Operations Concept for responding to Urgent Requests for NASA-ISRO Synthetic Aperture Radar (NISAR)

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Abstract— **The NASA-ISRO Synthetic Aperture Radar, or NISAR, mission is an Earth-mapping radar observatory to be launched from Sriharikota (India) in 2022. This mission is a collaboration between the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization (ISRO). This spacecraft will carry two instruments that will operate at radar wavelengths (L and S-band) and will provide data for understanding changes in the Earth's land surface. The scientific data from this mission will revolutionize our understanding of the causes and consequences of land surface changes on Earth, ranging from Solid Earth Deformation in the form of natural hazards like earthquakes, volcanic eruptions and landslides, to ecosystem disturbances, to changes in the cryosphere (measurements of polar ice caps, ice sheets and sea ice).**

A nominal Reference Observation Plan, that repeats roughly every 12-24 days, developed prior to launch by the NISAR Mission Planning team, in consultation with the Science Team, will form the basis of science data collection by the payload instruments onboard the NISAR observatory after launch. Scheduling of science observations for the mission requires accounting for limited spacecraft resources like onboard data storage, downlink capacity, energy/power, thermal limits and instrument duty cycles. In addition to nominal science data collection, the project has a Level 1 requirement to respond to requests for urgent data acquisition over disaster sites (natural or anthropogenic) by scheduling new acquisitions within 24 hrs of notification and delivering science data within 5 hours of data acquisition. This capability is to be exercised on a 'best-efforts basis'.

While the definition of what constitutes an 'urgent request', and how such requests would be submitted to the project, is within the domain of the Science Team, the Mission System team is responsible for developing the baseline operations concept and implementation approach for responding to such requests. Given the 'best-efforts' nature of this requirement, a few high-level guidelines have been developed to help guide the formulation of the operations concept, and are presented in this paper. Requests for urgent response data will be accommodated following the guiding principle of minimal to no impact on nominal science and planned engineering activities. No change in satellite orbit or attitude will be made for urgent response. Restricting response approaches to only changing the downlink and/or ground processing priority for existing observations, and adding new observations only in areas where NISAR will not be nominally imaging, allows for minimal impact on the Reference science Observation Plan. No instrument mode changes will be allowed for urgent response (except for high-priority requests), and no new observations that impact either planned science or engineering activities will be scheduled. Additionally, data requests must fit within the available project resource margins (both spacecraft and ground resources are to be evaluated). Both JPL and ISRO will be involved at various steps of the implementation, irrespective of whether the urgent request is for L-SAR (NASA instrument) or S-SAR (ISRO instrument) or a joint dataset.

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1. INTRODUCTION

The NASA-ISRO Synthetic Aperture Radar mission is planned to be launched in 2022, and will generate global maps of the Earth's land and ice-covered surfaces every 12 days at L and S-band radar wavelengths (23 cm and 9 cm, respectively). The dual-wavelength nature of the dataset, and the frequency of coverage, will make this observatory uniquely suited for observing temporal changes in the Earth's land surface through its uninterrupted time-series datasets. The data resulting from this mission will yield exponential leaps in the state-of-the-art of a multitude of scientific disciplines, including but not limited to, Solid Earth Deformation (natural hazards, water resources, geological studies), Ecosystems (global biomass and its disturbance, agriculture, inundation) and Cryosphere (polar ice caps, ice sheets, sea ice, glaciers) [1-3].

The joint collaboration between NASA and ISRO implies that both agencies will be providing components of the observatory. The I3K spacecraft bus, the S-SAR instrument, along with the GSLV Mark-II launch vehicle will be ISRO's responsibility, while NASA will be supplying the L-SAR instrument [4, 5], the Engineering Payload (interface between NASA components and ISRO spacecraft bus) and the Radar Antenna (which includes the 9-meter long boom and the 12-meter-in-diameter wide reflector). Figure 1 shows the NISAR observatory in fully-deployed configuration after launch, while Figures 2 and 3 show the hardware components and the contributions from NASA and ISRO.

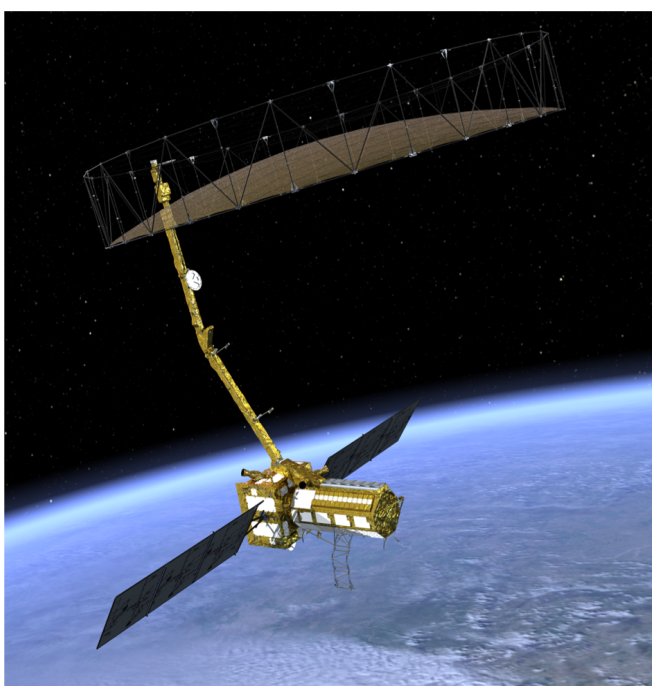


Figure 1. NISAR observatory in fully deployed configuration (artist's concept)

The observatory will be flying in a near-polar (98.4 degrees inclination), sun-synchronous, 6PM-6AM (dawn-dusk) orbit, at an altitude of 747 km in a 12-day repeat cycle, in a nominal left-looking orientation. Each orbit will be approximately 100 minutes in duration. The orbit will be tightly controlled within a diamond-shaped orbital corridor to enable interferometry (achieved via repeated imaging of the same ground target in the same orbit and attitude for the observatory), which forms the basis of science data collection for this mission [6]. Orbit maintenance will be done approximately twice per week through executing Drag Make-Up maneuvers and Inclination Adjust maneuvers [7].

The unprecedented data volume to be collected by this satellite drives the capabilities and design of the Ground Data System (GDS) and Science Data System (SDS). An average of 35.1 Tbits/day of data will be acquired by NISAR, requiring downlink rates of the order of 4Gbps to NASA Ka-band ground stations (part of the constellation of Near Earth Network (NEN) stations), and at a rate of 2.88 Gbps to ISRO Ka-band ground stations (Figure 4). Data from the NASA L-SAR instrument is currently planned to be downlinked to NEN stations in Alaska, Svalbard (Norway), Punta Arenas (Chile) and Wallops, while ISRO ground stations in Shadnagar (India) and Antarctica are planned to be used for downlinking S-SAR data as well as a sub-set of selected L-SAR data (Figure 5). The 12 Terabits-sized Solid State Recorder (SSR; 8.3 Tbits allocated to science data at End-Of-Life) onboard the observatory will have to be emptied an average of 4 times per day to keep up with the rate of data acquisition. In addition, data collection and downlink do not interfere and can be concurrent. Data storage, processing and analysis will take advantage of cloud computing environments such as Amazon Web Services (AWS). The NASA Distributed Active Archive Center (DAAC) at the Alaska Satellite Facility (ASF) will be used for long-term archival storage of the science data from this mission.

