NRDZ Partnership and Workshop Series

NRDZ Workshop-02:
Shattering siloed spectrum sharing mechanisms for future NRDZs

Held virtually on 16-17 November-2021
http://www.cs.albany.edu/nrdz-ra/meetings/workshop2/
Workshop organizers:

- Christopher R. Anderson, Electrical and Computer Engineering, USNA.
- Mariya Zheleva, Computer Science, University at Albany - SUNY.
- Chris DePree, NRAO
- Mustafa Aksoy, SUNY
- Joel Johnson, Ohio State University

I. <u>Opening remarks from the organizers and from Dr. John Chapin, NSF, Division of Astronomical Sciences</u>

Opening remarks

- Different opinions on what an NRDZ can be used for depending on who you ask. Thoughts from the OC: (1) test and implement new spectrum sharing technologies and understand the impacts of RFI on radio astronomy (2) enable wide band transmissions for channel modeling, which is integral to spectrum sharing methods; (3) allow the exploration of previously unavailable bands for earth and space exploration to increase the scientific output of remote missions; and (4) provide a playground for the development of automated sensing and spectrum use characterisation algorithms.
- more about the NRDZ partnership workshops and outputs from our discussions can be found at the following link: https://www.cs.albany.edu/nrdz-ra/

NSF remarks:

- NSF initiatives in radio spectrum: activities and investments that (1) ensure spectrum is available and (2) promote efficient use of the radio spectrum. Under (1) fall spectrum management, enhanced spectrum capabilities and spectrum science. NRDZ is part of promoting fundamental spectrum science.
- Spectrum innovation initiative - SII-NRDZ - to support the development of at scale test beds and pilots, strategically positioned to tackle key coexistence issues. Program solicitation possible in FY22.
- Program developed in consultation research community (PIs from FY21 and the NRDZ workshop series), within NSF (across scientific directorates) and with federal stakeholders.

- Terminology: 1) RDZs - a general category that supports testing of a range of spectrum sharing concepts; 2) ***the*** NRDZ - a single national RDZ to be developed in the future, highly-capable, developed through legislation/regulation (like NRQZs) to facilitate national needs in spectrum R&D.
- Additional definitions: (1) RDZ is defined in space and frequency; can be non-contiguous. Provides automatic active management of the emitted energy, which is performed by the zone management system (i.e. either locally in the zone or nationally or in a distributed fashion). How do you differentiate between what is happening inside vs. outside the zone? (2) The dynamic coordination region - the region around the RDZ, which accounts for other users outside the zone that have to be taken into account when decisions in the zone are made.
- RDZ functions – (1) dynamic transmission zone (wireless research facility that prevents interference from inside experiments to outside users), zone management prevents interference; (2) dynamic protection zone – preventing interference from outside the zone to inside users; (3) dynamic coexistence zone – a campus/base where the zone management system provides spectrum coordination. One RDZ might implement one or more functions.
- Broader impacts of the NRDZ/RDZ: (1) near-term - wireless research facilities to enhance spectrum access for various users (wireless research, radio astronomy and satellite-borne terrestrial and space research); (2) mid-term - how to enable wider use of spectrum sharing facilities - overcoming technical barriers to approval and providing reusable components and tools; (3) long-term - building trust in spectrum sharing between disparate users and accelerating spectrum innovation.
- Relevant information for the community – see last slide in https://drive.google.com/file/d/1mRmJ8Z2D9AhLJtnMQ33O-g7ijCGJ-1Ff/view?usp=sharing.

II. Fireside Chat: "Now that there is pie on the table, how do we divide it?"

Moderator: Dr. Monisha Ghosh, Notre Dame

Participants: John Zuzek (National Spectrum Program Manager at NASA)
Wayne Phoel (Institute for Systems Research, University of Maryland)
Paul Kolodzy (Kolodzy Consulting)

The session began with brief introductions and moved quickly to the first question for each of the participants:

Q1: From your perspective, what are some good problems to address with an NRDZ?

John Zuzek emphasized the importance of international agreements to any experiments or results that arose from an NRDZ. From his perspective, the most interesting problem is Earth/Space spectrum sharing scenarios, but also this is a difficult problem to address in an NRDZ. One of the most important problems to address in an NRDZ would be how to protect highly sensitive radio astronomy and remote sensing systems from RFI. Also important to address: how to get access to larger pieces of the spectrum for passive systems and how to protect passive systems from out of band emissions. He ended with the importance of communication.

