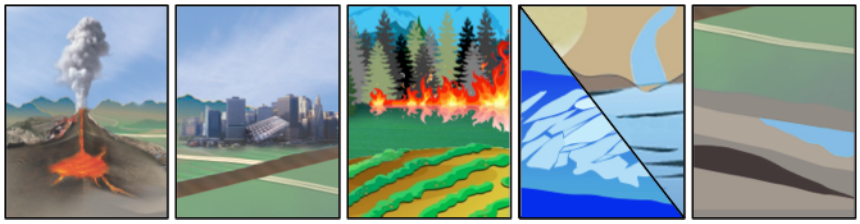

2017 NISAR Applications Workshop:

CRITICAL INFRASTRUCTURE

Dept. of Homeland Security
National Protection and Programs Division
1401 S. Clark St., Arlington, VA 22201
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Workshop Report

NISAR
NASA - ISRO SAR Mission

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1 Executive Summary

Critical infrastructure (CI) touches every U.S. citizen every day, from the roads and waterways that we move on, to the water that we drink, to the energy that powers our homes and workplaces. Accurate and timely information concerning the status of these facilities, transportation systems, and structures is essential to the Nation's security and economy. The joint NASA/DHS workshop focused on improving CI resilience using synthetic aperture radar (SAR) remote sensing data from the NASA-ISRO SAR (NISAR) mission. Participants were primarily from Directorates within DHS or NASA, and included scientists, technicians, program managers, and end users with responsibility for data acquisition, data exploitation, product development, product delivery, product use, and R&D to develop capabilities for all of the above. Discussions were held over two days to convey DHS's information needs, the mission and procedures for various DHS offices and programs involved in the delivery of geospatial products, and the capabilities and status of the NISAR mission. Case studies were presented to demonstrate the current state of practice in the use of SAR remote sensing for applications of direct importance to the DHS participants. Six Critical Infrastructure Sectors and one program office from the Office of Infrastructure Protection (OIP) presented their information requirements in response to a set of questions provided by the NASA team, then the NASA team responded by describing the degree to which NISAR could meet the requirements.

The general findings of this workshop were that (a) the data and products produced from the NISAR mission would be very valuable to the operational mission of DHS OIP in both cost savings and quality of information; (b) the information that NISAR could provide is not being provided to OIP in other ways; and (c) a recommended way to move into operational use of NISAR is through cooperative R&D between NASA and DHS. Three high priority focus areas were identified in which NISAR data could provide high value information to support CI protection, based upon the needs of all the various DHS offices and associated agencies present at the workshop. The greatest value was placed on routine monitoring using time series of surface deformation for situational awareness to identify long term trends and developing conditions that could lead to degradation, increased threats, or failure. Coverage was needed across the entire U.S. because of the wide distribution of infrastructure. Flood maps and maps of damaged structures were considered the highest value tactical information, particularly for cascading disasters and events with large geographical extent. Recommendations were made to seek ways to increase the spatial resolution of acquired data over the U.S. though increased downlink capacity and to work to establish pilot projects to incorporate SAR into DHS workflows in advance of NISAR launch.

2 Workshop Overview

Monitoring and measurement from earth observing satellites has been a means for understanding the natural resources of our planet for over 40 years. However, in the last 10 years, with the development of innovative signal processing techniques, the ability to measure changes in "hard targets" to the survey quality required by engineers opens a new frontier for the monitoring and assessment of critical infrastructure from space. NASA's upcoming NISAR mission will be unique in providing comprehensive and frequent imaging of all U.S. lands and open access to the data. This is potentially a game-changer for planning and management of critical infrastructure in the United States, and the workshop was held to determine how best to leverage the NISAR mission for critical infrastructure protection.

2.1 Workshop Objectives

The 2017 NISAR Critical Infrastructure Applications Workshop was organized in conjunction with the Department of Homeland Security (DHS) National Protection and Programs Directorate (NPPD) with the theme *Improving Infrastructure Resilience using NISAR Remote Sensing Data*. The 2-day meeting was held June 6-7, 2017, in Crystal City, Virginia. The workshop addressed those applications pertinent to disaster cycle management of critical infrastructure containing hard target facilities or structures.

The workshop objectives were to

1. Define the applications that have the highest priority for the user community, and match them to the NISAR observation modes and data products that can provide the highest value information.
2. Establish meaningful partnerships that result in sustained use of NISAR data, and more generally of SAR data, by the communities responsible for building and maintaining critical infrastructure.

NISAR applications workshops in previous years socialized NISAR's capabilities to a broad community of potential users in omnibus meetings covering a wide range of applications. This meeting was the first of the NISAR applications workshops focused to a particular topic. The new format is intended to foster more in-depth discussions between the NISAR team and members of a specific application community.

At the 2017 critical infrastructure meeting, representatives from the different organizations within DHS/NPPD including the Office of Infrastructure Protection (OIP), the Office of Cyber and Infrastructure Analysis (OCIA), and the Protective Security Advisors along with representatives from several critical infrastructure sectors (Sectors) were present. These organizations represent the full continuum of geospatial data generation, product development and end users. In addition to these organizations, participation in the workshop included representatives from DHS/Federal Emergency Management Agency (FEMA), DHS/Information and Analysis (I&A), and DHS/Science and Technology (S&T), and the National Geospatial-Intelligence Agency (NGA). The participant list is provided in an appendix.

2.2 Workshop Format

The intent of the change in NISAR Applications workshop format was to allow a 'deeper dive' into the needs of a specific community and to identify practical pathways for near-term active engagement between the end users and SAR experts, which would be followed up post-workshop at the NASA NISAR Program and agency partner level to facilitate sustained collaboration and facilitate usage of NISAR products. The following aspects of the workshop contributed to its success.

- The attendance was limited so that a single conversation could occur that included everyone.
- In-person attendance was by-invitation-only, with web-based attendance open to a broader community. This workshop had 50-60 attendees on each of the two days of meetings.
- The majority of the attendees were from the critical infrastructure applications community.
- Radar remote sensing presentations were limited to examples directly relevant to critical infrastructure monitoring and showed results from projects involving active engagement with end-user partners.
- The majority of the workshop was devoted to the discussion of Sector requirements and the technical trade-space available within the NISAR mission to address those requirements. DHS Sector and Program overviews were kept to a minimum and used only to establish understanding of who was there and where they fit into the larger organization.
- The NISAR team provided a set of focused questions to guide the presentations by Sector representatives, and contacted individual speakers prior to the meeting to discuss the questions and modify them if necessary to directly pertain to a specific Sector.
- The NASA representatives provided an immediate response to the Sector presentation to specify what was possible, what was likely to provide high value

reliable information, and how the information might be delivered as a product. In particular, acquisitions and products with cross-discipline utility were identified.

- All of the key DHS organizations that would have a role in accessing the data and potentially developing higher level information products were present at the workshop. This included NGA, which may have a role in acquisition of imagery for DHS/NPPD, as well as other agencies involved in monitoring critical infrastructure. This permitted a full discussion of methods for data acquisition, format issues, processing techniques, product descriptions, and product delivery options.

2.2.1 Workshop – Day 1

The workshop started by providing participants with a fundamental understanding of NASA/NISAR, NASA/Disasters, and DHS/National Protection Programs Directorate (NPPD), and the DHS/NPPD/Office of Cyber and Infrastructure Analysis (OCIA) programs (see Appendix A). Following these presentations, the NASA participants presented a set of remote sensing applications focused on the use of SAR for critical infrastructure monitoring. This set the stage for representatives from selected critical infrastructure Sectors to present their requirements for information products. The Sector representatives were asked to incorporate their answers to the following questions in their presentations in order to guide the presentations and make the discussions more productive.

