NISAR Utilization Plan

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1 Utilization Plan Overview

1.1 MISSION AND PLAN OVERVIEW

The NASA–ISRO Synthetic Aperture Radar (NISAR) mission is a partnership between NASA and the Indian Space Research Organization (ISRO), currently scheduled to launch in late 2021 and to have a minimum mission lifetime of three years. The mission is optimized for studying hazards and global environmental change, specifically in support of its three core science disciplines: Ecosystems, Cryosphere, and Earth Surface and Interior. The satellite is designed to provide a detailed view of the Earth to observe and measure some of the planet's most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards. In addition to its science requirements, the mission has a requirement to be capable of supporting disaster response through expedited event-driven downlinking, processing, and delivery of relevant data (See Appendix 4.1). As for all NASA missions, NISAR data will be openly available, free of charge.

NISAR will utilize two synthetic aperture radar (SAR) instruments operating at different frequencies to study the Earth. NASA will provide an L-band SAR and ISRO will provide an S-band SAR. Table 1 shows some of the mission instrument and imaging parameters, and the types of measurements that they enable. NISAR's L-band radar instrument will provide all-weather, day/night imaging of nearly the entire land and ice masses of the Earth, and the S-band instrument will provide additional coverage of India and parts of the polar regions. Most areas will be imaged 4-6 times per month, with exact repeat of the orbits at 12-day intervals. NISAR's imaging resolution will be 3-50 meters, depending upon the operating mode. The repeat orbit images can be used to identify and track subtle movement of the Earth's land using interferometric synthetic aperture radar (InSAR) that can detect small-scale surface deformation before it is visible to the eye. Consistent, repeated, frequent, and long-term imaging enables dynamic tracking of changes as conditions evolve (situational monitoring).

Although the three science disciplines drive NISAR mission requirements, there are a wide variety of applications and other science topics that can also benefit from early and sustained engagement between the various elements of the NISAR program and the broader user community throughout NISAR's development, launch and operation. A series of

NISAR Characteristic:	Enables:
L-band (24 cm wavelength)	Low temporal decorrelation and good foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 30% observation duty cycle	Near-complete land/ice coverage

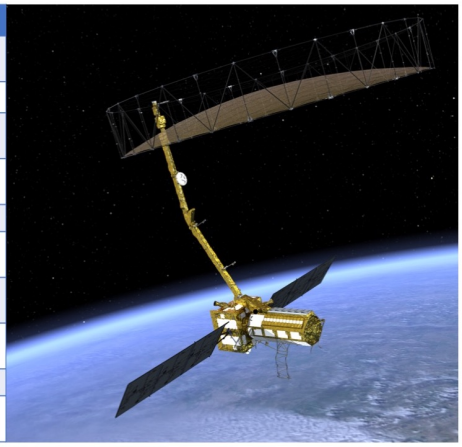


Table 1 – NISAR characteristics and capabilities.

white papers highlight a number of the applications that the mission can support (https://nisar.jpl.nasa.gov/applications/).

The NISAR Utilization Plan (UP) document describes NASA's plan to engage the stakeholder community and increase the utility, accessibility and discoverability of NISAR data by:

- demonstrating the value of the NISAR mission within a broad societal context,
- supporting activities that engage a diverse user community,
- educating a broader community on the utility of SAR data,
- working with interested end users to develop information products, and
- contributing to an observation plan and data delivery schedule that facilitates both science and applications within mission constraints.

It is written for interested parties, be they in the stakeholder community, at NASA centers, academia, or elsewhere.

This plan includes input and contributions from the broader stakeholder community including universities, state and federal agencies, commercial sector, non-profits, as well as the cognizant components responsible for development and implementation of the NISAR project including NASA Headquarters, the NISAR Project at JPL, the Applications Coordinators, the NISAR Science Team, the Alaska Satellite Facility (ASF) Data Active Archive Center (DAAC), and the Indian Space Research Organization (ISRO). The plan articulates each stakeholder's responsibility and the associated support (financial or otherwise) in each activity. Planned activities were informed by community input in both the 2014 and 2015 NISAR Applications Workshops (2014 NISAR Applications Workshop Report; 2015 NISAR Applications Workshop Report) with additional input from the NISAR Science Team selected in 2016.

The report is divided into three sections: 1) an overview of the Utilization Plan and NISAR's goals and objectives for advancing the utilization of its data products for applications; 2) specific activities to be undertaken to achieve the applications goals and objectives; and 3) the roles and responsibilities of stakeholders, NASA headquarters, the NISAR Project, and NISAR Applications Coordinators, among others, in implementing the Utilization Plan. A separate document, the NISAR Urgent Response Plan, presents activities and protocols for urgent response that support the response communities needs before, during and after a disaster.

1.2 GOALS AND OBJECTIVES

The overarching goals of the Utilization Plan are to develop the framework that:

- Increase the utility, accessibility and discoverability of NISAR data by a broad community.
- Increase the societal value of the NISAR mission.
- Increase the use of NISAR data for hazard/disaster management.
- Broaden the communities of users of NISAR data.

These goals are to be achieved through identification of application focus areas that will most benefit from L-band synthetic aperture radar (SAR) and facilitating critical activities that contributing groups can implement before and after the launch of NISAR.

The objectives of the Utilization Plan are to:

- Engage with the user community to identify the highest value potential applications of NISAR to those communities.
- Work with those communities to identify gaps that may limit NISAR data utilization for specific high-value applications.
- Inform the NISAR Project on latency, resolution, and acquisition modes that would significantly advance the utility of NISAR to the applications community.
- Foster projects in collaboration with users that prepare the community to use the NISAR data from start of acquisition.
- Develop and disseminate educational information to aid and expand the independent use of SAR data in general and NISAR data in particular.

2 ADVANCING APPLICATIONS WITH NISAR

The NISAR mission will provide data sets covering nearly all the Earth's land areas and coastal oceans to meet the requirements for the NISAR science disciplines. However, for each science use case, the same data could potentially be used by one or more science and application communities, often with little or no change in the core observables. Deformation of a land surface can impact roads and buildings; crop status affects irrigation and food supply; sea ice can be tracked near shipping lanes. In some cases, utility depends on how quickly the information can be generated or its spatial resolution, which are governed by the observation plan and processing system, and constrained by data transfer, storage, and computing capacity. Under the nominal observation plan, NISAR will provide near-global coverage of all land surfaces and many sea ice-covered regions on both ascending and descending orbits of a dawn/dusk sun-synchronous orbit with 12-day revisit period. The baseline observation strategy is fairly mature, but has not been finalized as of publication date of this document and is subject to minor revisions prior to launch. Details of the science goals and observation plan can be found at: https://nisar.jpl.nasa.gov/missionthemes/# and https://nisar.jpl.nasa.gov/nisarmission/observationstrategy/#. Planned nominal spatial resolution in most areas is 12-m, but operational modes can support 3-50 m resolution. Although the science requirement is 30-day maximum latency, the NISAR project's goal is delivery of Level-1/2 products within 24-48 hours of acquisition. Input from the applications community is required to identify high value uses of NISAR data, and whether reasonable and achievable alterations in the observation, downlink or processing strategy could significantly improve this mission's societal value.

NISAR's broad range of science goals drives a very robust data acquisition scenario, essentially observing the Earth at least twice every 12-days (ascending and descending orbits), and NASA's open data policy enables widespread use of the mission's data. Given the versatility of SAR, there are a large number of applications for which SAR could provide useful, and in some cases unique, information. Applications range across the three core science disciplines with the addition of hydrology and subsurface reservoirs, oceanography, and atmospheric science. Potential applications encompass the mission's requirements related to its role during emergency response, and extend to the full disaster management cycle of (1) understanding underlying processes, (2) hazard/risk assessment, (3) forecast/warning, (4) situational awareness, (5) response, (6) recovery, and (7) mitigation.

2.1 APPLICATIONS OVERVIEW

In the following sub-sections we provide a brief overview of relevant applications for NISAR as discussed at the 2017 focused Applications Workshops for Critical Infrastructure and Sea Ice, the 2014 NISAR Applications Workshop and 2015 NISAR Applications Workshop. The omnibus workshops held in 2014 and 2015 will be updated through focused workshops with specific communities [2.3.1] before NISAR launch. The Application Workshop reports, hosted on the NISAR website (https://nisar.jpl.nasa.gov/applications/), contain detailed information about the highest value applications for specific communities and the acquisition modes and processing latency required for NISAR data in that focus area. New reports will be posted as additional workshops are held.

Building on the findings of the omnibus workshops, the NISAR Science Team developed draft Application Traceability Matrices (ATM) working in coordination with relevant stakeholders within each of six application areas: Ecosystems, Hydrology and Subsurface Reservoirs, Maritime, Critical Infrastructure, Geologic Hazards, and Other. The Other category captures topics outside of the core science requirements such as the use of SAR data for atmospheric science or measuring soil moisture. Urgent response encompasses disaster response and other low latency, high priority requested acquisitions. Urgent response applications cross-cut many application areas. The ATMs consolidate information about the acquisition, processing, and latency parameters needed for each application and an assessment of the application readiness level or degree of maturity. The ATMs are useful to help prioritize various prospective applications in terms of how well NISAR data can meet associated requirements and what level of effort may be needed to advance that particular application to maturity. These ATMs serve as "living" documents through which the NISAR Program, Project, and Science Team can track applications and science topics that extend beyond the principle NISAR science objectives.