Paul Kolodzy addressed two major goals for an NRDZ: (1) what science can be done to help us use the spectrum more efficiently and (2) how can we do better science with the spectrum. He emphasized the importance of looking to the future, not how we do things now - and in particular the use of time coordination to help science and active uses coexist. An NRDZ would allow explorations of the impact of infrastructure and coordination. Paul described possibly two zones, one located where there are large areas of space with little/no spectrum use (rural), and another (or others) where there is already heavy spectrum use (urban). Also, it may be possible in regions with less infrastructure to have “autonomous” coordination between passive and active users (where there are more degrees of freedom).

Discussion: The generation of wireless systems (6G) has to be developed in coordination with science/passive use. Could they be demonstrated in an NRDZ?

Wayne discussed his experience in defense and tactical networks and the importance of avoiding interference in those networks. He spoke about the importance of recognizing that you can be “using” a portion of the spectrum without emitting energy into it at all times. An NRDZ could be used to explore the impact/consequences of interference in various systems/resilience to interference. An initial use of the NRDZ could be understanding what the boundary region between a dynamic zone and the users outside looks like, and explore how close we can push to the boundary. He recommended an approach of characterization and then mitigation.

Q2: We often design for “worst case scenarios” when these rarely happen. How could we exchange enough information so that all parties involved have a way to evaluate interference probabilistically?

Paul supported the idea of using an NRDZ to explore probabilistic interference, and talked about the difference between worst case versus statistical analysis. Could there be remediation automatically built into systems? Instead of pointing at power, we should look at the impact on systems in terms of utility. We tend to do energy analysis.

Moderator: This approach is complicated with passive systems. What would be the metrics?

John pointed out that this topic is often discussed in the international realm, where probabilistic analysis is done. In the era of weather forecasting - how do you quantify missing an

observation? Or where a hurricane will hit? Not all interference is created equal. It is important to look at the application, and see what can take the interference or not.
Many communications systems are adaptable in real time, and passive sensors automatically throw out interference, but you end up losing data. How much data can I lose?

Wayne agreed with the others. It is important to know the system that you designed: what can throw it off, and what can it survive? There are different ways of encoding data that can be more resistant to RFI. Designers need to model which types of interference can be survived.

Paul suggested that there are two ways to solve problems: (1) through policy, and (2) to ask the question - what is possible if I have to be inventive or have the opportunity to be inventive? Could get answers in an NRDZ.

Q3: How could we use our experiences with CBRS and TV white spaces; are there lessons to be learned from these sharing models in an NRDZ?

The discussion here centered around the fact that the CBRS model was not designed for passive users, and whether it could be extended to passive/active sharing. *Wayne* pointed out that the coordination function - what frequencies when and where - could be useful as a model, but that it would need to be more dynamic and more fine grained. *John* pointed out that TV white space is a very limited example/application, and that CBRS may be a better example. The shortcoming is that we are talking about terrestrial-terrestrial sharing. This is a very different problem than sharing with systems in space. If there were to be a CBRS-like system for space-terrestrial sharing, it would have to involve a database of space systems, and these are global systems in motion. *John* pointed out that a global database that you can guarantee is correct/usable is a daunting, maybe impossible, task.

Paul offered a few ways in which the CBRS model might be helpful: (1) It involved a user who needed to be protected anonymously - that was a big step in how the database was produced - DoD is a big portion of the spectrum use, (2) Beacons work well if I can beacon a short portion of time - there is a way to say “leave me alone”. He admitted that databases for satellite systems are difficult, but that it might be an engineering problem, not a science problem.

Moderator: If there were a beaconing packet (like a MAC protocol), this could be useful. Maybe there is a space to design protocols that coexist with passive services. That could be the function of an NRDZ. Testing these protocols out.

Q4: How do we determine priorities in an NRDZ - how do we police such a region?
Both in an NRDZ and in the wider world?

John allowed that the question of who determines priorities and what is the most important use of the spectrum is a very tough policy question. Automatic management could be set by priorities, but how do you get to that point?

Moderator: What is most important, a 911 call or a cat video?

Paul emphasized again that we haven't asked the question: what are the alternatives to how we do things now? We need to make new architectures and a strategic POV that asks, where do we want to be in 20 years?

Audience Questions:

1. Is there to be only one NRDZ or multiple ones? Can one NRDZ suffice?

Wayne: Multiple is important. Various sizes - dependent on location and surroundings. Or a larger one.

Moderator: Different zones might be surrounded by different things.

2. Interference tolerance for legacy systems. Interference protection for new systems. What is the line between legacy systems and new systems?

