

# An Overview of NASA's Surface Deformation and Change Designated Observable Architecture Study

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# Background

- NASA is responding to the 2017 US National Academies of Sciences, Engineering, and Medicine Decadal Survey in a multifaceted set of studies, initiatives and programs
  - Near-term priorities: Architecture studies for 5 designated observables – surface deformation and change, mass change, aerosols, clouds and precipitation, and surface biology and geology
  - Mid-term: Explorer program of innovative lower cost science missions
  - Longer-term: Incubator program to develop technologies and measurement concepts
- For Designated Observables, NASA has commissioned multi-year studies to prepare for competed implementations
- This talk describes the goals, progress, and status of the Surface Deformation and Change Designated Observable Architecture Study

# Surface and Deformation Change (SDC) Designated Observable Study

## Goal

Define an affordable synthetic aperture radar-based system or systems that would meet the recommendations of the 2017 US National Academies of Sciences, Engineering, and Medicine Decadal Survey to address fundamental scientific questions about the nature of hazards, disasters, landscape change, and serve applications communities.

*Keep non-geodetic measurements and downstream sciences in the trade space.*

When: October 2018 – October 2023 (5 Years)

Approach: The study will be conducted in 4 phases:

- Scoping the architectural trade space;
- Assessing the science and applications value of each identified architecture;
- Down-selecting to one or two final candidates and performing detailed assessments;
- Final reporting and preparation for mission formulation.

Engagement: national expertise in Earth Science research, applications, technology, mission formulation and implementation, as well as the international community, government, academia, and industry.

# 2017 Decadal Survey Surface Deformation and Change Designated Observable – Capabilities for Different Science Objectives

Objective	Spatial resolution	Precision	Time Series		
			Frequency	Duration	
S-1a	<b>10 m</b>	<b>10 mm</b>	<b>event-dependent</b>		
S-1b	<b>10 m</b>	<b>10 mm</b>	<b>12 days</b>	<b>10+ yr</b>	
S-1c	50 m	1 mm/yr	< seasonal		
S-2a	<b>10 m</b>	<b>10 mm</b>	<b>event-dependent</b>		"hours to days"
S-2b	10 m	1 mm/yr	event-dependent		
S-2c	100 m	1 mm/yr	event-dependent	5+ yr	
S-3a	<b>100 m</b>	<b>10 mm/yr</b>	<b>&lt; seasonal</b>		
S-3b	<b>&lt;50 m</b>	<b>5–10 mm</b>	<b>weekly</b>	<b>10+ yr</b>	
S-4a	<b>&lt;5 m</b>	<b>5–10 mm</b>	<b>weekly</b>	<b>10+ yr</b>	
S-5a	100 m	10 mm			
S-6a	5 m	10 mm	weekly		
S-6b	5 m	3 mm/yr	weekly		<b><i>Most Important in bold</i></b>
S-7a	5 m	10 mm	weekly		

- Explicit: event dependent objectives are in the “most important” category, and entail sub-weekly sampling
- Explicit: \$500M cost to NASA (Phase A-D)
- Implicit: Measurements can be made anywhere, at any time

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

# SDC Architecture Study Elements

- Architecture is more than just the flight segment design
  - Mission concepts
  - Projected costs
  - Science return
  - Partnership possibilities
  - Commercial data buys
- Open to developing commercial SAR sector
- Open to international partnerships that can be secured before study completion
- Cost constrained
- Involvement of multiple NASA centers
- Community openness

# NASA Center SDC Participants

JPL - Jet Propulsion Laboratory (Lead)