2.1.1 Ecosystems

NISAR can address many ecosystem applications including annual carbon accounting and mapping and characterization of wildlife habitats, wetlands, land use, agriculture, water availability, and wildland disturbance. A core benefit of spaceborne SAR data is its active remote sensing capability in cloud-covered conditions independent of solar-illumination. Since the abundance of vegetation is strongly correlated with abundance of rainwater availability, clouds are a major impediment to high-resolution optical remote sensing at high temporal repeat. The high temporal and spatial resolution of NISAR observations thus complement optical instruments for a range of key ecosystems needs. SAR observations at longer wavelength (e.g., L-band) have also proven particularly useful since they are inherently sensitive to changes in two core target variables that characterize ecosystems: structure and moisture.

Annual retrievals of biomass (for regions with above-ground biomass < 100 Mg/ha) can be used to refine baselines for emissions estimates in the accounting framework of carbon treaties. Dependable repeat time-series observations from SAR are also used for the mapping of spatial and temporal characteristics of agricultural land use to inform agricultural crop classification and crop inventory assessments used in national and international reporting of import/export markets and setting rates for subsidies. Similarly, SAR mapping of land use change (e.g., conversion of forest to agroforest like oil palm plantations) can help enforcement agencies with political mandates to protect the land, particularly in the tropics where there is dense cloud cover. Lastly, information on vegetation structure inferred from backscatter power and time-series analysis enables characterization of the spatial extent of wildland disturbances (e.g., wildfire), which is key for near-real time response and pre- and post-disturbance mitigation and recovery, particularly at high latitudes and in the tropics, both of which have dense cloud cover.

On a more experimental basis, repeat-pass InSAR has been used for estimating vegetation height. Such measures can be applied to annual carbon for regions with above-ground biomass > 100 Mg/ha, and for characterizing wildlife habitat and developing land management plans that protect endangered species.

Retrievals of soil moisture and inundation extent are valuable for wetland restoration and mapping the spread of disease vectors, ecosystem health, and wetland bio-geochemistry (e.g., methane emissions, in particular in tropical and boreal environments) as well as planning and investing in infrastructure, (e.g., cattle watering holes, levees, dams and irrigation) and mapping wildfire hazard potential.

2.1.2 Hydrology and Subsurface Reservoirs

Hydrology and subsurface reservoir applications of NISAR include measuring ground surface subsidence and rebound to within centimeter accuracy as well as mapping soil moisture, surface water, snow, and deformation associated with water and hydrocarbon withdrawal, wastewater injection, and carbon sequestration. NISAR's L-band SAR, compared to shorter wavelength SAR, will enable detection of surface water below vegetation, especially in inundated areas. NISAR's plan for routine, repeat-pass observations will enable better monitoring of several key parameters for hydrologic studies (e.g., ground height over aquifers, used to infer changes in groundwater). As with other application topics, the capability of spaceborne SAR to make observations in cloud-covered conditions independent of solar-illumination is important, enabling regular measurements in tropical as well as high-latitude regions.

Mapping and monitoring surface water has implications for soil moisture, coastal (ocean, lakes, rivers, etc.) zones, and snow. SAR is used to assess changes in soil moisture and surface water levels, which is relevant for agricultural applications such as assessing water availability for water resource management (e.g., irrigation). Observations of soil moisture also help determine flood potential before a storm. In coastal zones, surface-water extent and level is essential to monitoring inundation, tidal fluctuations, wetlands, changes in shoreline (river, lake and ocean), and floods. Lastly, snow cover extent, snow melt and snow water equivalent (i.e., density and depth of snow) are very important for determining the timing and amount of water available for resource management. Determining the timing of snow-off conditions is important for agencies to identify the start of the fire season.

Estimates of ground surface height change are important for applications related to subsurface resource management, in addition to a number of hydrology applications. Information on elevation changes are useful for accurate flood and erosional hazard mapping, in particular where localized subsidence occurs near critical infrastructure (e.g., roads, canals, railroads). Changes in ground surface subsidence over oil, gas, and hydrothermal reservoirs provides estimates of changes in the water table (hydraulic head), location and depth of oil and gas, help manage fracking activities, and resolve the shape and characteristics of the hydrothermal reservoirs. Such observations can be leveraged even further when combined with downhole information to constrain important fluid flow parameters (e.g., skeletal storage coefficients)

2.1.3 Marine and Coastal Hazards

Marine and coastal hazards include mapping and classifying hard targets (e.g., ships and icebegs), shorelines, and storm damage; monitoring marine wind speed, wave spectra and severe storms; and identifying oil spills. The capability of spaceborne SAR to make observations in all-weather and day-night conditions is important, enabling regular measurements in tropical regions

(imaging, e.g., major storms) as well as high-latitude regions (e.g., sea ice coverage). Also, the high-resolution (10-25 m pixels) of NISAR is optimal for sea ice classification and hard target detection. The unique dual-polarization (dual-pol) and quad-pol mode capability of NISAR for is particularly useful for improving algorithms for sea ice classification and ship detection, wind speed, shoreline monitoring, and storm characterization. Lastly, the regular repeat observations and coverage of coastal waters from NISAR will aid oil spill detection and response.

Detection and classification of sea ice, icebergs and ships is used by ice service agencies (e.g., U.S. National Ice Center and Canadian Ice Services) to aid navigation particularly for shipping trade routes, search and rescue, and coastal border patrols. The key to ship and iceberg target detection is a latency of a few hours between acquisition and data download. Similarly, low latency is needed for sea-ice monitoring, determining marine wind speeds and wave spectra for operational applications such as coastal area weather/storm forecasting (i.e., track and intensity) and wave monitoring. In addition to wind and wave monitoring, SAR imagery has been used to measure other hurricane and severe storm parameters (i.e., eye location/shape, rain-band location, and characteristics of roll vortices). Another common and valuable marine application requiring relatively low latency and regular repeat observations is locating and characterizing oil/toxic spill slicks (i.e., thickness, oil-to-water ratio, type, etc.) for response and recovery activities. High-resolution SAR is also useful for mapping shorelines, specifically shallow bathymetry, subaqueous channels, erosion and other disturbances (e.g., caused by severe storms or tsunamis).

2.1.4 Critical Infrastructure

NISAR can be of use across the full disaster management cycle for assessing the status of critical infrastructure. The 2017 Critical Infrastructure Workshop identified NISAR's most valuable and unique contribution to be sustained, regular observations for situational awareness both of critical infrastructure itself and of the general area around the facilities. Change detection and flood extent measurements during disaster response and recovery were also given high value. The benefit of NISAR for critical infrastructure monitoring derives primarily from the 12-day temporal repeat, the near-complete land imaging, and the day/night observation capability. Both intensity image and InSAR products could be used, but the InSAR products provided information that is more difficult to obtain and generally lacking in most areas. Particularly high value was given to finer spatial resolution, i.e., 6-m resolution, which is an instrument capability but not standard in the current observation plan. For disaster response, NISAR adds additional coverage to the suite of international satellite SAR instruments, reducing the time to acquiring post-event imaging in some cases, and most importantly, provides a baseline pre-event image for many areas that are not routinely observed by other SARs.

Situational awareness information derived from intensity images include land use, extent of standing water, and progression of upstream flooding, and are used for planning purposes. Situational awareness information derived from InSAR products include structure deformation, subsidence and geologic hazards proximal to critical structures or facilities, and short-term change detection, all of which can inform short-term and long-term planning and disaster/hazard avoidance. Continual monitoring enables detection of abrupt changes in rates of movement that can precede imminent catastrophic failure. Monitoring for movements resulting from localized

subsidence is an important SAR capability for operation and maintenance of a wide range of critical infrastructure (e.g., levees, aqueducts, water pipelines, canals, energy production facilities, and transportation infrastructure – bridges and highways). SAR observations for disaster response have great potential to provide rapid damage detection across large spatial scales, complementary to more traditional damage mapping based on optical data that requires daylight and that can be obscured by clouds. Specifically, maps of building and infrastructure damage can be crucial for responding to earthquakes, tsunamis, tropical cyclones, and tornadoes, as well as ground surface change due to liquefaction, volcanic deposits, and landslides. Post-fire erosion and debris flow potential or flood extent mapping can also be measured from SAR, which has implications for infrastructure hazard mitigation due to natural disturbances. SAR data have proven useful in assessing off-shore oil platform changes after large storms, particularly if moored platforms have drifted or smaller unmanned platforms been destroyed.

2.1.5 Geologic and Anthropogenic Hazards

NISAR will enable regular measurements of surface movement, important for assessing risk and enabling response and recovery activities associated with earthquakes, volcanos, landslides, sinkholes, and secondary hazards such as tsunamis that are generated by earthquakes and landslides. In some cases, NISAR will provide observations with which precursory activity can be identified (e.g., at restless volcanoes before they erupt). The same observations are relevant to detection and characterization of hazards arising from anthropogenic sources, such as subsidence caused by groundwater or oil extraction or mining. The benefit primarily derives from NISAR's 12-day repeat imaging and routine imaging of all land areas. This dense time series of images enables the measurement of slow surface deformation and the tracking of abrupt changes in the rate of deformation through the use of InSAR time series processing methods.