John: Whatever you design, it must deal with legacy systems. Example of autonomous vehicles. Much more likely to happen in a commercial system (no one still uses an iPhone 3 from 2010). NASA uses existing systems (often because they are cheaper and proven). Not sure how NRDZ deals with this. The older systems won't become more tolerant.

Paul: Maybe it's all interference tolerance, and tolerance changes. Interference tolerance in the city versus in a QZ?

3. Could an NRDZ help with measuring interference tolerance levels?

Wayne: We will need protocols for coordination. Geographically or in the frequency domain.

Paul: The academic community could formalize interference tolerance, perform the theoretical analysis and use the NRDZ to validate this analysis.

John: Passive receiver - transmitter with high filtering. NRDZ could address these concepts by testing.

III. NRDZ Workshop Panel Summary

Moderator: Liese van Zee, Department of Astronomy, Indiana University – Bloomington

Panelists: James Neel, Danijela Cabric, Greg Taylor, Jeff Piepmeier, Kimberly Baum, Kobus Van der Merwe

James Neel, Senior Technologist, Federated Wireless

- NRDZ is an engineering problem rather than a pure science problem.
  - Focus on replicating current spectrum sharing strategies like CBRS systems.
  - Utilize cloud-based software for scale - put the complexity and customization in the cloud rather than end-user devices.
  - “Share” spectrum, don’t create a “Spectrum Grab”. Make sure that solutions maximize value for and incentives for all parties. Don’t want to create access that doesn’t provide value.
- Try to reduce hard problems into a series of easy problems.
  - Maximize our use of side-channel information (e.g., satellite schedules).
  - Latency can be a limiting factor for real-time operations. Take advantage of pre-computing information where possible to get a head start on long or involved calculations.
  - Policy problems can be much more intractable than technical problems. Need to make sure all communities can buy into the idea and approach.

Danijela Cabric, Electrical and Computer Engineering, UCLA

- Need to have enough evidence and tools to demonstrate that an NRDZ is a feasible system. RF environments are very difficult to model and understand, especially at fine spatial resolutions.
- TVWS and CBRS are very specific types of spectrum sharing.
- Need an ‘active’ type of spectrum sharing where both parties are ‘transmitting’ or ‘sharing’ information about themselves.
- The science is on what types of side channel information we need and how to use that to compute interference, dynamically adapt to it.
- Key enablers to a dynamic NRDZ
  - Spectrum Sensors
  - Data and data processing
  - Intelligence
  - Adaptability
- Need to incorporate machine learning into our propagation and interference models to handle sparse data sets.
  - Use deep learning to learn physics models.

    - Demonstrated success of using RSS measurements to predict signal strength and coverage even when the system doesn't know the transmitter locations.
    - Next step is to use the model to predict coverage when a new transmitter is introduced into the environment.

Greg Taylor, Department of Physics and Astronomy, UNM

- Telescopes are scheduled dynamically and with realization that there may be targets of opportunity to observe with reaction times of seconds.
- Sensitivity is extremely high – if an active receiver can even detect a signal, it's interference to the VLA/LWA. Aggregate interference (even undetectable by a single receiver) can impact the VLA/LWA.
- Key characteristics of an NRDZ
    - Ability to request "sharing times" in interesting bands, or possibly with some duty cycle.
    - Ability to request "quiet times" with no transmission for a broad frequency/time window.
    - Monitoring the spectrum, 3 MHz – 300 GHz is a very broad range of frequencies that can impact the VLA/LWA.
    - What's the method for handling interference reports and how quickly can the system react to address them?

Jeff Piepmeier, Chief Passive Microwave Instrument Engineer, NASA

- Weather forecasting is the primary application of EESS, primarily in the 10-200 GHz frequency range.
- Microwave instrumentation is extremely important for monitoring climate.
- Satellite orbits are predictable with a high degree of accuracy.
- All EESS satellites are LEO, although China is considering launching a Geostationary satellite.
- Most of the interferers are legacy equipment (CCTV cameras) that are malfunctioning and can produce significant interference into the satellite.
    - 1W transmitter in the main beam overwhelms the RX.
    - Even at the horizon, a single 1W transmitter on land can be right at the interference threshold.
- Idea of controlling the energy out of an NRDZ and interference into other systems is an interesting engineering challenge, but we may still be in an architecture phase.

