SpectrumX Updates for the WInnForum

Dr. Nick Laneman
Center Director & Professor of Electrical Engineering
Email: jnl@nd.edu

WInnComm 2022
December 13, 2022

WIRELESS INSTITUTE

UNIVERSITY OF NOTRE DAME

Executive Summary

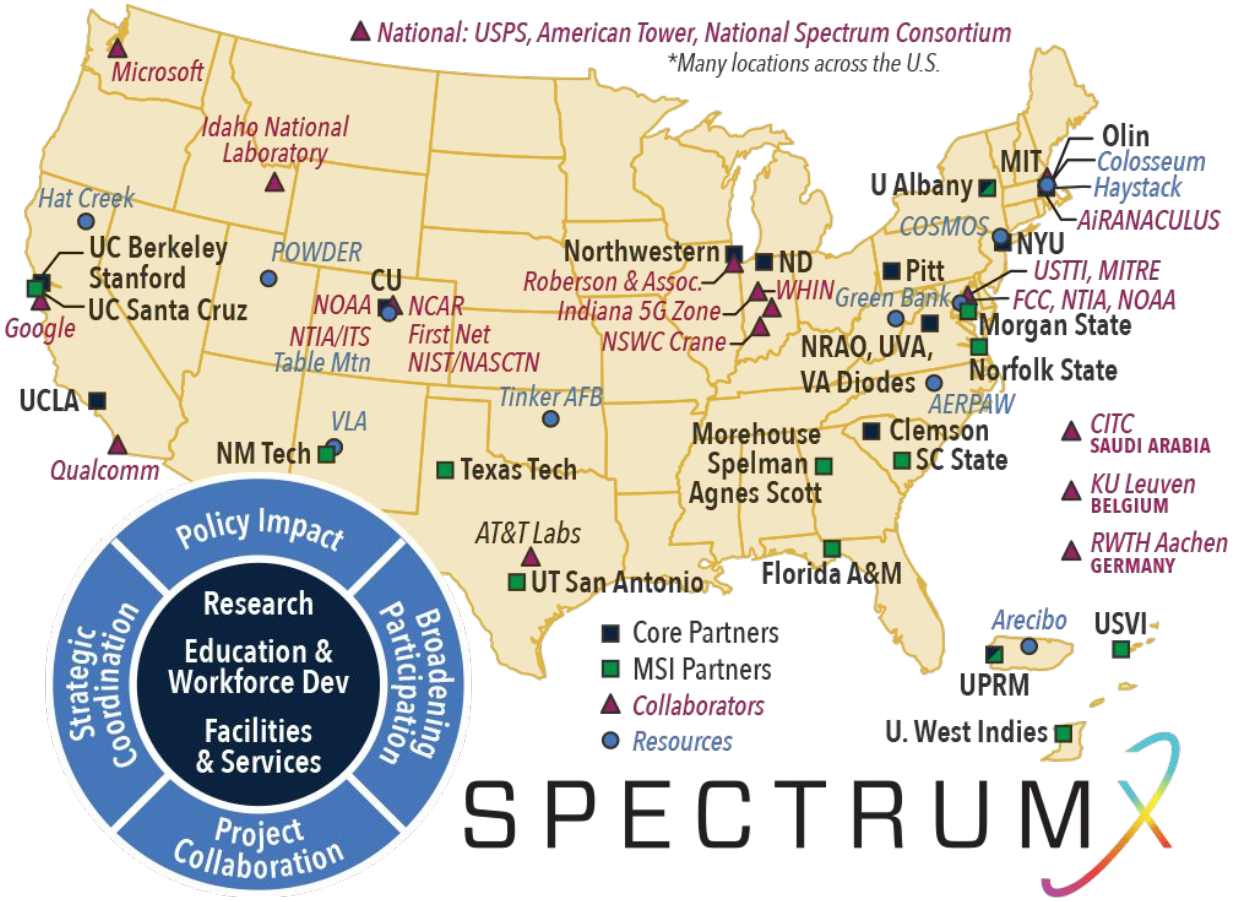
- SpectrumX in Q1 of Year 2 (of a 5-Year Initial Grant)
- Many Highlights in Year 1, Updating Plans for Year 2+
- Substantial Engagement with NSF, External Advisory Board (EAB), NTIA, FCC, and NSF Annual Review Panel
- Several RFPs Out (REU, MS Courses, New Research Projects)
- Expanding Outreach and Collaboration with Industry and Government Stakeholders through a Collaboration Advisory Board (CAB)
- Invite your Feedback on Projects, Participation in our Center Events and Working Group Meetings