The ability to map surface deformation and surface change at high resolution over large spatial extents is important for supporting response efforts related to large devastating earthquakes, which can happen in remote regions that have few instruments on the ground, or have compromised communications to the outside world due to the damage caused by the event. Change in SAR reflectance is used to map damage caused by building collapse, landslides and liquefaction. SAR's ability to image large regions through clouds make it complementary to the optical imagery traditionally used for mapping damaging effects from earthquakes. NISAR will also be capable of directly mapping earthquake location, surface rupture extent, tilt, uplift/subsidence, shearing, and amount of surface fault slip. This information can help provide more accurate estimates of ground shaking, change in flow in canals or water pipes, and flood potential. Repeat-pass space-based SAR/InSAR are frequently used by the volcanic hazards community to track magma movement below the surface by measuring the surface displacements generated as magma pushes its way towards the volcanic vent. Changes in SAR reflectance properties are also used to define the spatial extent of surficial lava flows, ash, or lahar deposits. For monitoring active volcanoes, the ability to make observations from space, without placing researchers on the ground in harm's way and in all weather conditions, is extremely valuable.

2.2 NISAR TARGETED APPLICATIONS

While there are many applications that can be served by the open availability of NISAR data (Section 2.1), there are limitations to the breadth and depth of advancing all such applications within the time frame and resources available before the NISAR launch. As such, this Utilization Plan includes a mechanism to sub-select specific applications for targeted development. These targeted applications are informed by discussions at application-area specific workshops, the ATMs that identify the maturity, the feasibility (within NISAR mission design), the impact to the stakeholder communities, the level of stakeholder interest and engagement, and other programmatic considerations. The selection of targeted focus applications for NISAR will be informed by the application area-specific workshops (section 2.3.1) and the Application Working Groups (Section 2.3.2). It is expected that an initial set of utilization focus areas will be selected as the focused workshops are held.

2.3 EARLY ENGAGEMENT

Early Engagement activities are elements of the NISAR Utilization Plan that provide interaction between the broader end user community and the NISAR project/program prior to launch. These interactions are designed to inform and expand the potential NISAR user community through increased awareness of the NISAR mission, its data, and their utility. The activities will also provide important venues for the user community to communicate their SAR data needs to the Applications Team and NISAR project.

2.3.1 Application Area-Specific Workshops

The NISAR applications workshops from FY17 forward were tailored to specific application communities and were held directly with a particular set of end users in order to focus on determining how NISAR can make a significant contribution and facilitating effective collaborations that prepare end users for using NISAR products in advance of launch. Each workshop focused on that particular application community by identifying the current state-of-the-art and informational needs of that community relative to potential adoption and integration of NISAR data. The workshops were designed to identify how NISAR can provide the highest value and unique information to a given community and to prepare action plans for future engagement. This change from general to targeted community engagement was motivated by a recognition of the need to deepen the engagement with the community of end users to develop partnerships that facilitate the incorporation of NISAR data/products into their agencies' workflow and funded in part, or in whole, by the end user community, with the goal of being prepared to use NISAR data as soon as it becomes available.

2.3.1.1 Goals

The primary goals of the workshops are:

1. To facilitate dialogue between the end user applications communities and the various components of the NISAR project (at NASA HQ and JPL), the NISAR Science Team (ST), the Applied Science Program and its Applications Coordinators to determine the current use of SAR by that community; and furthermore, to define specific NISAR mission capabilities

necessary for applications of high value to the community that are feasible within the NISAR mission design. Community requirements include the modes of operation (i.e., polarizations), the observation strategy (extent, geographic location(s), resolutions, duration and seasonality), and the processing timeline. These conversations would also inform development of, or potential changes to, the associated applications traceability matrices.
2. To facilitate the development of a community composed of SAR experts and application end users for specific applications such that partnerships and collaborations may ensue. To further this specific goal, people will be recruited through the workshops to participate in Application Working Groups (Section 2.3.2).
3. To increase SAR literacy among the broader applications community to expand the operational utility of SAR.
4. To provide input for the Urgent Response Plan (Section 2.7) for applications that require near real time (NRT) response.

2.3.1.2 Logistics

The NISAR Applications Coordinators and ST will form an organizing committee that will engage a leading agency/organization in the end user applications community (e.g., DHS for critical infrastructure, NOAA for oceans and coastal hazards) to organize and run the workshop, and to prepare a report documenting the findings and prospective path forward that come out of the meeting. The organizing committee will be responsible for writing, delivering and circulating a report to participants and the public (via the NISAR project website).

Each workshop will engage the broader stakeholder community including participants from across academic, private, public, and non-profit sectors and the international community as appropriate. Additionally, relevant members of the NASA and NISAR communities will also participate (e.g., from the NASA Research and Analysis and Applied Science programs, NISAR project, NISAR Science Team, and DAACs). The NISAR Project and the Applied Science Program will support time spent organizing workshops by the NISAR Applications Coordinators. NISAR Science Team members may propose participation in Utilization Plan related activities such as workshops within the scope of their ST proposals. If additional funding is needed to support specific workshops, the Applications Coordinators may submit a proposal to the ROSES E.2 Topical Workshops call.

The venue for each workshop will be coordinated with relevant end user communities in order to engage the broader stakeholder community. Meetings for different target applications could have different detailed organizational strategies to maximize the output for the specific set of applications based on the needs of each stakeholder community.

The goal is to host multiple workshops in FY17, 18, and 19 with the prospective list to include:

1. Oceans/Maritime Applications: Sea Ice (FY17)
2. Critical Infrastructure (FY17)
3. Forests and Disturbance (FY18)
4. Agriculture and Soil Moisture (FY18)
5. Wetlands (FY19)
6. Geologic Hazards: Landslides (FY19)
7. Geologic Hazards: Volcanos (FY19)

8. Geologic Hazards: Seismology/Tsunamis (FY20)
9. Flood Hazards (FY20)
10. Hydrology: Ground water/oil extraction and induced seismicity (FY20)

The specific schedule will be determined in coordination with the target communities to optimize participation. In addition to the workshops listed above, we plan to conduct follow-on workshops and meetings with the stakeholder communities in FY19 - FY20 (Oct. 2018- Oct. 2021) as needed to prepare the communities for utilization of NISAR data before its launch.

2.3.2 Application Working Groups

A limited number of ad hoc Application Working Groups will be formed with two goals. First, working groups will provide a forum for connecting members of the stakeholder community for specific applications focus areas (Section 2.2) with each other and with NISAR experts, who can advise on the utility of SAR within the scope of the observation plan for NISAR. Second, Working Groups are expected to provide feedback to NISAR regarding the utility of NISAR data for their stated objectives. As an example, a working group may define the need for a Level-3 or higher informational product, an algorithm for generation of such a product along with a prospective workflow to process NISAR data, prototype these on pre-NISAR surrogate data sets, and conduct post-launch calibration and validation activities for such a product. The Working Groups are intended to both coordinate such activities and to communicate both impediments and successes to the NISAR Project and to NASA.

The overarching goal of the NISAR Utilization Plan is to more fully realize the applications potential of NISAR data. The specific objective of an Applications Working Group is to facilitate progress towards that goal for a specific application or closely related group of applications that share a common purpose. Examples are near-surface soil moisture, infrastructure damage assessment, or surface freeze/thaw state. The exact activities of each group will be defined as each group is created, but will include:

- Define needed information and stakeholder priorities by which to quantify value added (Section 2.5.1)
- Establish and coordinate or lead projects (Section 2.4.1) that develop needed L3+ information products including calibration and validation of those products (Section 2.6),
- Provide feedback to the NISAR project and ST regarding data usability of L0-L2 products (e.g., data formats, projection) for integration into an L3 product production pipeline.
- Demonstrate information product utility by publishing in the peer-reviewed literature the utility of SAR and quantifying value added (Section 2.5.4)
- Advocate, on the basis of success, for sustained support within collaborating agencies and organizations of further use of NISAR data
- Take part in disaster response if the working group has interests and algorithms aligned with an ongoing event. Provide feedback to NISAR project and science teams on identified roadblocks and their potential solutions with respect to disaster response.

The end user communities play the central role in formation of the Application Working Groups, through which they can engage more directly with the NISAR mission elements. Community

members can request formation of a working group to advise them, e.g., on the usage of NISAR data and/or to get started using SAR data from existing sources. Members must include the stakeholder community. Working Group membership will be determined via a proposal process vetted by the NISAR Project (NASA and JPL) and by the Applications Coordinators, and in some instances may be solicited to ensure that all necessary roles are filled to meet the working group objectives. Membership will vary depending on each group and the specific needs of the stakeholder requesting the working group, but can include calibration/validation partners, data producers/providers, data distributers, other NASA mission early adopters, NISAR Project Staff, the NISAR Applications Coordinators, or NISAR ST. The group will nominate a Working Group Chair who will be responsible for coordinating group activities. The Working Group will define a prospective work plan covering the above listed activities or others as deemed appropriate and regularly communicate progress back to NISAR and NASA.

Additional more project-specific working groups that do not directly engage with a specific stakeholder community can be recommended by the NISAR ST, the NISAR Project (NASA or JPL), or by the Applications Coordinators, e.g., to advise the program or project on urgent response activities or to engage with ISRO scientists.