The Nominal Science Phase for NISAR will be 3 years in duration, with enough consumables being carried for a mission lifetime of 5 years. The first 90 days after launch will be dedicated to Commissioning or In-Orbit Checkout, which will be a step-by-step build-up in capability to full observatory operations [8, 9]. Observatory orbit will be slowly raised to the Reference Science Orbit, and science attitude will be achieved during this early phase. All JPL components will be off at launch, and will be powered-on for the first time and checked out in the first 90 days. Once it has been demonstrated that the project is ready to begin science operations, the nominal science phase will begin. The first 5 months of the science phase will be used for science cal/val, during which the NISAR Joint Science Team will be conducting cal/val field campaigns for collection of ground truth data, for validation of NISAR data [10, 11]. Intermittent cal/val campaigns will then be continued for the entire three-year duration of the mission, for the purpose of monitoring and fine-tuning the quality of the science data products. At the end of the three years of the nominal science phase, the observatory will be decommissioned to a disposal orbit

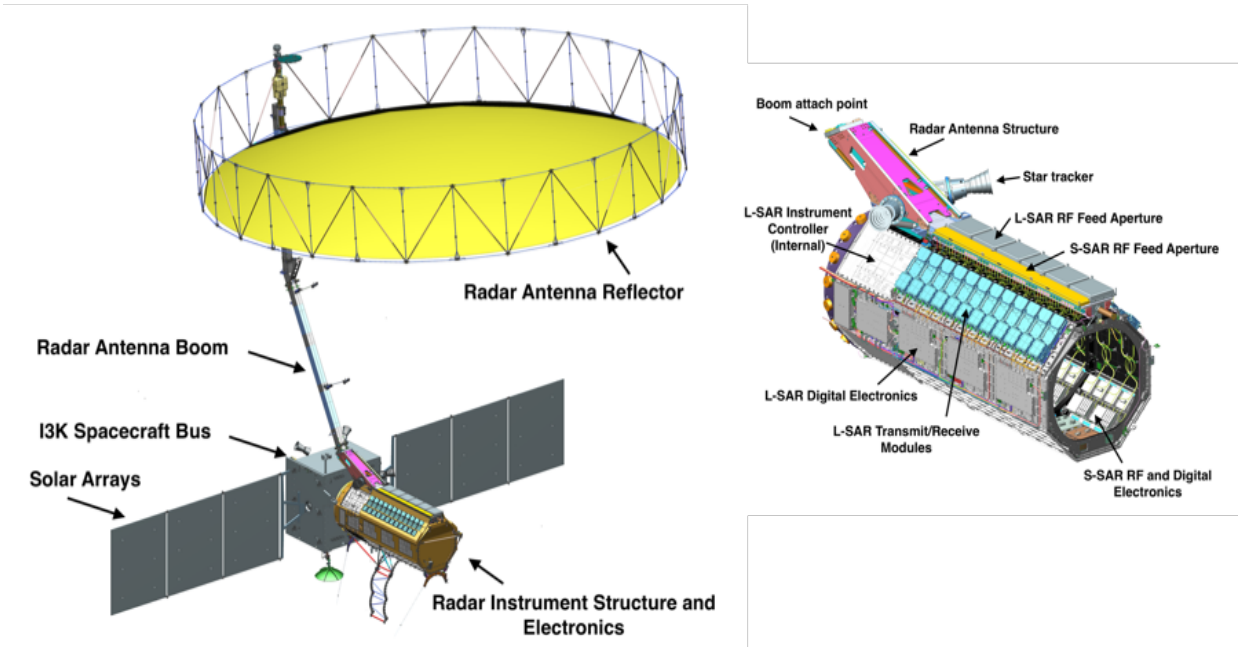


Figure 2. NISAR observatory components

over the course of the next 90 days. Figure 6 shows the overall mission timeline for NISAR.

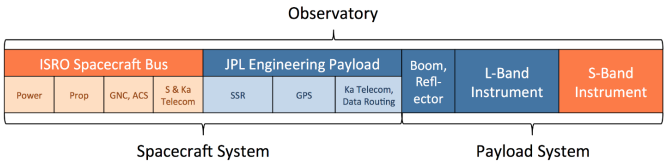


Figure 3. Hardware component contributions on the NISAR observatory from NASA and ISRO

Section 2 of this paper describes the operations, in particular the nominal observation planning, to be executed during the Nominal Science Phase of the mission. An introduction of the requirement on the NISAR project to respond to urgent requests is the focus of Section 3, along with a description of what constitutes an urgent request. Section 4 provides an in-depth discussion of the operations concept, and implementation approach being developed for responding to urgent requests. Finally, Section 5 summarizes the results presented in this paper.

2. Nominal Science Operations

The three-year science operations phase for NISAR will be a period of near-continuous instrument data collection and return. The observatory will be maintained in a gravity-gradient-minimized (16.33 degrees rolled off nadir) left-looking attitude, except for brief periods when propulsive maneuvers may require off-science attitude to maintain the orbit (thrusters have been located to minimize attitude deviation). Maneuvers will be commanded separately and timed to take place in predefined "quiet periods" with little or no impact to science observations whenever possible. Orbit-maintenance maneuvers will be performed on average two times per week.

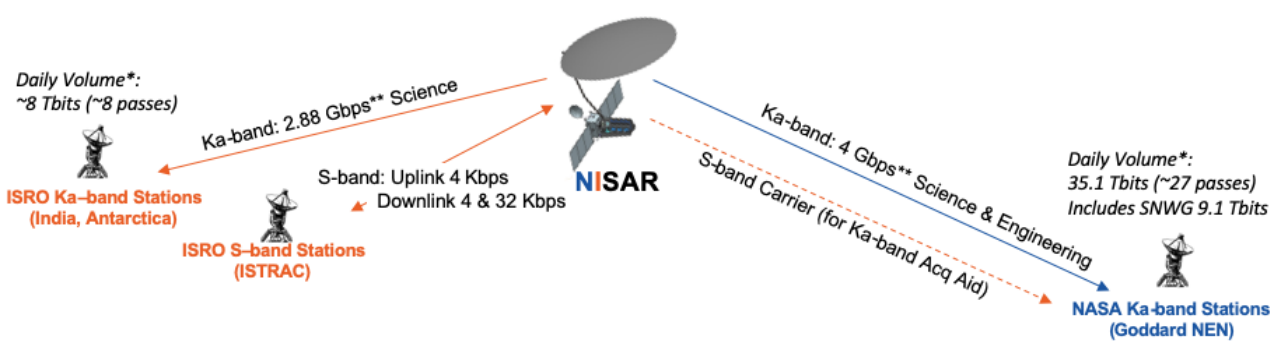


Figure 4. NISAR telecommunications links include Ka-band downlink to NASA and ISRO stations at 4 Gbps and 2.88 Gbps respectively, and S-band uplink and downlink from and to ISRO ground stations.