Center Overview & Collaborator Engagement

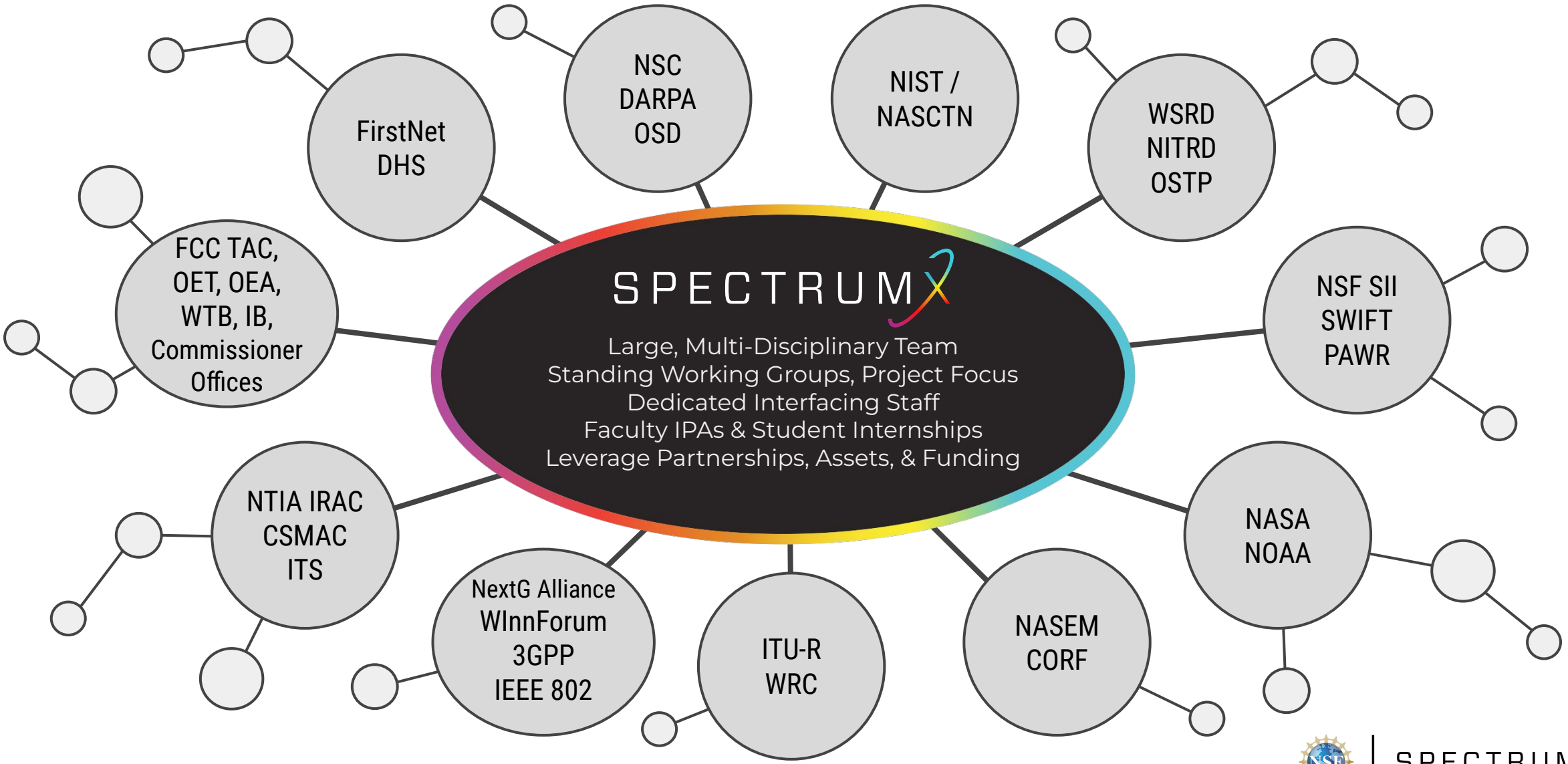
SPECTRUMX

SpectrumX - An NSF Spectrum Innovation Center

- 5-year, $25M center award from the US National Science Foundation (NSF)
- Launched mid September 2021
- Part of the new NSF Spectrum Innovation Initiative (SII)
- 27 top universities, including 14 Minority-Serving Institutions (MSIs)
- Numerous industry & government collaborators
- Led by ND Wireless Institute