2.3.3 NISAR Envoy Program

The NISAR Envoy Program is a volunteer-based community of committed SAR users with considerable experience working with NASA, JPL and other SAR users. Members will have currently or previously had successful and relevant SAR application experience that they can present at major meetings, specialized application-specific workshops and through existing NASA capacity building programs (e.g., SERVIR, DEVELOP or ARSET). Envoy members are expected to provide to the NISAR Applications Coordinators a list of relevant conferences/workshops of high impact to the application end user community for which they are already attending and for which they can raise awareness of existing SAR applications and the potential for NISAR data. Lastly, Envoy members will be featured on the NISAR applications webpage.

The specific objectives of the Envoy are four-fold. First, members of the Envoy will help respond to inquiries from the applications community about how they have used SAR to address specific applications including both the research results and final integration into partner decision support/information product systems. Second, Envoy members will discuss NISAR as an upcoming available source of openly available public data at meetings where they are already presenting. Third, members will, through conversations about NISAR at professional meetings, help to identify to the NISAR Applications Coordinators active and willing partners (managers, researchers, etc.) for further potential engagement. The NISAR ST, Project, Program, and ASF DAAC will nominate members for the Envoy program. Fourth, the NISAR Applications Coordinators will suggest Envoy speakers for Education and Training programs and the NISAR Project is responsible for hosting a list of envoy members on the NISAR applications website.

2.4 SAR LITERACY AND CAPACITY BUILDING

Improving SAR literacy and capacity building were identified at both the 2014 and 2015 Applications Workshops as key to practical usage of SAR by many decision support and applications communities, for whom SAR has not been a standard data source. In response, the NISAR Utilization Plan includes several activities to increase SAR literacy and build capacity to prepare applications communities for using SAR data. An initial action will be convening a Workshop on Synthetic Aperture Radar Literacy and Training in FY2019 to discuss options and develop a strategy for responding to this specific need. It is expected that the workshop will engage different SAR users and educators, both individuals and organizations, with a demonstrated interest in SAR training and capacity building. Discussion of education-focused activities and options for implementation strategy will be a major component of the workshop, with selection of those to implement determined by a combination of the workshop findings and programmatic considerations.

One effective form of capacity building is development of open access online virtual SAR labs that come installed with relevant SAR processing and GIS tools. A specific planned activity is the design of a multi-faceted library of educational resources that includes curricula and education material tailored to various levels of users. In addition, the NISAR Applications Coordinators will collaborate with NASA Applied Science Capacity Building programs such as ARSET, SERVIR and DEVELOP both in the design and distribution of SAR literacy materials, including material currently being developed through those programs. These specific literacy and capacity building activities are discussed in subsections below.

2.4.1 Library of Educational Resources

Even though the SAR community has run training and outreach programs in the past, there is currently no coordinated sets of material available ready for use by a broader applications community. Furthermore, past educational efforts of the community have mainly focused on a rather narrow set of users, specifically SAR-interested members of the geophysics community. Considering the extensive and growing diversity within the SAR user community, there is a pressing need to develop a more diverse library of educational resources, webinars, and curricula, each of which is tailored to a specific science or applications community.

Developing these materials effectively and efficiently requires the cooperation with two relevant groups: target audiences and existing SAR educators. To assess the relevancy of developed resources, it is prudent to involve members of the targeted community early in the development process and solicit their feedback on technical content, desired data products, and high impact applications. Second, groups that are already engaged in SAR education should be involved to efficiently develop material.

All curricula and material will be developed considering the best practices advised by NASA Applied Remote Sensing Training (ARSET).

Lastly, it may be necessary to recruit instructors for instructing specialized webinars and on-site trainings. Thus, subject matter experts (e.g., from the NISAR Envoy – Section 2.3.3) could be

selected to match the expertise required by an application-specific training and will be associated with this training.

The Project plans to host, via its website Applications, links to educational resources provided by the Applications Coordinators, ST, and ASF. The list of educational resources will be collected starting during FY17-18 and updated over the life of the NISAR Project. The ASF-DAAC also hosts relevant SAR educational resources.

2.4.2 Online Virtual SAR Lab

Often SAR literacy courses are limited to seminars that discuss the theory of SAR processing or in-person workshops that require significant logistical effort to prepare ad hoc computing pools pre-installed with all relevant SAR processing software. These typically-used teaching approaches, however, significantly limit the audience who can actually gain hands-on experience in SAR data analysis. Also, ad hoc computing pools are often prone to performance issues and they can differ from the processing environment an end user would encounter when using operational processing systems such as those envisioned for NISAR.

A cloud- or web-based training "virtual SAR lab" could overcome these common limitations if it comes with sufficiently-sized hardware specifications, as well as pre-installed necessary and relevant SAR and GIS software tools,. The NISAR Project will not be responsible for developing the SAR lab itself, but could work with another organization such as UNAVCO or ASF-DAAC, to realize a capability that would be readily usable by non-experts. To be useful for a broad range of SAR user communities, the virtual SAR lab would include a graphical user interface, demonstration data sets, and pre-scripted work flows for a range of user applications. The advantages of a cloud- or web-based lab include (1) universal accessibility from any computer with a web browser; (2) a ready-to-use broad suite of public-domain processing tools that are available without requiring painful software installation; and (3) a sufficiently-sized processing server that can handle the processing loads without requiring hardware purchase. There are three issues that need to be overcome when developing the virtual SAR lab. First, the lab must be developed using open-source processing software relevant to the NISAR mission, and to facilitate easy and standard access across all SAR user communities. The NISAR Project has supported this effort by making SAR processing software (InSAR Scientific Computing Environment – ISCE) available with a no-cost license for non-commercial uses, and is working towards an open source license that will be free and open for both research and commercial uses. To advance this activity, the Applications Coordinators and ST could work with UNAVCO and other partners to identify leads for creating and sustaining the open-access virtual lab. The ST or project could contribute to example data sets and demonstration workflows for a range of relevant NISAR applications.

2.4.3 Relevant NASA Applied Science Program Elements

2.4.3.1 Applied Remote SEnsing Training (ARSET)

ARSET provides both online webinars and hands-on lab experience to thousands of end users worldwide. To increase the education and training for NISAR, the Applications Coordinators will work with NASA ARSET to ensure that SAR tutorials introduce the NISAR project and

application focus areas (Section 2.2), provide a Project status update, and identify relevant speakers from the Envoy (Section 2.3.3). The thematic workshops (Section 2.3.1) hosted by the Project, possibly supplemented with financial support from ROSES E.2 Topical Workshops, will leverage ARSET's guide to best practices (https://arset.gsfc.nasa.gov/all/webinars/best-practices-2016; Accessed 20 November 2016).

2.4.3.2 SERVIR

SERVIR is a joint venture between U.S. Agency for International Development (USAID) and NASA to provide satellite Earth monitoring data and GIS tools to help improve environmental decision-making in developing nations in Africa and Asia. To increase the applications utility of NISAR, the NISAR Applications Coordinators, Envoy, and potentially the Applications Working Groups will communicate and coordinate as appropriate with the SERVIR program. The ASF DAAC and Applications Coordinators are responsible for engaging with the SERVIR program to advertise relevant NISAR application activities, thus increasing participation and "train the trainers" (i.e., the SERVIR Science Team). For example, the Applications Coordinators could help to pair interested SERVIR science team members with NISAR Envoy participants and Applications Working Groups to facilitate new partnerships that can: 1) help build capacity for SAR in developing countries, and 2) provide demonstration cases for the application utility of NISAR to a broader community.

2.4.3.3 DEVELOP

DEVELOP is a US domestic capacity building program under NASA ASP that provides professional development for early career professionals. The DEVELOP program establishes teams of typically 3-6 people, primarily undergraduate and graduate students, to help decision makers perform feasibility studies for integrating Earth observations into their decision support. These teams work together for 10 weeks and provide deliverables of code, presentations and technical reports to partner agencies. On these teams, there can also be DEVELOP fellows that work for a year often cycling through 10-week team activities and on develop more comprehensive professional skills (e.g., managing the team). The Applications Coordinators will coordinate with DEVELOP to identify SAR-demonstration projects and relevant mentors for them through the Envoy and Application Working Groups.

2.5 BEYOND NISAR DATA TO ACTIONABLE INFORMATION

This section discusses the set of activities that move beyond Early Engagement with stakeholders to the actual incorporation of information derived from NISAR data into decision support and operational monitoring systems. For many potential end-users of NISAR, the value lies in derived informational products and not necessarily SAR/InSAR data (L0-2, where L0 is the raw data and L2 the most refined processing product delivered by the NISAR mission). For example, they want to know the amount of surface deformation, not see an InSAR interferogram. The NISAR project is responsible for production of L1/2 products for archive/distribution through ASF DAAC, and the production of limited L3 products for calibration/validation (cal/val) of NISAR L-1/2 requirements at a regional scale and for specific test sites. The development of additional L3 or derived information products is not currently within the NISAR project scope. Determination of such additional L3 or derived informational products that may ultimately be

produced, where/when/how often, by whom, using what algorithms/work-flows are largely to-be-determined, and may be highly dependent on the outcomes of early engagement with stakeholders under the Utilization Plan.