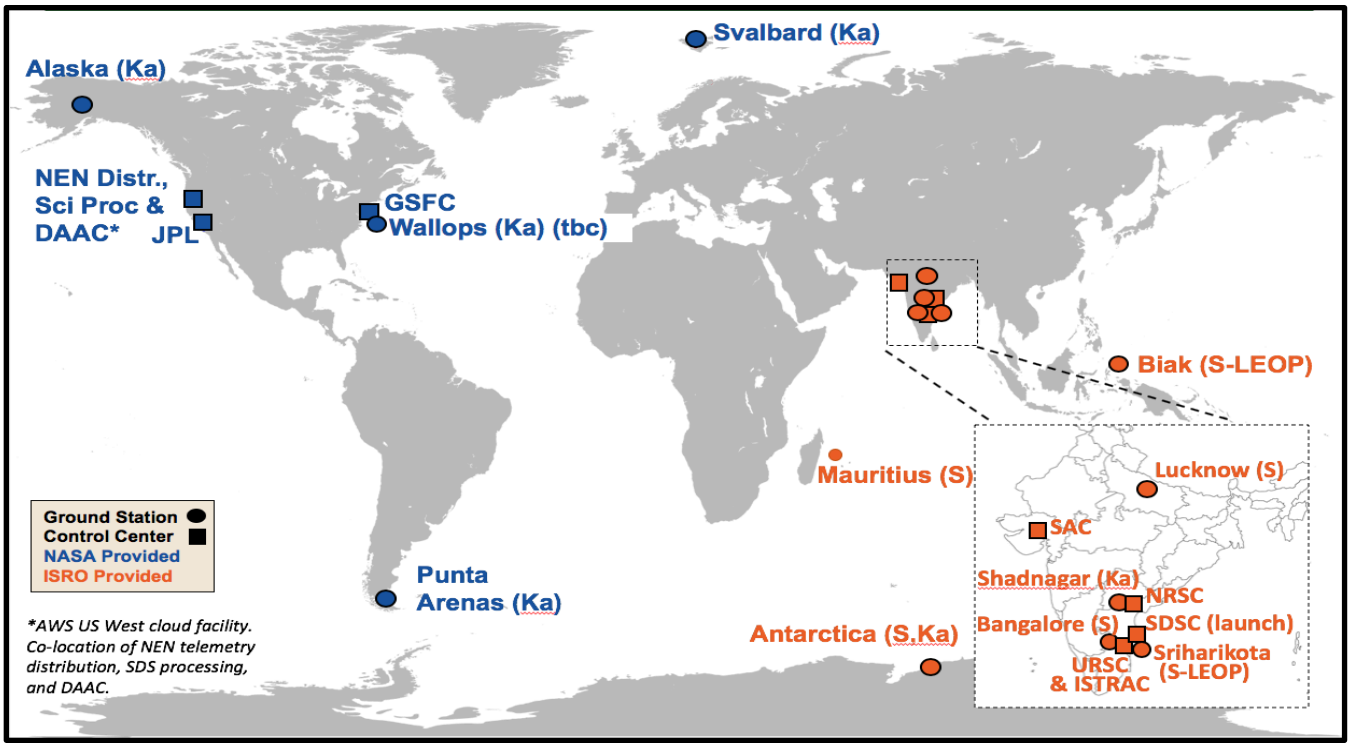


Figure 5. NISAR ground stations (including the NASA Near-Earth Network stations in Alaska, Svalbard, Punta Arenas and Wallops; ISRO stations in Antarctica, Shadnagar, Bangalore, Lucknow, Mauritius, Biak), control center and launch location (Sriharikota (SDSC), India).