1. Describe the facilities or structures that comprise your Sector. What are they, how many are there, where are they located? Examples: urban settings, suburban neighborhoods, rural countryside, wilderness, in water bodies.
2. Do your facilities operate by discharging any material? Examples: water, exhaust, steam, hard material such as rock or fine particulate.
3. Does your Sector have a requirement of routine surveillance? If yes, does a particular aspect of facilities, structures, or some other feature need to be monitored (i.e. pipelines, retaining walls, or waste pond) or is it for situational awareness of the facility and the surrounding environment?
4. Does your Sector have a response mission in the event of a disaster? If so what primary information products do you rely on?
5. What aspect of any facility or structure needs to be monitored? Examples: dam wall stability, bridge movement, levee height, pipeline location.
6. Do your Sector partners use remote sensing (aerial photography or satellite imagery) to monitor facilities or structures or the surrounding environment? If so, describe the type of data and applications.

7. What are the greatest threats to your facilities or structures? Do these vary by geographic region?
8. If your facility or structure began to fail, how would this failure manifest itself (slow leak, subsidence, expansion of containment vessel, erosion of support material)?
9. What are the most challenging problems that you face where external monitoring could significantly enhance reliability and security?

Following the presentation of information requirements by Sector representatives, the NASA team presented an initial technical response on the potential for NISAR to address these requirements. This response was designed to give the Sector representatives initial feedback, confirm that NASA had interpreted what was said correctly, and provided an overview of what the technical product might look like. The NISAR team considered what mode of acquisitions could meet the needs of multiple Sectors.

With the information requirements outlined and a technical specification to address those requirements understood, the Workshop attendees spent the next period of time discussing research and development (R&D) needs to address identified technical gaps. The day concluded with an overview discussion of key findings from the day and an outline for Day 2.

2.2.2 Workshop – Day 2

The workshop resumed on Day 2 with presentations on SAR-based critical infrastructure monitoring from SAR practitioners from academic, state and federal government agencies. The projects presented were focused on the use of SAR remote sensing for monitoring levee systems in New Orleans, damage assessment following catastrophic disasters, measurements of building and bridge structural deformation, and detection of ground deformation in the Washington D.C. area associated with different land use activities. These presentations were directly related to many of the requirements presented by Sector representatives and generated valuable discussion on both the value of remote sensing and the potential for this technology to address operational issues. These presentations and the discussions on how they might relate to Sector requirements set the stage for a deeper dive into the final products that would be created from NISAR data. Leading into this discussion, a presentation was made on how DHS/NPPD/OCIA conducts workflows, the data they use, product generation, approval process for product release, and the diversity of customers supported. This presentation provided valuable context for the following discussion focused on final products that would address Sector requirements described during Day 1. The discussion on final NISAR products to address Sector requirements followed the outline:

a. What do the final products look like?
b. Do any of the products serve multiple Sector requirements?
c. What is the technical specification for the NISAR radar product?
d. What is the best way to deliver the final product?
e. What is the best way to get from NISAR radar products to critical infrastructure final products?
f. How do we put that in place?

This session proved to be very productive in identifying significant issues, defining solutions, and clarifying the potential for NISAR to address Sector requirements. It leveraged the presentations by Sector representatives and served to further define the technical specifications for required products. This discussion flowed into a discussion on the Work Plan and continued to define solutions and lay out a path for DHS/NPPD and NASA to follow. The highest priority critical infrastructure application focus areas and the highest priority recommendations for work going forward identified in these discussions are summarized in Sections 8 and 9. During the wrap-up session the major workshop themes and action items were summarized and highlighted. The action plan is incorporated into the recommendations summary (Section 9).

3 Mission Overview

3.1 Mission Design

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 ecosystem, cryosphere, and solid earth science. 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.

3.2 Mission Capabilities

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 resampling*
3 – 10 meters mode-dependent ground resolution	*Small-scale observations*
Pointing control < 273 arcseconds	*Deformation interferometry*
Orbit control < 500 meters	*Deformation interferometry*
> 30% observation duty cycle	*Complete land/ice coverage*
Left/Right pointing capability	*North & South Pole coverage*

Figure 1 – NISAR characteristics and capabilities.

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 kinds 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 repeated 4-6 times per month, and the S-band instrument will provide additional coverage of India and parts of the polar regions. NISAR's orbiting radars can image at resolutions of 3-50 meters, depending upon the operating mode, to identify and track subtle movement of the Earth's land and its sea ice, and even provide information about what is happening below the surface in areas where subsurface processes result in surface deformation. Regularly and consistently repeated images can be used to detect small-scale changes before they are visible to the eye and to track dynamic changes as conditions evolve.

Table 1 shows the NISAR radar modes, which include different polarization states, with operational modes operating in single-polarization (SP) HH or VV (the first letter indicates the transmit polarization and the second indicates the receive polarization, either horizontal or vertical); dual-polarization (DP) HH/HV, VV/VH, or co-polarization HH/VV; and quad-polarization (QP) HH/HV/VV/VH, or quasi-quad polarization (slightly different frequency HH and VV transmit) depending upon the area (see section 3.3). The ground resolution in the cross-track direction is set by the pulse bandwidth, and is 3m/6m/12m/50m for 80/40/20/5 MHz, respectively. The ground resolution in the along-track direction is 8 m for all modes.

Table 1 – NISAR L-band and S-band radar modes, science targets, polarizations, pulse bandwidth (BW), pulse repetition frequency (PRF), pulse width (PW), and image swath width.

Science			Performance			
Primary Science Target	Freq Band	Polarization	BW (MHz)	PRF (Hz)	PW [µ sec]	Swath [km]
Background Land	L	DP HH/HV	20+5	1650	25	242
Background Land Soil Moisture	L	QQ	20+5	1650	25	242
Background Land Soil Moisture Hi Pwr	L	QQ	20+5	1650	20	242
Land Ice	L	SP HH	80	1650	40	121
Land Ice Low Res	L	SP HH	40+5	1650	45	242
Low Data Rate Study Mode SinglePol	L	SP HH	20+5	1650	25	242
Sea Ice Dynamics	L	SP VV	5	1600	25	242
Open Ocean	L	QD HH/VV	5+5	1650	20	242
India Land Characterization	L	DP VV/VH	20+5	1650	25	242
Urban Areas, Himalayas	L	DP HH/HV	40+5	1650	45	242
Urban Areas, Himalayas SM	L	QQ	40+5	1650	45	242
Urban Areas, Himalayas SM Hi Pwr	L	QQ	40+5	1650	40	242
US Agriculture, India Agriculture	L	QP HH/HV/VH/VV	40+5	1600*	45	242
US Agriculture, India Agriculture Low Res	L	QP HH/HV/VH/VV	20+5	1600*	45	242
Experimental CP mode	L	CP RH/RV	20+20	1650	40	242
Experimental QQ mode	L	QQ	20+20	1650	20	242
Experimental SP mode	L	SP HH	80	1650	20	242
ISRO Ice/sea-ice	L	DP VV/VH	5	1650	25	242
ISRO Ice/sea-ice - alternate	L	QD HH/VV	5	1650	25	242
Solid Earth/Ice/Veg/Coast/Bathym	S	Quasi-Quad	37.5	2200	10+10	244
Ecosystem/Coastal Ocean/Cryosphere	S	DP HH/HV	10	2200	25	244
Agriculture/Sea Ice	S	CP RH/RV	25	2200	25	244
Glacial Ice-High Res	S	CP RH/RV	37.5	2200	25	244
New mode	S	DP HH/HV	37.5	2200	25	244
Deformation	S	SP HH (or SP VV)	25	2200	25	244
Deformation-Max Res	S	SP HH (or SP VV)	75	2200	25	244

3.3 Current Mission Observation Plan

The current observation plan is shown in Figure 2. This near-final plan has NISAR L-band SAR 12mx8m spatial resolution, HH/HV mode acquisitions at a 12-day repeat interval across most of the land area outside of the polar regions and Greenland. Current plans are for NISAR to image almost all land surfaces of the Earth at least once every 6 days (once on the ascending orbit and once on the descending orbit). NISAR's continual background acquisitions of the Earth's land surfaces are nominally planned at 12mx8m single pixel resolution, which could be decreased to 6mx8m through acquisition in the higher resolution mode. Higher resolution will give greater resolving power and higher confidence in detection based upon movement spread across more adjacent pixels, however it would increase the volume of data to be downlinked from the satellite, which unfortunately is already too high for the planned ground-based downlink stations to handle.

