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2018 NISAR Applications Workshop: Forest and Disturbance

Workshop Report

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1 Executive Summary

Forest lands cover the globe and are important sources for providing ecosystem services including: carbon sequestration, biodiversity, timber, air and water quality. As such, counties around the world have dedicated programs for managing them. Accurate and timely information concerning the status of these forests (moisture, biomass, disturbance type, etc.) is essential to those Nations' human and ecological health as well as economy. The joint NASA/US Forest Service workshop focused on arming forest land managers with observations and remote sensing information from the upcoming NASA-ISRO SAR (NISAR) satellite mission (expected to launch early 2022). Participants included representatives from different US Federal Agencies, private sector, and non-governmental organizations (NGO) that are key players in facilitating integration of Earth Observations (EO) into forest management and decision support workflows. They included scientists, technicians, and program managers with a responsibility for data acquisition and exploitation such as product development, delivery, and use, and capacity building. Discussions were held over two days to convey the broader forest and disturbance community information needs for various representative participants and programs and to facilitate the delivery of NISAR mission geospatial products and observational capabilities. Case studies were presented to demonstrate the current state of practice in the use of SAR remote sensing for applications of direct importance to forest and disturbance land management community. Eleven organizations 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 these requirements. Discussion ensued about needed data product specifications to increase utility (e.g., projection, latency, etc.), tools and capacity building.

The general findings of this workshop were that (a) NISAR observations will be particularly useful to the global forest carbon and disturbance monitoring applications, but that certain data product design decisions (projections and radiometric and terrain corrections) need to be considered to increase utility; b) the biomass and disturbance detection algorithms meet many of the community needs, however there are other information products of value (e.g., soil moisture or disturbance classification, not just detection) and all products should be compliant with existing community standards for reporting uncertainty; c) providing SAR education to the community will be key specifically thinking about putting the information first and the SAR theory second, providing a simple guide of standard data processing steps (e.g., dB to power conversion and speckle filtering); d) the community needs a user-friendly interface for finding free, archived data over their geographic regions of interest; e) user-friendly tools that connect to open-sources GIS software (e.g., QGIS) that include a graphical user interface (GUI) for SAR processing that enables both download and cloud processing. To integrate these findings and prepare the community before NISAR launches, it was suggested that there be a dedicated NISAR Forest and Disturbance Applications Working Group (as per the specifications in the NISAR Utilization Plan). After launch, it was decided that the community continue capacity building activities.

2 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 moisture

content and structure, aboveground biomass and changes of forest cover to the survey quality required by land managers opens a new frontier for the monitoring and assessment of forests from space. NASA's upcoming NISAR mission will be unique in providing comprehensive and frequent imaging of all lands globally twice every twelve days with open access to the data. This is potentially a game-changer for planning and management of forests globally, particularly in areas with dense cloud cover in tropical regions and the vast seasonal and dynamic forests of the high latitudes with limited sunlight conditions. The NISAR Forest and Disturbance Applications Workshop was held on June 13-14, 2018 at the United States Department of Agriculture Forest Service (USFS) International Programme Office in Washington DC with representative members from the broader forestry community (e.g., non-profits, private, and government agencies) to determine how best to leverage the NISAR mission for monitoring forest globally.

2.1 Workshop Objectives

The NISAR Forest and Disturbance Applications Workshop focused on three overarching objectives derived from inputs provided in the omnibus 2015 NISAR Applications Workshop. In the 2015 workshop NISAR received a recommendation to focus the workshops around different communities as each has very different experience levels with Synthetic Aperture Radar (SAR), community capabilities, and requirements. To meet these recommendations, NISAR worked with the USFS to tailor the objectives:

1. ***To identify high impact applications for integrating NISAR into Forest Ecosystem Applications***. High impact was defined to be a function of the SAR data use to many organizations and agencies working in the forest land management sector, feasibility of the NISAR observation and latency of geospatial products to meet application requirements, feasibility of the user community to ingest and use the data, and maturity of algorithms for producing information, value-added products (Data Level 3+) for operational deployment globally.
2. ***To develop a roadmap for realizing integration of SAR into forest land management decision support systems***. The focus was on the identified high impact applications, recognizing that NISAR can complement the long-standing, established forest community of practice and decades of developed infrastructure already used for forest land management decision making.
3. ***Early engagement with user communities as part of the Early Engagers (analogous to "early adopters"; see the NISAR Utilization Plan) to help develop value-added information products.*** The main contribution of early adopters will be to define any potential level 3+ data products for different forestry applications, test the integration of the data in existing decision-making tools, and to work towards introducing and distributing the NISAR data and products to a broader Forest land management community.

2.2 Workshop Format

To meet the two-day workshop objectives, the first day focused on identifying high impact applications and the second focused on developing a road map and identifying early engagers.

2.2.1 Workshop – Day 1

The workshop opened by introductory remarks and perspectives on workshop goals and expectations from NASA, US Forest Service (USFS), and US Geological Survey (USGS), and was followed by NISAR science team presentations on the NISAR methodology to produce the forest aboveground biomass and forest disturbance detection. These presentations set the stage for the rest of the participants from the application community to present their agency/organization overall goals, scope of work, challenges, and interests for satellite observation data relatively detailed characteristics of information needs in terms information needs' spatial and temporal resolutions and latencies. The presentation from the community also covered their existing remote sensing capabilities and/or major limitations in expertise and resources within their agency/organization to work with the EO data. Specifically, participants answered the following questions:

- What is the mission of your organization?
- Describe the lands that your agency/organization works on. What are they (wetlands, shrubland, savannah, dense forest, tropical forest, tundra, managed and/or unmanaged forests, protected, secondary forests, old growth forests, etc.)? how many are there? where are they located? Part of protected wildlife corridors or other policy management (REDD)?
- Does your organization have a requirement of routine monitoring? If yes, what particular feature or characteristic needs to be monitored? Examples: biomass, tree height, disturbance, moisture status, growing stock volume, etc. What are your latency requirements?
- Does your organization have a response mission in the event of a disaster or major disturbance? If so what primary information products do you rely on? What are your latency requirements?
- How are remote sensing data used in your decision support systems? If so, describe the type of data and applications. What is your organization's capability for integrating in remote sensing data?
- What are the most challenging problems that you face where external monitoring could significantly enhance reliability and security?
- How would a twice-every-12 day-repeat, cloud-free, hectare-scale SAR monitoring capability impact your workflow/decision support system?

The open discussions after presentations focused on clarifying the data needs and highlighting the similarities and differences across agencies and organizations. During the discussion, the NISAR Science Team further clarified the science and application data products and addressed how the existing Level 2 and 3 data products and planed latency of NISAR deliverables can meet the needs, what extra products, capacity development and tools would be needed. The first day of the workshop concluded with a note from NASA Headquarters on currently funded NISAR products and application related activities and the potential future opportunities to fulfill additional needs.

2.2.2 Workshop – Day 2

The second day focused on developing a roadmap for integrating NISAR into the Forest land management community decision support infrastructure, and identifying the potential for early engagers through an ad hoc working group. Morning presentations highlighted feasibility studies that used SAR data to produce value-added products and to integrate them into the decision-making context. These presentations addressed a number of questions:

- What was the organization/decision making context?
- What was the information gap?
- Why was SAR a good fit?
- What did the algorithm look like (keep this on the short side because we care about the other questions here just as much as the algorithm)? Which band and frequency were used? How well did it perform?
- How was it integrated and tested in the decision-making context?
- What were the challenges or lessons learned about integrating SAR data into a local decision-making context? What worked? What didn't? Why didn't it?
- Is it something that will be sustained or augmented once L-band SAR from NISAR is made globally and publicly available? Can we possibly use this in other places (i.e., how extractable is it)?

The discussions on these questions resulted in articulating and refining the forest sector requirements and developing a plan for further NISAR mission engagement with the community. At the end, NASA program managers provided some perspectives on how the community can engage in the related programs in NASA. Woody Turner, the NASA Applied Science Ecological Forecasting Program Manager, discussed the program approach for facilitating integration of NASA observations into decision support systems, and Craig Dobson, the NASA NISAR Program Scientist, outlined the next steps for the NISAR mission activities and opportunities for community engagement.

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 early 2022 and to have a minimum mission lifetime of three years with consumables up to 15 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 most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards. For more information please see: link to NISAR webpage.

Table 1 – NISAR characteristics and capabilities.

NISAR Characteristic:	Enables:
L-band (24 cm wavelength)	Foliage penetration and interferometric persistence
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR[1] 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 < 350 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, north and south

[1] SweepSAR is a technique to achieve wide swath at full resolution. See Section 4.7 for a more detailed description.

3.2 Mission Capabilities

NISAR will utilize two 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 considering both ascending and descending orbits, and the S-band instrument will provide additional coverage of India and parts of the polar regions. Depending upon the operating mode, NISAR's orbiting radar can image at resolutions of 3-50 meters, 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. Regular and consistent repeat imagery can be used to detect small-scale changes before they are visible to the naked eye and to track dynamic changes as conditions evolve.