Kimberly Baum, Vice President Spectrum Engineering and Strategy, OneWeb

- Large constellation of satellites (~650) at 1200km orbit, operating in Ku- and Ka- band, with gateway ground stations and user terminals.
- Many frequency bands are adjacent or co-frequency with radio astronomy bands.
    - Setup agreements with various RA observatories on frequency band use.

    - o Understanding user requirements as early as possible is crucial to implementing solutions, particularly when there's a long design lead time.
    - o Need continuous dialogue between active and passive users.
- NRDZ would be useful for testing systems like OneWeb and their ability to coexist with passive systems.

Kobus Van der Merwe, School of Computing, University of Utah

- Context is POWDER testbed – a mobile and wireless testbed in Salt Lake City.
    - o Building block approach to the design of the platform and uses software-defined radios.
    - o Facility that enables experimentation and exploration of ideas within the spectrum limits conferred by the FCC.
- Can we use the POWDER (or POWDER-like platforms) to explore the creation of an NRDZ? Key research activities:
    - o Spectrum monitoring
    - o Channel Models
    - o Spectrum sharing virtualization
    - o Interference prediction and measurement
    - o Create prototypes and tools that might inform an NRDZ platform.
- View of NRDZ:
    - o Specific geographic area, likely isolated.
    - o Allow experimental systems to push the boundaries of radio technology.
    - o Focus on the tools, mechanisms, and equipment.
    - o Develop the building blocks for "universal spectrum sharing"

<u>Panel Questions</u>

1. When thinking about an NRDZ, who do you think writes, enforces, manages, and oversees policies and resource management?
    a. Each RDZ can have an admin that can define the rules that govern their specific RDZ and see what works out best.
    b. Harder question is "how do you come up with the rules?" The RDZ operators may not be able to do that unilaterally without considering the needs of other affected users.
    c. Think about the zone as a 3D environment for creating policies.
    d. Don't write the rules such that they stifle innovation and experimentation.
    e. Establishing trust is probably the most important aspect of policy creation and probably the most difficult aspect to attain.

2. How can we establish the trust between active and passive users in order to make these zones viable.
    a. CBRS gave DoD a "kill switch" for CBRS transmissions so that if something bad happened they can turn off all transmitters.

3. Lots of discussions have revolved around time-sharing of the spectrum. Is this feasible and on what time scale?
    a. Latency is an issue – milliseconds is about the best we can do for 5G type systems. For other systems, we cannot expect that a system can adapt or change rapidly, we may be in the seconds regime.
    b. For RA projects, time-sharing could be effective as most natural sources are emitting continuously. Pulsars, etc. could be an issue as they are more bursty and synchronizing the time sharing could be a problem.
    c. Commercial users want service when they want it and may not tolerate "outages". Could we supplement time-sharing with opportunistic spectrum use?
    d. Sharing is easier when the coordination is hard-wired in (down to 300 microsecond increments).
    e. The finer you slice the time, the more likely you are to have residual interference, because it takes time to turn off systems.

<u>Audience Questions and Answers</u>

4. Can we conduct preliminary studies on how the active community would impact the passive community and what studies would we want to use to understand the impact of active on passive systems?
    a. Passive users might become part of active test environments in some way. What would you put in, say, POWDER that looks like a passive user given the sensitivities of the instruments?
    b. Could you develop sensors that provide a sense of how well a test environment works at creating a quiet spectrum?
    c. Out of band emissions is a significant concern, understanding the interference impact to satellites starts with simulation, but models need significant update.
    d. Could we do testing in existing exclusion zones to get a sense of the existing background interference level as well as how much the interference level rises as emitters are activated or begin to encroach on the band?
5. Can we perform opportunistic sensing using existing active or passive devices to help perform spectrum monitoring? For example, satellite ground stations that may not be in use for active communications.

   a. This would be a useful idea to explore – systems coexistence from the sensing point of view. How many 5G/6G communication receivers could be used to help spectrum sensing, and would their performance be adequate?
   b. *** Implication is that rather than sharing creating a problem, could we orchestrate sharing so that it provides a benefit to passive users? Extra spectrum sensing, perhaps using the active devices to make additional passive observations?

6. The NRDZ will not work without trust - it is a major shift in spectrum policy. For each community, what are ways that we can build trust?
   a. Each community needs to understand the needs and requirements of the others. Make sure we have an awareness of and understanding of what is happening in the other areas.
   b. Understand that we will make mistakes, especially early on – trust comes down to being able to correct these mistakes and understanding that it's not intentional.
   c. Actively work together with the organization you're trying to share with to create a mutually agreeable test plan and how the information from the test can be disseminated more broadly.
   d. Engineers scrutinize each other's work to ensure that the technical implementation is solid. Talking engineering with policy people is a much more challenging communications problem - we have to simplify the engineering such that the policy can create the right rules.
   e. Start with simple, well-defined scenario that we can agree on and work from there.
   f. Failure recognition, mitigation, resolution process needs to be an important component of the NRDZ. The key is to making sure a mistake doesn't happen again.