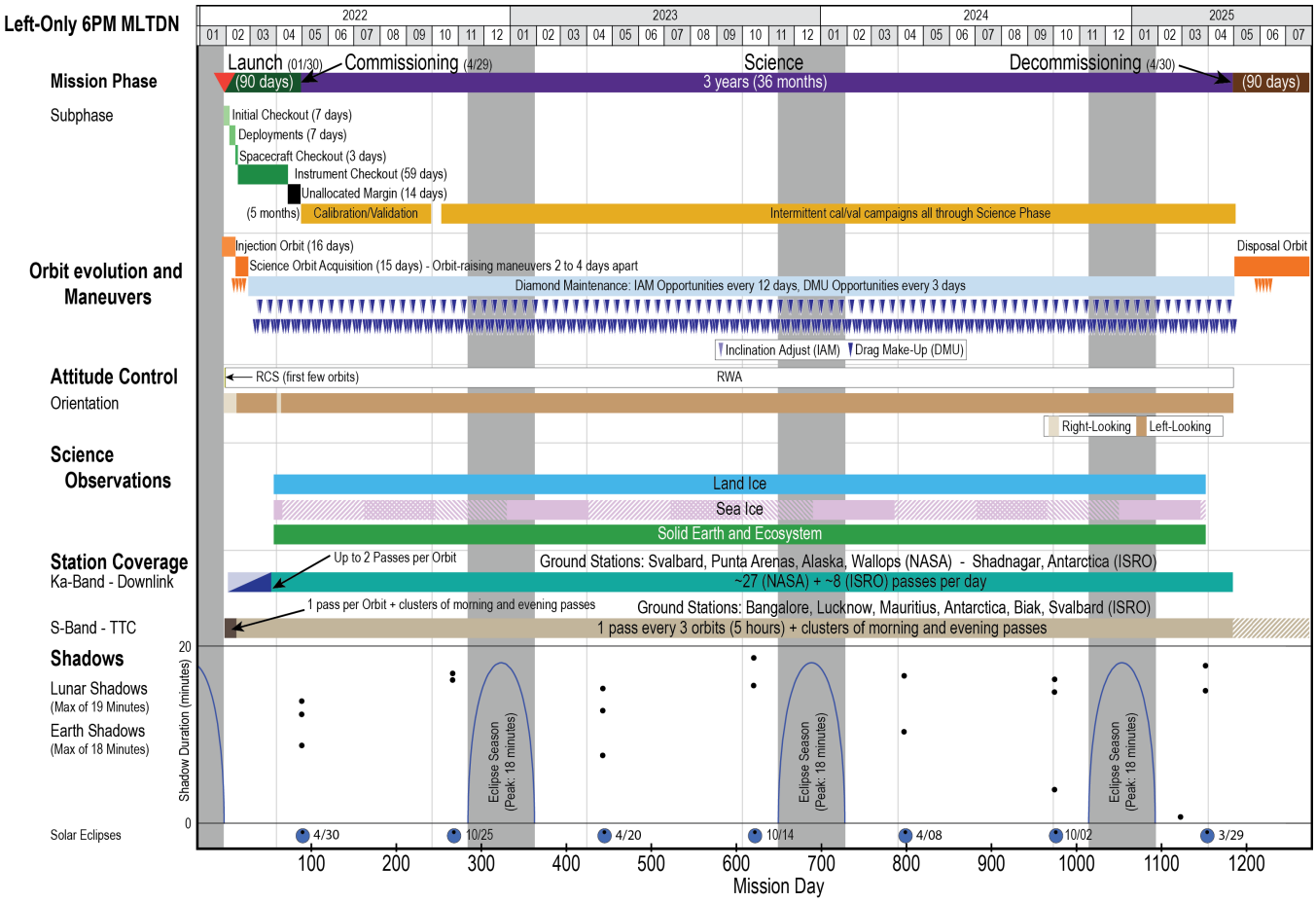


Figure 6. NISAR Overall Mission Timeline

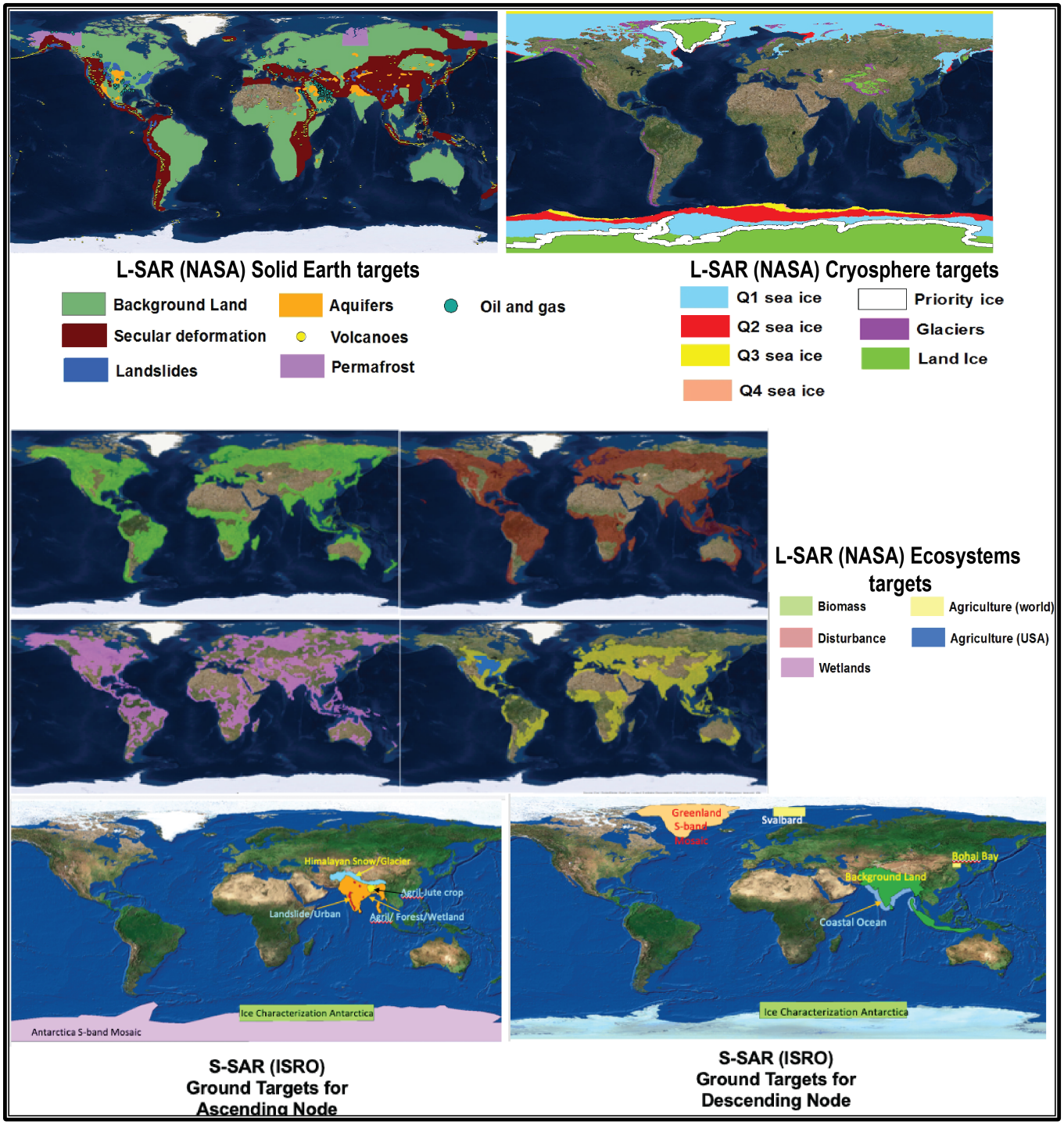


Figure 7. Global science target maps provided by the Joint Science Team, corresponding to each of the three science disciplines for NISAR (Solid Earth Deformation, Ecosystems and Cryospheric sciences).

Prior to launch, a reference mission will be developed, and except in the case of major operations anomalies, observatory operations will be conducted in accordance with this reference mission. Each week, the ground team will take a piece of the reference mission "off the shelf", perform minor updates to timing and scheduling, and uplink the resulting commands via the ISRO command uplink. Sequences containing time-tagged radar observation commands will execute on-board to control observation data takes. Uplink passes via ISRO's TTC stations will be available at least once every 5 hours.

Approximately 30 NASA and ISRO downlink passes per day will be used for downlinking L-SAR and S-SAR science data. All downlink passes will be scheduled and confirmed via a

weekly coordinated process with the NASA and ISRO scheduling services.

Operations will be jointly conducted by teams at ISRO and JPL. Given the 12.5 hour time difference between the locations (this is the time difference between Indian Standard Time and Pacific Daylight Time; it increases to 13.5 hrs with respect to Pacific Standard Time), operations procedures will be developed to be primarily independent of each other (with the exception being during early Commissioning and anomaly response).

The plan for acquisition of the science dataset via operating the two radar instruments, called the Reference Observation Plan (ROP) is being developed prior to launch by the NISAR Mission Planning team, and is based on inputs provided by the Joint Science Team, as well as the Payload Instrument and Flight System teams on the project. The process begins with the Joint Science Team (which includes scientists from NASA and ISRO) providing science target areas of interest, ideal instrument modes of operation (L-SAR/S-SAR/joint) and desired coverage frequency. Figure 7 shows the science target areas for the L-SAR and S-SAR instruments, specified by the Science Team. The Payload Instrument Team provides the list of possible radar modes, corresponding data rates, energy consumption values, permissible instrument duty cycles, while the Flight System team's input is primarily in the form of power/energy consumption by the spacecraft and other observatory elements, and any thermal constraints.

An optimized observation plan, based on the inputs described above, is generated and verified against spacecraft resources. This plan details the instrument on-off times, modes of operation, ground target being imaged and scientific objective being satisfied corresponding to each observation. This plan will form the basis of sequence tables and

