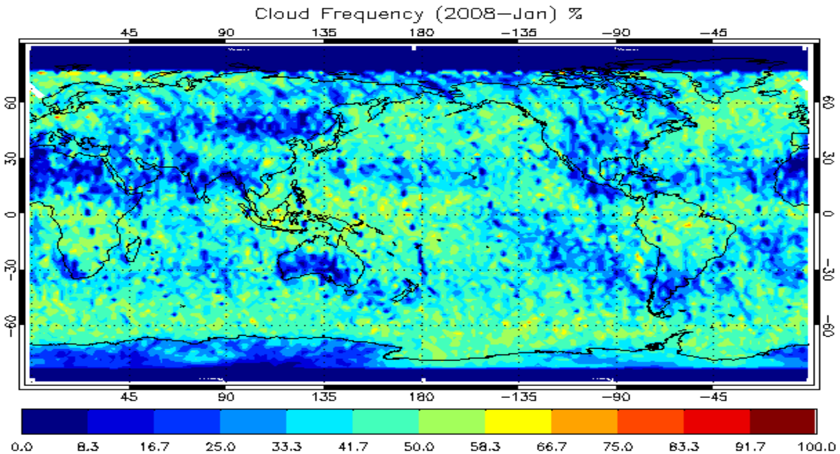
Money can be used for local shopping

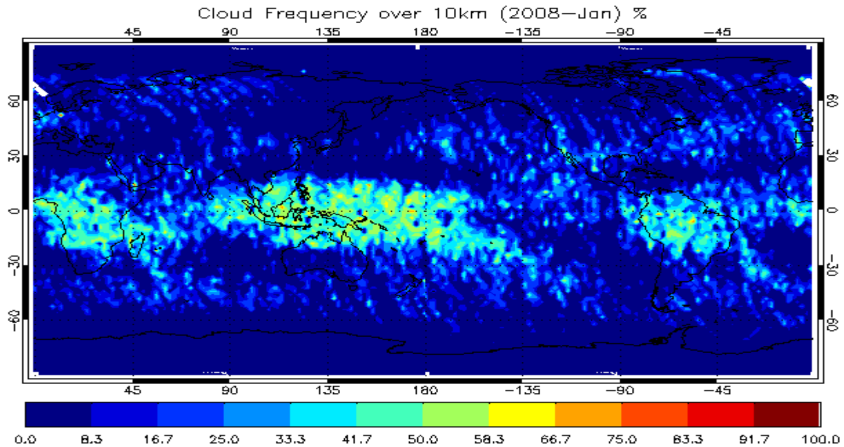
Remote Sensing Science Considerations for 2025

- Synergistic use of multi-variate observations – environmental prediction & earth system science
- Most science / decision-making value/return for investment – our ability to quantify or do relative comparison on this is poor.
- Practical concerns of observations will completely outweigh curiosity driven science; and science will be a means only to pragmatic and immediate societal benefits – smart city

Potential Science Achieved by Multivariate Data

- Vegetation 3-D Structure, Biomass, & Disturbance
  - Terrestrial carbon stocks & species habitat characterized
- Global cloud characterization and soil moisture
  - Routine probabilistic forecasts of precipitation, surface temperature, and soil moisture
  - Mean global cloud cover is 50 – 60% from Calypso/CloudSAT
- Earthquake monitoring (GPS network)
  - High temporal and spatial resolution of earthquake and volcanos
- Weather monitoring
  - air quality projection, and better imagery of snow/ice cover and severe weather phenomena like hurricanes and floods