- Radar mission capabilities and design

ARC - Ames Research Center

- Small satellite and constellation design

GSFC - Goddard Space Flight Center

- Candidate architecture design

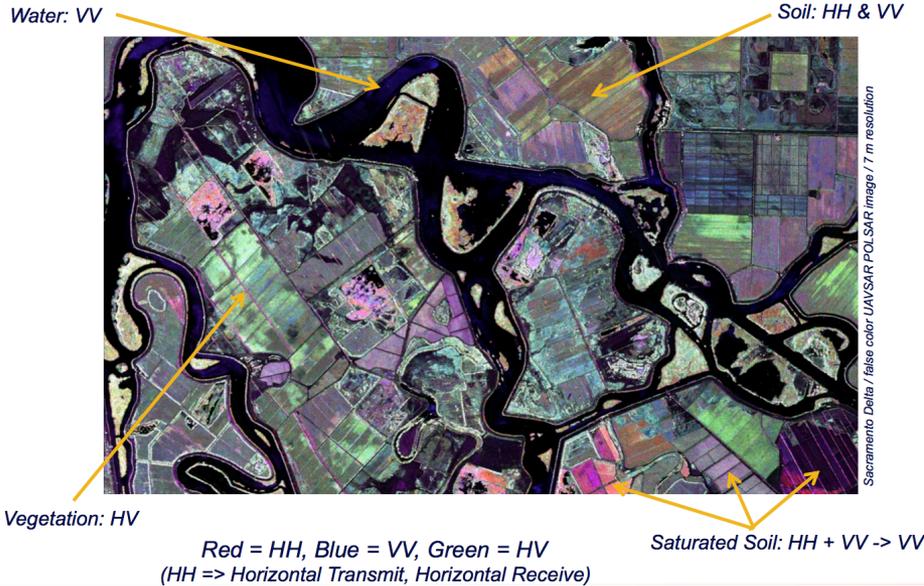
LaRC - Langley Research Center

- Mission architecture studies/cost estimation

MSFC - Marshall Space Flight Center

- Research and applications

# Versatility of SAR for Studying Earth Change

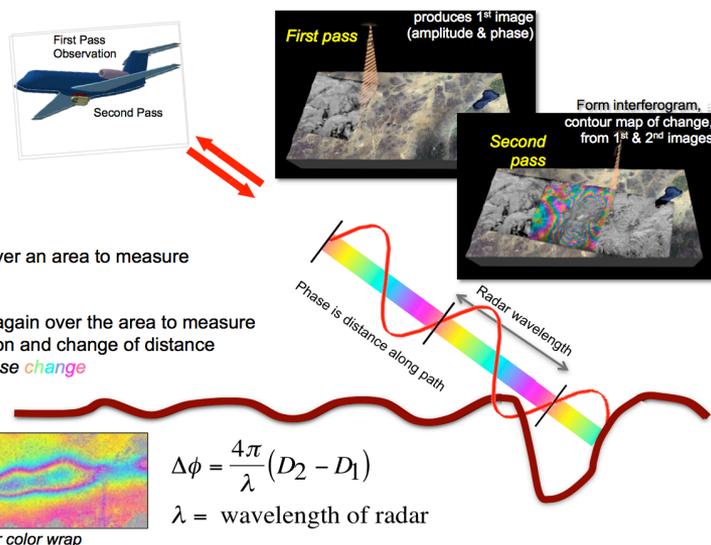


## Polarimetric SAR

Use of polarization to determine surface properties

### Applications:

- Flood extent (w/ & w/o vegetation)
- Land loss/gain
- Coastal bathymetry
- Biomass
- Vegetation type, status
- Pollution & pollution impact (water, coastal land)
- Water flow in some deltaic islands



## Interferometric SAR

Use of phase change to determine surface displacement

### Applications:

- Geophysical modeling
- Subsidence due to fluid withdrawal
- Inundation (w/vegetation)
- Change in flood extent
- Water flow through wetlands



# NASA SAR Program Elements

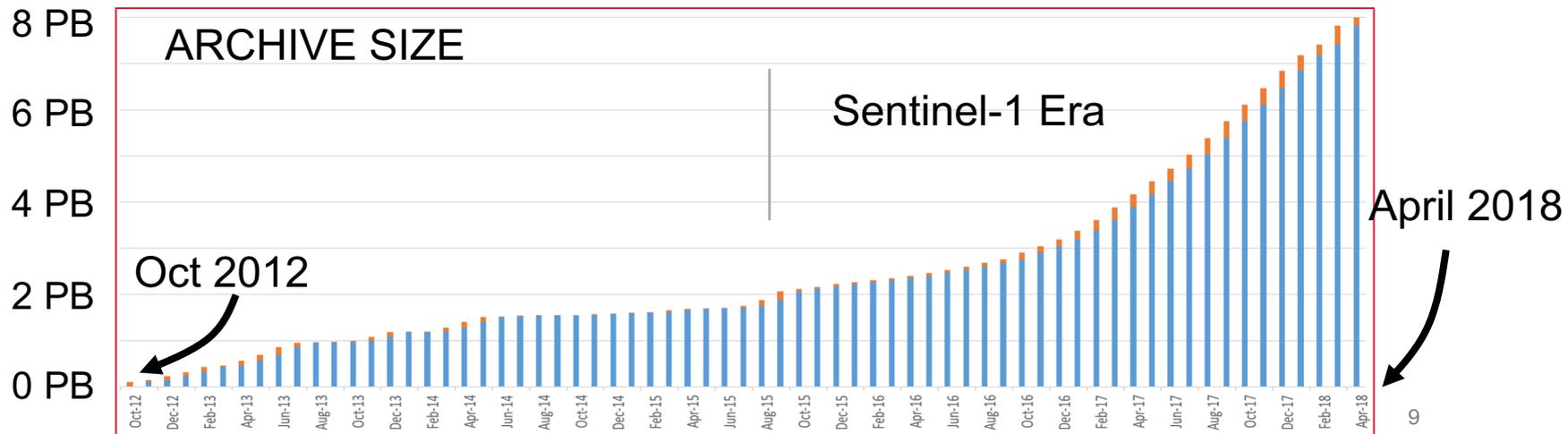
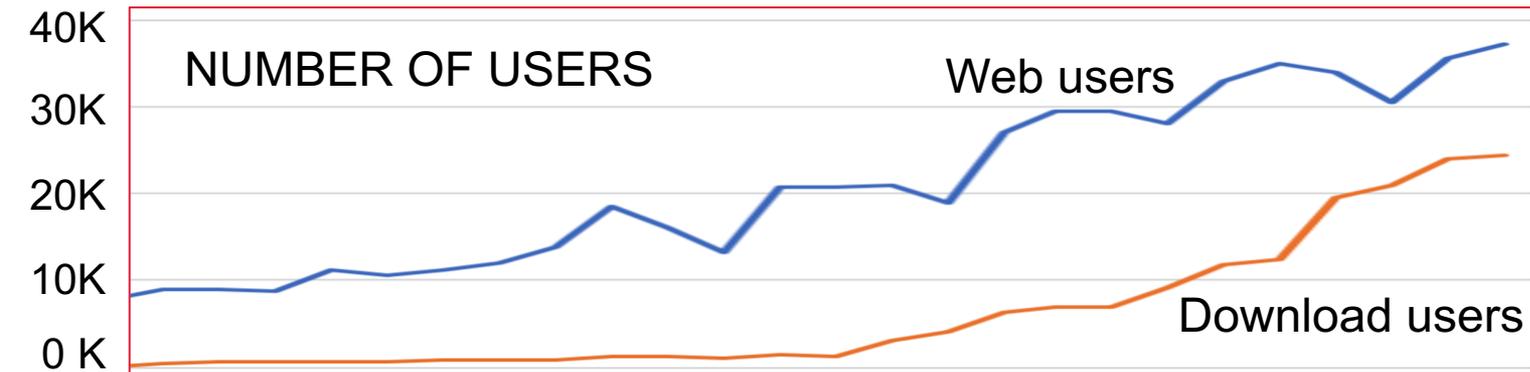
- Open public access archives to airborne and spaceborne SAR data (Seasat to present) through ASF DAAC
- UAVSAR Reconfigurable Imaging Radar Testbed for Sub-orbital Science
- NASA-ISRO Synthetic Aperture Radar (NISAR) Mission
- Competed proposals open to NASA centers and academia
  - Science exploiting SAR/InSAR
  - Space radar technologies
  - Software and algorithm development
  - Computational and cloud technologies
- New program element: 2017 Decadal Survey Designated Observables associated with SAR/InSAR measurements