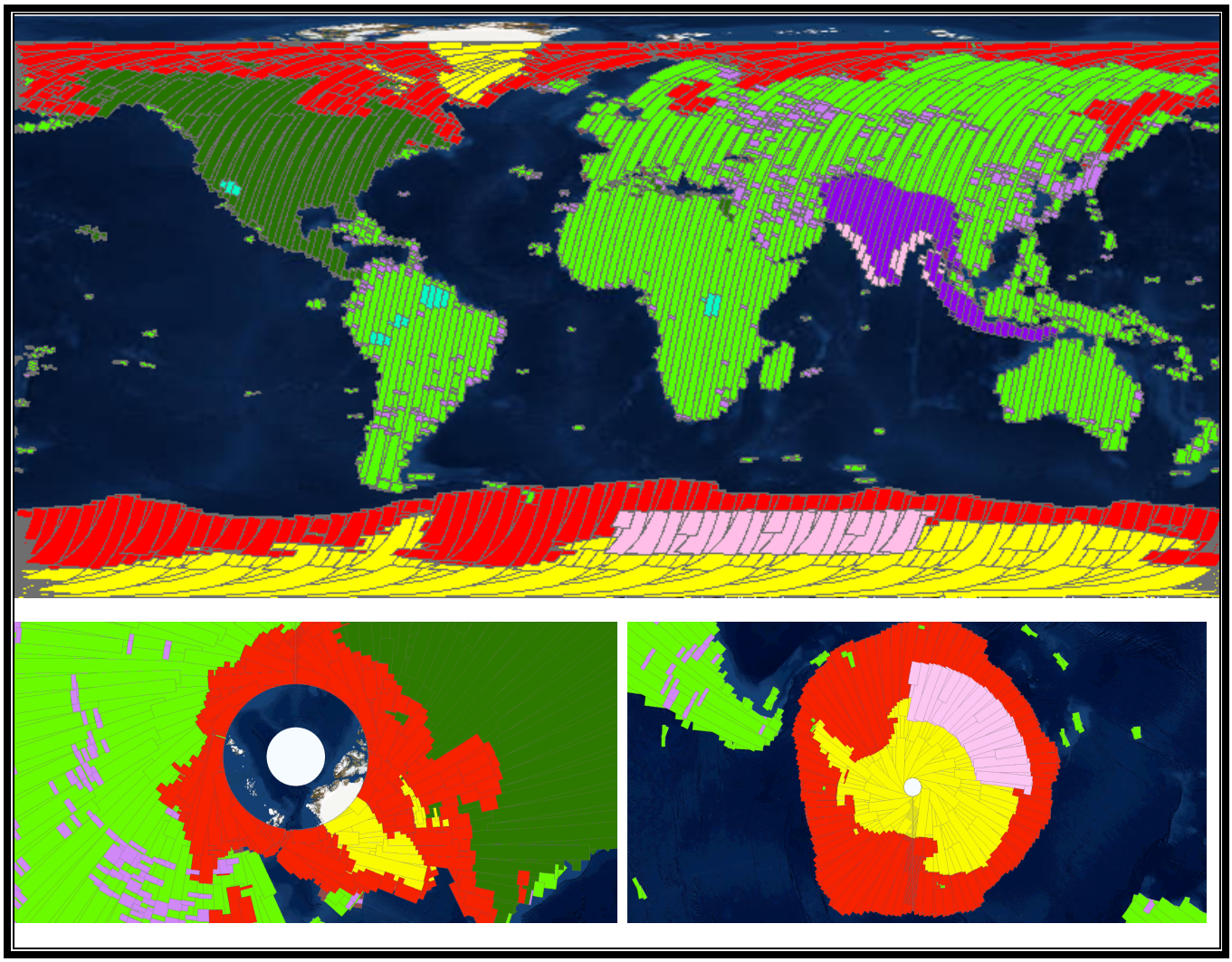


Figure 8. Global coverage of land and ice-covered surfaces by NISAR every 12 days. Each colored region represents a single radar mode chosen to satisfy multiple science objectives over that area. This avoids mode contention that would interrupt time series. The top row shows a global view focusing on data collection for Solid Earth deformation and Ecosystems sciences, while the bottom two views are focused on the poles, to show the data collection pertinent for the Cryospheric science discipline.

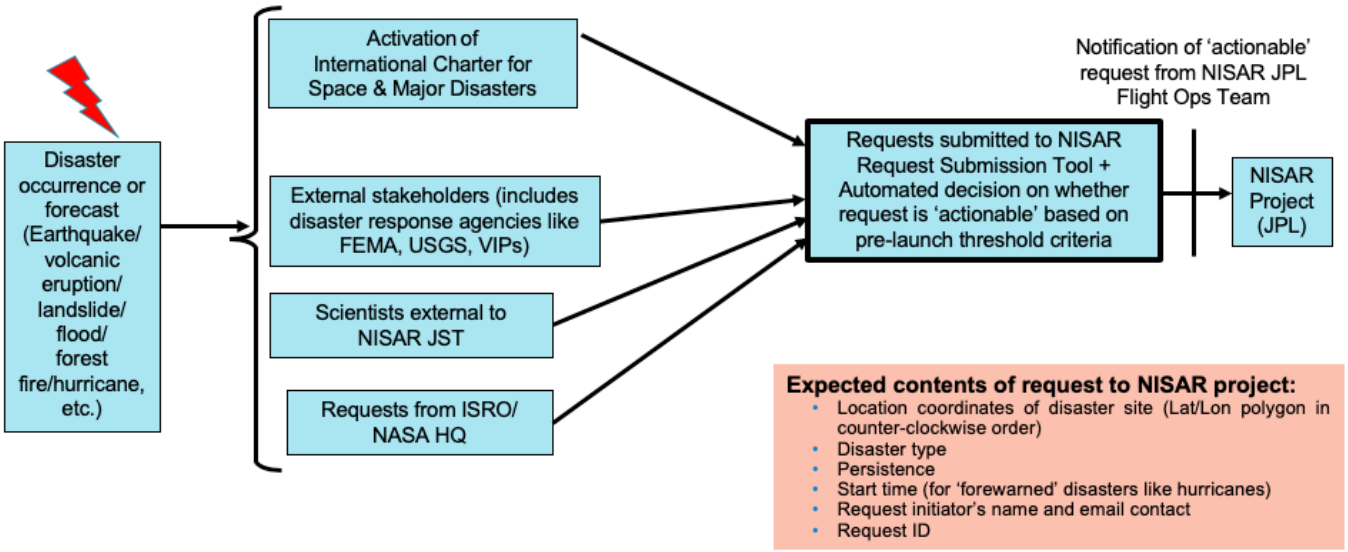


Figure 9. After a disaster occurrence, a request for imaging the disaster site may be initiated from a number of sources. All such requests will be collected by an interface being developed by the NISAR Joint Science Team. Input requests will be evaluated against pre-defined thresholds to determine if they should be responded to by the NISAR project. Only 'actionable' requests in a standardized format will be forwarded to the project.

command products generated next in the process, to operate the two instruments. Figure 8 shows the coverage of the Earth's surface that NISAR will be able to provide every 12 days.

A long term re-planning process, initiated by the joint NASA/ISRO science team, will be in place to effect strategic changes to the reference mission based on in-flight performance of the radar and evolving scientific priorities, as well as real-world events. This long-term re-planning process will be scheduled to occur semi-annually.

This nominally repeating global plan for science data acquisition will have to be modified intermittently, in response to requests for data acquisition for urgent response over disaster sites. The next two sections describe the nature of these urgent requests, the operations concept, and implementation approach being developed by the NISAR project, to respond to such requests in a manner so as to minimize any interruption of the global time-series data.

3. URGENT RESPONSE REQUESTS

One of the unique aspects of the NISAR mission is the requirement on the project to have the capability to respond on a best-efforts basis, to requests for acquisition of data over disaster sites. A new acquisition over the target area (if not already included in the Reference Observation Plan prepared pre-launch), or an update to an existing observation, is to be scheduled (uplinked to the observatory) within 24 hours of a notification being received by the project. In addition, once the satellite flies over the ground target and acquires the data, the resulting L0b data products are to be made available within 5 hours (L0b products will be the Radar Raw Signal Data (RRSD), i.e., corrected, aligned radar pulse data derived from the Radar Raw Science Telemetry (RRST) or L0a data products).