Revisions of the observation plan are underway, but not finalized, to reduce the acquired data volume through a combination of increased temporal repeat intervals or single polarization acquisitions over low priority areas. This reduction is driven by NISAR's primary data volume limitations of 1) a maximum data downlink volume constraint, and 2) thermal constraints for several instruments on the spacecraft. At this time, the former sets the upper limit of 26 Tbits/day, with the limitation in the ground segment capability, not in the satellite hardware. The data downlink constraint is set by the number of ground stations that NISAR anticipates using and their throughput limits (Figure 3). This is important because the instrument maturity is at the stage where design of the hardware to be launched cannot be changed without significant impact to mission cost and schedule. In contrast, changes to the ground segment, including downlink capability at this point in time would not significantly impact mission schedule, though would add cost for downlink, transfer, processing, and storage for downlinked data volumes in excess of 26 Tb/d.

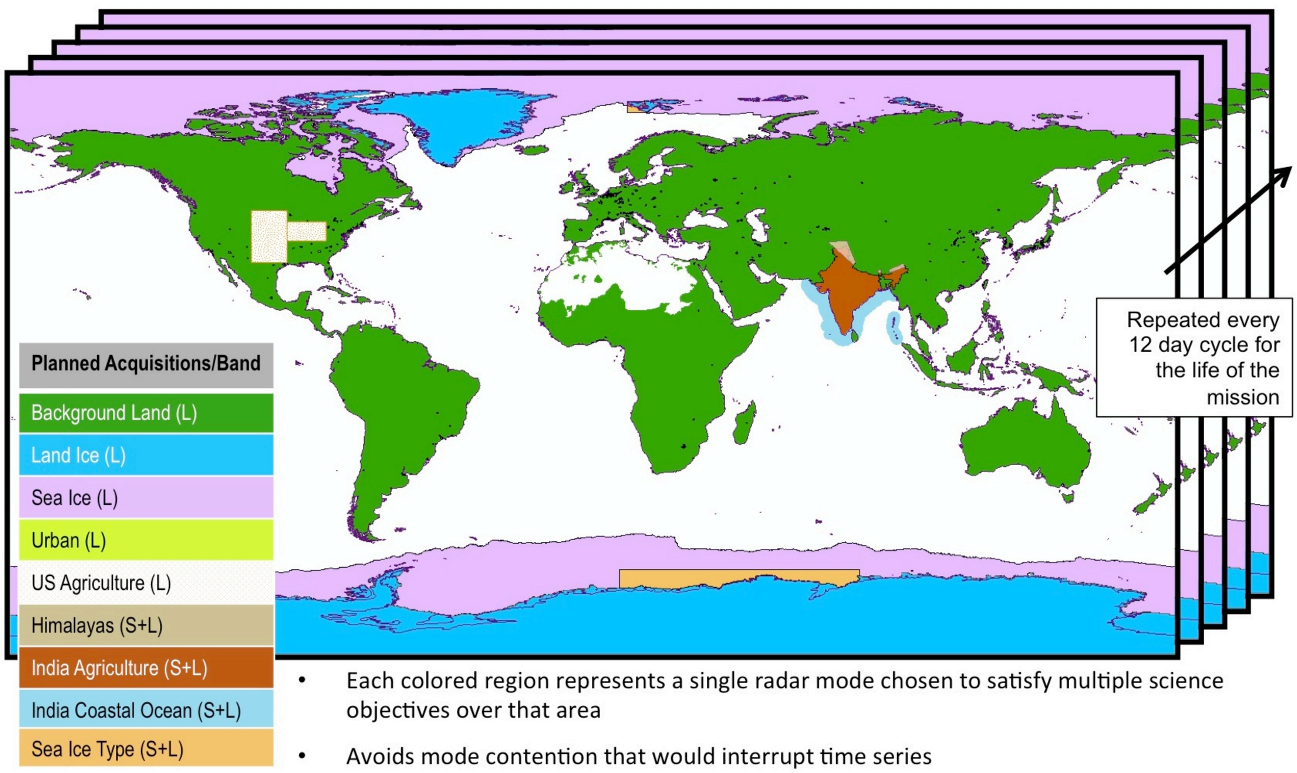

Figure 2 – Near-final mission observation plan. Revisions that increase data volume will require additional ground stations to increase downlink capability to be added.

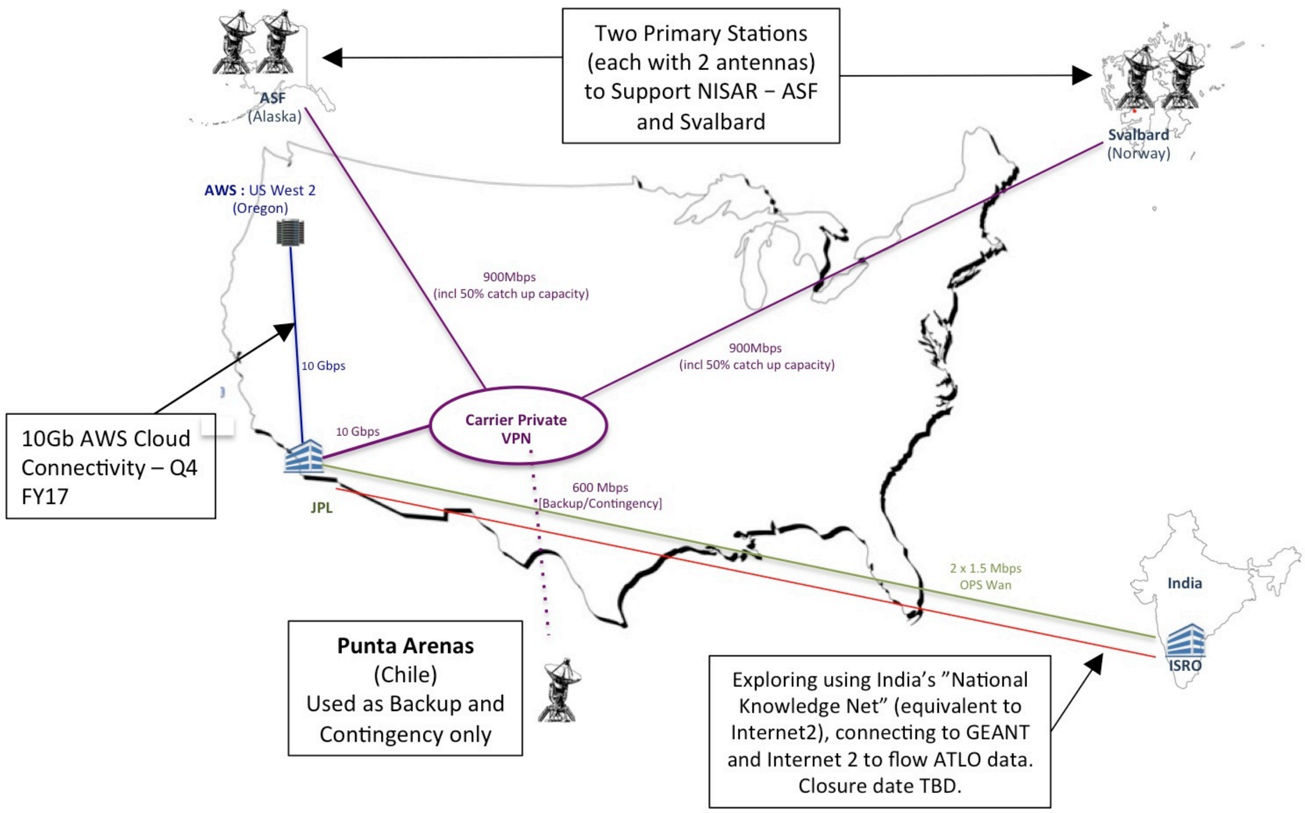

Figure 3 – Current ground station network envisioned for NISAR. Data transfer between the downlink stations and the processing centers is also shown. Processing will be done at ISRO and at a center in Oregon, with U.S. transfer funneling through JPL.