# Alaska Satellite Facility

## NASA's SAR Archive

- UAVSAR, SeaSAT, SIR-C, AIRMOSS, SMAP, PALSAR-1 Americas, Sentinel-1A/B, ERS, JERS, RADARSAT-1
- Future home of NISAR data archive



# NASA-ISRO SAR (NISAR) Mission



Jet Propulsion Laboratory  
California Institute of Technology

## Solid Earth, Ecosystems, Cryosphere Science and Applications Mission

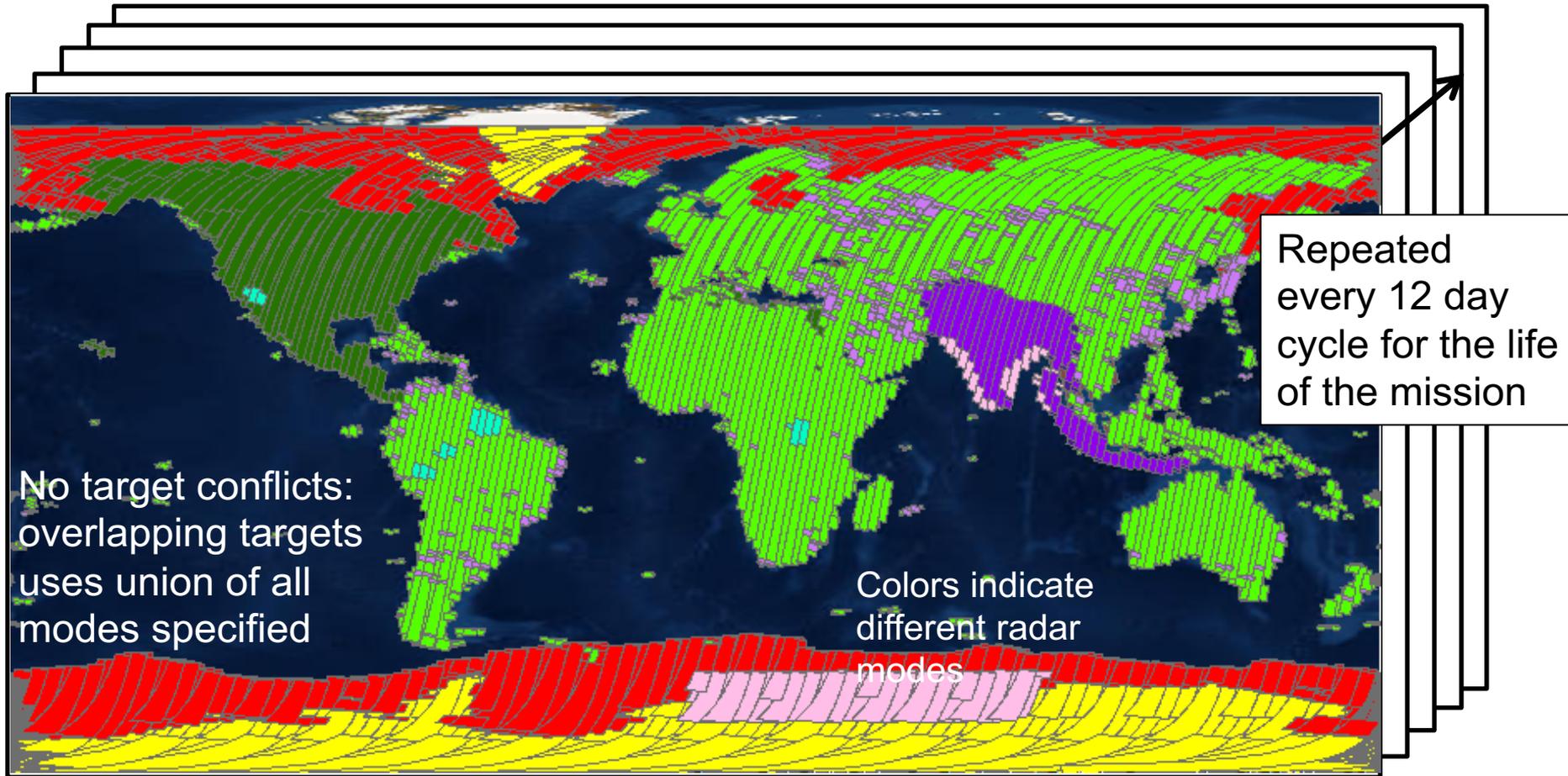
NISAR Characteristic:	Enables:
<i>L-band (24 cm wavelength)</i>	<i>Low temporal decorrelation and foliage penetration</i>
<i>S-band (9 cm wavelength)</i>	<i>Sensitivity to lighter vegetation</i>
<i>SweepSAR technique with Imaging Swath &gt; 240 km</i>	<i>Global data collection</i>
<i>Polarimetry (Single/Dual/Quad)</i>	<i>Surface characterization and biomass estimation</i>
<i>12-day exact repeat</i>	<i>Rapid Sampling</i>
<i>3 – 10 meters mode-dependent SAR resolution</i>	<i>Small-scale observations</i>
<i>Pointing control &lt; 273 arcseconds</i>	<i>Deformation interferometry</i>
<i>Orbit control &lt; 500 meters</i>	<i>Deformation interferometry</i>
<i>L/S-band &gt; 50/10% observation duty cycle</i>	<i>Complete land/ice coverage</i>
<i>Left-only pointing (Left/Right capability)</i>	<i>Uninterrupted time-series Rely on Sentinel-1 for Arctic</i>