Therefore, we include in the Utilization Plan a framework for how stakeholders can engage with NISAR in order to generate, archive and distribute information products that are needed by the broader stakeholder community. The application focus-area workshops are just the beginning of such an engagement. One of the goals of the Applications Working Groups is to establish partnerships between decision makers (e.g., state and federal agencies), researchers, and data producers/distributors (e.g., commercial companies and DAACs). These working groups can help define and develop application-relevant information (L3+) products. In addition, the stakeholders and the NISAR Program should be involved in products archive and distribution. Finally, it will be of value to the mission for stakeholders to provide feedback, including if possible quantifiable metrics, on the value added by using NISAR data. Each of these steps are discussed below.

2.5.1 Stakeholder Capability Development: Identify Needs

Given the potential volume of NISAR data that could be used, the broader stakeholder community may need to build capability within their organizations for realizing the full utility of the data. Therefore, stakeholders may need to identify where in their workflows NISAR data will be used to build capability and capacity. As described within this document (the NISAR Utilization Plan), the application area-specific workshops (Section 2.3.1) are the first vehicle by which stakeholder requirements are identified. The Application Working Groups (Section 2.3.2) then are a vehicle available to continue collaborative work between stakeholders and NISAR experts to define and develop products of utility to the stakeholders.

2.5.2 Information Product (L3+) Generation

The stakeholder community will *need to actively participate* in the development, validation, and integration of information products (L3+) derived from SAR into their local (decision support or research) workflows to ensure familiarity with and confidence in the data once NISAR launches. Here we describe some potential opportunities for support from NASA and other agencies to help facilitate such activities. These activities may or may not fall under the purview of an Applications Working Group (Section 2.3.1). Depending upon the specific opportunity, the stakeholder community is encouraged to shoulder or share primary support through cost-sharing or other mechanisms.

2.5.2.1 NASA Research Opportunities for Space and Earth Science (ROSES)

NASA ROSES announcement, released annually on or around February 14th, often provides additional opportunities to support advancing the utility of SAR/NISAR data such as: (i) conducting basic research, (ii) generating data sets, and (iii) increasing SAR literacy and capacity building. Specific to basic research for new uses of SAR data are topical ROSES solicitations from R&A, NASA ASP, and the Earth Science Technology Office (ESTO). Solicitations relevant to data set generation include Advancing Collaborative Connections for Earth System Science (ACCESS) and Making Earth System Data Records for Use in Research Environments (MEaSUREs). ACCESS and MEaSUREs solicitations often contain language that invites

proposals to leverage the relatively long record of existing SAR satellites to provide long-term geophysical records, and this can be used to prepare the community for the NISAR mission. These solicitations also can support work on the integration of SAR sensors' data with other geospatial or geodetic observations such as those from Landsat, MODIS, GPS, or NextRAD. NISAR Program managers and DPAs interact on a regular basis with other NASA Programs regarding the potential integration of language that supports NISAR into relevant ROSES solicitations. It is the responsibility of working groups and the broader stakeholder community to apply for and complete ROSES projects that prepare them for using NISAR data when it becomes available.

ROSES also provides opportunities for increasing SAR literacy and capacity building (i.e., ability of agencies/organizations to ingest SAR into current decision support systems). SERVIR offers an opportunity for SAR-trained scientists to build capacity in developing countries across many application areas. Similarly, the ASP Group on Earth Observations (GEO) Work Programme calls for proposals to advance the availability, accessibility and utility of Earth observations that have societal benefit. The last ROSES solicitation of particular relevance is the E.2. Topical Workshop solicitation that is open every year and can fund additional table top exercises/hands-on workshops (Section 2.3.1) that go beyond the scope of the applications workshops funded directly by the NISAR project.

2.5.2.2 Non-NASA Opportunities for Support

Support from the stakeholder community will be key to development of higher-level information products that support the needs of specific end user communities. Stakeholders are encouraged to evaluate their own in-house resources and budget allocations to support Utilization Plan activities. In some cases, funding opportunities from non-NASA agencies and organizations exist to support projects that develop end user capability of value to those agencies and organizations. It is recognized that it may be necessary for agencies (i.e., NASA and non-NASA federal agencies) to develop programmatic partnerships to facilitate interagency collaborations and these must be agreed upon by the responsible party (i.e., program managers if need be) at the respective agencies. Other partnerships, for example at the state-level, may leverage existing projects to develop capability for ingesting NISAR data when it becomes available.

2.5.3 Data Archives and Distribution

NASA missions, such as NISAR, archive data products at the Distributed Active Archive Centers (DAACs). Utilization Plan activities may anticipate generation of additional L3+ products and should therefore consider potential options for product archive and distribution. The NASA DAACs, such as the ASF DAAC, should be consulted for such purposes as they understand data management standards and how to store and report data and metadata such that it maintains its value through time and across disciplines. In some cases, the DAACs may be a logical place for L3+ archive and distribution and can advise on the relevant processes at a given DAAC. There are many other data archive options including private sector (e.g., Google Earth Engine), non-profit (e.g., World Resources Institute – WRI) and agency-owned (e.g., NOAA, USGS, etc.). Working Groups (Section 2.3.1) are encouraged to work with and include data archive and distribution representatives so that developed products can be used and distributed as widely as possible. Here we detail NASA archive centers as one option.

NASA Archives: Distributed Active Archive Centers (DAACs)

The Utilization Plan includes the potential of interacting with the NASA DAACs (Table 2), which are part of the NASA Flight Project Division Earth Observing System (EOS) Data and Information System (EOSDIS) managed by the Earth Science Data and Information System (ESDIS) Project.

DAACs are responsible for end-to-end capabilities for managing NASA's Earth science data while serving a large and diverse user community, generally providing capabilities and specialized services such as generating Level 1-4 science data products for EOS flight projects (e.g., NISAR), and archiving and distributing data products from EOS and other satellite missions, aircraft and field measurement campaigns that are led by Principal Investigators (PI). DAACs also provide user support services such as educational material about data products and accessing hosted data products.

DACCs must be approached by the PI of any potential NISAR product to host data products from non-flight projects. As such, it is the responsibility of the Applications Working Groups to determine if a NASA DAAC is most appropriate for their product distribution; if so, the working groups are encouraged to consider inclusion of DAAC representatives. The broader stakeholder community can also approach DAACs with their products to determine if they are appropriate for NASA archive. The Applications Coordinators can also interact with DAACs to present and demonstrate relevant NISAR products at annual DAAC User Working Group meetings as appropriate. Such presentations could include work done by the Applications Working Groups, Project and ST. In addition, the DAACs with relevant responsibilities (Table 2) will be invited to participate in NISAR Applications Workshops (Section 2.3.1) and Applications Working Groups (Section 2.3.2).

Table 2. *The specific responsibilities of each NASA Distributed Active Archive Center (DAAC) with potential significance for NISAR applications.*

DAAC	Responsible for:
Atmospheric Science Data Center (ASDC)	Working with the Science Directorate's Climate Science Branch, Atmospheric Composition Branch, and Chemistry and Dynamics Branch to study changes in Earth's Atmosphere
Alaska Satellite Facility (ASF)	Acquiring, processing, archiving, and distributing SAR data
Crustal Dynamics Data Information System (CDDIS)	Supporting the space geodesy and geodynamics community through NASA's Space Geodesy Project as well as NASA's Earth Science Enterprise
Goddard Earth Sciences Data and Information Services Center (GES DISC)	Providing access to a wide range of global climate data, concentrated primarily in the areas of atmospheric composition, atmospheric dynamics, global precipitation, and solar irradiance
Global Hydrology Resource Center (GHRC)	Archiving of both data and knowledge augmentation services, with a focus on hazardous weather, its governing dynamical and physical processes, and associated applications

Land Processes (LP)	Processing land processes data products and contributing to inter-disciplinary studies of the integrated Earth system
National Snow and Ice Data Center (NSIDC)	Archiving and distributing cryosphere and climate-related products and providing general data and information services to the cryosphere and polar processes research community
Ocean Biology (OB.DAAC)	Processing, archiving and distributing ocean biology data
Oak Ridge National Laboratory (ORNL)	Providing data and information relevant to biogeochemical dynamics, ecological data, and environmental processes, critical for understanding the dynamics relating the biological, geological, and chemical components of Earth's environment
Physical Oceanography (PO.DAAC)	Providing data and related information pertaining to the physical processes and conditions of the global oceans, including measurements of ocean winds, temperature, topography, salinity, circulation and currents, and sea ice
Socioeconomic Data and Applications Center (SEDAC)	Synthesizing Earth science and socioeconomic data and information in ways useful to a wide range of decision makers and other applied users, and to provide an "Information Gateway" between the socioeconomic and Earth science data and information domains

2.5.4 Demonstrating Utility

There are many ways to quantify and demonstrate the utility of NISAR data through value-added to the stakeholder community. Some of these include conducting table-top exercises (Section 2.3.1) where stakeholders run through workflows with and without information derived from NISAR data and determine the differences in the workflow. Alternatively, when information products are initially defined, if stakeholders determine metrics based on the priorities within their organization (e.g., speed at making a decision – rapid response), then that metric can be tracked both before and after NISAR data is introduced (Section 2.5.1). Another common way for determining value-added is for organizations to operate both under business as usual and then assess how their operations would change if they used the additional information, and approach that is analogous to beta testing.

Once value-added is assessed, the results will be reported to the NASA Program and Project and to the user community. Engaged end users and supporting SAR experts, like the NISAR Envoys (Section 2.3.3), will report the utility to the broader stakeholder community via workshops and conferences that they attend.