Table 2 – Near-final list of the standard NISAR data products to be delivered within 2 days of acquisition. The range-doppler SLC, a product that is posted in the radar reference frame (i.e., not geocoded), is the base-level (Level 1, or L-1) product from which all others are derived.

Product	Scope	Description
Range-Doppler Single Look Complex (SLC)	Global and all channels	Standard L1 product that will be used to generate all higher level products
Geocoded SLC (GSLC)	Global and all channels	Geocoded SLC product using medium orbit ephemeris (MOE) and a DEM.
Geocoded Nearest-Time Interferogram (GIFG)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded interferogram with interferometric phase and coherence.
Geocoded Nearest-Time Unwrapped Interferogram (GUNW)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded multi-looked unwrapped differential interferogram.
Polarimetric Covariance Matrix (COV) [Will rename this backscatter product to reflect inclusion of single pol data]	Everywhere. All channels. All pols including single pol.	Backscatter product in Range-Doppler coordinates.
Geocoded Polarimetric Covariance Matrix (GCOV) [to be renamed]	Everywhere. All channels. All pols including single pol.	Geocoded backscatter product in Range-Doppler coordinates.

3.4 NISAR Products and Latency

All NISAR data will be processed into a set of standard polarimetric (PolSAR) image and interferometric synthetic aperture radar (InSAR) data products (Table 2) by the NASA NISAR project team. These data products are expected to be available 24-48 hours after observation. The standard products include polarization-dependent images, interferograms, and interferometric coherence. The latter two can be used for change detection and for measurement of surface displacement.

In addition to the standard acquisition and processing stream, an urgent response capability will be available through which lower latency products can be made available. The details have not yet been worked out, but the goal is to deliver the products listed in Table 2 with <12 hour latency following acquisition when urgent response acquisitions are initiated.

For urgent response, one of the most important parameters is the latency between when an event occurs and when the data products can be delivered. This 'latency' is different from the typical latency defined for SAR data processing (and specified above), which is the time between when the image is acquired by the instrument and when the products are delivered, and encompasses data downlink, transfer, processing to form products, and product delivery to an archive. The time between when an event occurs and when the next NISAR image of the area can be made depends upon when the next pass of the satellite over the event location occurs and is random within the maximum 6-day period for coverage considering that the area could be imaged on either ascending or descending orbits. At continental U.S. latitudes, there is a 77% probability of imaging any location within 4 days of a disaster.

4 NISAR's Applicability to Critical Infrastructure

NISAR data can be used across the entire disaster management cycle, which encompasses mitigation and preparedness before a disaster occurs, the disaster response phase, and the recovery post-disaster. It can be used to monitor nearly all critical infrastructure that have hard targets for change detection and movement. By 'hard targets' we mean structures located above the surface, not covered by earth or vegetation, and having stable position and surface characteristics. Radar has the advantage of being able to image through clouds and without solar illumination. Furthermore, because the NISAR instrument operates at L-band, the radar pulses can also penetrate foliage to measure ground movement. Surface displacement is measured using interferometric SAR (InSAR) processing techniques applied to repeated acquisitions. Relative movement of structures compared to nearby stable areas is particularly easy to identify using InSAR, and in this way NISAR data could be used to identify anomalous movement that could precede failure or degraded performance. Because repeated NISAR images (same orbit and sensor look direction) will be acquired at 12-day intervals, a time series of movement can be established to detect both long-term rates of steady movement and anomalous, more rapid movement. Examples shown in talks at the workshop included subsidence of aqueducts, subsidence and cracking of earthen levees, bridge movement, subsidence above subway tunnels, differential settlement of high-rise buildings, differential movement of levee wall segments with different designs and construction, uplift/subsidence associated with oil extraction, slow moving landslide encroachment on roads and other critical infrastructure, and post-disaster identification of damaged structures.

It was also shown how NISAR data can be used to identify flood extent either using image amplitude products, which are based on the fact that standing water appears radar-dark, or using interferometric change detection to identify change in flood extent. Similar methods apply to identifying fire burn areas, ice flows, or other ground disturbance processes.

5 DHS Sectors Overview

This workshop was focused on understanding the information requirements of those critical infrastructure Sectors with monitoring or management responsibilities for hard target facilities or structures as well as the Infrastructure Development and Recovery program within the DHS/NPPD/OIP. The Critical Infrastructure Sectors participating in this workshop included:

- Dams
- Water and Wastewater
- Government Facilities
- Nuclear Reactors and Materials
- Transportation Systems
- Emergency Services

The Energy Sector was invited but the presenter was unable to attend. Each Sector was asked to make a presentation (length ~15 min.) addressing the questions that were sent by the NASA team (Section 2.2.1). Approximately 15 minutes were allocated to questions and answers after each presentation.

5.1 Dams Sector and Levee Subsector

The Dams Sector delivers critical water retention and control services in the United States for more than 90,000 dams, including hydroelectric power generation, municipal and industrial water supplies, agricultural irrigation, sediment and flood control, river navigation for inland bulk shipping, industrial waste management, and recreation. Its key services support multiple critical infrastructure sectors and industries. Dams Sector assets irrigate at least 10 percent of U.S. cropland, help protect more than 43 percent of the U.S. population from flooding, and generate about 60 percent of electricity in the Pacific Northwest.

Significant findings from the presentation and discussion about the Dams Sector and Levee Subsector include:

- Dams have a requirement for routine monitoring of the entire structure for safety purposes. While inspection by an engineer is necessary to diagnose issues, significant cost savings could be achieved using remote sensing to alert monitoring officials to potential problems.
- A synoptic view of monitoring that includes not only the dam structure but also the surrounding earthwork (i.e. upstream slope, downstream slope, and abutments) is necessary.
- Dams are inspected on a regular basis and currently very little remote sensing is incorporated into this monitoring although LiDAR and thermal imaging through the use of UAS assets is increasing at some facilities.
- The remote locations of many facilities make them difficult to access and monitor by field teams.
- The incorporation of monitoring from satellite platforms would increase the number of dams being monitored with only a marginal increase in data processing and analysis costs.

5.2 Water and Wastewater

There are approximately 153,000 public drinking water systems and more than 16,000 publicly owned wastewater treatment systems in the United States. More than 80 percent of the U.S. population receives their potable water from these drinking water systems, and about 75 percent of the U.S. population has its sanitary sewerage treated by these wastewater systems. The Water and Wastewater Sector works with their partners to ensure the supply of drinking water and wastewater treatment and services to the Nation.

Significant findings from the presentation and discussion about the Water and Wastewater Sector include:

- All aspects of the facilities and structures require daily monitoring for integrity, security, and operations. This is currently done by on-site personnel but could be enhanced by the use of remote sensing.
- There is an immediate need for strategic information such as surrounding land cover classification and urban expansion trends to improved facility management.
- State and local governments, particularly rural systems, rely on universities for expertise in monitoring water and wastewater facilities as well as other critical infrastructure.