Academic Hub in the Radio Spectrum Ecosystem



NSF | SPECTRUMX

Celebrating Year 1 Successes

Building a Community

- 29 Participating Institutions
- 22 Participating Partners
- 461 unique Participants
  - 52 Researchers & Staff
  - 51 UGs/Grad/Postdoc Students
  - 10 EAB Members
  - 116 industry participants
  - 95 government participants

New Funding to Support Growth

- Broadband Mapping Project with 4 MSIs (NSF and Google)
- 8 SII-GRS Fellowships (NSF)
- 27 AY REU Projects (NSF)
- NTIA ITS Liaison (NSF)

Leadership and Engagement

- 18 Working Groups & Project Teams
- 3 Center Meetings
- 2 EAB Meetings
- 12 Radio Shop Chats
- 1000+ Followers on Social Media

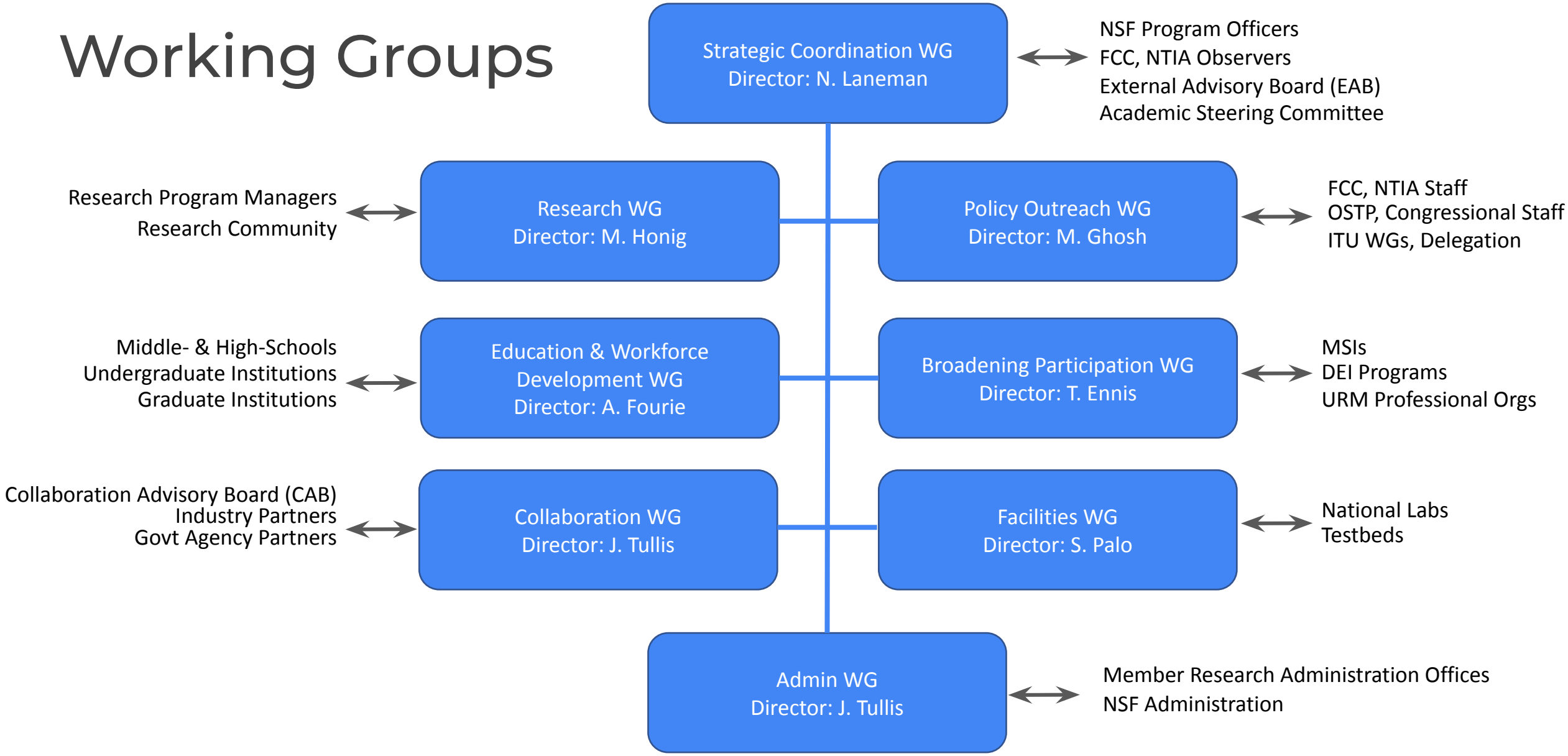
Making an Impact (through Y1Q4)

- 13 journal publications
- 26 conference papers
- 19 other publications
- 1 patent

NSF | SPECTRUMX

Outreach: Presentations by SpectrumX

Working Groups



NSF | SPECTRUMX

Inreach: Join Collaboration Advisory Board (CAB)

BENEFITS

INFLUENCE

PARTICIPATE

ACCESS

No-cost to federal government agencies; tiered membership fee for industry based upon revenue.