Table 2 – 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)	Swath (km)
Background Land	L	DP HH/HV	20 + 5	242
Background Land Soil Moisture	L	QQ	20 + 5	242
Background Land Soil Moisture Hi Pwr	L	QQ	20 + 5	242
Land Ice	L	SP HH	80	121
Land Ice Low Res	L	SP HH	40 + 5	242
Low Data Rate Study Mod SinglePol	L	SP HH	20 + 5	242
Sea Ice Dynamics	L	SP VV	5	242
Open Ocean	L	QD HH/VV	5 + 5	242
India Land Characterization	L	DP VV/VH	20 + 5	242
Urban Areas, Himalayas	L	DP HH/HV	40 + 5	242
Urban Areas, Himalayas SM	L	QQ	40 + 5	242
Urban Areas, Himalayas SM Hi Pwr	L	QQ	40 + 5	242
US Agriculture, India Agriculture	L	QP HH/HV/VH/VV	40 + 5	242
US Agriculture, India Agriculture Low Res	L	QP HH/HV/VH/VV	20 + 5	242
Experimental CP mode	L	CP RH/RV	20 + 20	242
Experimental QQ mode	L	QQ	20 + 20	242
Experimental SP mode	L	SP HH	80	242
ISRO Ice/Sea-Ice	L	DP VV/VH	5	242
ISRO Ice/Sea-Ice - alternate	L	QD HH/VV	5	242
Solid Earth/Ice/Veg/Coast/Bathymetry	S	QQ	37.5	244
Ecosystem/Coastal Ocean/Cryosphere	S	DP HH/HV	10	244
Agriculture/Sea-Ice	S	CP RH/RV	25	244
Glacial Ice-High Res	S	CP RH/RV	37.5	244
New Mode	S	DP HH/HV	37.5	244
Deformation	S	SP HH (or SP VV)	25	244
Deformation-Max Res	S	SP HH (or SP VV)	75	244

Table 2 shows the NISAR acquisition modes for the L-band and S-band antennas, along with parameters specific to each mode. The ground resolution in the cross-track direction is set by the pulse bandwidth (BW), and is 3/6/12 or 50 m for 80/40/20 or 5 MHz, respectively. The ground resolution in the along-track direction is 8 m for all modes. The instruments can operate 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/HVor VV/VH; co-polarization (QD) HH/VV; quad-polarization (QP) HH/HV/VV/VH, or quasi-quad polarization (QQ) (HH/HV/VV/VH with slightly different frequency H and V transmit). The mode selected depends upon the science target for a given location (see section 3.3). The L-band instrument can also operate in Compact Polarimetry (CP) mode transmitting right circular polarization (R), but there are no plans for using that mode operationally.

3.3 Current Mission Observation Plan

The current observation plan is shown in Figure 1. This near-final observing plan will be dominated by L-band SAR HH/HV observations with a 12m x 8m spatial resolution and a 12-day repeat interval across most of the land area outside of the polar regions and Greenland. A funding augmentation currently underway will provide 6m x 8m spatial resolution data over North America lands (Figure 1). Revisions of the observation plan are under consideration, but not finalized, to limit the acquired data volume to the downlink capacity 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 (Tb/d) (to become 35 Tb/d with the augmentation), 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 2). 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 added downlinked data volumes.

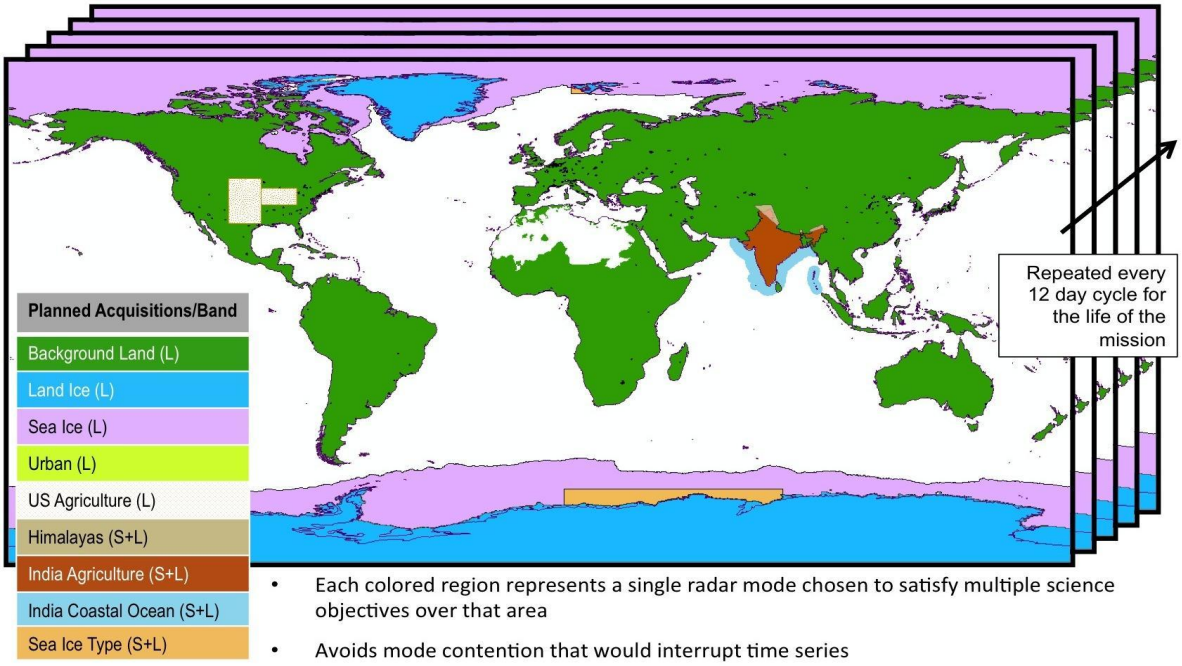

Figure 1 – Near-final mission observation plan. Revisions that increase data volume will require additional ground stations to increase downlink capability to be added.

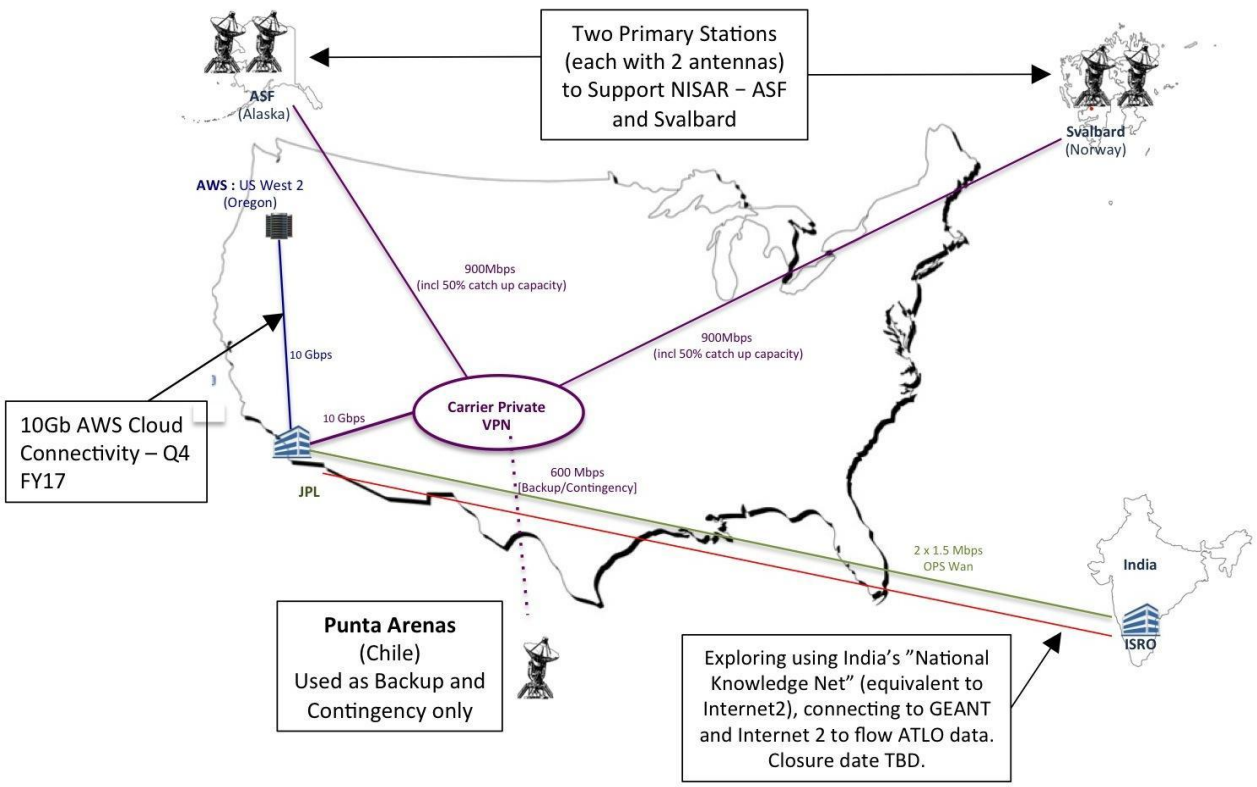

Figure 2 – Current ground station network envisioned for NISAR. Data transfer between the downlink stations and the processing centers is also shown. Processing will be done at ISRO and at a center in Oregon, with U.S. transfer funneling through JPL.