Climate Continuity Measurements

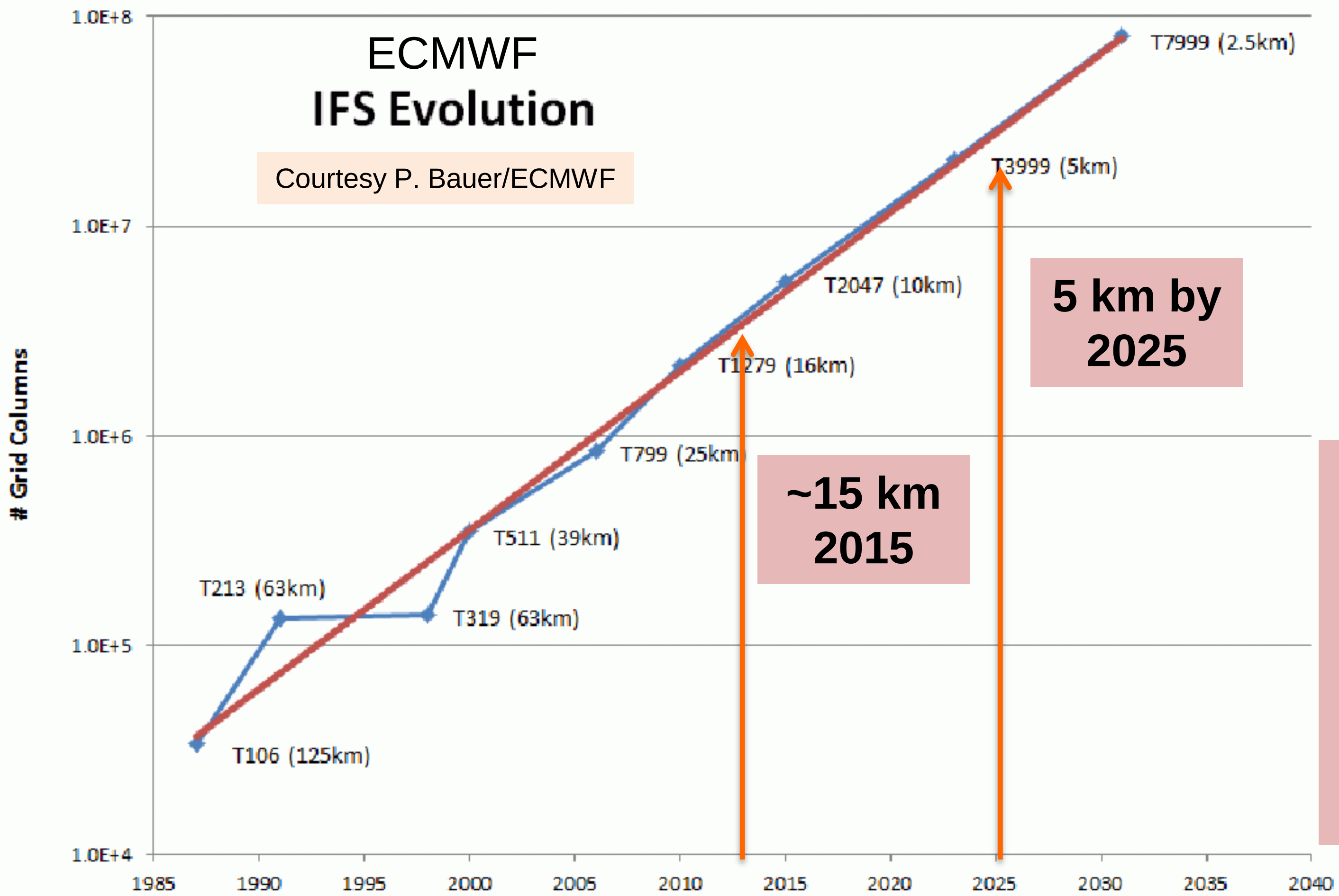
International Cooperation will have been or will nearly be established on a core set of climate continuity measurements (e.g. GEO, CEOS).

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:**[1] Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget. **Upper-air:**[2] Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance). **Composition:** Carbon dioxide, Methane, and other long-lived greenhouse gases[3], Ozone and Aerosol, supported by their precursors[4].
Oceanic	**Surface:**[5] Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.