IV. <u>Grand Challenge Sprints</u>

<u>Sprint 1: NRDZ Spectrum Policy</u> **Facilitators:** *Joel Johnson and Kim Baum*

Overview. This sprint attempts to build a policy framework for NRDZ. There are two extremes for a potential policy framework including (i) no licensing procedures; all unlicensed, show up, plug into the system and do whatever experiments you need in the zone; and (ii) fully-fleshed FCC+NTIA licensing. Where does an NRDZ need to be on this spectrum to allow quick experimentation with stakeholder protections? How do we realize this? An overview of the topics discussed is provided below.

Topics discussed.

Build a policy framework for NRDZ: two extremes of the policy framework are (i) no licensing procedures; all unlicensed, show up, plug into the system and do whatever experiments you need in the zone; and (ii) fully-fleshed FCC+NTIA licensing. Where does an NRDZ need to be on this spectrum to allow quick experimentation with stakeholder protections? How do we realize this?

- The participants agreed that future RDZ's should be closer to the "open access" paradigm than to the past "fully licensed" paradigm so that experimentation can be performed flexibly. However it was acknowledged that some policies will still be required to avoid harmful interference among users.
    - Whether these policies could be self-enforced or would require an external arbiter was difficult to assess, but the expectation generally was that some form of arbiter would be required.
        - Transparent auditability of arbiter's access granted would be required to ensure system is operating "fairly"
    - One idea for a self-enforced procedure is a "two-sided" market approach in which resources (funds, reciprocal access, etc.) are provided in exchange for access.
        - Reciprocal access may be of more interest to passive scientific users since the scientific applications performed typically have "public good" rather than economic incentives.
    - It was noted that distinct policies would need to apply to users inside and outside the zone. Generally we should expect a non-interference requirement for users outside the zone.
        - This may motivate at least some RDZ's being in remote locations where there would be limited spatial proximity to other users outside the zone.
        - Interference to/from satellites (which are rapidly proliferating) and/or aircraft would still be an issue in such cases.
    - The user information that would need to be provided to implement an access policy was also discussed. These could include:
        - information on use of time, frequency, polarization, angle, location, power, and modulation.
        - Users could potentially also be required to provide information on their own knowledge of local spectrum use by other users.

        - Note that angle information would vary for systems operating on platforms or in the vicinity of other objects so this could complicate the scheme.
        - Reliable propagation modeling would be needed also.
        - The level of access granted could potentially be related to the level of fidelity provided by the requesting user, e.g. in terms of knowledge of system parameters, antenna patterns, propagation prediction, etc.. Higher fidelity information may allow user to operate closer to edge of the RDZ for example.
        - Require periodic self identification of users so that they can be clearly identifiable to the arbiter

    - Penalties for policy violations were also discussed:
        - Fines? But difficult to expect this to apply in an early RDZ where experimentation is encouraged
        - Loss of "reputation" and future access with the arbiter

- Potential motivations for participating in an RDZ were also discussed.

    - Passive users:
        - obtain access to scientific measurements in portions of the spectrum that are currently challenging due to their high occupancy by active users.
        - Maintain "gold standard" science measurements in protected bands. Any sharing of these bands is viewed with high concern.

    - Active users:
        - obtain more flexible operation to improve system performance.
        - Sharing may be possible if impact on system performance can be managed.
        - Interest in sharing within protected passive bands if that can be allowed.

- Minimum viable experiment
    - Dynamic time sharing of spectrum between passive and active users based on simple clock synchronization and passive use e.g. of first 100 msec of every second (i.e. active users do not transmit during this time).
    - An initial experiment could be performed for example with a passive facility running its own active Tx to demonstrate the concept
    - It may be more realistic to have actual active and passive users involved rather than a single entity controlling both

Sprint 2: Spectrum Monitoring Sprint **Facilitators:** Mariya Zheleva, Jeffrey Piepmeier

Overview. In this sprint, we discussed a spectrum monitoring system for NRDZ that can support (i) the wide range of target frequencies (30MHz - 200GHz and potentially into THz); (ii) the vastly different sensitivity levels required by participating technologies (i.e. 120dB difference between radio astronomy and active communications); and (iii) the differences in the geographical footprint of NRDZ technologies? An overview of the topics discussed is provided below.