5.3 Government Facilities

The Government Facilities Sector works with their state, local, tribal, and territorial partners located in 56 states and territories, 3,031 counties, 85,973 local governments, and 567 federally-recognized tribal nations to manage and monitor over 900,000 assets. These assets include a wide variety of buildings, located in the United States and overseas, that are owned or leased by federal, state, local, and tribal governments. Many government facilities are open to the public for business activities, commercial transactions, or recreational activities while others that are not open to the public contain highly sensitive information, materials, processes, and equipment. These facilities include general-use office buildings and special-use military installations, embassies, courthouses, national laboratories, and structures that may house critical equipment, systems, networks, and functions.

Significant findings from the presentation and discussion about the Government Facilities Sector include:

- Regular surveillance and monitoring are conducted by law enforcement personnel for intelligence purposes but remote sensing could contribute to situational awareness.
- This Sector is currently using aerial photography as well as ground level photography (Google Maps Streetview, CCTV, Traffic cameras, and Open Source photos) for situational awareness during criminal investigations, major events, and domestic terrorist attacks. Satellite platforms could enhance this set of assets.
- There is concern by Sector representatives about interruptions to facility service from both natural and manmade events that could be either internal or external to the facility itself. Internal events include a burst pipe, broken HVAC, internal electrical failure, etc. An external event could be a forest fire, area flooding, external electrical failure, etc.

- Having actionable information from images immediately as a situation unfolds is very important but situational awareness could use lower latency images for context as other information is developed.

5.4 Nuclear Reactors and Materials

The Nuclear Reactor and Materials Sector includes the Nation's 99 commercial nuclear power plants; 31 research, training, and test reactors (RTTRs); 8 active fuel cycle facilities; waste management; 18 power reactors; and 6 fuel cycle facilities that are in decommission or inactive. It also includes the transport, storage, use, and safe disposal of more than 3 million packages of radioactive or nuclear materials and waste annually. The private sector primarily owns and operates all civilian nuclear assets under a large framework of regulations that require robust and redundant security measures and specialized emergency response. The Nuclear Reactor and Materials Sector coordinates voluntary activities that the sector customers support or undertake to reduce risk above and beyond what is required by regulation.

Significant findings from the presentation and discussion about the Nuclear Reactors and Materials Sector include:

- Nuclear facility operators have a good understanding of what is going on at their facility proper. The niche for remote sensing is that it could play an important role in understanding neighborhood and regional environmental threats and land use trends that increase risk. For example, understanding the underlying geology is very important for monitoring the nuclear power plant and long-term trends in the physical nature of the facility.
- Monitoring of the cooling towers is very important. Some facilities are using thermal imaging to monitor vent temperature. All facilities need accurate information on the physical condition of the cooling towers (minor movement from settling, cracks, wind erosion).

5.5 Transportation Systems

The Transportation Systems Sector works with their partners to ensure that the nation's transportation system quickly, safely, and securely moves people and goods through the country and overseas. This Sector consists of the following subsectors:

- Aviation includes aircraft, air traffic control systems, and about 19,700 airports, heliports, and landing strips. Approximately 500 of the assets provide commercial aviation services at civil and joint-use military airports, heliports, and sea plane bases. In addition, the aviation subsector includes commercial and recreational aircrafts (manned and unmanned) and a wide-variety of support services, such as aircraft repair stations, fueling facilities, navigation aids, and flight schools.

- Highway and Motor Carrier encompasses more than 4 million miles of roadway, more than 600,000 bridges, and more than 350 tunnels. Vehicles include trucks, including those carrying hazardous materials; other commercial vehicles, including commercial motor coaches and school buses; vehicle and driver licensing systems; traffic management systems; and cyber systems used for operational management.
- Maritime Transportation System, which consists of about 95,000 miles of coastline, 361 ports, more than 25,000 miles of waterways, and intermodal landside connections that allow the various modes of transportation to move people and goods to, from, and on the water.
- Mass Transit and Passenger Rail includes terminals, operational systems, and supporting infrastructure for passenger services by transit buses, trolleybuses, monorail, heavy rail—also known as subways or metros—light rail, passenger rail, and vanpool/rideshare. Public transportation and passenger rail operations provided an estimated 10.8 billion passenger trips in 2014.
- Pipeline Systems consist of more than 2.5 million miles of pipelines spanning the country and carrying nearly all of the nation's natural gas and about 65 percent of hazardous liquids, as well as various chemicals. Also included are above-ground assets, such as compressor stations and pumping stations.
- Freight Rail consists of seven major carriers, hundreds of smaller railroads, over 138,000 miles of active railroad, over 1.33 million freight cars, and approximately 20,000 locomotives. An estimated 12,000 trains operate daily. The Department of Defense has designated 30,000 miles of track and structure as critical to mobilization and resupply of U.S. forces.
- Postal and Shipping moves about 720 million letters and packages each day and includes large integrated carriers, regional and local courier services, mail services, mail management firms, and chartered and delivery services.

Significant findings from the presentation and discussion about the Transportation Sector include:

- Although site inspection by engineering teams is required for safety and reliability, NISAR could play a significant role in identifying problems early to avoid serious issues later and to optimize engineering team efficiency.
- Remote sensing monitoring following a disaster can provide up-to-date imagery and information on affected transportation assets that may otherwise have significant lag-time between updates. This can allow OCIA to provide better consequence analysis for Federal, State, and local leaders, who in turn can use this analysis to drive their decision-making on the ground.

- Accurate and timely information about the status and stability of transportation systems, especially bridges and tunnels is very important following a disaster.

5.6 Emergency Services

The mission of the Emergency Services Sector (ESS) is to save lives, protect property and the environment, assist communities impacted by disasters, and aid recovery during emergencies. Five distinct disciplines compose the ESS, encompassing a wide range of emergency response functions and roles: 1) Law Enforcement, 2) Fire and Emergency Services, 3) Emergency Medical Services, 4) Emergency Management, and 5) Public Works.

Significant findings from the presentation and discussion about the Emergency Services Sector include:

- There is a significant need for trend analysis to alert emergency services to a problem in a structure or facility early.
- An updated land cover map or image is very important for situational awareness. Being able to understand the landscape of a disaster allows response teams to position assets in the best locations for immediate or later use.
- A trusted source providing consistent "wholesome" data to end users at the local level would help promote informed decisions. A "middleman" creating useful products would be valuable, but that process needs to be clearly understood by all parties in the response chain. In particular, products should be easily understood by the responder.
- Training is required so that other agencies' personnel can understand the potential of NISAR better; the goal would be for agency personnel to not necessarily become signal analysts but to gain ability to understand, evaluate, and discuss possible applications and products.
- The utility/value of remote sensing data depends on how close it is to real time following an event. If analysis takes too long, just send the image. A possible scenario for the use of remote sensing might be to provide the "image" as soon as possible and the derived product as soon as possible after analysis.
- Temporal requirements are driven by the type of event. Most are near-real time (NRT), but some events that occur over a longer period of time (e.g., floods or that are extensive and catastrophic in geographic terms) are very good applications for satellite remote sensing. In these cases, data with lower latency retains value.

5.7 Infrastructure Development and Recovery (IDR)

DHS established the IDR Program to promote cross-sector, multi-threat/multi-hazard resilience solutions that expand the Federal government's capabilities to further the long-term security and resilience of the Nation's critical infrastructure. The focus of this effort is on infrastructure development, operations and maintenance, and recovery using integrated approaches that utilize data and best practices from a wide variety of partners including community planning, sustainable design engineering, civil & environmental engineering, cyber resilience, social sciences, economics, strategy development, risk management, and operational planning. At the Federal level, IDR partners with the Dept. of Defense (DOD), U.S. Army Corp of Engineers (USACE), Dept. of State (DOS), Dept. of Commerce (DOC), National Institute of Science and Technology (NIST), Dept. of Transportation (DOT), Dept. of Energy (DOE), Dept. of Housing and Urban Development (HUD), and FEMA. IDR is NPPD/OIP's lead for their recovery mission following a disaster. IDR is currently developing the Critical Infrastructure Resilience Toolkit (CIRT) which could take advantage of information derived from NISAR and other remote sensing data.