Such requests for urgent data could originate from a number of sources external to the project, including disaster response agencies like Federal Emergency Management Agency (FEMA), Department of Homeland Security (DHS), United States Geological Survey (USGS), other international agencies; through activation of the International Charter for Space and Major Disasters [12]; NASA or ISRO Headquarters; or from scientists at worldwide institutions interested in scientific investigations of the disaster site. A variety of disaster occurrences (identified by the Joint Science Team) could result in invoking of such requests, including but not limited to, volcanic eruptions, earthquakes, landslides, other geological hazards, levee/dam/bridge failure, industrial accident, secondary impact of other events, mine/cavity collapse, induced seismicity, storm surge flooding, riverine floods, ice jams, forest fires, hurricanes, oil spills, oceanic storm, icebergs, tsunami, ship or aircraft distress. For each of these disaster types, the Joint Science Team will define thresholds, i.e., quantifiable characteristics of a disaster event, that can be used to evaluate whether NISAR is the right asset (in terms of wavelength, coverage, etc.) for imaging the disaster site, and whether the disaster warrants NISAR response and the use of project resources. Examples of disaster thresholds include earthquake magnitude, extent of surface area affected, disaster proximity to high-population area, etc.

The Joint Science Team will be responsible for collecting all urgent response requests from disparate sources, for L-SAR/S-SAR/joint observations, evaluating them against the set of pre-defined thresholds for disaster types alluded to

above, and forwarding the 'actionable' requests that satisfy the thresholds, to the project team for response. Figure 9 shows the notional early steps in the process of collection and evaluation of urgent requests, before they are received by the project. As the figure shows, the receipt of the 'actionable' request by the Mission Planning element of the Flight Operations Team (FOT-MP) at JPL, marks the time of notification to the project, from which the 24 hour timer (from the Level 1 requirement) for scheduling a new acquisition/updating an existing acquisition begins.

4. OPERATIONS CONCEPT FOR RESPONDING TO URGENT REQUESTS

Given the 'best-efforts' nature of the urgent response requirement on NISAR, some guiding principles have been outlined to help constrain the range of possible responses, and develop an implementation approach to accommodate all those responses in a timely manner (as desired by the requirement).

- Since the primary objective of the NISAR satellite is to collect uninterrupted time-series of global Synthetic Aperture Radar (SAR) science data, any urgent response request that impacts nominal science data collection will be rejected (there will be a few exceptions to this, e.g. Presidential Directives from both US and India will be given a higher priority compared to other requests, and such requests for observing high-priority disasters may be accommodated, even if they result in interruptions in the observation plan developed prior to launch).

- If the disaster site does not lie within the nominal ground tracks of the satellite, i.e., if imaging the site would require changing either the orbit or the attitude of the satellite, then it will not be considered for response by the project.

- Urgent requests will be accommodated on a best-efforts basis, when in conflict with any planned engineering activities, since such activities may be critical for health and safety of observatory, or for ensuring nominal science data collection (e.g. orbit maintenance within diamond corridor via maneuvers).

- Any new observations for urgent response in areas not nominally imaged by NISAR will only be added if they fit within the available spacecraft resource margins that vary from orbit to orbit (onboard data storage, downlink capacity and station downlink schedules, energy/power, thermal limits and instrument duty cycles). Violation of this guideline can impact the project team significantly, by requiring them to do in-depth re-planning (either truncate input requests or accept the risk of losing science data), that will require time and effort and will reduce the probability of meeting latency requirements. If we only add urgent observations that fit within margins, it will help to minimize the complexity of re-planning and minimize impact on time-series of nominal science data.

- ISRO Operations team will have the capability to uplink updated JPL command products (sequences) for urgent response any day of the week, even though the nominal uplink window for the weekly JPL command products will be on Thursdays during nominal science operations.

- The project team at JPL will not be staffed 24/7 for nominal science operations (only to be staffed for prime shift). Therefore, the NISAR project will aim to meet latency requirements for scheduling new acquisitions (24 hrs) and delivery of L0b data (5 hrs) for requests only on a best-efforts basis.

Based on the guidelines stated above, JPL systems/processes on the NISAR project are being designed for a limited range of response for urgent requests. The operations concept for urgent response focuses on three primary response approaches for both the L-SAR and S-SAR instruments: 1) changing the downlink priority for an existing observation, 2) changing the ground (SDS) processing priority for an existing observation, and 3) adding a new observation (for disaster sites not included in NISAR's Reference Observation Plan (ROP)). Any one or a combination of these response approaches may be executed by the JPL Flight Operations Team, depending on the location of the disaster site (already being imaged or not), and the timing of the next upcoming earliest observation opportunity over the site (which would determine if there's enough time available for a combined ground and flight response requiring uplinks, or only a ground response) (Figure 10).

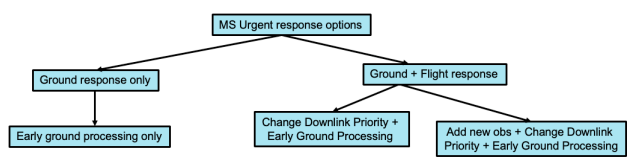


Figure 10. Three response approaches have been identified for responding to urgent requests submitted to the NISAR project: changing downlink priority, changing ground processing priority or adding a new urgent observation.

Since NISAR will be imaging almost all of the land surface and ice-covered surfaces of the Earth (with the exception of the Sahara desert, some culled polar areas and some islands), there is a high probability that any disaster that occurs on land will be imaged by NISAR as part of its Reference Observation Plan. Monte-Carlo simulations show that given NISAR's 12-day repeat cycle, there is >97% probability of the satellite flying over any arbitrary latitude within 8 days (Figure 11). Thus, even without any action on the part of the project in response to an urgent request for data over a disaster site, there is a high probability that NISAR will be

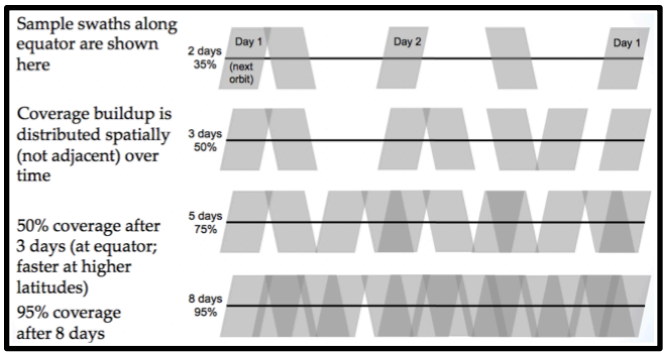


Figure 11. 12-day Repeat Cycle coverage for NISAR. Monte-Carlo simulations show that given NISAR's 12-day repeat cycle, there is >97% probability of the satellite flying over any arbitrary latitude within 8 days.

imaging the site (if on land). Moreover, the NISAR Science Team has determined that the nominal instrument modes used for imaging in the ROP, will be suitable for urgent response, and are capable for imaging disaster sites. In addition, if instrument mode was to be changed for observing a disaster site, in the middle of a nominal datatake, then the resulting mode transition would introduce gaps in data collection. Essentially, continuing data collection in the nominal mode will serve urgent response better than event-driven changes to the plan. Therefore, L-SAR and S-SAR

instrument modes will not be changed for existing observations over disaster sites, that are already part of the ROP.

For maritime disasters in the oceans like oil spills, hurricanes/typhoons/cyclones (or for disasters over the small portion of global land surface not imaged by NISAR, as indicated above), new observations over the disaster site will be added, if spacecraft resource margins allow. For these new acquisitions, that are not part of the ROP, preferred instrument modes (depending on disaster type) identified by NISAR Science Team prior to launch will be used.