2.6 URGENT RESPONSE APPLICATIONS

NASA has made a commitment to design into the NISAR mission the capability to acquire and expedite processing of images in response to disasters (urgent response, UR), with redirection of the satellite acquisitions within 24-hours to prioritize downlink, and a special processing stream for UR product generation and delivery within 24 hours of acquisition. Urgent response cuts across all the NISAR applications areas (Section 2.2), including, e.g., forest fire, oil spill, earthquake, major storm, volcanic unrest, and catastrophic levee failure. A separate document,

the Urgent Response Plan, is being developed to provide the end-to-end framework for how response will be implemented, covering activities that include which levels of events will automatically generate response (e.g., earthquake magnitude), how stakeholders will request imaging, and all the steps through receiving feedback on how the data was used and how useful it was. The NISAR ST is taking the lead in generating that document, supported by the DPAs. It is planned that an Urgent Response Working Group will advise the NISAR Program and the NISAR ST on urgent response implementation, with work plans phased to support the NISAR project's implementation of urgent response request and processing, and including engaging the response community in developing plans for requesting urgent response acquisitions and guidance on how best to deliver products. Further work with the responders may be needed for development of L3+ response products that could be generated from the L0-2 UR products that are generated by the NISAR Project. This too will be described in the UR Plan.

2.7 POST-LAUNCH ACTIVITIES

The NISAR Utilization Plan mainly deals with activities that need to be completed before launch so that NISAR data are useful from the beginning of the mission onwards. However, there are a number of activities post-launch from which NISAR and stakeholders can derive mutual benefit, particularly in how they impact NISAR's societal value and the potential for data continuity after the nominal mission lifetime. After launch there will be six types of activities supporting the utilization of NISAR data: 1) support during instrument calibration/validation, 2) feedback to the NISAR project on product utilization and utility, 3) urgent response, 4) follow-on research into derived information, 5) SAR literacy education and 6) application workshops:

1. The NISAR project can benefit from engagement with some stakeholder communities who can provide data for instrument and algorithm calibration and validation. It is anticipated that partnerships will be established before launch and continue through calibration/validation (cal/val) activities, possibly with the working groups as an initial vehicle for collaboration.
2. The NISAR mission team needs to obtain continued feedback from end users on the how NISAR data are being used, what could be improved, and the quality of NISAR data products in relation to what is observed locally.
3. NISAR urgent response acquisitions and processing will begin and the project will receive feedback on the process and integrate feedback as part of the Urgent Response Plan (2.6).
4. After launch of NISAR, a considerable volume of data will be publicly available. NASA will offer solicitations for research and applications that use NISAR data as appropriate in the post launch period, including opportunities to participate in the NISAR Science Team.
5. The NISAR Applications Coordinators will continue to work with ARSET and DEVELOP to educate users regarding the utility of SAR data. The ST will be responsible for updating any material from pre-launch activities. The Applications Coordinators team will work with existing NASA ASP capacity building programs to investigate opportunities for providing hands-on tutorials with NISAR data.
6. After launch, there will be at least one omnibus applications workshop that includes all applications. This workshop will allow early engagers to present their work and demonstrate the utility (Section 2.5.4) of the data to a broader community. These may be in the form of a single omnibus workshop, or as special sessions at professional meetings

(e.g., the American Geophysical Union (AGU)). The Applications Coordinators will be responsible for working with the Project and NISAR Program to host these workshops.

3 Implementation

3.1 ROLES AND RESPONSIBILITIES

Because there are many contributing groups responsible and involved in development, implementation, and operations of the NISAR mission, each has different set of responsibilities with respect to supporting applications generally and the Utilization Plan in particular. The different activities described in Section 2 and how they relate to different groups is shown in Fig. 1. A description of each contributing group and associated responsibilities is given in the subsections below and outlined in Table 3.

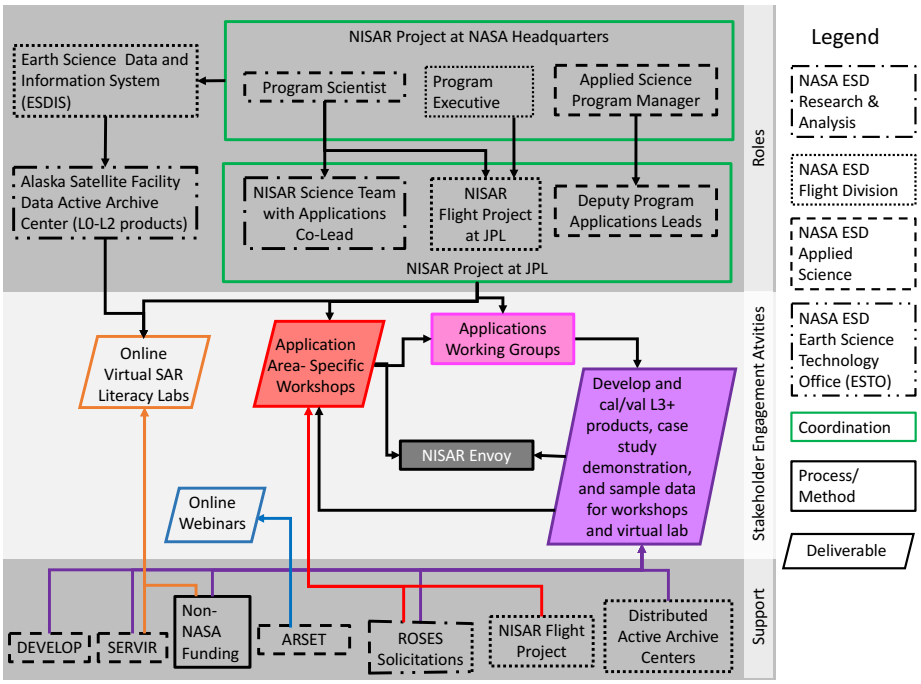


Figure 1. *A flow diagram of the NASA NISAR Utilization Plan including roles, activities and funding sources where arrows represent relationships, rectangles represent a process or method for meeting deliverables and parallelograms represent deliverables. Shaded shapes within activities represent Early Engagement by the larger community with NISAR (inclusive of the NISAR Project, Program, Science Team and Applications Coordinators (i.e., Science Team Applications Co-Lead and Deputy Applications Leads). The color associated with each shape is to enable easy tracking between support and the engagement activity.*

Responsibilities			Roles							
			NASA HQ NISAR Project		NISAR Applications Coordinators		NISAR Science Team	JPL NISAR Project	Alaska Satellite Facility DAAC	Braoder Stakeholder Community
			NASA Applied Science	NASA Research and Analysis	Deputy Program Application (DPA) Leads	Science Team Applications Co-Lead				
Early Engagement with NISAR	Application Area-Specific Workshops	Oceans	Participate in Applications workshops		Organize, propose (if necessary) for additional funding, and run the workshops, as well as deliver and circulate a report of the workshop to participants, the public (via NISAR website) and appropriate NASA Program Managers		Help organize, participate and report findings from the workshop	Pay for time spent directly supporting the workshop by the NISAR Applications Coordinators and NISAR Project staff; and host workshop reports on the NISAR website	Participate in Applications workshops	
		Critical Infrastructure								
		Forests								
		Agriculture								
		Geologic Hazards								
		Hydrology								
		Wetlands								
	Application Working Groups	L3+ Product Generation, Cal/Val, Demonstrate Utility	Suggest and participate in working groups to increase NISAR utility							
	Envoy Program	Attend Professional Meetings	Nominate members for the Envoy program		Facilitate between Envoy and the NISAR Project (NASA and JPL), ST and stakeholders regarding relevant professional meetings		Nominate members for the Envoy program			
		Lecturers			Suggest Envoy speakers for Education and Training		Provide up-to-date, relevant lecture materials as needed	Host Envoy list via website	None	Provide up-to-date, relevant lecture materials as needed
SAR Literacy and Capacity Building	Education and Training	SAR Educators Workshop	Participate in workshop							
		Educational Resource Library	None		Identify, design and distribute SAR literacy materials compliant with ARSET best practices		Identify and provide SAR literacy materials	Host Education and Training Resources via NISAR website	Identify and provide SAR literacy materials	Use provided education resources
		Online Virtual SAR Lab			Identify a host for sustaining open-access of the virtual SAR lab		Lead partnership with ASF and UNAVCO and contribute demonstration workflows and data	Ensure that SAR-processing software (ISCE) has a no-cost license	Partner with ST and UNAVCO to develop a virtual SAR lab	
		ARSET			Work with ARSET to introduce NISAR, provide project status, and identify relevant speakers from the Envoy		Identify and provide SAR literacy materials	None	None	
		DEVELOP			Identify SAR-demonstration projects and mentors		Provide input and/or mentor DEVELOP teams		None	Identify feasibility studies and work with coordination team
		SERVIR			Engage with SERVIR to advertise SAR education and training and facilitate partnerships between SERVIR ST, NISAR ST and NISAR Envoy		None	None	None	Use provided education resources
Beyond Data to Information	Identify Capability Development	Early Engagement	None		Facilitate communications between stakeholders and NISAR scientists in Working Groups		Participate in Working Group		None	Participate in Working Groups
	Information Product Generation	NASA ROSES	Discuss with non-NISAR NASA Programs the integration of language that supports NISAR into future, relevant ROSES solicitations				Apply for grants, conduct research, and develop products	None	None	Apply for grants, conduct research, and develop products
	Data Archive and Distribution	NASA DAACs	None		Present and demonstrate NISAR products at UWG meetings and invite DAACs to participate in Workshops and Working Groups		Work with DAACs to archive PI-developed L3+ products	Provide updated information to Applications Coordinators	Work with PIs to archive products	Work with DAACs to archive PI-developed L3+ products
	Demonstrating Utility	Early Engagment	None							Conduct table top exercies, track metrics before and after NISAR integration, or perform beta-testing
			Participate in and report at Applications Workshops and NISAR Envoy							
Follow-Up	Plan for Urgent Response(PUR)		None		Provide input and work with the Project, ST and ASF to develop and distribute the PUR		Lead and participate in Working Group	Participate in Working Group and integrate feedback	Participate in Working Group	
	Post-Launch	Working Groups	None		Participate in Working Groups					
		Urgent Response	None					Respond to requests and feedback	None	Provide feedback to JPL NISAR Project
		Research and Analysis	Discuss with non-NISAR NASA Programs the integration of language that supports NISAR into future, relevant ROSES solicitations				Apply for and conduct research	None		Apply for and conduct research
		SAR Literacy	None		Work with NISAR ASP to update and continue NISAR literacy training		Provide updates to materials	None		Use and share SAR education resources
		Workshops	Participate in Applications workshops		Organize and report on workshops		Participate in workshops			

Table 3. Specific roles and responsibilities of each party in implementing the NISAR Utilization Plan.