Significant findings from the presentation and discussion about the Infrastructure Development and Recovery program include:

- Accurate and current map information on critical infrastructure and their vulnerabilities is of high value.
- The utilization of remote sensing to edit and update existing land use/cover maps would save a lot of time for IDR projects and programs that rely on this information. This includes an accurate assessment of environmental conditions within and surrounding the communities with whom IDR works.
- Change detection products or trend analysis of the following would be very useful to IDR:
  - Environmental conditions
  - Residential, commercial, and industrial development
  - Local or regional hazards such as subsidence or flood plain characteristics that would increase risk to critical infrastructure
- The provision of damage assessment information following a disaster and the ability to update this product on an as-needed basis throughout recovery would be very valuable.
- Data with NRT latency is not a high priority for this Sector.

6 NASA/NISAR Technical Response to DHS Sector Information Requirements

Following the presentations by the critical infrastructure Sector representatives and IDR, the NASA team prepared and presented an initial technical response. This discussion set the stage for a longer discussion on Day 2 to define specific products that would address the stated requirements. Furthermore, this discussion was to echo back to DHS what

NASA had heard, summarize the information requirements into a general product list, and inform all the presenters on the potential for NISAR to address their information needs.

6.1 Synopsis of the Combined Sector Needs Addressable by NISAR

Below we summarize the discussion during NASA's technical response about the overlap between the information needs of the different Sectors and which NISAR data and derived information products could be of value to the critical infrastructure applications community. The highest priority applications are summarized in Section 8. The following attempts to capture a wider range of beneficial uses of NISAR by the DHS Sector members discussed at the workshop.

- DHS/NPPD information needs are strategic and tactical.
- Routine monitoring is the primary game-changing value of NISAR to the CI community.
- Data for emergency response is very useful, but it is affected by latency. Satellite assets appear to be more valuable for those operations which are not time sensitive, such as recovery. In any case there needs to be a robust, well-defined, and automated process for requesting emergency response acquisitions.
- Regarding NISAR operational coverage, infrastructure requiring routine acquisition is distributed throughout the country, not localized in urban areas.
- The following would be of benefit to the Sectors:
    - Trend analysis (temporal change). This was considered the highest value because it is not information that they currently have in most cases.
    - Situational awareness (geographic setting) monitored at multi-scales including the local area, regions, and multi-state (i.e. land use/land cover).
    - Tactical information during urgent response. The need is particularly acute for incidents that occur in remote areas or that cover large geographic areas.
    - The attendees indicated that urgent response data would generally need to have low latency (time between when an event occurs and when the product is available) to be of high value under all circumstances, but indicated that any data would retain value for situational awareness during the later stages of response, particularly during impact assessment (recovery phase).
    - Damage assessment for response and recovery
    - Facility assessments
        - Assessments of buildings and other structures – change detection
        - Site stability - deformation (pre-failure)
        - Geological stability - synoptic overview
        - Cross-Sector observations to identify cascading effects and interdependencies of different types of critical infrastructure
        - Information to support site selection during new project planning

- Derived products
    - Surface deformation
    - Time series of long-term surface movement
    - Time series of land use changes (includes urbanization, construction)
    - Leaks (seeps and spills)
    - Forest extent and disturbance
    - Land use maps

Following the presentation of NASA's technical response there was a very productive discussion by the entire group of workshop attendees. It was strongly agreed on by all participants that collaboration using prototype pilot projects to develop specific products with the transition to an operational workflow was both important and doable by both agencies. It was also noted that DHS/S&T recently signed a Memorandum of Agreement (MOA) with NASA to conduct collaborative research and development tasks, thus providing a mechanism to move forward on pilot project work. The issue of data downlink availability was brought up and recommendations were made to possibly partner with other agencies (e.g., NGA) to increase the ability of NISAR to acquire at higher resolutions over more geography. DHS has a working relationship with NGA for data during declared disasters so there might be a pathway for access to downlink facilities through those channels. It was noted by the NISAR Project that the limited downlink is not a limitation of the satellite, but rather with the current number of downlink stations available to NISAR.

6.2 Requests by NASA/NISAR for Additional Information

In recognition of the fact that the NASA/NISAR team members are not experts on critical infrastructure monitoring and would benefit from guidance from DHS, the following were requested from DHS:

- Priorities or a process to adjudicate priorities for collecting urgent requests/high resolution. NISAR needs priorities list in the first year following this workshop for contribution to the Urgent Response Plan
- Partnership in the development of information products. Working in collaboration is more efficient and will produce a better product.
- Guidance from DHS, which has a leadership role in disaster response and recovery as well as established relationships with many agencies, to make NASA NISAR data and capabilities available to a broader community.

6.3 Technical Gaps

The following technical gaps that affected data usage by some of the Sectors were identified as having the highest impact:

- The community supported expanding the NISAR downlink capabilities to handle the higher resolution acquisition mode over a larger geographic area in order to meet the needs of critical infrastructure Sectors. Suggestions were made that non-NASA support, e.g., from NGA, be made available to increase the downlink capability specifically in support of critical infrastructure applications.
- Several Sector representatives pointed out that access to appropriate tools and the training in the use of NISAR data is a big gap for some states and many local communities. At the state and local level there is likely no manpower or capability to conduct the SAR analysis in-house, but end-users still need to have access to an information product that informs them about the status of their infrastructure with a communication pathway to experts that can answer questions about that product.
- A method needs to be developed in advance of launch to rapidly re-task NISAR for episodic nationally significant events to permit acquisition and analysis optimized for information products needed by emergency management officials. DHS is interested in facilitating the socialization of that method within their Sectors.

One suggested solution to solve the technical gaps of temporal resolution and expanding the utilization of and familiarity with SAR data was that PALSAR/ALOS-2, an L-band SAR operated by JAXA, the Japanese Space Agency, be investigated as a possible surrogate data source prior to NISAR launch because it is an L-band SAR and hence most similar to NISAR for penetrating foliage and maintaining temporal coherence. It was also mentioned that SAOCOM, an Argentinian satellite expected to launch in 18 months, could also be a valuable source of L-band SAR data.

7 Capability Development for NISAR Critical Infrastructure Applications

7.1 Information Product Characteristics and Requirements

On Day 2, there was a discussion about the specifications and characteristics of information products that would be most useful to and usable by the DHS Sector communities.

The technical specifications for products discussed at this workshop were:

1. Geocoded, orthorectified, in GIS (preferred) or Google Earth ready formats
2. Interferograms and their derived information products were of greatest value, with images being of value specifically for flood and inundation mapping.
3. Brightness images produced quickly following acquisition.
4. Thematic maps with a simple classification of red, yellow, and green, univariate in nature. This would be a quick look product for incident commanders to gain an

understanding of a single aspect of the disaster (structure stability, flood depth in relation to homes, subsidence).

Because of the wide range of product specifications, particularly for geocoding and format, there was support for a 'dashboard in the cloud' menu system for product selection. DHS participants at the meeting generally preferred to generate products through on-demand processing in a cloud environment. This cloud processing could either take the NISAR data into a product from the point that NASA delivers it or build higher level information products from NISAR data processed by a DHS service organization, e.g., OCIA, NGA, or I&A, or a contractor with whom they worked directly. The I&A directorate have some responsibility for remote sensing data tasking and collection management across the entire agency.

The workshop consensus was that the best way to deliver the final products was through a data archive, e.g. a NASA Distributed Active Archive Center (DAAC) or the DHS Geospatial Information Infrastructure (GII), where end users could directly download the data using a graphical interface and a specified polygon area of interest.