NSF | SPECTRUMX

Annual Calendar

Aspect	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Center Meetings: Team + CAB + EAB		Progress Reporting (Mar)		Planning / Brainstorming (Sep)
Stakeholder Outreach	WSRD, WInnForum	PPSG?	WSRD?, IRAC?	OSTP?, NSC?
EAB	In-Person Meeting (Nov)	Virtual Meeting (Feb)	In-Person Meeting (May)	Virtual Meeting (Aug)
Review & Evaluation	NSF Annual Review (Oct)		Update Implementation Plan (May)	Center Evaluation
Subawards			Detailed Scopes & Budget Allocations (Jun)	Finalize (Sep)

Working Group Meeting Schedule

"SX MEETING CALENDAR.DOCX"
Updated 8.23.2022

Eastern Time	Monday		Tuesday		Wednesday		Thursday	
1:00pm - 2:00pm	PT Sensing	Admin	PT Active					
	PT Sensing	CIC	PT Active					
2:00pm - 3:00pm	RWG Data	EWD	RWG Coexist	(½) PT Rights		PT Data		
	RWG Tech	EWD	(½) RWG Econ/Policy	(½) PT Enforce		PT Data		
3:00pm - 4:00pm			BP	Radio Shop Chat	POLICY	SC	PT Passive	
			BP	Team Meeting	POLICY	SC	PT Passive	