The focus of the NISAR Urgent Response requirement is two-fold; part of it is related to urgent observation scheduling within 24 hrs of notification (as discussed above), while the other part deals with making the urgent data available to end-users as soon as possible, once acquired by the satellite instruments (within 5 hrs of the acquisition at the latest). The process from data acquisition to the final delivery to end-users involves a number of intermediate steps: downlinking the data from the satellite to one of the NEN ground stations, transferring it from the ground station to the JPL SDS (located in the AWS cloud), and finally the processing of the raw telemetry into L0a and L0b products for delivery to the end-users. Each of these intermediate steps needs to be executed at a faster pace than what is being planned for nominal operations, in order to satisfy the 5hr data delivery latency listed in the requirement, and thus requires changes from the nominal process.

The NISAR SSR will be used in a FIFO mode (First-In, First Out), i.e., data will be continuously recorded, and downlinked in the order in which it was recorded, unless the downlink priority of an observation is higher relative to other observations, in which case it will be pushed ahead of the queue and downlinked first. If an urgent response observation happens to be recorded at the end of an already-full SSR, it can take as long as 9 hrs to be downlinked in FIFO mode (thus making it impossible to satisfy the 5 hr urgent data delivery latency requirement). To circumvent this, the SSR has a built-in capability to prioritize datasets for downlink; thus, the urgent observation will have to be updated to the higher downlink priority, which will allow it to be downlinked as fast as within 2.5 hrs of acquisition, irrespective of the order in which it was stored on the SSR (assuming urgent response data is restricted to 7% of daily data volume, data downlink rate of 4Gbps via Ka-band, and a downlink pass gap of no longer than 2.5 hours (1.5 orbits)). Assuming urgent response data is no more than 7% of daily data volume, it can be transferred from the ground station to JPL SDS in ~30 mins. The current best estimate for the amount of time needed by the SDS to process nominal science raw telemetry to L0b is ~12 hrs; however to satisfy the 5 hr data delivery latency requirement for urgent response, the urgent observation will be marked with an early ground processing priority, as a result of which the SDS will process that observation ahead of the other observations received on the ground, and will be able to provide urgent L0b data within 2 hrs of the receipt of

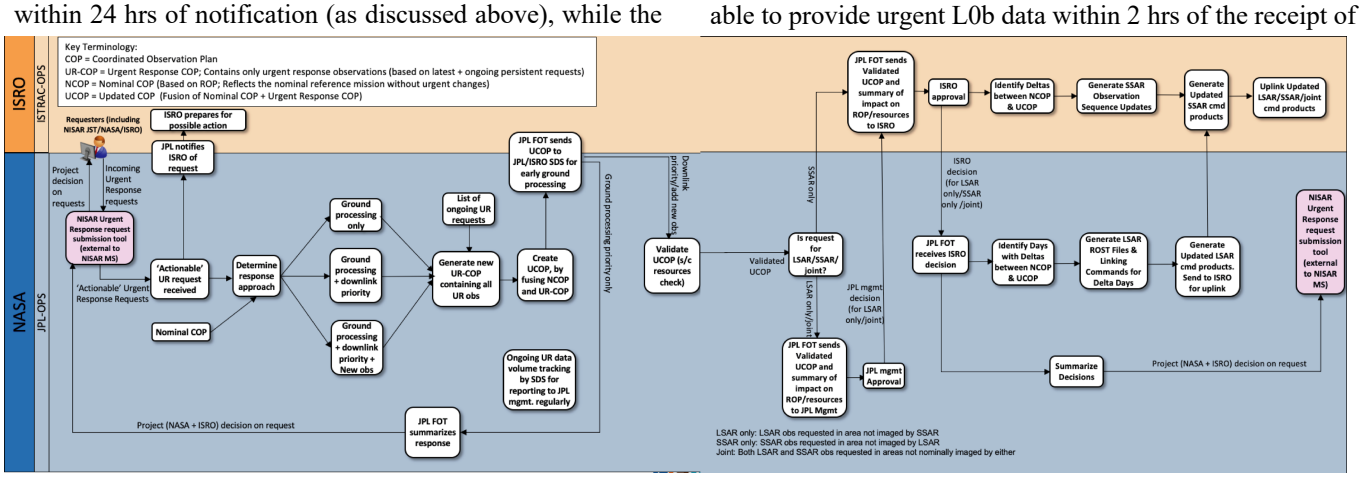
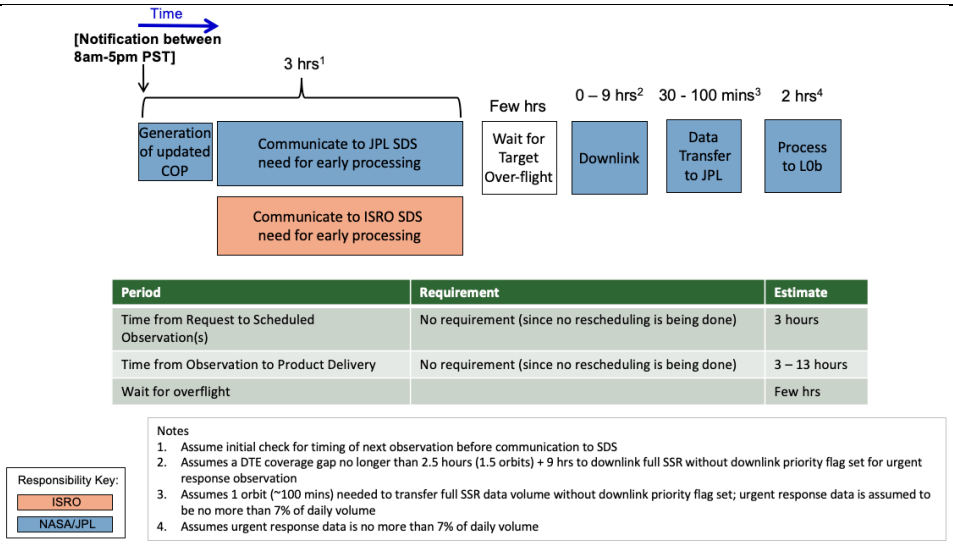
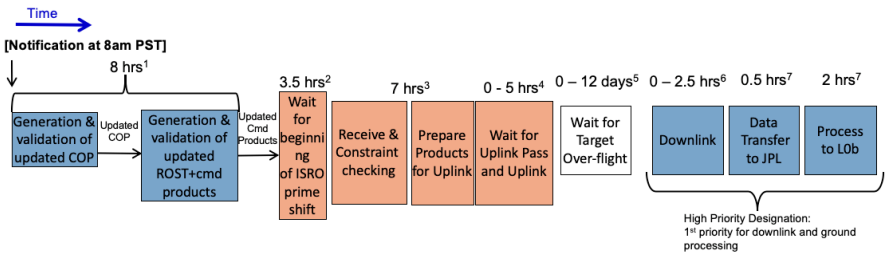


Figure 12. Process diagram showing the steps involved in implementing a response to an urgent request for imaging a disaster site. Division of responsibilities between JPL and ISRO is shown.