7.2 Recommendations for Product Development

Actionable recommendations for how to put in place the collaborations necessary to make NISAR data of use to the critical infrastructure community were the following:

1. Establish projects for prototype product development, test, and evaluation.
2. Expand the existing MOU/MOA between NASA and DHS S&T for cooperative R&D.
3. Develop a new MOU between NASA and DHS HQ and its component organizations.
4. Identify how data needs of specific DHS Sectors potentially affect the NISAR data downlink volume, which is the bottleneck to acquiring higher resolution data. The NISAR team asked for DHS to follow up in the six months after the meeting with an estimation of the impact on data utility/value if the background 12mx8m acquisition mode was used for all of the U.S. instead of the higher resolution 6mx8m spatial resolution. This was particularly addressed to OCIA because of their familiarity with information products for all Sectors.
5. Engage with the DHS Centers of Excellence in projects moving forward.

7.3 Areas for Cooperative Research and Development between NASA and DHS/NPPD

The following were identified as specific areas of productive collaboration to advance the use of NISAR:

- DHS managers at the workshop thought that the highest priority for collaboration should be development and demonstration of feasible, high-impact information products/applications that can be socialized within and vetted by the end user community.
  - Prototype product development, test, and evaluation that leads to the operational incorporation of NISAR and other radar data as an accepted method for critical infrastructure monitoring on a national scale.
- NPPD was open to a sustained partnership with NASA that leads to the development and application of tools that identify and mitigate threats to critical infrastructure.
  - Optimization of processing methodologies to efficiently produce specified products to DHS/NPPD time scale.
- DHS/NPPD/OCIA has a role in the development of capabilities for interpreting derived products from imagery. A partnership with NASA to develop such a capability for NISAR data would be valuable.

8 Summary: Findings on Critical Infrastructure Application Focus Areas

8.1 Priority Applications and Information Products

Most of the Sectors that presented at the workshop could use NISAR data for disaster management decision support in all phases of the disaster management cycle. Regarding higher-level information products, e.g., surface deformation or ground subsidence, many of the Sectors would use the same product such that a single product would serve multiple Sectors.

The most useful information products in order of priority are:

1. Times series of surface displacement for situational awareness both pre- and post-disaster. The ability to identify and monitor small-scale movement all the time, not just post-disaster, was particularly unique and valuable.
2. Flood extent maps post-disaster
3. Damage proxy maps post-disaster (e.g., obtained through coherent change detection)

Although the need for derived products, e.g., damage proxy maps, was acknowledged, there was consensus that 'unfiltered' image and interferogram products were also of great value to the community. There was strong interest in developing the in-house (e.g., DHS/OCIA) or non-NASA (e.g., through NGA or commercial contractors) capability to analyze or interpret SAR data.

8.2 Geographic Coverage

The participants at the workshop stressed the utility of SAR data covering the entire U.S., encompassing both the states and its territories, as opposed to concentrating on acquisitions over urban areas. It was particularly noted that acquiring NISAR data for 'small town' USA would have a high impact because those cities are spread across large geographic regions and are not considered "targets of opportunity" and therefore not imaged on a regular basis by other countries' space borne radar instruments. This lack of consistent data acquisition is a barrier to accurate monitoring of critical infrastructure.

8.3 Modes of Acquisition

Obtaining high resolution data was considered a top priority by this community, and it was needed not just in urban areas but throughout the country because of the wide distribution of critical infrastructure. Given a choice between higher resolution (6mx8m vs. 12mx8m horizontal resolution) and more frequent acquisitions (12-day repeats vs. 24-day repeats), priority was given to higher spatial resolution products. This means that obtaining NISAR data in 40 MHz mode (6m resolution) over the U.S. would be of great value, even if it could only be done in either ascending or descending orbits. There was no preference for a particular polarization of the data for the high priority applications.

8.4 Data Latency

Situation awareness data needs do not require product latency less than the 24-48 hour latency of normal NISAR processing. Product latency (section 3.2) is the time between when the instrument images an area and when the products are delivered to the archive.

The workshop attendees thought that for NRT disaster response the current 0-6 day lag between when an event happens and when the satellite passes over the area to acquire data is too long, and therefore a variety of SAR instruments should be used to minimize the time between when an event occurs and when SAR information is delivered. During the post-disaster recovery and mitigation phases, the current NISAR temporal resolution would be acceptable in many instances. The potential lag is also acceptable for spatially extensive disasters, where response will be limited by available resources; for disasters in areas that are difficult to access from the ground; and for cascading disasters, e.g., incipient landslides or structural weakening following major earthquake.

9 Summary: High Priority Recommendations & Action Plan

From the discussions that took place during this workshop it is apparent that (a) the data and products produced from the NISAR mission would be very valuable to the operational mission of DHS/NPPD/OIP in both cost savings and quality of information, (b) the information that NISAR could provide is not being provided to OIP in other ways, and (c) a good way to move into operational use of NISAR is through cooperative R&D between NASA and DHS.

The following are the highest priority actionable recommendations for how to facilitate and improve NISAR data usage within the critical infrastructure community.

1. Investigate how to increase NISAR downlink capability so that high resolution 40-MHz (6mx8m) data are acquired across the U.S. land and territories at every opportunity.
    a. OCIA indicated that they would be willing to provide a map or other documents on high value target areas.
2. Cooperative prototype product development, test, and evaluation should be initiated as soon as possible and should focus on the identified DHS/NPPD priority information needs, products, and format (Section 8).
    a. During the period between this workshop and operational use of NISAR it would be very valuable for DHS to have NASA's guidance on identifying the optimal SAR remote sensing assets for DHS/NPPD needs as well as assistance in the development of appropriate processing methodologies.
    b. Development projects should use other satellite data now and prepare for ingestion of NISAR data in the future.
    c. Work on requirements for data collection and dissemination so that the process could provide viable near-real-time information to owners and operators.
    d. Establish a format, or work to educate owners and operators in data usage, so that the data can be easily interpreted by owners and operators.
3. Leverage the existing MOU/MOA between NASA and DHS S&T to jump start cooperative R&D, and seek a broader MOA to incorporate other DHS Component Agencies, possibly with GMO.
4. NASA should include the DHS Centers of Excellence universities in the discussions concerning NISAR applications. The DHS Centers of Excellence is a Program executed out of the Universities Program at DHS/Science and Technology. There are eleven Centers of Excellence but two stand out as obvious potential partners:

    Coastal Resilience Center of Excellence (CRC), led by the University of North Carolina at Chapel Hill, conducts research and education to enhance the Nation's ability to safeguard people, infrastructure, and economies from catastrophic coastal natural disasters such as floods and hurricanes.

Critical Infrastructure Resilience Institute (CIRI), led by the University of Illinois at Urbana-Champaign, conducts research and education to enhance the resilience of the Nation's critical infrastructure and its owners and operators.

5. Include in capability development projects the organizations that are currently partners with state and local governments.
    a. This includes but is not limited to the American Planning Association, the National Governors Association, the Urban Land Institute, and the American Farmland Trust. They have programs that produce products used by smaller communities for planning.