3.1.1 NASA Headquarters NISAR Project

3.1.1.1 NASA NISAR PROJECT

At NASA Headquarters, the NISAR Program Scientist (PS) and Program Executive (PE) provide oversight for the successful formulation, development, launch and operations of the NISAR mission. The PS and PE have the following responsibilities related to applications and the Utilization Plan:

- Ensure that the Mission meets the Level 1 Urgent Response requirement.
- Lead coordination with international space agencies, other U.S. government agencies, and other NASA program offices where appropriate to support activities that will increase the utilization of NISAR data.
- Coordinate with the Applied Science Program Manager assigned to NISAR.
- Work with the Applications Coordinators to define the scope and facilitate implementation of the Utilization Plan.

3.1.1.2 NASA APPLIED SCIENCE PROGRAM

The NASA Applied Science Program supports satellite mission planning, including identifying potential applications early in the planning for future missions. The Applied Science Program consists of a program manager at NASA Headquarters and the Deputy Program Application Leads (DPAs, Section 1.2.2.2) at NASA Centers. The Applied Science Program Manager has the following responsibilities related to mission applications prior to launch:

- Appoint the appropriate DPAs to work with the NISAR Science Team and the NISAR project (at JPL and NASA HQ).
- Work with the DPAs to leverage existing Applied Science programs and resources (e.g., ARSET, DEVELOP) to increase the applications value of NISAR.
- Work with the DPAs on defining the scope of the Utilization Plan.

3.1.2 NISAR Applications Coordinators

3.1.2.1 NASA NISAR Science Team Applications Co-Lead

The NASA NISAR Science Team (ST) Applications Co-Lead is selected at the time of the Science Team selection through a competed ROSES solicitation. The Applications Co-Lead has responsibilities to:

- Coordinate and regularly interface with the NISAR ST, the NISAR Program Scientist and Applied Science Program Manager, and the NISAR Project Scientist at JPL with respect to applications, advocating for the interests of applications throughout mission planning, development and implementation.
- Engage with the NISAR DPAs to define and implement a Utilization Plan.
- Work with each of the science co-leads and the DPAs to help identify appropriate applications communities.
- Identify applications and science that are not addressed by the three primary science disciplines.

- Lead development of the Urgent Response Plan.
- Work with the NISAR Project to ensure that there are viable protocols for responding to urgent application needs (e.g., during disaster events).
- Work with the NISAR Program and Project to facilitate NISAR's utility for urgent response, being capable of providing observations before, during, and after disasters (as possible) that are of high value to forecasters and responders.

3.1.2.2 NASA NISAR Deputy Program Application Leads (DPA)

The DPAs are selected by the NASA Applied Science Program Manager. DPAs are located at one of the NASA centers or JPL. The responsibilities of the DPAs are to:

- Provide information to the NASA Applied Sciences Program office on activities that would increase the applications value of the NISAR mission.
- Report to the NASA Headquarters the needs and interests of applications communities.
- Provide NISAR Project status updates to the Applied Science Program.
- Develop and implement the NISAR Utilization Plan.
- Provide regular application activities updates.
- Participate in conferences and workshops relevant for representing NISAR interests and capability.
- Lead organization of the NISAR Applications Workshops.

3.1.3 NISAR Project at JPL

The NISAR Project at JPL is the engineering and science team responsible for building hardware, developing software, and generally executing work leading to successful launch and operation of the NISAR mission. With respect to this Utilization Plan, the Project has the following responsibilities:

- Meet all L1 and L2 requirements for urgent response.
- Support the Science Team in formulating the recommendations to the NISAR Program Manager on mission application goals and objectives, within the scope of trade studies, designs and development needed to meet the L1 and L2 requirements, and within the scope of project budget and schedule.
- Respond to requests from the NASA HQ Program Scientist and Executive to address recommendations, including a) determination of scope relative to the Project Level Requirement Agreement (PLRA), b) assessment of cost and schedule implications of necessary trade studies or design and potential implementation, and c) implementation of authorized requirements consistent with budget and schedule constraints.
- Hold at least one application workshop per year.
- Support implementation of the Utilization Plan within the scope of the Project budget and responsibilities as directed by the NASA HQ Program Scientist and Executive.

3.1.4 Indian Space Research Organization (ISRO)

ISRO Earth observation missions are highly focused on applications of practical and quantifiable benefit to society, whether it is routine monitoring or rapid response. ISRO does not have a formal role in NASA's Utilization Plan, however, they have a number of complementary programs that have natural analogs to NASA's Applications Program and they have an established framework for developing their own utilization plan for their missions.

1. ISRO Utilization Program: A year or two before launch of an ISRO Earth observation mission, a Utilization Program is established and managed by a program director at ISRO Space Applications Research Centre (SAC). The Utilization Program goals are to develop applications for utilization of the data from the mission with the intent of developing operational applications. The UP is a competed program, and over a 3-5-year period, algorithms and software are developed and their operational utility for specific agencies of the Indian government is demonstrated. Successful algorithms are operationalized by agencies (e.g., RISAT-1 crop monitoring and biomass inventory of India).
2. Urgent Response: ISRO maintains a round-the-clock urgent response team at the National Remote Sensing Centre (NRSC). This team receives International Charter and other coordinated disaster requests, monitors available ISRO space assets for the suitability of making an observation to satisfy the requests, and develops tasking requests for ISRO satellites. The coordination of NISAR's role in ISRO's satellite fleet for disaster response will be done through the NRSC team with the NASA project following the accepted and funded NASA program recommendations.

3.1.5 Distributed Active Archive Centers (DAACs)

The NASA Distributed Active Archive Centers (DAACs) are part of the NASA Flight Project Division Earth Observing System (EOS) Data and Information System (EOSDIS) managed by the Earth Science Data and Information System (ESDIS) Project. DAACs have the general responsibility to archive and distribute NASA mission products to Level-3. The NASA Earth Science Data and Information System (ESDIS) Program has designated the Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC) as the NISAR DAAC for science products up to Level 2 (L2) products. As the mission DAAC, ASF is responsible for:

- Generating, archiving and distributing NISAR L1-L2 science data products.
- Supporting large and diverse user communities, including the applications user community, by generally providing capabilities and specialized services.

Selection of DAACs to host L3+ NISAR products has not been made. There are currently thirteen DAACs (https://earthdata.nasa.gov/about/daacs), which each have a specific discipline orientation. L3+ products could be assigned to different DAACs for archiving, depending upon their end user community.

3.1.6 Broader Stakeholder Community

The broader stakeholder community includes all who anticipate using NISAR data products, irrespective of their organization, including universities, state and federal agencies, non-profit,

commercial sector, etc. Those wishing to benefit from and participate in early engagement with NISAR are encouraged to engage with the NISAR Applications coordinators, the NISAR project at NASA HQ and JPL. Specific roles and potential responsibilities include one or more of the following as may be appropriate:

- Participate in NISAR Applications workshops
- Participate in working groups specific to their area of expertise
- Nominate and participate in the NISAR Envoy program,
- Participate in research and development of information products that increase the visibility and utility of NISAR for a broader range uses
- Work with the Applications Coordinators and their organizations to identify needed feasibility studies or demonstration projects
- Use and disseminate provided education resources
- Provide feedback to NASA HQ and the NISAR Project at JPL concerning the utility of NISAR data and tools/services