Table 3 – 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)	Everywhere. All channels. All pols including single pol.	Backscatter product in Range-Doppler coordinates.
Geocoded Polarimetric Covariance Matrix (GCOV)	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 by the NISAR project team into a set of standard polarimetric (PolSAR) image and interferometric SAR (InSAR) data products (Table 3). 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 be able to deliver the products listed in Table 2 with less than a 12-hour latency (goal of 5 hours) following acquisition when urgent response acquisitions are initiated. 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 varies within the maximum 6-day period for coverage considering that the area could be imaged on either ascending or descending orbits.

4 NISAR's Applicability to Forest Mapping and Monitoring

NISAR will provide imaging data for mapping and monitoring of the United States' and international forest resources. The timber industry, domestic and foreign forest services, natural resource managers, non-profit organizations concerned with forest monitoring, and policy makers alike will benefit from the novel data from the NISAR mission.

In order to sustainably manage forests and their numerous ecosystem services requires knowledge of how forests grow and change over time in response to natural disturbances and management activities. Forest disturbances include both stresses and destructive agents; these include invasive species, diseases as well as plant and animal pests; fire; changes in climate and serious weather events such as tornadoes, hurricanes and ice storms; pollution of the air, water, and soil; real estate development of forest lands; and timber harvest.

With the world's population critically dependent on sustainably managed and utilized forest resources, the need is greater now than ever before for the application of modern technology to provide detailed and timely informational map data. Satellite imaging is routinely used to guide policy decision-makers and commercial interests alike, for example, in order to plan forest management activities, support preparation of information for forest real estate transactions domestically and in foreign countries, and to monitor the effects of forest policy changes like logging concessions or track illegal logging in a dynamic global marketplace.

The upcoming NISAR mission will complement the fleet of optical (e.g., Landsat, Sentinel-2) and shorter wavelength SAR missions (e.g. Sentinel-1) to address these needs through a dependable observing strategy that will collect high resolution (15-25 m) imagery over 90% of the Earth's land surfaces up to sixty times per year. The use of actively generated microwave signals (L- and S-band, or equivalently, 24 cm and 10 cm wavelength) on board the satellite, means that the observations

will be able to be reliably planned, collected and distributed at time scales that are commensurate with the satellite's 12-day repeat cycle. SAR images from satellites such as NISAR are known for their ability to penetrate through clouds and their day/night imaging capability. Hence even under near-perpetual dense tropical or frequent temperate cloud cover that are characteristics of global forest ecosystems, SAR imagery will provide bi-weekly observations that complement optical data and provide independent information that is sensitive to the mapping of forest disturbance, including below-canopy inundation from natural and catastrophic flooding events. In case of emergencies like large forest fires, NISAR data can be made available with low latency. L-band wavelengths at cross-polarization is particularly suitable for forest monitoring because of its sensitivity to forest structural changes (disturbance) and regrowing biomass. The like-polarized L-band signals are known to allow detection of inundation beneath canopies.

5 Forest Applications Agency/Organization Overview

This workshop was focused on understanding the information requirements of representative agencies and organizations that can help bridge the gap between the low-level data that NASA provides and the information needed by forest land managers. There were two talks presented by USFS and USGS Program Managers of the agency organization and priorities, and subsequent talks by each of the relevant agency departments and organizations participating; specifically:

- USFS Forest Inventory Analysis (FIA) program
- USFS/USGS/EPA SilvaCarbon program
- USFS Geospatial Technology and Applications Center (GTAC) – formerly the Remote Sensing Applications Center (RSAC)
- USGS Earth Resources Observation Science (EROS)
- United States Bureau of Land Management
- United States National Park Service
- World Wildlife Fund (WWF)
- World Resources Institute (WRI)
- Conservation International (CI)
- World Bank
- Timber Consulting Firm: SilviaTerra

Each agency/organization was asked to make a presentation addressing the questions that were sent by the NASA team (Section 2.2.1). The information requirements are summarized in the following section.

5.1 USFS Remote Sensing National Program Overview

The USFS Remote Sensing National Program is constantly accommodating challenges in a fast-changing world of technology. There have been declining budgets that affect the National Agricultural Imagery Program (NAIP), access to remote sensing imagery, centralizing geospatial capabilities, loss of institutional knowledge and expertise as well as use of enterprise architecture, software and field equipment. In general, much of the world happens at the GTAC, which has the ability to provide web services and x-band antenna downlink capability.

The program focuses on Unmanned Aerial Systems (UAS), LIDAR, Wildland Fire Support and the National Agricultural Imagery Program (NAIP). Integrating UAS into more operational use at the USFS involves fostering safe, legal, respectful and enjoyable uses that are efficient and cost-effective. The UAS Program includes considering aviation management, the agency, service providers, public use, business need, and the FAA/FCC and other laws. USFS LIDAR is used for multiple applications including vegetation modeling, stream delineation, floodplain mapping, travel management, landslide detection and viewshed analysis. The USFS Remote Sensing Program has a lot of knowledge and expertise in using LIDAR and they often conduct technology evaluations, research, and technology demonstrations to increase USFS knowledge on ways to ingrate LIDAR. The purpose is to use their expertise to increase knowledge across USFS, coordinate efforts nationally, and work with tactical operators at the regional remote sensing centers. Key to meeting this purpose of the LIDAR program is providing national guidelines, training, and tools (e.g., FUSION – point cloud inspection analysis, LIDAR data viewer, LIDAR regression tools, and enterprise software) to expedite USFS use of LIDAR. Lastly, the LIDAR program facilitates the procurement of LIDAR data through advanced collaboration and partnership developments, potential cost sharing and multiple different contract vehicles. All data is available as point clouds via external harddrive, as LAS repositories with USGS (Earth Explorer and National Map 3DEP) and NOAA through the Digital Coast Data Access Viewer, or as LIDAR-derived topographic and canopy structure products through the USFS ArcGIS server. The National Remote Sensing Program provides support to fire managers through a civil applications committee that broadly encompasses the Tactical Fire Remote Sensing Advisory Committee (TFRSAC) composed of state and federal agencies, academic institutions, international partners, and vendor communities, and the Thermal Working Group (TWG) composed of civil and Department of Defense/Intelligence community members that have a common interest and mission in thermal detection reporting. TFRSAC and TWG both inform the Fire Imaging Technology and Intelligence Steering Committee. The NAIP is the largest, longest-running, consistent airborne civilian program that offers public domain high-resolution (60 cm – 2 m spatial resolution) optical imagery and is funded by the Farm Service Agency and cost-share partners.

5.2 USGS Program Overview

USGS provides science about the natural hazards that threaten lives and livelihoods; the water, energy, minerals, and other natural resources we rely on; the health of our ecosystems and environment; and the impacts of climate and land-use change. To do this, the USGS has seven mission areas: land resources, core science systems, ecosystems, energy and minerals, environmental health, natural hazards, and water.

The USGS supports the science needs of the Department of the Interior (DOI), Federal and State organizations, partners and international activities. DOI responsibilities span the Nation, from the Arctic in Alaska to the southern tip of Florida, and from Midway Island in the Pacific Ocean to the Virgin Islands in the Caribbean can manage 500 million lands primarily located in the western states and 1.7 billion acres on the outer Continental Shelf.

To better understand and document current, future, and unment needs of Earth Observations, the USGS assembled the National Land Imaging Program (NLIP). The USGS NLIP Requirements, Capabilities and Analysis Branch provides an enterprise-wide, enduring civil user requirements and analysis capability for guiding investments in, and use of land imaging technology and products. Specifically, NLIP captures and understands current and forward-looking science and operational land imaging user needs, characterizes current and emerging land imaging system capabilities, compares requirements to capabilities in assessing potential technology solutions, applies needs to inform development of mission architectures, imagery programs and product development, and supports national earth observation assessments.

NLIP has found that current users of satellite SAR data indicated the lack of availability, high cost, and low temporal revisit of current SAR data sources as key limitations – these could be addressed by a NISAR capability. In particular, the USGS has a wide variety of activities that rely upon information about vegetation structure, ecosystem identification, canopy cover, biomass, and leaf area index for which NISAR data will be useful for assessing fire fuels, invasive cheat grass distribution, and above-ground biomass for carbon sequestration and ecosystem change studies. Fundamental to the USGS Land Resources Mission area (LRMA) within USGS is providing a routine and consistent land cover classification product that is widely used not only within USGS but by users across the federal government, academia, the private sector, and the general public. Users identified classification accuracy, spatial resolution, and update frequency as areas for enhancement in current land cover products. Improved spatial resolution and classification accuracy would benefit water quality modeling, applications where accurate identification of impervious areas is important, and urbanization studies, particularly where new developments and low density residential areas are relevant but often currently missed, habitat studies where finer scale features and variations in land cover are important.

NLIP user requirements are The specification of the characteristics of an Earth observation, product, or service to meet a user need. Requirements are tied to a specific activity or product produced by an agency and a description of the activity or product is included in the database of requirements. The database identifies the fundamental information needed by the user and is stated in the form of a "Geophysical Parameter" along with the relevant attributes: geophysical parameter (what), geographic coverage (where), usable observation frequency (when/how often), data latency (how quickly), spatial resolution (physical scale), spectral characteristics, and other – latency, collection conditions, accuracy, data rights, etc. For each attribute a value, the units, and comments/rationale for the values is provided. This is determined through structured interviews with multiple subject matter experts in a given elicitation to capture the collective view. All requirements are observing system agnostic.