10 Appendices

10.1 Agenda

DAY 1

Tuesday, June 6, 2017

1. 7:30 - 8:00 AM – Arrival & Sign-In
2. 8:00 – 8:15 Welcome - Craig Dobson, NISAR Program Scientist (NASA/HQ/Earth Science Division)
3. 8:15 – 8:45 NASA Disasters Program Overview – David Green, Program Manager (NASA/HQ/Applied Science Division)
4. 8:45 – 9:15 DHS/NPPD/OIP Overview – Damion Higbe, Deputy Director, SP&B (NPPD/OIP)
5. 9:15 – 9:45 NISAR Mission Overview – Bradford Hager (Director, Earth Resources Laboratory, Massachusetts Institute of Technology)
6. 9:45 – 10:00 *Break*
7. 10:00 – 10:30 Office of Cyber and Infrastructure Analysis Overview – Charles Covell (DHS/NPPD/OCIA)
8. 10:30 – 11:00 Use of SAR Remote Sensing for CI Applications – Cathleen Jones (NASA/JPL)
9. 11:00 – 12:00 Critical Infrastructure Sector Information Product Requirements – Critical Infrastructure Sector Representatives – Bruce Davis, facilitator
    a) Dams Sector – Reis Thomas - (DHS/NPPD/OCIA)
    b) Emergency Services Sector – Dan Schultz (DHS/NPPD/OIP)
10. 12:00 – 1:00 *Lunch / Email Break*
11. 1:00 – 2:45 Critical Infrastructure Sector Information Product Requirements – OIP Sector Leads
    c) Water and Wastewater - John Laws (DHS/NPPDSOPD), Marilee Orr (DHS/NPPD/OCIA)
    d) Government Facilities - Christopher Coleman (DHS/NPPD/FPS)
    e) Nuclear Reactors and Materials – William Murray and Rachel Liang (DHS/NPPD/OIP)
    f) Transportation Systems Sector - Andrew Pasternak (DHS/NPPD/OCIA)
    g) Infrastructure Development and Recovery - Wynne Kwan (DHS/NPPD/OIP)
12. 2:45 – 3:00 *Break*

13. 3:00 – 4:00 Technical Response to Information Requirements Discussion - Cathleen Jones (JPL/NASA)
14. 4:00 – 4:30 R&D Needs to Address Identified Technical Gaps – Gerald Bawden (NASA/HQ)
15. 4:30 – 5:00 Next Steps and Day 1 Wrap Up – Cathleen Jones (JPL/NASA)

DAY 2

Wednesday, June 7, 2017

2. 7:30 – 8:00 AM – Arrival & Sign-In
3. 8:00 – 8:10 Day 2 Action Plan - Cathleen Jones (NASA/JPL)
4. 8:10 – 8:30 New Orleans Levee monitoring via remote sensing and in situ instrumentation - Victoria Bennett (Rensselaer Polytechnic Institute)
5. 8:30 – 8:50 Radar mapping of post-disaster damage - Susan Owen (NASA/JPL)
6. 8:50 – 9:10 Radar remote sensing of displacement of bridges and similar structures - Daniele Perissin (Purdue Univ.) (*presented by Cathleen Jones*)
7. 9:10 – 9:30 Ground deformation in the Washington D.C. Area - Edward Hoppe (Virginia DOT)
8. 9:30 – 9:45 Roundtable Discussion / Q&A with Speakers – Gerald Bawden, facilitator
9. 9:45 – 10:00 *Break*
10. 10:00 – 10:30 OCIA work flow for geospatial products - Christopher Marques (DHS/NPPD/OCIA/PMD/GAB)
11. 10:30 – 10:45 NASA/JPL ARIA satellite data processing - Susan Owen (NASA/JPL)
12. 10:45 – 11:30 Detailed Sector requirements - Bruce Davis, Lead, Group Discussion
    a. What do the final products look like?
    b. Do any of the products serve multiple Sector requirements?
    c. What is the technical specification for the NISAR radar product?
    d. What is the best way to deliver the final product?
    e. What is the best way pathway to get from NISAR radar products to CI final products?
    f. How do we put that in place?
13. 11:30 – 12:30 *Lunch / Email Break*
14. 12:30 – 1:30 cont. discussion on Detailed Sector requirements - Bruce Davis, Lead, Group Discussion
15. 1:30 – 2:30 Work Plan discussion - Cathleen Jones (NASA/JPL), Lead, Group Discussion

16. 2:30 – 2:45 *Break*
17. 2:45 – 3:30 Next Steps and Wrap Up - Craig Dobson (NASA/HQ/Earth Science)

10.2 Participants

Craig Dobson (NASA HQ)
Cathleen Jones (JPL/Caltech)
Natasha Stavros (JPL/Caltech)
Susan Owen (JPL/Caltech)
David Green (NASA HQ)
Bruce Davis (Davis Consulting, Inc.)
Drew Kittel (NASA ESDIS Goddard)
Ed Hoppe (Virginia DOT)
Victoria Bennett (Rensselaer Polytechnic Institute)
Benhan Jai (JPL/Caltech)
Glen Havens (JPL/Caltech)
Bradford Hager (MIT)
Ben Phillips (NASA HQ)
Jordan Bell (NASA Marshall)
Gerald Bawden (NASA HQ)
Damion Higbe (NPPD/OIP)
Georgette Holmes (DHS/NPPD/OCIA)
Wynne Kwan (DHS/NPPD/IDR)
Chris Brehany (DHS GMO)
Marilee Orr (DHS/NPPD/OCIA)
Reis Thomas (DHS/NPPD/OCIA)
Dan Schultz (DHS/NPPD/OIP)
Andrew Pasternak (DHS/NPPD/OCIA)
Charles Covell (DHS/NPPD/OCIA)
Christopher Coleman (DHS/NPPD/FPS)
Rachel Liang (DHS/NPPD/OIP)
William Murray (DHS/NPPD/OIP)
Wynne Kwan (DHS/NPPD/OIP)
Christopher Marques (DHS/NPPD/OCIA)
John Laws (DHS/NPPD)
Kara Buckley (DHS/NPPD/OCIA)
Bryan Burley (DHS/NPPD/OCIA)
Anthony Bruno (DHS/NPPD/OCIA)
Desta O'Connor (DHS/NPPD/OCIA)
Martin Waysome (DHS/FEMA)
Lee Spaulding (DHS I&A)
Kendrick Faison (DHS FPS)

Kyle Foster (NGA)
Christopher Vaughan (FEMA)
J. Robert Brown (VA Dept. of Emergency Management)
Matthew Barger (DHS/NPPD)
Michael Matthews (DHS/S&T)
Enrique Matheu (DHS/NPPD)
Jun Zou (DHS)

Via Webex:

Daniele Perissin (Purdue Univ.)
Matthew Pritchard (Cornell Univ.)
Rowena Lohman (Cornell Univ.)
Dalia Kirschbaum (NASA Goddard)
Ramesh Singh (Chapman U.)
Bibhuti Panda (Amec-Foster-Wheeler)

10.3 Acronyms

CI	Critical Infrastructure
CIRI	Critical Infrastructure Resilience Institute
CIRT	Critical Infrastructure Resilience Toolkit
CRC	Coastal Resilience Center of Excellence
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DHS	Department of Homeland Security
DOC	Dept. of Commerce
DOD	Dept. of Defense
DOE	Dept. of Energy
DOS	Dept. of State
DOT	Dept. of Transportation
ESS	Emergency Services Sector
FEMA	Federal Emergency Management Agency
GII	Geospatial Information Infrastructure
GIS	Geographic Information System
HUD	Dept. of Housing and Urban Development
I&A	Information and Analysis Directorate
IDR	Infrastructure Development and Recovery
InSAR	Interferometric Synthetic Aperture Radar
ISRO	Indian Space Research Organization
JAXA	Japanese Space Agency
JPL	Jet Propulsion Laboratory
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NISAR	NASA-ISRO Synthetic Aperture Radar
NIST	National Institute of Science and Technology
NPPD	National Protection and Programs Directorate
NRT	Near Real Time
OCIA	Office of Cyber and Infrastructure Analysis
OIP	Office of Infrastructure Protection

PolSAR	Polarimetric Synthetic Aperture Radar
PSA	Protective Security Advisor
R&D	Research and Development
S&T	Science and Technology Directorate
SAR	Synthetic Aperture Radar
SOPD	Sector Outreach and Programs Division
USACE	U.S. Army Corp of Engineers