Planned Launch: January 2022



# NISAR Systematic Observations



No target conflicts:  
overlapping targets  
uses union of all  
modes specified

Colors indicate  
different radar  
modes

Repeated  
every 12 day  
cycle for the life  
of the mission

Persistent updated measurements of Earth  
41 Tbits / day total L+S band science data downlink  
120 Tbytes / day total L+S band L0-L2 data products

J. Doubleday  
P. Sharma, JPL

# Data Processing and Access Moving to the Cloud



- Cloud Processing and distribution allows scalability and localization with users
- On-demand processing allows users to satisfy their needs without high-capability computing and networks.
- Prototyped with ARIA/GRFN Cloud Processing System

### Selection of Data

type: ? 10 count ↓ OR range

SI-W\_SLC x

slc (302)

1 - 10 of 302 next » Trigger Rules On-Demand

dataset: ? 10 count ↓ OR range

S1-W\_SLC (302)

platform: ? 10 count ↓ OR range

Sentinel-1A (291)  
Sentinel-1B (11)

dataset version: ? 10 count ↓ OR range

v1.1 (302)

+ start date

+ stop date

temporal span (days)

country: ? 10 count ↓ OR range

United States (302)

region: ? 10 count ↓ OR range

California (302)  
Nevada (53)

### On-Demand (Process Results)

action parameters

Tag: e.g. south\_napa\_EQ

Condition: {  
 "filtered": {  
 "query": {  
 "bool": {  
 "must": {

Action: Sentinel-1 Interferogram Product [release

Queue: grfn-job\_worker-large

Priority: 0

hverts-in-scrifn-s1-ifg:release-20170321 param

### On-Demand (Process Results)

hysds-io-sciflo-s1-ifg:release-20170321 param

project: project

singlesceneOnly: singlesceneOnly

recentAsMaster: recentAsMaster

temporalBaseline: temporalBaseline

query\_pairs: query\_pairs

filter\_results: filter\_results

dataset: ? 10 count ↓ OR range

S1-IFG (6)

platform: ? 10 count ↓ OR range

Sentinel-1A (6)

dataset version: ? 10 count ↓ OR range

v1.1 (6)

start date

stop date

temporal span (days)

country: ? 10 count ↓ OR range

United States (6)

region: ? 10 count ↓ OR range

California (6)  
Nevada (2)

subregion: ? 10 count ↓ OR range

Santa Clara County (3)  
Washoe County (2)

### On-demand Products Generated on and Distributed from Cloud

polygons:

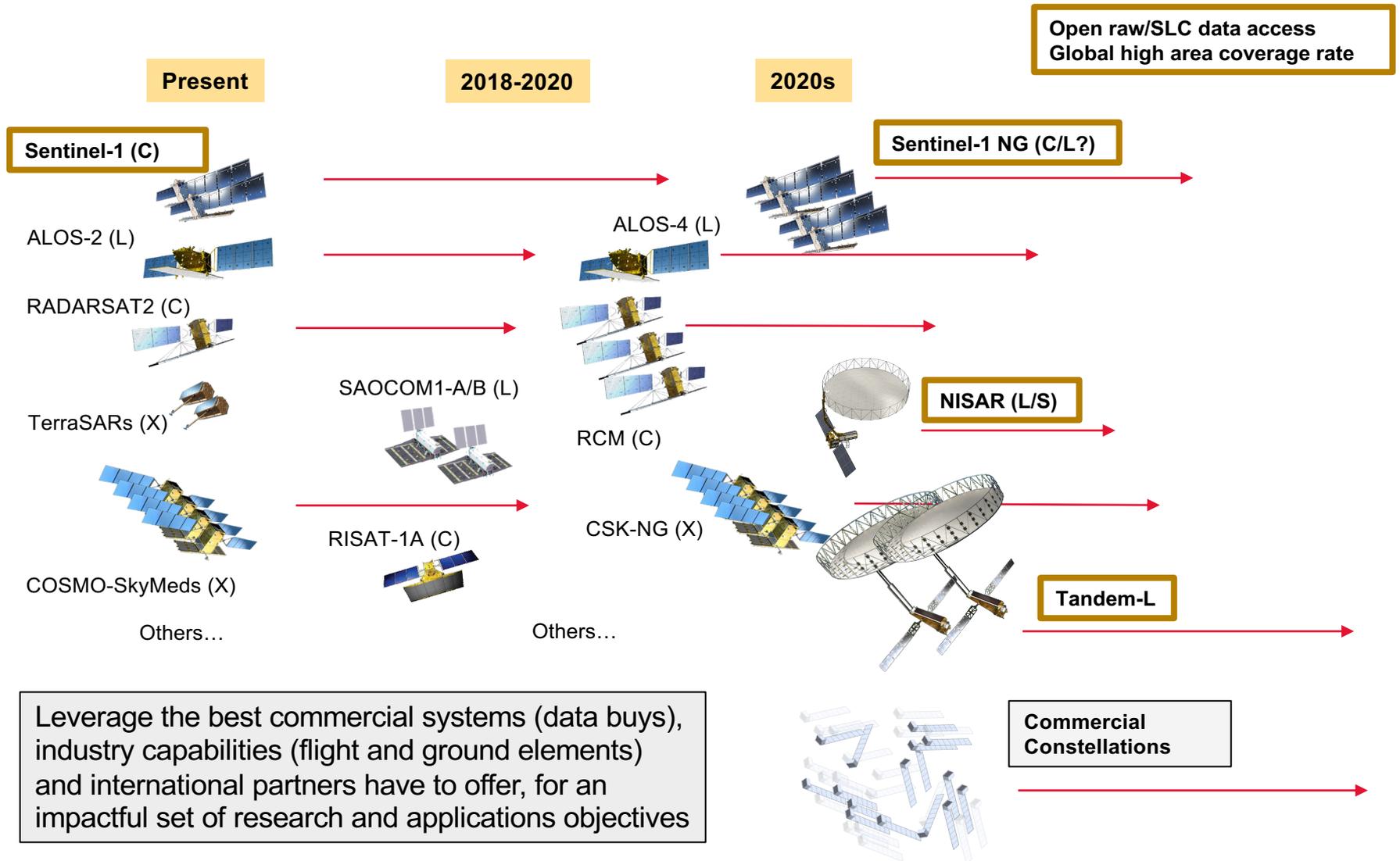


# NASA SAR Program

## History of Collaboration

- DLR and ASI:
  - Shuttle Imaging Radar – C instrument
  - SRTM instrument
- CSA: RADARSAT-1 launch and data downlink
- JAXA:
  - JERS cal/val joint activity
  - ALOS PALSAR-1 downlink/ground segment support
- ESA:
  - ERS downlink and archive distribution
  - Sentinel-1 distribution/archive
  - BIOMASS engineering support
- ISRO: NISAR joint mission

# Study Goals: SDC architecture in the dynamic context of SAR Systems used for geodetic imaging



# Options for Realizing the Decadal Survey beyond NISAR

Given \$500M (US contribution) development cap, partnerships and/or disruptive approaches are needed

- Sentinel-1 and potentially Tandem-L as backbone of international framework – Supplement with other SAR data
  - NASA comparable capability: NISAR-Follow On; NISAR-Lite; Small-SAR multi-use constellation
  - Other International SAR data as usual (e.g. PI studies)
  - Commercial data buys as appropriate
- Stand-alone geodetic constellation
  - Tailored for low cost and geodetic performance
    - Contextual imagery supplied by other systems
    - Phase suitable for science using displacement measurements
    - Less emphasis on radiometry
  - Sufficiently low cost to fit programmatically with improved characteristics\*
- Common radar architecture for international constellations
  - Whereby each international civil or commercial launch is a coordinated contributor to a larger observing strategy