NLIP has found that a wide range of user requirements have been collected for moderate resolution land imaging applications (typically optical). Although NISAR may be applicable to some of these requirements however these users may not have previous experience or access to radar data or derived products.

5.3 USFS Forest Inventory Analysis (FIA) Program

The USFS FIA Program Mission has three components: 1) to estimate the extent (area) of forest land, 2) to estimate the volume, growth, and removals of forest resources, and 3) to assess the health and condition of the forest.

The USFS FIA Program lands cover all 50 states of the United States, as well as American Samoa, Federated States of Micronesia, Guan, Republic of Palau, Republic of the Marshall Islands, Virgin Islands, and the Commonwealths of Northern Mariana Islands and Puerto Rico. Their approach is to provide a report for each state every 5 years. Sites are selected based on a national sampling design with sampling intensity as one plot/2400 ha. Sites are selected using a stratified estimation from classified satellite imagery. To ensure consistency at sites, they provide a national field manual and estimation of forest biomass and health using standardized formulae. There is a national database with user friendly access. All methods are peer reviewed and technical documentation published.

Routine Monitoring is the overarching purpose of the FIA program as they produce a report every 5 years for every state and all data is publicly available with plot level data, however the plot coordinates are not public record.

There is no disaster response mandate within FIA.

The remote sensing capability of the FIA is to use existing higher-level information products. Specifically, they use the National Landcover Database (NLCD) percent tree canopy cover and tree canopy cover strata, a forest type (deciduous v. evergreen needleleaf v. broadleaf), and a forested/non-forest map to perform the random stratified sampling design for site selection. Where forest is defined as being any 1 ha that has at least 10% canopy cover. In general, it is a non-trivial process to separate forest land cover from forest land use.

The biggest challenges for FIA are lack of an up-to-date stratification layer, a data layer on within canopy biomass and volume, an effective map of change detection, and an effective map of small area estimation. Specific to the stratification layer, they need updates consistent with the 5-year reporting cycle, but at present they get them ever 10 years.

The value of NISAR will be in providing information on structure, biomass and disturbance detection.

5.4 USFS/USGS/EPA SilvaCarbon program

The USFS/USGS/EPA SilvaCarbon Program mission is to narrow technical capacity gaps and assist countries in the implementation of their Monitoring, Reporting and Verification (MRV) systems for REDD+, and more recently, in preparing and analyzing data to report national greenhouse emissions from all sectors. Capacity building is led by cooperating agencies' expertise: USGS builds remote sensing capability with different partners (academia, NGOs and government), the USFS builds Forest Inventory capability, and the EPA builds capability for greenhouse gas inventory through the Agriculture and Land Use (ALU) tool.

The USFS/USGS/EPA SilvaCarbon lands cross international boards in the Americas, Africa and Asia. It works with countries that have a REDD+ strategy in place including: Costa Rica, El Salvador, Guatemala, Honduras, Panama, Dominican Republic, Colombia, Ecuador, Peru, Cameroon, Democratic Republic of Congo, Republic of Congo, Gabon, Bangladesh, Cambodia, Indonesia, Lao PDR, Nepal, Philippines, Thailand, and Vietnam.

SilvaCarbon does not have a routine monitoring mandate, rather a mandate to build capacity for routine monitoring.

SilvaCarbon does not have a disaster response mandate. However, the development of early warning systems for deforestation is sought after by many SilvaCarbon nations.

SilvaCarbon aims to build remote sensing capability internationally through workshops, bilateral technical assistance, South – South collaboration, tools and guidance development, research grants and study tours. There are two regional workshops per year per region. Workshops are short exchanges of technical knowledge that showcase available and operational tools and methodologies. After each workshop, there are follow-ups to see if they are interested on applying any of the methods showcased. Workshops are the first step to the bilateral collaborations and an opportunity to start South–South collaboration. Bilateral technical assistance involves experts going to countries for an extended period of time to work on a specific technical issue, or having country officials coming to the US to learn a tool or a methodology at the government or Universities. South-South collaborations are when SilvaCarbon supports one country to train a neighbor country. For tools and guidance development, SilvaCarbon supports the participation of US experts to write chapters of the Global Forest Observations Initiative (GFOI) Methods and Guidance document and supports a number of tools: University of Maryland Forest Cover Mapping and GLAD alerts, Collect Earth Online, ALU tool, Boston University Beeoda, GFOI tools (e.g., Landsat time series). SilvaCarbon has also supported 13 research grants internationally and supports study tours, where country officials come to different places in the US to learn and build capacity.

The biggest challenges are in optical and radar interoperability. The first challenge is that there is no currently free and continuous data for time series of radar data for algorithm development. Such algorithm development will be important for optimal integration of field data, specifically for national forest inventories that need informed classifications. Lastly, there is a need for annual validations of forest change, in particular with respect errors in change detection between sensors and in areas with dense canopy cover. Although it is recognized that other sensors like GEDI (from NASA) and BIOMASS (from ESA) will help with biomass estimation in areas with dense forests, special software is needed for the integration and the existing examples where this has been done (e.g., Congo) required additional funding by World Bank.

The value of NISAR will be in the free and open data, but there is much development that needs to be done for it to be useful in classification for relevant information.

5.5 USFS Geospatial Technology and Applications Center (GTAC)

The USFS GTAC mission is to lead geospatial science implementation in the USFS by exploring and developing emerging technologies, work with partners to demonstrate their application in land and resource management, provide solutions to inform decision making, and build capacity to support the agency mission.

The USFS GTAC lands span all USFS lands in the United States.

GTAC does routine monitoring by providing a number of geospatial data layers to the USFS and partners including: active fire detection and monitoring (frequency of observation: multiple times daily with latency: <1 hour to days), post-fire restoration monitoring maps within 30 days of fire containment (frequency: once per incident with latency within 4 hours of image availability), monitoring trends in burn severity (MTBS) maps (frequency: once per incident with latency: months to 1-year post-fire), the National Land Cover Database (NLCD) tree canopy cover maps as part of the multi-resolution land characteristics consortium (frequency: 5 years with latency: 2-3 years), and forest health monitoring for tactical (frequency: incident driven with latency: 1-3 days), landscape (frequency: upon request with latency 1-3 days) and strategic (frequency: 8 days with latency: 1-3 days) applications.

GTAC does has the disaster response mandate to provide several data products used to inform disaster response activities. Disaster response products include rapid imagery of burn area reflectance classifications (BARC; frequency: once per incident with latency: <4 hours of image availability) and hurricane disturbance assessment maps (frequency: multiple times per incident with latency: as soon as possible depending on quality).

GTAC remote sensing capability primarily relies on optical imagery in the visible to thermal infrared and is sensor independent – i.e., Sentinel 2, Landsat, GOES, MODIS, VIIRS, NAIP, and commercial assets such as Worldview 2 and 3. There are extensive airborne LIDAR mapping campaigns over many states' forest service lands (~1/3 flown ever year). Lastly, they have a continued relationship with NASA Direct Readout Laboratory and can read data direct from the NASA ground data systems. There is some capacity within GTAC for radar processing, but the skills are not as well developed. There is a desire to use more SAR data, but they would need to increase capacity.

GTAC did not directly express any challenges.

GTAC did not directly express any value added from NISAR, but they do serve high latitudes and many of their monitoring products suffer from lack of illumination and clouds in these areas.

5.6 USGS Earth Resources Observation Science (EROS)

The USGS EROS mission is to provide research and decision support tools for assessing land change across the United States and around the world, operate the Landsat satellite program with NASA, and maintain the largest civilian collection of images of the Earth's land surface in existence, including tens of millions of satellite images.

The USGS EROS forest and ecosystem lands are located around the United States on all types of lands. Primary support is given to Depart of Interior agencies (e.g., National Park Service and Bureau of Land Management), but partnerships also exist with other federal, state, local, and tribal agencies as well as private organizations and NGOs. They do have some international work, but mostly coordinated through partnerships

USGS EROS has several operational programs that provide datasets for routine monitoring including land cover/land use change, fuel cover based on vegetation characteristics, forest structural dynamics, biomass changes, and landscape disturbance characterization. For most programs, near real-time data is not necessary as most products are 1-4 years retrospective; rather data products are updated annually or less frequently. However, some near real-time data is used to support disaster response, such as burn severity mapping and debris flow modeling. No specific latency requirement, but as soon as possible in these applications.

USGS EROS supports disaster response by providing information products to inform response activities. Some of the products provided include quick browse imagery, thematic datasets (e.g., land cover, elevation, etc.), models and in situ monitoring (i.e., stream gauges). None of these products have specific latency requirements, rather best data available is used to provide support. Better support can be provided with more timely data. They typically support post-fire Burned Area Emergency Response (BAER) and international charter disaster activations (typically supported by the Hazards Data Distribution System – HDDS).