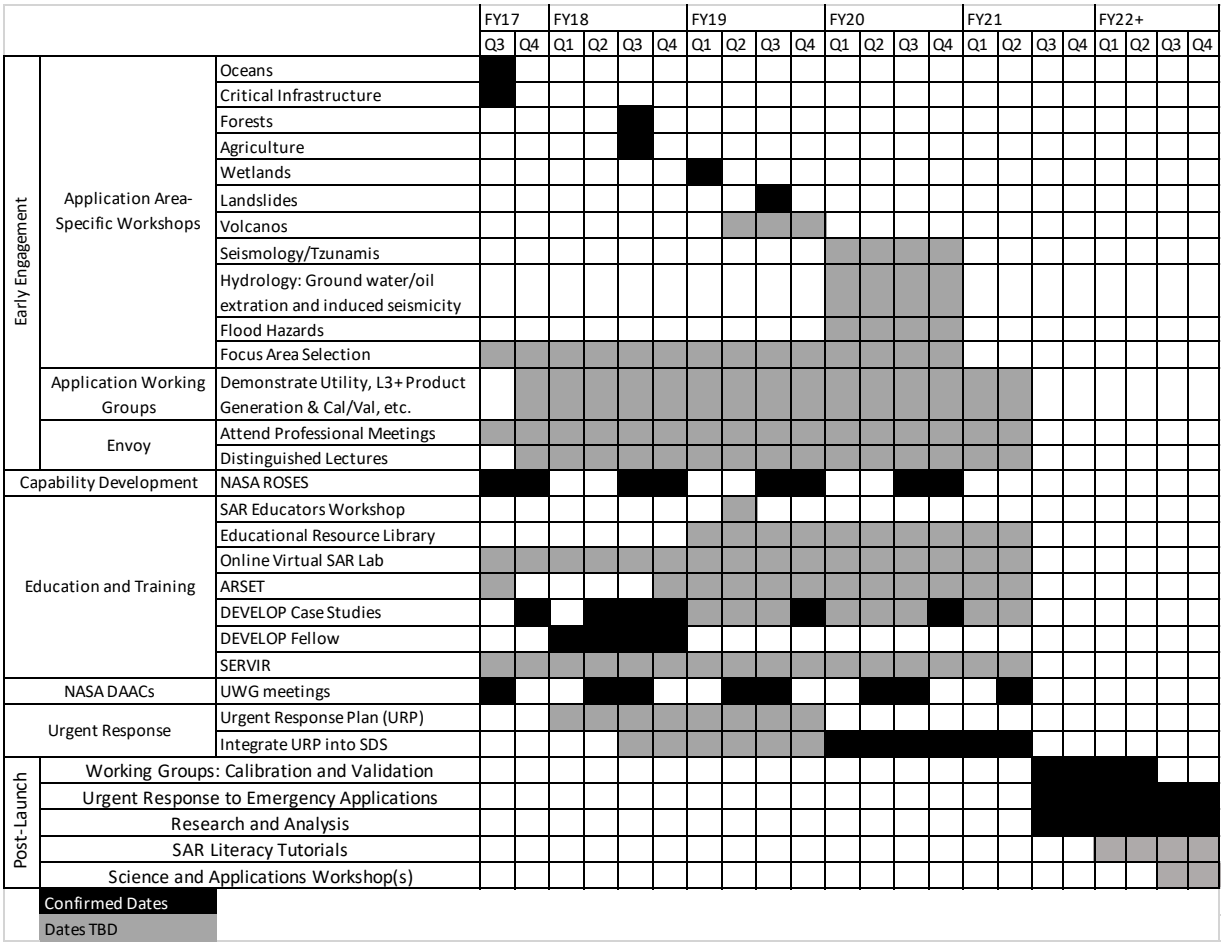
3.2 NASA APPLIED SCIENCE MISSION APPLICATION PLAN

Recognizing that all NASA flight projects provide data valuable for purposes beyond those for which requirements are developed, the NASA Earth Science Division initiated a directive for a Project Applications Program in 2017. This directive outlines a specific protocol and guidelines for engaging applications communities throughout flight project development, and it applies to missions currently in the pre-formulation stage. Since NISAR is past the pre-formulation mission phase, the prescribed activities are not required; nevertheless, the NISAR Utilization Plan is well aligned with the directive and offers activities analogous to many of the activities in the Project Applications Program. Table 4 provides a comparison of the activities in this plan and the directive.

NASA Earth Science Division: Project Applications Program Prescribed Activities		NISAR Utilization Plan Analogous Activities
Community Assessment	X	2014 and 2015 Applications Workshops
Project Studies	X	Urgent Response: Latency vs. Accuracy
Application Plan	X	Utilization Plan
Application Traceability Matrix	X	Application Traceability Matrices
Project Applications Workshops	X	Area-Specific Workshops
Focus Sessions	X	
Tutorials	X	ARSET Webinar Series + Online Virtual Lab
Event Reports	X	Event Reports
Community Contact List (working Group)	X	Application Working Groups
Early Adopter Program	X	Early Engagement
Use Cases/ Case Studies	X	DEVELOP studies + other
Project Application Posters	X	Project Application Posters at Workshops
Early Adopter Workshop		
Early Adopter Benchmark Meeting	X	Area-Specific Workshops
Data Workshops	X	Follow-on Area-Specific Workshops
Short Courses	X	
Post-Launch EA program	X	Post-Launch Activities
Impact Workshop	X	Post-Launch Omnibus Workshop

Table 4. *Comparison of the NASA Applied Science Programs prescribed guideline activities for flight projects, initiated in 2017, to the planned analogous activities in the NISAR Utilization Plan.*

3.3 SCHEDULE



4 Acknowledgements

The NISAR Utilization Plan was developed through the dedication and under the leadership of Craig Dobson, NISAR Program Scientist, who retired from NASA in August 2018. The NISAR Science Team and the NISAR Project thank him for his invaluable input to a plan whereby NISAR data will be accessible and useful to the widest range of users, maximizing both the scientific and societal value of the mission. This plan implements his vision that we should "leave no photon unused."

5 Appendices

5.1 LEVEL 1 & LEVEL 2 REQUIREMENTS FOR URGENT RESPONSE

5.1.1 NISAR Level 1 Urgent Response Requirement

There is a single NISAR Level 1 requirement addressing rapid retargeting and low latency processing in support of urgent response that the mission must meet [Ref: D-80911, NISAR L1 Science Requirements]. All Level 2+ requirements for urgent response flow down from this one requirement.

> *In support of response to major natural or anthropogenic disasters, the mission system shall be capable of providing revised scheduling for new acquisitions within 24 hours of an event or an event forecast notification and delivering data within 5 hours of being collected, and shall exercise this capability on a best efforts basis.*

The requirement lays out the timeline for two specific actions to be taken by the NISAR Project:

1. Within 24 hours of a disaster notification, the NISAR mission system will provide ISRO with revised scheduling for new acquisitions.
2. Within 5 hours of collection, data covering the disaster site will be delivered.

5.1.2 NISAR Level 2 Urgent Response Requirements

The NISAR Project has defined how it will meet Level 1 disaster response requirement through two Level 2 project requirements [Ref: D-76287, NISAR Project Systems Requirements Document], which have been approved by the Program.

> ***L2-PRS-510 Urgent Response Latency:*** *For major natural or anthropogenic disasters response, the NISAR project shall have the capability to reschedule the Observatory's planned observations within 24 (TBR*) hours of event notification to mission team.*
>
> *Note: The 24 hours (TBR*) refers to the scheduling process for file uplink + radiation of new observation instructions to the spacecraft and not to the data acquisition window.*
>
> * *TBR - to be resolved; a representative value/parameter has been identified with a known conflict.* [No resolution at the time of preparation of the Utilization Plan.]
>
> .
>
> ***L2-PRS-511 Urgent Response Data Delivery Latency:*** *For major natural or anthropogenic disasters response, the NISAR project shall have the capability to deliver the L0B data products of the "rescheduled" disaster observation to users within 5 (TBR*) hours of data acquisition.*
>
> * No resolution has been identified at the time of preparation of this Utilization Plan.

In defining how the project will meet the Level 1 disaster response requirement, the project has done the following:

1. Specified that the 24-hour period begins when the mission team receives notification that an event requires response.
2. Limited the data to be delivered within 5 hours to L0B products, i.e., raw data plus ancillary information. In practice, the processing system is likely to be designed to generate products through L2 in the urgent response data processing workflow.

5.2 ACRONYMS

Acronym	Description
ACCESS	Advancing Collaborative Connections for Earth System Science
AGU	American Geophysical Union
ARSET	Applied Remote Sensing Training
ASF	Alaska Satellite Facility
ASP	Applied Science Program
ATM	Application Traceability Matrix
DAAC	Data Active Archive Center
DPA	Deputy Application Lead
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
ESDIS	Earth Science Data and Information System
ESTO	Earth Science Technology Office
FY##	Fiscal Year 20##
GEO	Group on Earth Observations
GIS	Geographic Information System
GPS	Global Positioning System
InSAR	Interferometric Synthetic Aperture Radar
ISCE	InSAR Scientific Computing Environment
ISRO	Indian Space Research Organization
JPL	Jet Propulsion Laboratory
L#	Data Product Level #
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MODIS	MODerate Resolution Imaging Spectroradiometer
NASA HQ	NASA Headquarters
NISAR	NASA-ISRO Synthetic Aperture Radar
NOAA	National Oceanic and Atmospheric Administration
NRSC	National Remote Sensing Centre
NRT	Near real time
PE	Program Executive

PLRA	Project Level Requirement Agreement
PS	Program Scientist
R&A	Research and Analysis
ROSES	Research Opportunities for Space and Earth Science
SAC	Space Applications Research Centre
SAR	Synthetic Aperture Radar
ST	Science Team
TBD	To be determined
TBR	To be resolved
UR	Urgent Response
USAID	US Agency for International Development
USFS	US Forest Service
USGS	US Geological Survey
WRI	World Resources Institute