Topics discussed.

- **Why do we need a monitoring system?**
  - Primary purpose is to do RFI hunting (for both radio astronomy and remote sensing applications.
  - Discern terrestrial and airborne interference (at least sky vs horizon).
  - Need a way to characterize what interfering signals are in order to counteract them. Interested in center frequency, location and bandwidth.
  - Applies to generic NRDZ - someone's transmission is another person's interference.
  - Helps quantify the harm that RFI is causing.
  - The sensitivity of the monitoring system should cater to analysis of local terrestrial transmitters.
  - A monitoring system can also be helpful in designing/calibrating remote sensing instruments (e.g. in understanding anticipated power levels).
  - Monitor long-term environmental changes, such as the roll-out of 5G and its effect on passive systems.
  - To validate propagation models.
- **Data collection and management:**
  - Data should be open and available to everyone. Plans for open data from radio-observatory-based spectrum sensing systems. AN everyone-aware-of-everything approach will promote openness and trust.
  - Various ways to interact with the data – some desire spectrum occupancy characteristics (e.g. how often was spectrum occupied and at what duty cycle), others desire long-term trends in RFI levels.
  - To support open data, we need to establish a shared unified standard for data collection and processing. There should be a community effort to develop and agree upon a data schema and processing pipeline.
- **What are the key and/or driving requirements?**
  - General Radio/RF specifications (e.g., spectral resolution, minimum detectable signal, dynamic range, radiometric resolution).
  - Frequency/geographic/temporal range, resolution, sampling, revisit.
  - What do we do with all this data? (Requirements for archive and distribution)
- **What are the immediate steps/research that needs to be undertaken?**
  - Drive data unification efforts to streamline monitoring from day 1.

Sprint 3: Experiment Management **Facilitators:** Chris DePree, Kobus Van Der Merwe

Overview. In this sprint we conceptualize an experiment management system to allocate NRDZ resources to experiments considering all stakeholders needs. Develop a schema for information exchange across disparate stakeholders in support of NRDZ resource allocation. An overview of the topics discussed is provided below.

Topics discussed.

- The participants started the sprint by discussing possible locations for future NRDZ experiments. It was agreed that a controlled region which includes several users (radio astronomy, cellular networks etc.) such as a radio dynamic zone would be ideal for NRDZ experiments.

- Regarding the stakeholders, it was recommended that the experiments should start with a narrow scope, maybe with few trusted partners using a small portion of the spectrum. Then, more stakeholders can be added. For example, experiments can start with radio astronomy and commercial stakeholders within a narrow frequency band and then expand into DoD or FCC (their 3.5 GHz 5G testbed, FCC's 4.9 GHz public safety band) bands as they become available after agreements with NSF and such stakeholders.

- The structure of future NRDZ experiments were discussed in terms of the following aspects:

  Functionality:

  - The experiments should have access to usable spectrum.
  - A controlled testbed-like infrastructure with a spectrum allocation/management setup should be established for stakeholders to participate.
  - Mechanisms where stakeholders can request certain time/frequency for their measurements/applications currently exist (e.g., in radio astronomy observatories), and NRDZ experiments can follow similar rules provided that faster communication links between users are established. Reaction time and spectrum allocations can be test/measurement specific. NRDZ modalities can be determined by the coordinator through proposals.

  Flow of Information:

        - ❖ Identities, test objectives, locations, spectrum usage, and radiation characteristics of the stakeholders as well as other incumbent users (inside and outside NRDZ) should be known and, if the stakeholders agree, shared.
        - ❖ Stakeholders can pay for increased privacy.

    Intermediate steps that Need to be Undertaken:

        - ❖ A pilot area where interested stakeholders exist should be identified.
        - ❖ Collaborative research and projects should be undertaken for trust building between different communities (radio astronomy, satellites, wireless communications etc.). There are NSF fundings available to do that.

- ○ The killer app or the driving force for stakeholder participation was mentioned as broad and clean bandwidth access which would be not possible outside NRDZ. In addition, commercial companies can utilize NRDZ for their new technology experiments/demonstrations without a need for obtaining a license from FCC. This might be quite attractive as they would not need to publicly release any information.

- ○ Current roadblocks for NRDZ experiments were identified as (1) access to usable spectrum for a reasonably long time in order that devices and instruments could be developed for experiments, and (2) establishing natural collaborations between commercial entities and science users.