USGS EROS has high remote sensing capability it provides a clearinghouse of remote sensing data for numerous forests and ecosystems applications (both monitoring and disaster response). Remote sensing data products assist land managers with planning and forecasting potential impacts of spatial change over time and are used to provide immediate and ongoing situational awareness and incident support for disasters (often in response to International Charter disaster activations). Most of the experience with remote sensing data is with optical imagery and LIDAR, but there is some capacity for radar data utilization (typically related to earthquake or volcano applications). There is an activity underway to standardize openly available LIDAR data across the contiguous United States.

The biggest challenges for USGS EROS are near real-time landscape disturbance detection, data availability in high latitude regions and areas with constant cloud cover, integration of new data sources with existing products, and outreach and training to enable data producers and data users to fully understand and utilize new types of data. Since most of their experience is in optical data, there is minimal use of SAR data and it is primarily for earthquake or volcano applications.

The value of NISAR for USGS EROS will be in guaranteed cloud-free data with reliable repeat schedule. These data would enable more consistent and robust characterization of land cover, vegetation structure, wetlands, biomass, etc., which would lead to significant improvements in USGS science data products, provided the capacity to utilize these data could be developed. If the latency is reasonable, the ability to provide near real-time event characterization would be improved for events such as wildfire, where heavy smoke during active fire can obscure optical imagery. Importantly, whatever is produced from NISAR should have the capability to be consistent with previous observations (e.g., GLAS data with ALOS or LIDAR).

5.7 United States Bureau of Land Management (BLM)

The BLM's mission is to sustain the health, diversity, and productivity of the United States' public lands for the multiple use and enjoyment of present and future generations. The Bureau is mandated to manage public lands for multiple purposes including recreation, grazing, mining, timber harvesting, and energy development. Finally, the BLM is tasked with protecting natural, cultural, and historical resources.

The BLM lands include over 245 million surface, and 700 million sub-surface acres across the United States. This equates to more than ten percent of the nation's surface area, and thirty percent of its minerals and soils. Much of the BLM holdings are located in the Western United States. The agency also manages "special units," which are part of the National Conservation Lands System. These lands include forests (e.g., coniferous, deciduous, old growth, secondary growth, wetlands and woodlands), grasslands, riparian lands, shrublands and tundra.

BLM routine monitoring span many different aspects of land management. This includes Assessment, Inventory and Monitoring (AIM), a standardized, *in-situ* data collection program to identify the condition and spatial distribution of vegetation and other resources on BLM lands. Other pertinent monitoring efforts include: conifer encroachment upon Great Sage Grouse habitats (with yearly to periodic – based on need – monitoring), continuous forest inventory (reported every 10 years), ecological site inventory (periodic revisions as data become available), emergency stabilization and rehabilitation (ESR), ice morphology (quarterly and yearly), and lentic inventories of lakes, ponds, and wetlands (quarterly and yearly).

BLM disaster response includes support during wildfire events on BLM land and emergency stabilization and rehabilitation (ESR) activities. Support includes delivery of pre- and post-fire imagery, data products delineating the fire perimeter and burned/unburned cover, bulldozer disturbance, and fire retardant lines (each upon request by field office). ESR activities are implemented to prevent degradation of natural and cultural resources, minimize threats to life and property upon burned lands, following a fire event, stabilize soil and water, and treat fuels. Support is theoretically provided within 10 days following fire containment, with revisits up to three years). However, in practice, delivery of derived products varies based upon available data, and (unique) mission needs.

BLM remote sensing capability is high as it uses a host of remote sensing systems, both monoscopic and stereoscopic, to help address resource management questions at multiple geographic scales. These systems include close-range photography, traditional aerial photography, high-resolution to synoptic spaceborne platforms (optical and SAR), LIDAR, and UAS hosting multiple imaging systems. The BLM has increasingly integrated remote sensing information and products into its decision support systems to address resource management questions. However, this integration has neither been seamless, nor fully realized.

BLM challenges include developing appropriate data processing/exploitation tools for field interests. Additionally, the BLM needs to ensure that field interests possess the technical proficiency necessary to leverage remote sensing information and products to meet resource management

objectives. Specifically, the wider integration of SAR products into the BLM's "toolkit" will be challenging due to the limited geospatial field capacity of the organization, and the steep learning curve for using SAR information. Senior BLM technical leadership would need to provide guidance, training materials, and examples demonstrating how this information could be used to realize resource management objectives.

The value of NISAR for the BLM will be in monitoring disaster events, such as wildfires, floods, and volcanic activity. NISAR could be leveraged to monitor other disturbances (e.g., conifer encroachment, erosion, overgrazing, and trespass). Other applications for which NISAR could provide monitoring enhancements include mine production verification, soil moisture, water cover, and vegetation structure, height, volume, and areal cover extent. NISAR products would improve the Bureau's ability to monitor and characterize land condition, regardless of time of day, weather, or fire effects. Depending on the polarization of the data, NISAR will be useful for different applications. Quad-pol will be important for polarimetric decompositions, while polarization composite and ratios have proven very useful to analysts as they provide something analogous and complementary to multispectral image composites, such as those displaying SWIR, NIR, and green bands.

5.8 United States National Park Service (NPS)

The NPS mission is to "preserve unimpaired the natural and cultural resources and values for the enjoyment, education, and inspiration of this and future generations" and to "cooperate with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world."

The NPS lands cover dense forest, tropical forest, managed forest and wilderness areas.

NPS routine monitoring includes forest fire fuel identification (e.g., moisture content and biomass), forest regeneration (e.g., tree height, distribution and growing stock volumes). The latency need for these products varies by application, but in general – the more data, the better, the faster the better.

NPS disaster response mandates include resource protection. Resource protection needs information relevant to fire management, assessing infrastructure impacts, and mapping broad-scale encroachment. The latency need for these products is as close to real time as possible, but as long as the latency is consistent, the products can be worked into the modeling.

NPS remote sensing capability is high as they use various imagery for supporting pre-fire mitigation and post-fire management. The capacity of NPS to integrate NISAR into decision support systems is slowly growing through improved communication.

The biggest challenges from NPS are the decentralized nature and loss of institutional knowledge due to budget cuts, retirement, etc.

The value of NISAR is in the opportunities to rethink existing workflows that incorporate a different imagery source, leverage collaborative experience for derived product acquisition, and improve decision making outcomes.

5.9 World Wildlife Fund (WWF)

The WWF mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature; specifically, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption. Goals specific to forestry include effective protection or improved management for 50% of the world's forest, halted deforestation, and 350 million hectares of forested landscapes restored.

WWF works on lands that span nearly 100 countries around the world in 6 of the 7 continents.

WWF has a mandate for routine monitoring of biomass, tree heights, disturbance, moisture status, and growing stock volumes. Typically latency within a month of acquisition is good enough, but it really varies by application, so the answer may change depending on who is being served.

WWF Disaster Response is minimal, but not unprecedented. For example, WWF did some work in Nepal following the last major earthquake.

WWF remote sensing capability includes developing and disseminating (via several platforms) information relevant to the WWF goals. Specifically, WWF hosts the Global Observation and Biodiversity Information Portal (GLOBIL) provides open access to data from WWF projects and priority ecoregions. You can search, view, map, style, chart, and download data or share it all via your browser with no log in required. Another resource is the WWF-SIGHT, a global intelligence platform that enables users to bring together diverse spatial datasets and combine them with satellite imagery. In general, WWF works with countries to validate and understand where changes happen on the ground and provide educational materials that help translate scientific methods to those needed and understood by the end user.

The biggest challenges for WWF are in identifying how to provide resources, what resources are needed and for who to provide them. Specifically, how should resources be developed in a transparent way that assesses the impact that providing that resource has. What should be mapped may include wetland mapping, hydrologic patterns, forest fire scars, forest degradation, rubber (tree perennial crops) and deforestation-free commodities. Who to provide the information for depends very much on the country's capacity, and mandates for sustainability. Lastly, whatever is provided needs to be well-documented. Some lessons learned from building capacity for integrating optical imagery are that SAR data needs to be accessible to a broader user base. One example might be to provide more resources like the NASA-SERVIR Biomass Estimation manual. There also needs to be capacity building for the users and a communications strategy as an integral part of the workload.

Preliminary analyses at WWF are demonstrating the value of NISAR for WWF mission and goals.

5.10 World Resources Institute (WRI)

The WRI mission is to safeguard the world's forests from fragmentation, degradation, and deforestation, maintain forest quality through sound stewardship, restore forest connectivity, and restore lands to healthy forests, farms, plantations, and agroforests and silvopasture to forests. They do this by improving access via an online, free data portal (Global Forest Watch – GFW) to the best available data about forests, and creating unprecedented transparency about what is happening in forests worldwide. Better information supports smarter decisions about how to manage and protect forests for current and future generations, and greater transparency helps the public hold governments and companies accountable for how their decisions impact forests. local forests.

WRI lands include global forests, with an emphasis in the tropics. Priority areas are Peru, Brazil, Congo Basin, Liberia, Madagascar, and Indonesia. There are over 1.8 million unique users of GFW including national and local governments, civil society organizations, private sector (commodities), academics, and journalists.