- Surf & TOA Radiation Budget
- SST
- Column Water Vapor
- T(z), Q(z)
- Ocean Winds
- Sea Level Height
- Ozone
- CO_2 & Methane
- Aerosol
- Sea Level
- Ocean Color
- Gravity Anomalies / GRACE
- Bio Mass
- Soil Moisture
- Land Cover
- etc

Business – establishing benchmark, doing the same for less $ - OSSE capabilities key

Numerical Weather Prediction Grid Resolution

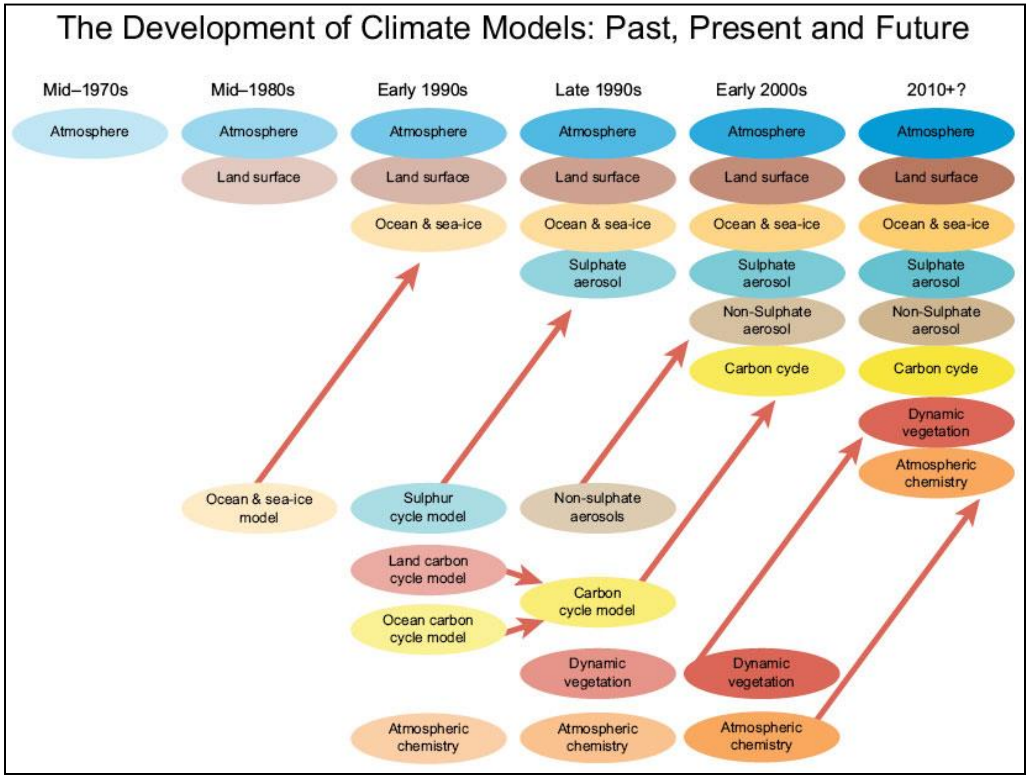


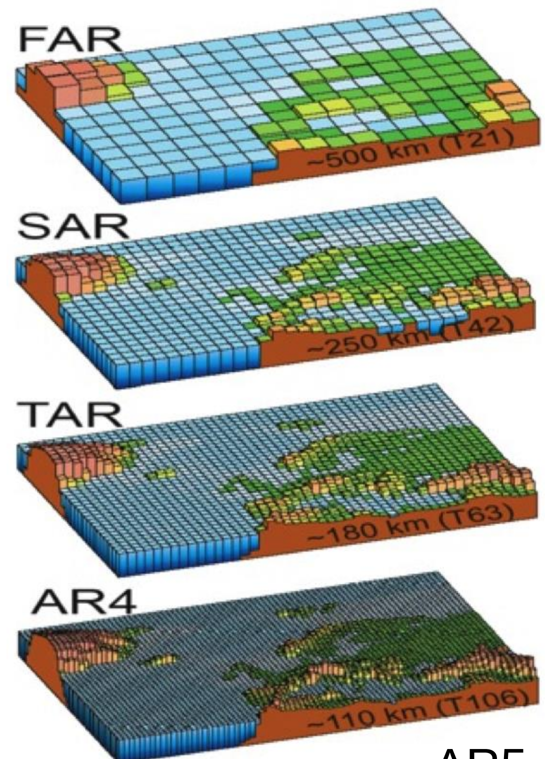
Global Numerical Weather Prediction (NWP) Models at **< 5km** Horizontal Grid Resolution