\* For example, improved vector diversity, resilience to failures, upgrade path

# Constellation Trade Example

NISAR

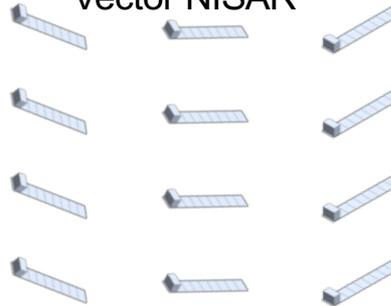


- 12 m reflector
- 2 m L+S-band feed
- **240 km SweepSAR Swath**
- 12 day repeat
- L-band Global
- S-band 10% duty
- Imaging
- Interferometry
- Polarimetry
- NES0 < -25 dB

\*and as a bonus: Possible “game-changing” atmospheric mitigation

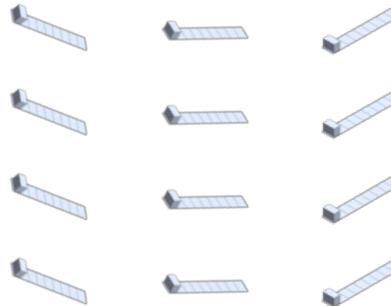
Geodetic Constellation 1

Vector NISAR\*



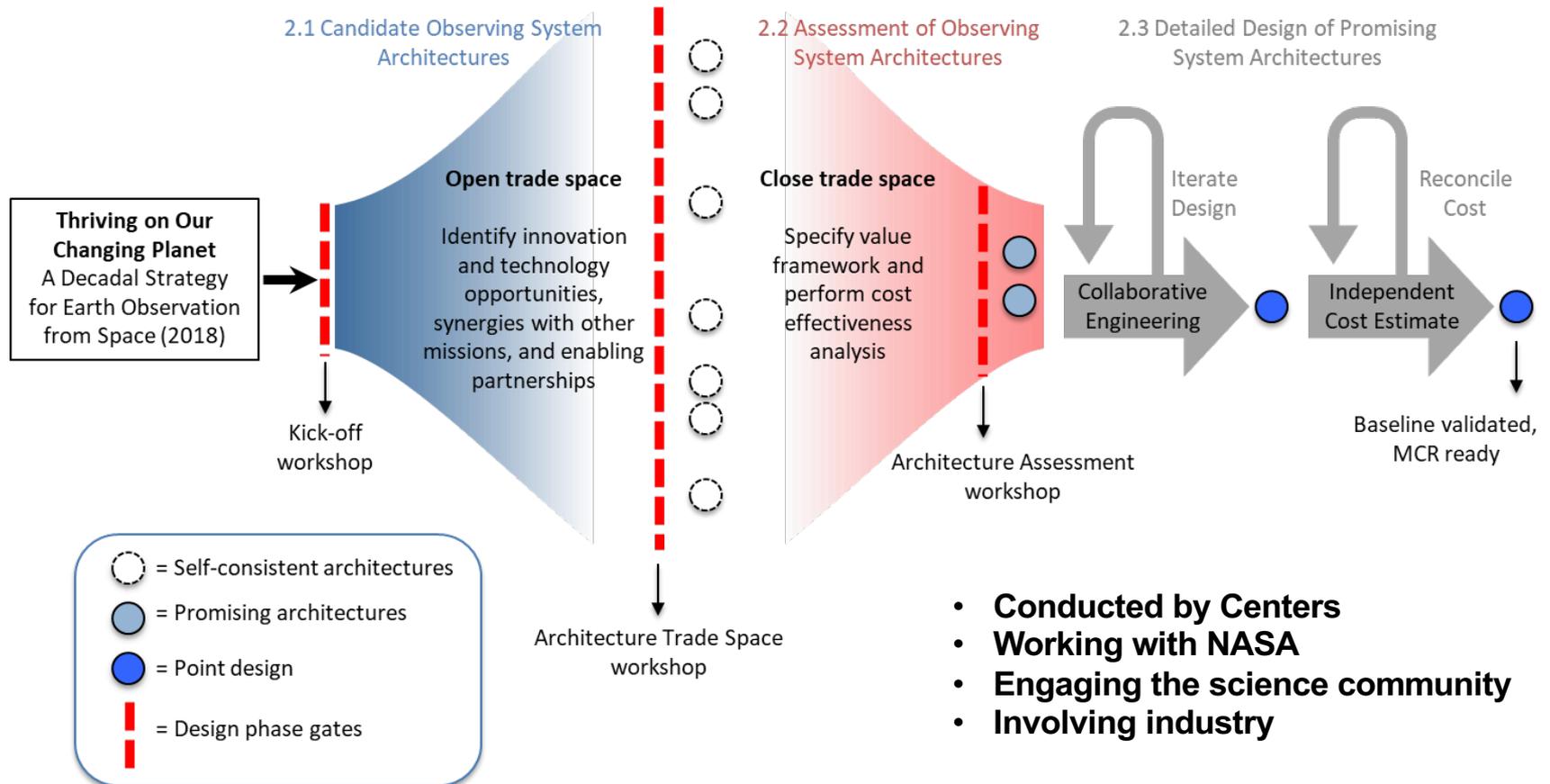
Geodetic Constellation 2

Vector 3X NISAR\*



- **60 km StripSAR Swath per satellite**
- S-band Global
- Interferometry
- NES0 < -12 dB
- Three satellites co-flying with fixed vector pointing offsets
- 12 satellites gives **12-day** max revisit
- **240 km ScanSAR Swath per satellite**
- S-band Global
- Interferometry
- NES0 < -12 dB
- Three satellites co-flying with fixed vector pointing offsets
- 12 satellites gives **3-day** max revisit