WRI does not directly conduct routine monitoring, but their partners do. They have developed a strong emphasis on near-real time (NRT) monitoring and have built capability to meet this need. Specifically, they have a current focus on weekly GLAD deforestation alerts (based on Landsat), a new Forest Watcher mobile app (to enable users to access alerts in the field), an automated alert filtering capability to identify most important alters for users, and research into users' needs for NRT information. Six specific applications have been identified for using NRT alerts: 1) prosecutors/police to prioritize efforts, 2) protected area managers, 3) supply chain monitors to respond to valuable crop (e.g., oil palm) land use changes, 4) investors to pay for ecosystem services and monitory compliance with agreements, 5) land defense by smallholders (e.g., indigenous people), and 6) journalists to create public awareness. Most of the applications require medium resolution (10-50 m) spatial information with high frequency (weekly observations), information despite cloud-cover limitations (e.g., lag times or incorrect disturbance dates), and are available without access to GIS software. The threshold for acceptance of false alarms varies by application. Some applications want to know even if there is a 90% chance it is a false alarms, while others have a very low tolerance and need to high reliability in the product. Thus, a probability of qualification (e.g., a categorical flag) of quality would be helpful.

WRI disaster response comes in the form of providing NRT data for monitoring.

WRI does not have a lot of direct remote sensing capability, however they partner with people that do.

Some of the challenges WRI encounters is that they need capable research partners, free/low cost access to data and consistent data formatting and processing to enable full automation. WRI partners with researchers to provide the higher-level information value-added products, so finding capable researchers willing to make a product can be challenging. Also, the consistency of data formatting and processing can be challenging with different sensors from different agencies.

The value of NISAR to WRI will be in overcoming limitations in cloud-dense areas and to see degradation in structure before the top of canopy is affected. NRT monitoring using optical imagery

in cloud-dense areas can lead to a number of errors such as disturbance detection date vs. data of disturbance. Use of NISAR to penetrate clouds would lead to more accurate estimates of true dates for deforestation events. Lastly, being able to monitor degradation to forest structure (despite maintenance of the top canopy) will be of value. Notably, whatever is done with NISAR to provide information, must be scalable from local to global application.

5.11 Conservation International (CI)

The CI mission is to build upon a strong foundation of science, partnership, and field demonstration, to empower societies to responsibly and sustainably care for nature, global biodiversity and the well-being of humanity.

CI focuses on lands in the America, Asia, Africa and the Pacific, but they invest and engage with the European Union, the United States, China and Japan because of their profound influence on public policy, production and consumption.

CI helps provide routine monitoring of freshwater, biodiversity, fire, and carbon (i.e., biomass). Specifically, they require accurate and reliable maps of: 1) biomass estimates in forests and mangroves for REDD+ and blue carbon baselines, 2) NRT (hourly) disturbance information to respond to emerging forest threats, 3) soil moisture to model agricultural suitability and monitor drought stress and fire danger, 4) sub-canopy structure to map shade-grown coffee, 5) land degradation to assess trends in ecosystem health and biodiversity, 6) deforestation to evaluate impact to conservation investments, and reporting of carbon emissions, 7) forest degradation to more accurately measure emissions from anthropogenic change, 8) NRT mapping of burn scars at 30 m x 30 m pixel resolution to rapidly assess area burned and associated emissions, 9) mangrove extent, and 10) post-fire deforestation land-use to accurately measure change in emissions (loss + gain).

CI does not directly have a disaster response, but they provide information relevant to disaster response activities. For example, they provide NRT fire detections from MODIS and VIIRs as well as illegal logging and illegal mining alerts. They also provide NRT burn scar mapping, which primarily uses optical imagery as they have had limited success using Sentinel-1 SAR data (particularly in mountainous terrain). These alerts update hourly and are pushed to email or a phone app.

CI remote sensing capability is high as they have worked to incorporate data from many different sensors including those providing both optical and radar data. They us Landsat and SAR for land cover land use mapping, zoning, land use planning, and conservation priority setting. Landsat is used for forest cover change and calculating emissions from biomass derived from remote sensing. Active fire detections rely on MODIS and VIIRS for rapid response to ecosystem threats, while fire danger and land degradation monitoring rely on MODIS. They also leverage the Global Precipitation Mission (GPM) for fire danger and drought monitoring. An important part of CI mission is to build international capacity for integrating remote sensing data; as such, most international offices have technical staff.

The biggest challenges for CI include building trust in the data by their stakeholders, providing transparency in how the data are generated, using open-source software, overcoming internet

bandwidth and computer power limitations, and understanding SAR and potential applications. The emphasis to overcome many of these challenges is in capacity building, providing open-sources tools that can be customized by individual stakeholder communities, and removing barriers associated with limited bandwidth and compute resources (e.g., by enabling cloud compute).

The value of NISAR to CI will be in the increased data availability in tropical areas with dense cloud cover, the potential for more accurate biomass and land cover/land use maps (particularly with integrated structure for identifying agroforestry systems – e.g., shade-grown coffee – and degradation), the ability to detect drought stress (as fire risk information), and improved quality and access to flood and landslides assessments. This, however, will require development. Specifically, CI will need automated processing to use NISAR data for NRT monitoring, which will place greater demand on their capacity to process and interpret a greater volume of information. Also, there will be additional challenges for capacity building because of the complexity and accessibility of data.

5.12 World Bank

The World Bank mission is to promote and reward reduced greenhouse gas emissions and increased sequestration through better land management, climate-smart agriculture, and smarter land use planning and policies. Specifically, this includes integrating sub-national development agendas with low-carbon pathways. Also, World Bank supports forest countries to maintain and improve livelihoods, conserve biodiversity and leverage significant private and public sector finance to achieve transformational change. They also demonstrate approaches that can be applied nationally i.e., national low-carbon strategies and global mechanisms of support such as REDD+. They accomplish their mission by providing grant funding and technical assistance for policy and strategy, capacity building, social inclusion, and consultation. They "crowd-in" financing from private and public companies (e.g., IDA, IBRD, and GEF) for investments in low-carbon development, sustainable management of forests, and climate-smart agriculture. The provide results-based financing for emission reductions to alleviate poverty, share prosperity, and mitigate and adapt under climate change.

World Bank providing financing to lands across the America, Africa, Asia and the Pacific. This includes 22 countries for climate-smart land use programs, 54 countries with REDD+ readiness support or projects, 19 countries with emission reduction programs under FCFP Carbon Fund, and 3 countries with emissions reductions programs under Carbon Fund (ISFL).

World Bank is interested in routine monitoring of deforestation and forest degradation (if it results in >10% loss of total forest emissions). They also require at least biennial monitoring of forest cover change (including reporting of uncertainties). Some countries are aiming for annual monitoring and even early warning systems, but this is not a requirement for World Bank. Emission Factors are estimated once, and could come from biomass maps, but uncertainties must be reported. For many of these applications, 1 ha-scale is adequate.

World Bank does not have a disaster response mandate, but does require that countries that receive funding have in place forest monitoring systems that are capable of identifying reversals (i.e., land use change.

World Bank does not directly have remote sensing capability, but they fud people that do. Generally, countries do not have processing chains capable of digesting SAR data (only study tests have been done). However, countries do tend to move their processing chains totally or partly to the cloud, which should be able to digest NISAR data. Even with processing on the cloud, countries need developers to work on specific tools that enable for quick and easy and processing of data, including forest-specific tools. Critical to providing such capabilities to countries is the integration and cross-operability of different sensors (co-registration, other standards).

The biggest challenges for World Bank are related to the capacity of countries to use the data that is available because of limited access to data processing chains and technical expertise for processing remote sensing data in a timely manner. World Bank has two tools that can help: Sen2mosaic and Sen1mosaic, which enable downloading the data and all pre-processing needed to get free cloud composites in Sentinel 1 and 2 and mosaics. At this point, they are exploring different options for linking these tools to cloud platforms (e.g., Google Earth Engine), but there are concerns that relying on any one company to sustain their platforms would be too risky. There is still a lot that needs to be worked out regarding funding models for processing on the cloud.

The value of NISAR for World Bank will be in detection of forest degradation, improved mapping of dry forests, annual monitoring in areas with high cloud cover, detection of different land uses and land management practices and the potential to estimate carbon stocks and changes in carbon stocks.

5.13 Timber Consulting Firm: SilvaTerra

SilvaTerra's mission is to facilitate informed forest management decision making for all forest landowners who are particularly interested in inventory, growth and harvesting cycles. Much of what they do is helping customers develop a forest management plan (only about 13% of forested land in the US has a forest management plan), which includes aligning accurate ground estimations and managing data flow with remote sensing data to inform that plan.

SilvaTerra consults on US Forest lands independent of their ownership (public, family, corporate, other). Most of their lands (~90%) are in the contiguous US, and the other 10% are international.

SilvaTerra routinely monitors disturbance, basal area, diameter distribution, TPA, and species distributions. They monitor on the one-year national inventory cycle for most of these, but also provide monthly disturbance monitoring. For gridded products, they provide 15-m resolution, but they also provide tree-list information such as diameter, species and total height. Earth observation data latency must be within 2 weeks to be incorporated. Important to their work is using ground data to predict a tree list given the remote sensing input.

SilvaTerra provides periodic disturbance monitoring in the event of a disaster. For this purpose, observations are needed at a frequency of approximately 2 weeks, but the final information product for the customers can typically be delivered within 2-3 months.