Forecast Expansions
- Longer Leads
- More Products
- More Sectors
- More of Earth Sys
- Better Accuracy
- Greater Reliance

Global Climate Modeling Grid Resolution

Continued development of "Earth System Models"

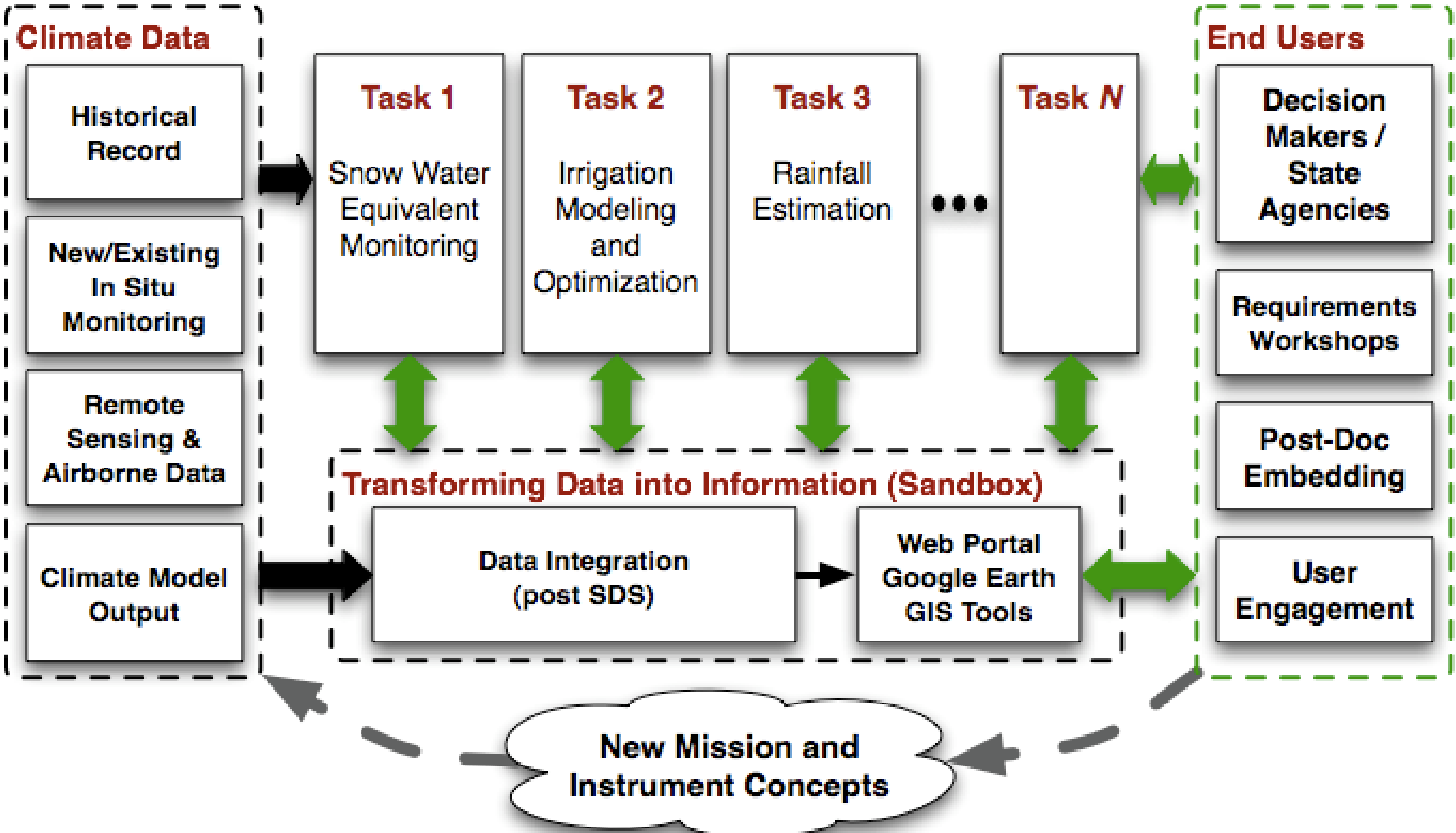




FAR	500km	1990
SAR	250km	1996
TAR	180km	2001
AR4	110km	2007
AR5	90km	2013
AR6	70km	2019
AR7	**50km**	**2025**