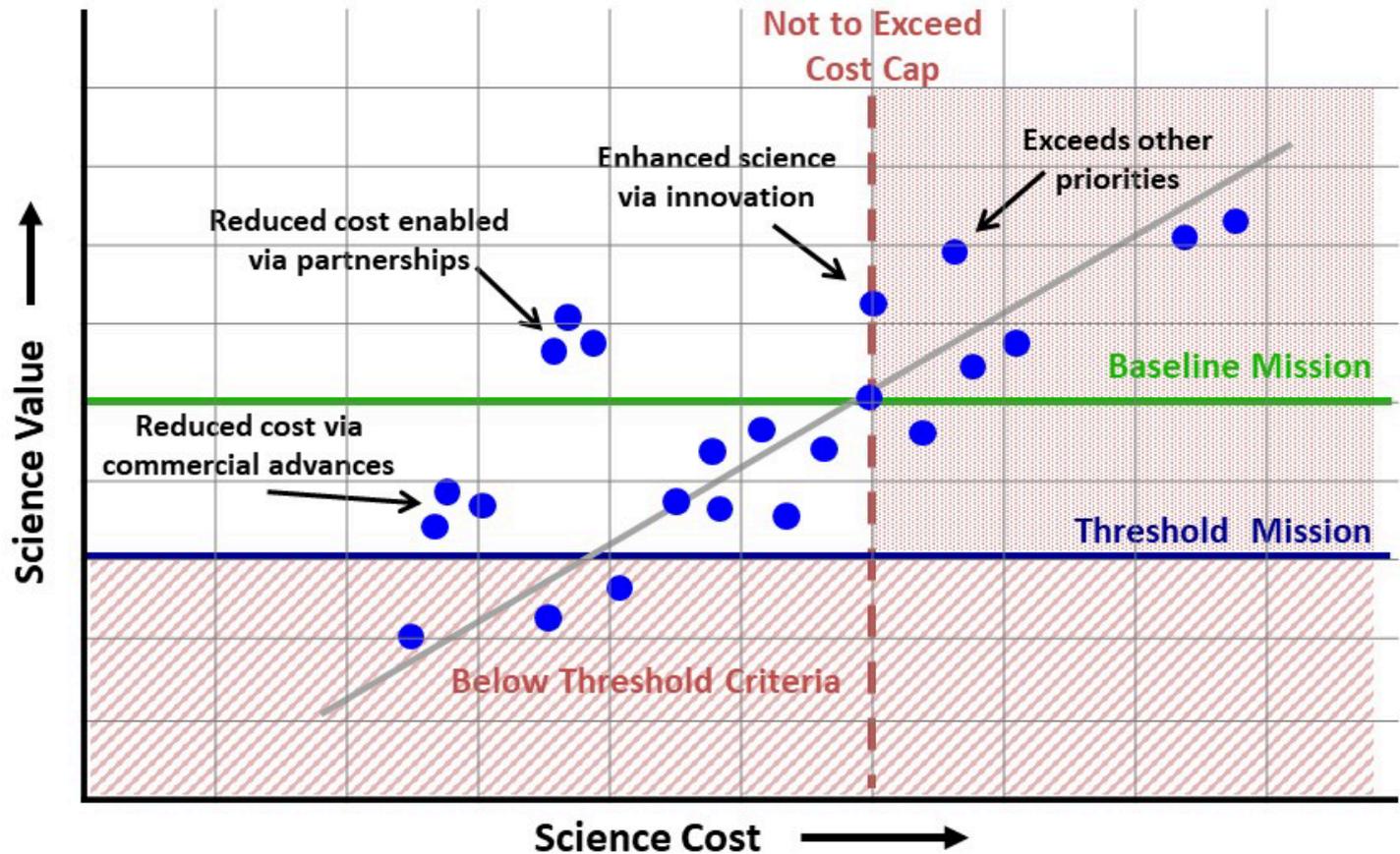
# SDC Study Approach



- **Conducted by Centers**
- **Working with NASA**
- **Engaging the science community**
- **Involving industry**