SilvaTerra's remote sensing capability is high as it includes optical, LIDAR and radar image processing. Their work integrates ground measurement data with multi-spectral sensor data from spring and fall including imagery from Landsat 2+, Sentinel-2, Planet Lab, NAIP (or other 1-4 m resolution imagery). They also integrate Sentinel-1 data and historically have relied on Radarsat-2

and Palsar 1 and 2. They use Digital Elevation Models (DEMs) to derive elevation, slope, aspect and topographic indices. Lastly, they will use LIDAR and Landcover data.

The primary challenges for SilvaTerra are in identifying natural disturbance (insect/pathogen, fire, wind, etc) and monitoring timber harvests (e.g., timber left and planned maintenance) as well as processing capability for using SAR data. While SAR is cheaper than LIDAR, there are a lot of concerns about processing the data. Specifically, if terrain correction and speckle filtering tools were provided, this would greatly increase the capacity for them to use SAR data. Furthermore, while SilvaTerra can coregister images, many of their customers cannot, so co-registering and aligning projections with existing data, while providing data in a GeoTiff, would greatly benefit and increase the utility of NISAR.

The value of NISAR for SilvaTerra private consulting activities will be in disturbance detection and forest structure (i.e., biomass) inventory/monitoring.

6 NASA/NISAR Technical Response to Sector Information Requirements

The NISAR Science Team listened to the current state of practice and needs presented by each representative agency and identified common themes:

	USFS FIA	USFS/USGS/EPA SilvaCarbon	USFS GTAC	USGS EROS	US BLM	US NPS	WWF	WRI	CI	World Bank	SilvaTerra
Need for Capacity Building		X	X		X						
Tool to provide radiometric, terrain corrected data					X						X
Tool to provide filter speckle					X						X
Tool to enable time series analysis		X			X		X				
Information need to identify small area forests	X				X						X
Information need for landcover classification of key forest crops (e.g., rubber, oil palm, etc.)	X						X				
Information need for biomass					X		X		X		
Information need for moisture status (soil or vegetation)					X				X	X	
Information need for disturbance type classification			X	X	X		X	X	X	X	X
Reduced latency for disaster response (e.g., inundation, debris flow, and burn severity)			X	X	X		X	X	X		X

7 Information Product Requirements

The community agreed that there were certain Level 2 product specifications that would increase the utility of NISAR data in their current workflows including needed pre-processing, spatial resolution, and latency; however, no consensus was reached about trades in polarization, temporal resolution, and accuracy. Agreed pre-processing included radiometric and terrain correction (RTC) for SAR

backscatter products and terrain correction interferometeric (InSAR) products. The community thought that providing a tool to decide on the speckle filter approach would be more useful than intrinsically building speckle-filtering into the products themselves because it would enable more applications of the data. Specifically, there was discussion of the trades between aggregating in space or time to reduce speckle. Some applications such as delineating edge effects would require finer resolution (12.5 x 12.5 m^2), while others such as change detection would need to track temporal signatures, thus coarser resolutions (20 x 20 m^2 minimum or 50 x 50 m^2 or even 100 x 100 m^2) would be more appropriate. No matter the resolution, higher-level products should align with the spatial resolutions of optical, DEMs, and ground truth (noting that there is a 5-10 m error on hand-held GPS) to enable data fusion applications. For example, NISAR and Landsat data could be co-registered such that joint time series analysis would be possible taking advantage of the strengths of both data types. The agreed latency of the Level-2 products was variable by application ranging from hours, to yearly, but Level 0 raw, uncalibrated products would be needed within 1 day and Level 2 products within a week. Because no conclusions were made to prioritize trades in polarization, temporal resolution and accuracy, this would be a topic for a working group. It was worth noting that most agreed they would rather have high temporal resolution than quad-pol data.

The community argued for "analysis ready data", which was defined to be "GIS ready" including specifications for data projection and format. For this purpose, the discussion of projection led to a debate between using a Lat/Lon projection that would be most compliant with existing products (e.g., Hansen Forest cover), or military grid reference system (MGRS), which derived from the UTM grid system. No resolution was found and it was suggested this be a topic for a dedicated NISAR Applications Working Group. Despite not resolving a needed projection, it was agreed that data should be delivered in GeoTiff (not HDF5). The international communities argued that many of their stakeholders do not have the capacity to download the data and so a cloud-data store is most helpful. The community recommended that if data were provided in a cloud-data store, the data system would need to enable people to bring their workflows to the data.

The workshop identified a number of potential Level 3 products beyond what NISAR will produce that include: disturbance classification, biomass, structure, soil moisture, flooding, burn severity, forest/non-forest mask for small-are land owners, and tree canopy cover. For biomass, the community agreed that distinguishable change in biomass (i.e., that better than uncertainty) would be very useful. With respect to biomass uncertainty reporting it would be most useful if were compliant with the Intergovernmental Panel on Climate Change (IPCC) GPG standards. Structure was specifically defined as vertical connectivity. Although burn severity is a research area, it would be useful beyond areas with minimal illumination (i.e., high latitudes) and dense cloud cover (i.e., tropics) if the product incorporated vegetation structure change and soil changes (e.g., sagging). For the forest/non-forest mask, forest was broadly defined to be anything with at least 30% tree canopy cover at 0.5 ha resolution. The NISAR Science Team explained that 50-meter canopy cover for the forest/non-forest mask would be challenging, but that 1 ha would be more feasible, and this is the compliant with the current NISAR disturbance detection requirement. Lastly, it was suggested that it would be useful to provide documentation on how to visualize polarizations the way that people discuss Landsat bands (e.g, as R-G-B images), and how that can be interpreted. Such documentation would take out the technical details and provide high-level understanding of the information in the SAR data.

8 Needs by the Community to Enable Use of NISAR Data

For NISAR to be useful for the Forest and Disturbance community, the data needs to be easier to access and work with than SAR data currently is. Most of the workshops participants lack the capability to process NISAR data to a level useful for their agencies' needs. To lower the bar of access, there needs to be a focus on capacity building that teaches the community how to generate new products (L2/L3/L4) and development of tools to enable easy access and utility.

For capacity building they recommended not only topics, but also strategies for engaging specifically with the Forest community internationally. Topics included: educating about proper SAR data processing (e.g., speckle filtering and dB vs sigma 0), cloud computing, deriving relevant information, and SAR data discovery. Specific to information that can be derived from SAR, there was the recommendation to discuss the information (e.g., indices) first, and the physics behind the SAR measurement if it explained why processing was needed. The community suggested taking the perspective of "SAR for Landsat Users". With respect to SAR data discovery, the community suggested having a user-friendly interface of archived data. This would be a game-changer for the applications as well because it would enable longer-time series. The community acknowledge that some tools are out there (e.g., Google Earth PanTropical data layers), but it is not very developed. The suggested strategies for capacity building suggested using open and freely available data, targeted training at certain user communities, coordinating with existing programs and engaging with universities. The suggestion to use free and open data (e.g., Sentinel, ALSO archive for the Americas, etc.) stemmed from feedback at current capacity building programs that users want to apply what they learn outside of the training. With respect to targeted training, there was an emphasis that trainings should "train the trainers" in order to create a multiplicative effect. The community also acknowledge that the forest community has many existing capacity building programs and trainings should be integrated into these; specifically: SilvaCarbon, SERVIR, and ARSET, SarEDU, USFS GTAC webinars, FIA Techniques Research, Conservation Biology Institute Webinars, WWF, Data Carpentry/Software Carpentry Program, National Center for Ecological Analysis and Synthesis, DOI Remote Sensing Working Group, Open Source Radar Imaging Software (OSRIS) quarterly meetings, and the Natural Areas Association. Lastly, they recommended providing short courses through specific agencies, organizations, and university geography departments.

In order to build capacity, there needs to be improved access to sample tools and datasets to learn those tools. Specific tools that would be very valuable are: a NISAR Acquisition search (past and future), a graphical user interface (GUI) for existing SAR processing tools (e.g., ISCE) and a plug-in to open-source QGIS software for SAR processing (with speckle filters, dB to power conversion, time series analysis, radar visualization, down-sampling tool with proper data handling for dB to power scaling). In addition, on-demand processing would be useful. Whatever tools are developed, they must be open-source and there must be an avenue for customer support. Lastly, distribution platforms need to enable both download and a cloud GUI and API options.

9 Roadmap to Launch

In the near term before NISAR launch (expected December 2021), it was suggested that a Forest and Disturbance Applications Working Group (as per the specifications of the NISAR Utilization Plan)

would be useful. Such a working group would focus on: 1) a path to global, added-value information product (Level 3) production and dissemination, 2) a clearing house of algorithms/recipes for those information products, providing Level 3+ demonstration datasets (based on PALSAR, Sentinel-1, UAVSAR, and other), 3) assessing different projection trade-offs and trades of polarization, temporal resolution and accuracy and recommending what the community needs, and 4) trade-offs of polarization for different information product requirements. In order to understand how the broader community can work together to produce and distribute value-added information products (Level 3+) to the forest and disturbance communities, there needs to be a matrix that states for each organization, the in-house capability and interest to produce products, interest to provide product calibration and validation support (in situ) for those products, interest to distribute/disseminate data to a broader community, and interest in offering capacity building. Also, information on each of these topics needs to be aggregated. For example, there needs to be a clearing house of algorithms/recipes for producing those products both on and off the cloud. Although the NASA Alaska Satellite Facility (ASF) Data Active Archive Center (DAAC) has begun to do this, the working group would need to help provide more, test them for global applicability, and refine them based on community feedback. Testing these algorithms for global applicability will be especially important for understanding uncertainty reporting.