Period	Requirement	Estimate
Time from Request to Scheduled Observation(s)	No requirement (since no rescheduling is being done)	3 hours
Time from Observation to Product Delivery	No requirement (since no rescheduling is being done)	3 – 13 hours
Wait for overflight		Few hrs

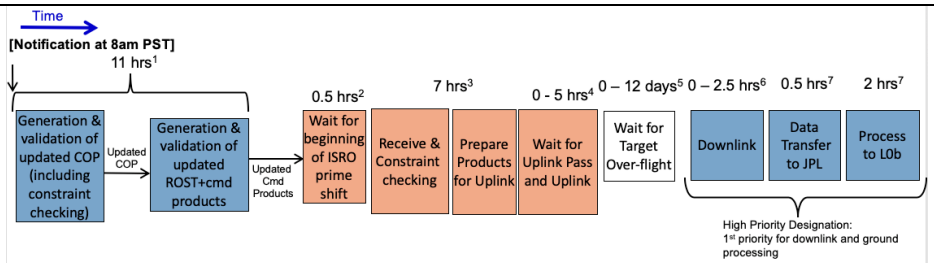
Notes
1. Assume initial check for timing of next observation before communication to SDS
2. Assumes a DTE coverage gap no longer than 2.5 hours (1.5 orbits) + 9 hrs to downlink full SSR without downlink priority flag set for urgent response observation
3. Assumes 1 orbit (~100 mins) needed to transfer full SSR data volume without downlink priority flag set; urgent response data is assumed to be no more than 7% of daily volume
4. Assumes urgent response data is no more than 7% of daily volume



Period	Requirement	Estimate
Time from Request to Scheduled Observation(s)	24 hours	18.5 – 23.5 hours
Time from Observation to Product Delivery	5 hours	3 – 5 hours
Wait for overflight		0 – 12 days

Notes
1. Only change in downlink priority from 'normal' to 'urgent'. (3 hr for COP generation & validation + 5 hr for cmd product prep and validation)
2. Assuming request received at 8am PST
3. Assumes 7 hour ISTRAC processing time.
4. Assume only one pass required for uplink, and ISRO can use commercial stations (Svalbard) for urgent response uplinks
5. Monte-Carlo analysis shows >97% probability of over-flight at an arbitrary latitude within 8 days
6. Assumes a DTE coverage gap no longer than 2.5 hours (1.5 orbits)
7. Assumes urgent response data is no more than 7% of daily volume

Responsibility Key:
ISRO
NASA/JPL



Period	Requirement	Estimate
Time from Request to Scheduled Observation(s)	24 hours	18.5 – 23.5 hours
Time from Observation to Product Delivery	5 hours	3 – 5 hours
Wait for overflight		0 – 12 days

Notes
1. Changing downlink priority + adding new obs. Assuming automated constraint checking (5 hr for COP generation & validation + 5 hr for cmd product prep and validation + 1 hr margin)
2. Assuming request received at 8am PST.
3. Assumes 7 hour ISTRAC processing time.
4. Assume only one pass required for uplink, and ISRO can use commercial stations (Svalbard) for urgent response uplinks
5. Monte-Carlo analysis shows >97% probability of over-flight at an arbitrary latitude within 8 days
6. Assumes a DTE coverage gap no longer than 2.5 hours (1.5 orbits)
7. Assumes urgent response data is no more than 7% of daily volume

Responsibility Key:
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Figure 13. Notional Timelines for the three response approaches being planned for urgent requests submitted to the NISAR project are shown. The timeline in the top row applies to the ground-only response, i.e., only change of ground processing priority by the SDS. The middle row timeline is for the case in which both ground processing and downlink priority is to be updated, while the bottom row indicates a notional timeline for the most complex response: adding a new urgent observation with higher downlink and ground processing priority. Note that changing the downlink priority or adding a new observation require constraint checking of the updated observation plan, as well as uplinks to the observatory, thus significantly impacting the timeline.

raw telemetry.

The division of responsibility between JPL and ISRO Science and Mission System/Flight Operations Teams for urgent response is documented in the project's Cooperative Project Plan (CPP). Using this document as a starting point and with the overall motivation of replicating as much of the nominal workflows as possible, the urgent response implementation approach is being developed to mimic the nominal weekly planning procedures to be used by JPL and ISRO. Therefore, all urgent response commanding will be managed through coordinated planning at JPL. This will allow the project team to replicate and take advantage of the nominal observation planning and command product uplink process that will be executed for scheduling acquisitions of nominal science data.

To initiate the project response to an urgent request, the Mission Planning element of the Flight Operations Team at JPL (FOT-MP) will receive the input request (this is similar to the process currently being followed for pre-launch nominal observation planning, in support of which JPL Mission Planning collects all inputs from science, instrument and spacecraft teams). Once the request is received, FOT-MP will determine which of the three response approaches outlined above (changing downlink priority or ground processing priority or adding new observation) is the appropriate one to proceed with. Note that the response approach will be chosen by JPL, irrespective of whether the request is for L-SAR only, S-SAR only, or joint observations. This will result in generation of a new observation plan, including the urgent observation, for the appropriate week (ongoing or next week). The new plan will be validated to ensure it does not result in violation of any spacecraft resource margins.

Based on the new observation plan, both JPL and ISRO teams will generate their own updated instrument observation tables/sequences and command products for uplink, only for the day on which the urgent observation is to be acquired (this is different from the new observation plan which is to be generated for the whole week, following the nominal weekly planning process). The JPL team will send their L-SAR command products to ISRO. The ISRO team will then uplink both L-SAR and S-SAR command products to the observatory.

This approach will allow us to systematically and efficiently respond to Urgent Response Requests, while following the same process as for nominal observation planning. Figure 12 shows the implementation approach being developed for the NISAR urgent response process, while Figure 13 shows three notional timelines corresponding to the three response approaches described above.

5. SUMMARY

The NISAR project is an international, first-of-its kind, collaboration between NASA and ISRO. This Earth-orbiting observatory to be launched in 2022 with two radar instruments onboard, will be continually mapping the land and ice-covered surfaces of the Earth for the three years of its prime science phase. The observation plan for collecting the continuous time-series data is being developed prior to launch, and will be executed off-the-shelf in operations, such that observations over ground targets will repeat every 12 days (6 days for ascending/descending orbits). However, the NISAR project also has a requirement to have a best-efforts capability to respond to intermittent and unplanned requests for urgent data for imaging disaster sites (natural or anthropogenic). The requirement specifically lists a latency of a maximum of 24 hours for scheduling acquisitions from the time of notification, and a 5 hour latency for delivery of L0b data products to the request initiator, from the time of data acquisition.

In order to minimize the impact of such urgent requests on the nominal science acquisition plan, and to aim to satisfy the latency requirements, three response approaches have been identified. Depending on the location of the disaster (which will determine whether the site is already being imaged by NISAR or not), and the timing of the next upcoming observation opportunity, the project team may decide to upgrade the downlink and/or ground processing priority for existing observations, or add a new urgent observation (this last approach is primarily to be exercised for maritime disasters). For existing observations, the instrument modes used for nominally imaging the disaster site will continue to be used, since mode transitions can result in gaps in data collection, and the nominal instrument modes are expected to be suitable for imaging disaster sites on land, For new observations of disasters in oceans, a set of pre-defined instrument modes will be utilized.

The operations concept for urgent response will be implemented in a manner so as to replicate the processes, workflows and division of responsibilities to be followed for nominal observation planning, with all urgent response commanding to be managed through coordinated planning at JPL. Future work-to-go related to this topic will focus on standardizing the interfaces between the different tools involved in urgent response, and automating as many of the steps in the process as possible, in order to meet the latency requirements on a best-efforts basis.

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