# Assessing Architectures through a Science Value Framework

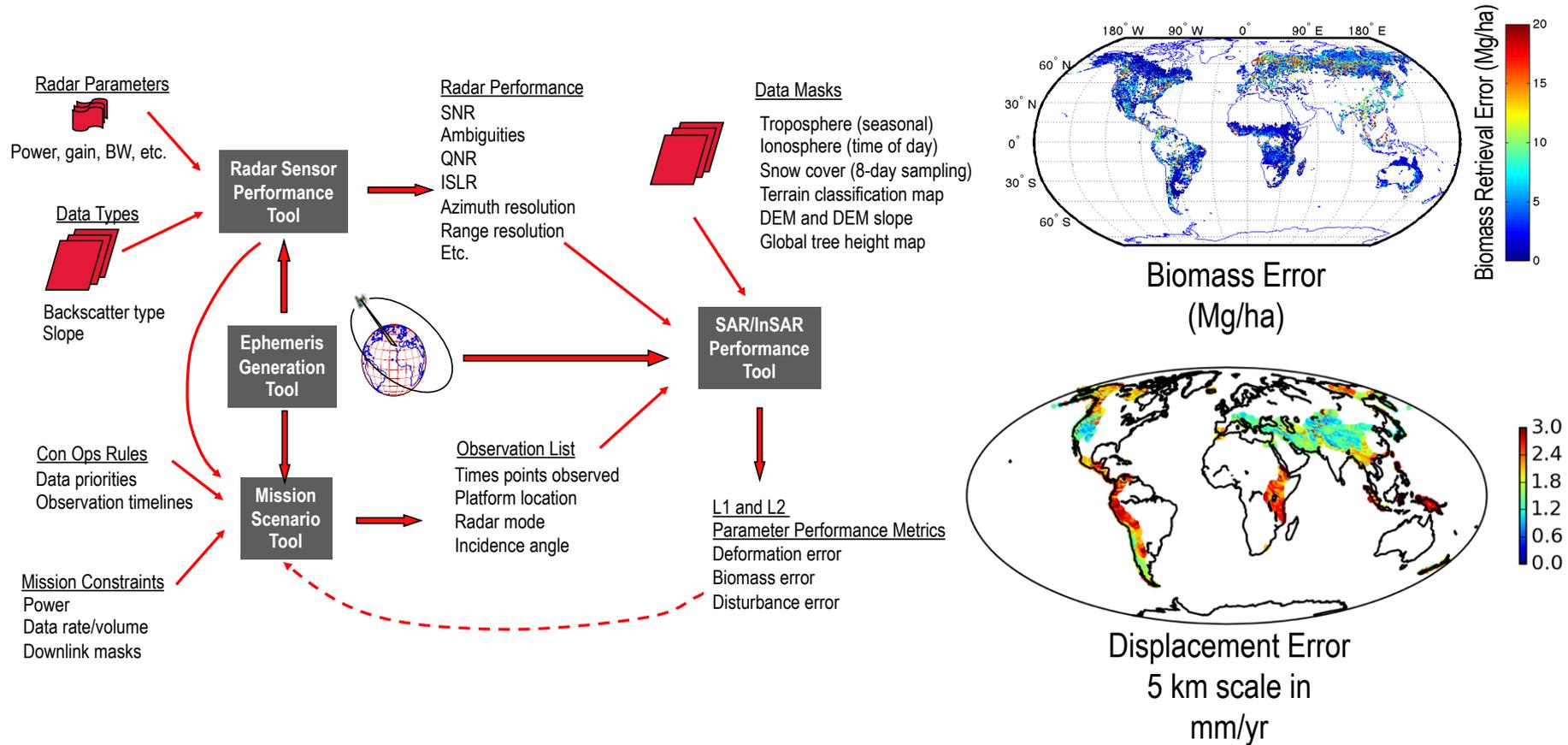
## Cost Effectiveness Tradespace



SDC Study Team  
needs Science  
Community help  
in defining  
*Science Value*

# Science Performance Tool as a Value Metric

Displacement, Biomass, Disturbance



# Upcoming Activities and Milestones

<b>20-22 May 2019*</b>	<b>Technology Workshop: To assess technology landscape for SDC</b>
19-20 Jun 2019	The A-Team (JPL): To define candidate architectures
July 2019	SDC website established
24-25 Sep 2019	HQ Status Briefing, 2019 (SDC annual report)
<b>Oct 2019*</b>	<b>Research &amp; Applications Community Workshop, DC area</b>
Oct 2019 (TBD)	International Astronautical Conference town hall, DC area
Oct 2019	Preliminary Capabilities Defined
Nov 2019	CEOS Plenary (NASA's report of Decadal Activities to CEOS)
<b>9-13 Dec 2019*</b>	<b>SDC Town Hall, Fall AGU, San Francisco</b>
Jan 2020	Completion of Performance Tool
Feb 2020	Preliminary evaluation of architectures
<b>Apr 2020*</b>	<b>Research &amp; Applications Community Workshop (Alabama)</b>
Jun 2020	Final Capabilities Document

As dates are finalized, they will be posted on the SDC website

\*Activities open to international research, applications, and technical communities

# Summary

- Surface Deformation and Change Architecture Study will lead to a mission architecture to fulfil 2017 Decadal Survey recommendation
- NASA would go forward with implementation in 2023 timeframe
- The SDC study team is exploring a wide range of implementation options
  - International partnerships
  - Commercial sector involvement
  - Continuing engagement with research and applications communities