Earth System Science, Coupled Complexity and Need for Multi-variate Process Constraints

Water Supply and Management in California

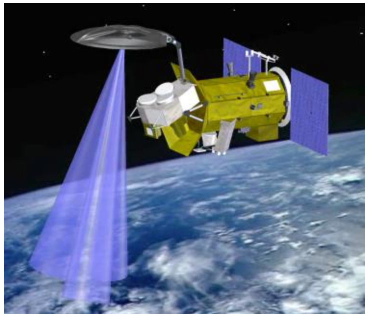


There are many use case scenarios developed by NASA and decision support agencies

Remote Sensing Market Vision
"*EarthNow*"

Enable every coordinate of global satellite imagery to hold local, grassroots knowledge about the geography, event, and people within it.

EarthNow links local knowledge and culture with scientific assessment by combining satellite-based remote sensing and mobile phone based data collection on a GIS framework



It is a people-centered approach to environmental stewardship and conservation along with time critical information based on events.

Search based on a GIS based location is a simple organizing principle to incentivize user contribution with monetary reward

It provides resources and knowledge near where you are and/or want to be

Citizen science, citizen stewardship

From Wikipedia to WikiCities and the emergence of citizen science, internet technologies have transformed our approach to knowledge gathering, offering *bottom-up* knowledge along side the top-down.

For example, users might:

Verify the automatic classifications of multispectral remote sensing imagery from a local group or individual perspective.

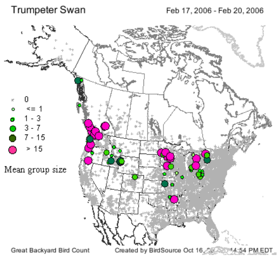
Contribute to questions posed by scientists and governments about the local reality of hot areas,

Annotate coordinate with text, photos, audio clips, etc. that tell the story of the location

Also, add events, aids, shopping, and personal interest on local scale

Precedent:

Photovoice



e-Bird

Open Platform

Components

Publically available LandSat imagery, MODIS, ASTER + future hyperspectral imager,

Data buy from Planet Labs, GeoEye, etc.

Model driven forecast and predictions,

Facebook Connect and Open Social Integration,

Annotate via Web, SMS, Twitter, Campaigner, Nokoscope,

Receive RSS, SMS push, Twitter, Flickr Stream, etc.

Location-aware via GPS, cell tower, provider service, geocoding,

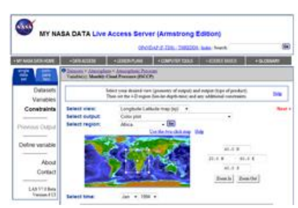
Access localized data and products from online markets/reviews (Amazon, Groupon, Yelp) through open Web Service API, and

ArcGIS backend.

Precedent:

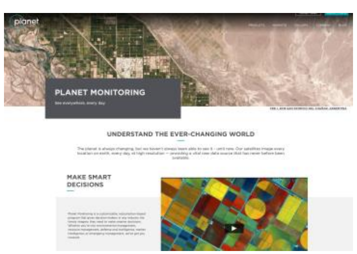
Ushahidi

Smart city

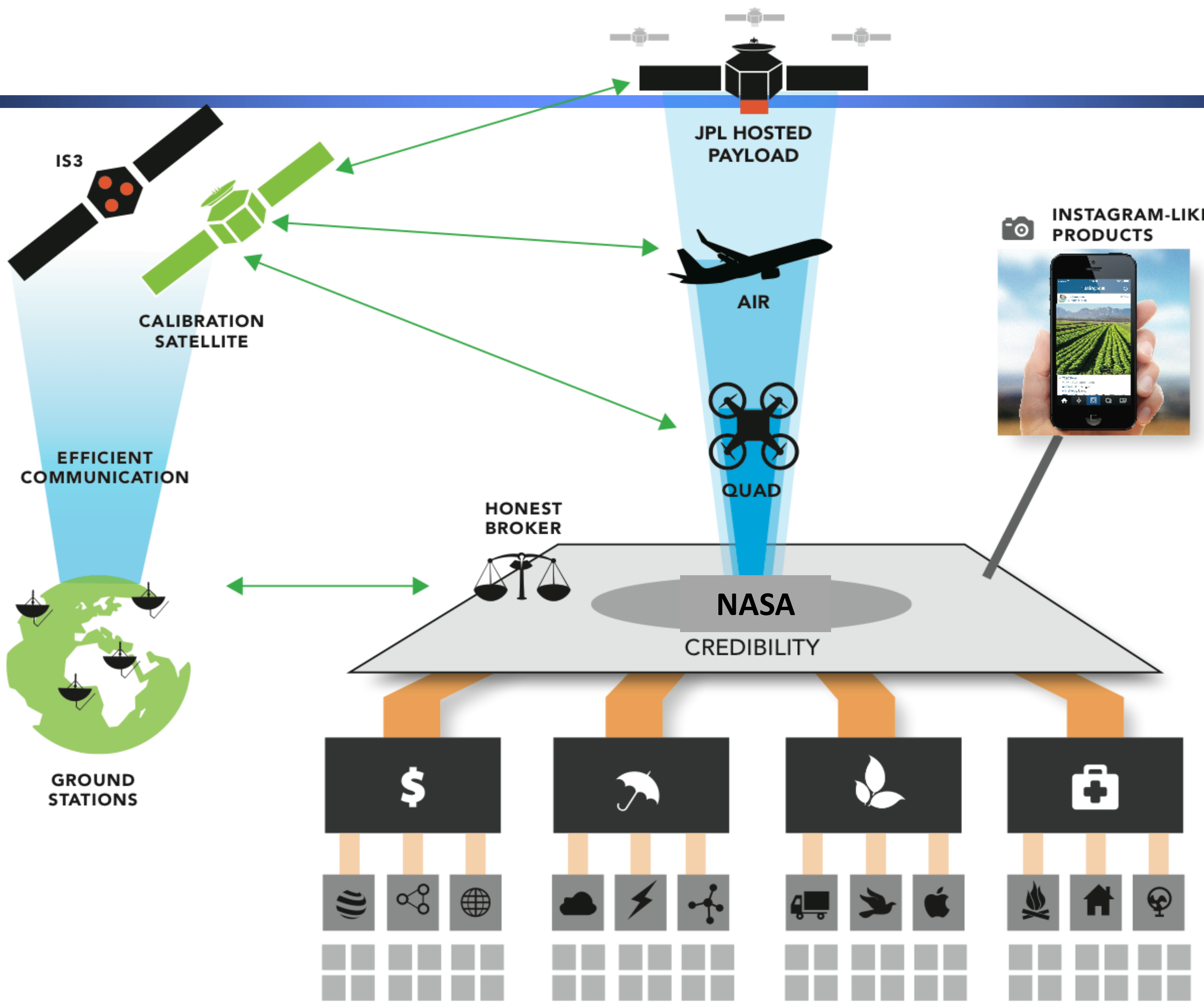


NASA DAAC

Citizen Science



Planet Labs


JPL HOSTED PAYLOAD
IS3
CALIBRATION SATELLITE
AIR
INSTAGRAM-LIKE PRODUCTS
EFFICIENT COMMUNICATION
QUAD
HONEST BROKER
NASA
CREDIBILITY
GROUND STATIONS

Space 2.0 or Earth Science 2.0

- Made up of Venture capitalists, startups, and aerospace
  - RS, telecomm, mining, and space manufacturing
- No new market demands for data
  - Absent on "ebay", commodity exchange, our scientists to understand data
  - Launch cost will not be lower due to higher demands
  - Led mostly by spacecraft/instrument driven startups – no data expertise
  - Much like 1999 era (GeoEye, Ikonos, etc) with cubesats
    - $1,500/m^2 -> $15/m^2 -> $1/m^2
- NASA is perceived as a gold standard for data verification
- No bubble unless there is demand for information products from RS data
  - Relying on government to sustain business will not survive
- We need a breakthrough in AI to provide relevant data for different use cases
  - *"people who used this data also look at that data"*