Over the long-term from now and beyond, we need to continue capacity building programs that specialize in reaching the unique needs of the forest and disturbance community.

10 Appendices

10.1 Agenda

DAY 1: Wednesday, June 13, 2018

7:30 - 8	Arrival & Sign-In	
8 – 8:15	Workshop Welcome	Alex Moad (USFS) and Natasha Stavros (NISAR Deputy Applications Lead for Ecosystems)
8:15-8:30	NASA Welcome	Craig Dobson, NISAR Program Scientist (NASA/HQ/Earth Science Division)
8:30- 9	USFS Remote Sensing Overview	Everett Hinkley, USFS National Remote Sensing Program Manager
9 – 9:30	USGS Remote Sensing Overview	Greg Snyder, Chief of Earth Observation Requirements, Capabilities and Analysis Branch
9:30 – 9:45	Break - Coffee/Tea Provided	
9:45-11:15	NISAR Mission Overview and Forest Structure, Biomass, and Disturbance	Sassan Saatchi, NISAR Science Team, JPL/CalTech and Josef Kellndorfer, NISAR Science Team, Earth BigData
Information Product Requirements – Sassan Saatchi facilitating		
11:15-12:00	USFS Forest Inventory and Analysis	Ron McRoberts, USFS
	USFS/USGS SilvaCarbon	Bradley Reed, USGS
	USFS Geospatial Technology and Applications Center	Brad Quayle, GTAC manager
12:10 – 1:10	Lunch	
Information Product Requirements continued		
1:20 – 1:35	World Wildlife Fund	Naikoa Aguilar-Amuchastegui
1:35- 1:50	Timber Industry Consulting	Zack Parisa, SilvaTerra
1:50 – 2:05	USGS Forestry and Ecosystems	Kurtis Nelson
2:05 – 2:25	World Resources Institute	Mikaela Weisse
2:25-2:45	Conservation International	Max Wright
2:45-3:10	BLM	Chris Cole
3:10-3:25	World Bank	Andres B. Espejo
3:25 – 3:40	Break - Coffee/Tea Provided	
3:40 – 4:00	Follow-up Q&A with all speakers – Open Discussion	
4:00-4:15	National Park Service	Brandon Lemire
4:15- 4:30	Technical Response to Information Requirements Discussion	Josef Kellndorfer, NISAR Science Team, Earth BigData
4:30-5:10	R&D Needs to Address Identified Technical Gaps	Gerald Bawden (NASA/HQ)

DAY 2: Thursday, June 14, 2018

7:30 - 8	Arrival & Sign-In	
Examples of how SAR could be integrated into existing Decision Support Workflows		
8:15 – 8:50	Biomass/Forest Inventory and Analysis	Hans-Erik Andersen, USFS

8:50 – 9:30	Fire Modeling	Mark Finney, USFS FARSITE
9:30 – 10:15	Forest Cover Monitoring	Naiara Pinto, JPL
10:15 – 10:30	Break - Coffee/Tea Provided	
10:30 – 11:00	SERVIR	Africa Flores, NASA SERVIR
11:00 -11:20	Ecosystem Structure Monitoring	Michele Slaton, USFS Region 5 Remote Sensing Lab
11:20-12:00	Forest monitoring activities in Gabon	Ghislain Mousanovu, AGEOS Gabon
12:00 – 1:30	Lunch	
1:30 – 4:10	Detailed Sector requirements (Josef Kellndorfer, facilitate group discussion): Do any of the products serve multiple Organizations/Agencies/Applications requirements? What do the final products look like? Variables? Spatial and temporal resolution? Accuracy? Latency? Time Series? Raster? What is the best way to deliver the final product? Data format? Distribution Platform? What is the best way to get from NISAR radar products to Forest final products? How do we put that in place?	
4:10 - 4:40	NASA Applied Science Program Overview	Woody Turner, Ecological Forecasting Applied Science Program Manager (NASA/HQ)
4:40 – 5:00	Next Steps and Wrap-Up	Craig Dobson (NASA/HQ/Earth Science)

10.2 Participants

Name	Affiliation
Africa Flores	SERVIR biomass
Amber Soja	NASA HQ - Disaster Program
Andres B. Espejo	World Bank, Lead of Forest Par
Batu Osmanoglu	NASA GSFC
Bradley Reed	USGS SilvaCarbon
Bruce Chapman	NISAR ST
Craig Dobson	NASA HQ
Evan Notman	USAID Program Manager, Forests and Climate Change
Everett Hinkley	USFS national RS manager
Gerald Bawden	NASA HQ
Ghislain Moussavou	AGEOS Gabon
Gregory Snyder	USGS Satellite Needs
Hank Margolis	NASA HQ
Hans-Erik Anderson	USFS PNW + AK FIA
Jim Ellenwood	USFS
John Jones	USGS - water extent/ inundation
Josef Kellndorfer	NISAR ST
Kathy Hibbard	NASA HQ
Kurtis Nelson	USGS EROS LANDFIRE data product developer
Linda Heath	USFS FIA carbon accounting
Liza Jenkins	MTRI
Margot Wood	Conservation International
Mark Finney	USFS FARSITE
Max Wright	Conservation International
Mikaela Weisse	WRI - Global Forest Watch
Mike Falkowski	Colorado State University
Naiara Pinto	JPL - UAVSAR
Naikoa Aguilar-Amuchastegui	WWF manager for REDD projects
Natasha Stavros	NISAR DPA
Paul Siquera	NISAR ST
Ronald McRoberts	USFS
Sassan Saatchi	NISAR ST
Sue Owen	NISAR DPA
Susan Minnemeyer	WRI - Global Forest Watch
Victoria Meyer	JPL
Zack Parisa	SilvaTerra

Farell Nzigou Nboucka	AGEOS- Gabon earth observation agency
Juliann Aukema	USAID, Office of Global Climate Change
Min Feng	UMD
MinJeong Jo	NASA GSFC
Shrabanti Hira	Silvacarbon Bangladesh
Unmesh Khati	JPL
Vanessa Ovono	AGEOS
Woody Turner	NASA HQ
Trisha Gopalakrishna	TNC
Alex Koltunov	UC Davis
Anand Roopsind	Boise State
André Beaudoin	Natural Resources Canada
Birgit Peterson	USGS EROS LANDFIRE data product developer
Brad Quayle	USFS RDAS manager
Brady Couvillion	USGS
Brandon Lemire	NPS
Brian Freitag	NASA MSFC
Brian Huberty	Fish and Wildlife Service
Chris Cole	BLM Remote Sensing Program
Hao Chen	Natural Resources Canada
Jennifer Corcoran	MN State Dept. Natural Resources
Josh Picotte	DOI BAER Remote Sensing Support Lead
Kelvin Brentzel	NASA GSFC DRL
Marco Lavalle	NISAR Project
Michelle Slaton	USFS regional office
Robert Treuhaft	JPL
Todd Hawbaker	USGS
Lori Schultz	NASA MSFC
Lori White	USFS

10.3 Acronyms

AIM	Assessment, Inventory, and Monitoring
ASF	Alaska Satellite Facility
BARC	Burn Area Reflectance Classification
BAER	Burned Area Emergency Response
BLM	Bureau of Land Management
CI	Conservation International
DAAC	Data Active Archive Center
DEM	Digital Elevation Model
DP	Dual-Polarization
EPA	Environmental Protection Agency
EROS	USGS Earth Resources Observation Science
ESR	Emergency Stabilization and Rehabilitation
FIA	Forest Inventory Analysis
GFOI	Global Forest Observations Initiative
GIFG	Geocoded nearest-time InterFeroGram
GLOBIL	Global Observation and Biodiversity Information portal
GPM	Global Precipitation Mission
GSLC	Geocoded Single Look Complex
GTAC	Geospatial Technology and Applications Center
GUI	Graphical User Interface
GUNW	Geocoded nearest-time UNWrapped interferogram
HDDS	Hazards Data Distribution System
HH	Horizontal-Horizontal (Co-polarized signal)
HV	Horizontal-Vertical (Cross-polarized signal)
ISRO	Indian Space Research Organisation
MHz	Mega-Hertz
MRV	Monitoring, Reporting and Verification
MTBS	Monitoring Trends in Burn Severity
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NISAR	NASA/ISRO Synthetic Aperture Radar Mission
NLCD	National Landcover Database
NRT	Near Real Time
QGIS	Quantum Geographic Information System
QP	Quad-Polarization
REDD	Reducing Emissions from Deforestation and forest Degradation
SAR	Synthetic Aperture Radar
SLC	Single Look Complex
SP	Single Polarization
USFS	United States Forest Service
USFWS	United Sates Fish and Wildlife Service
USGS	United States Geological Survey
VH	Vertical-Horizontal
VV	Vertical-Vertical

WRI	World Resources Institute
WWF	World Wildlife Fund