Meeting Rotations

Week 1	Week 2
Week 3	Week 4

Share Interests & Contact Info

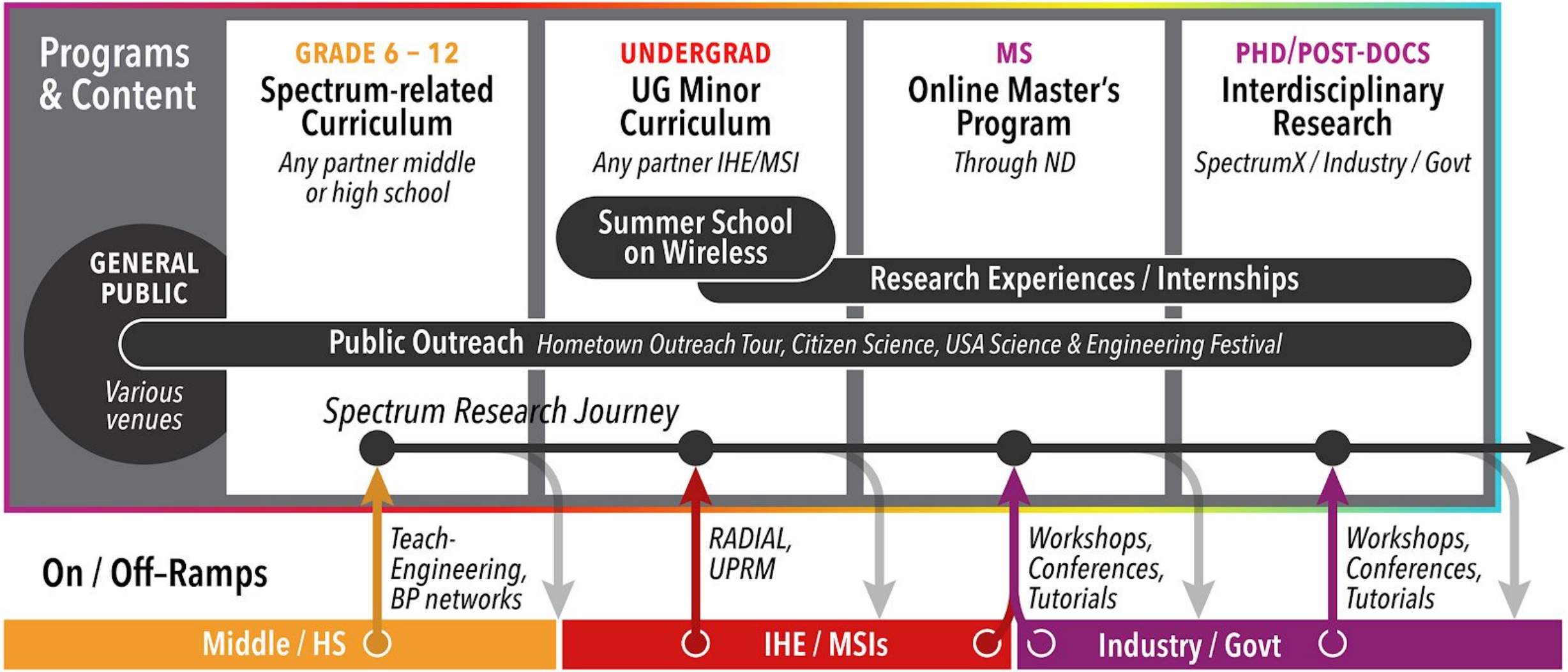
https://www.spectrumx.org/get-involved/

SPECTRUM X

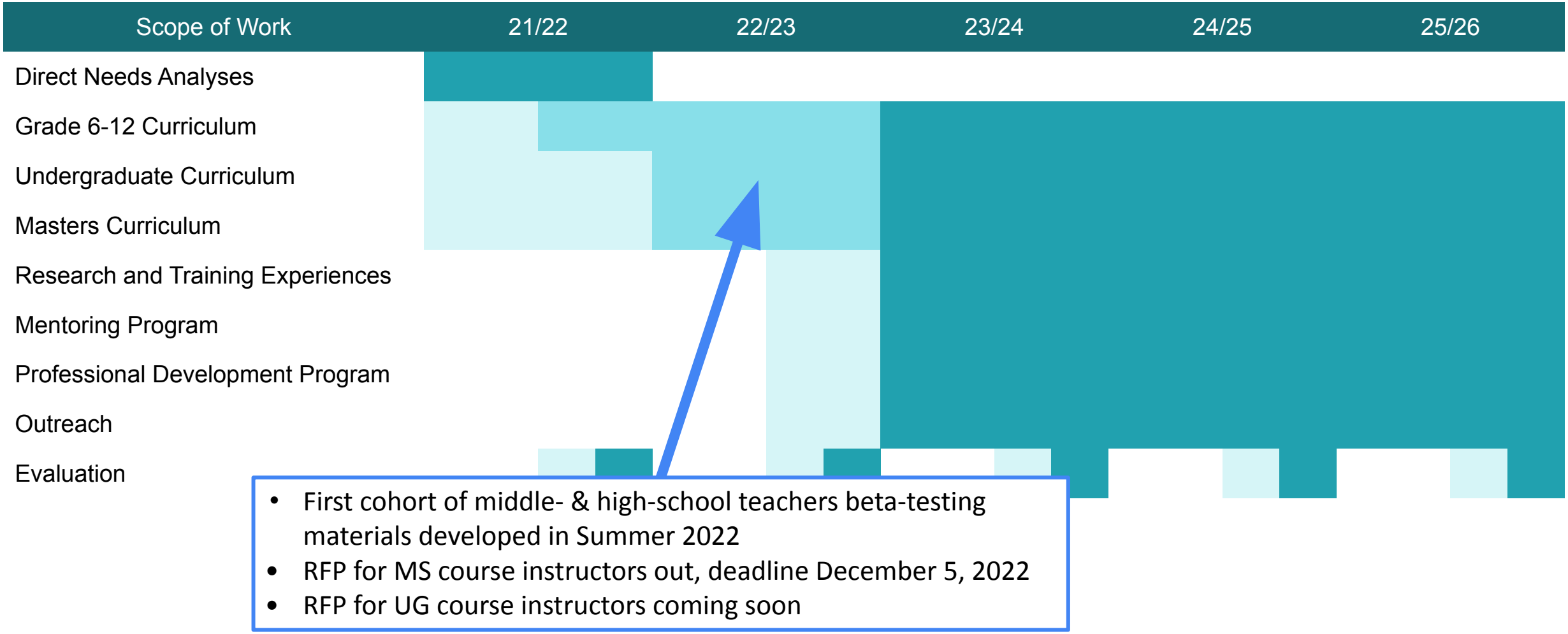
Working Group & Project Team Updates

SPECTRUMX

Education & Workforce Development (EWD)



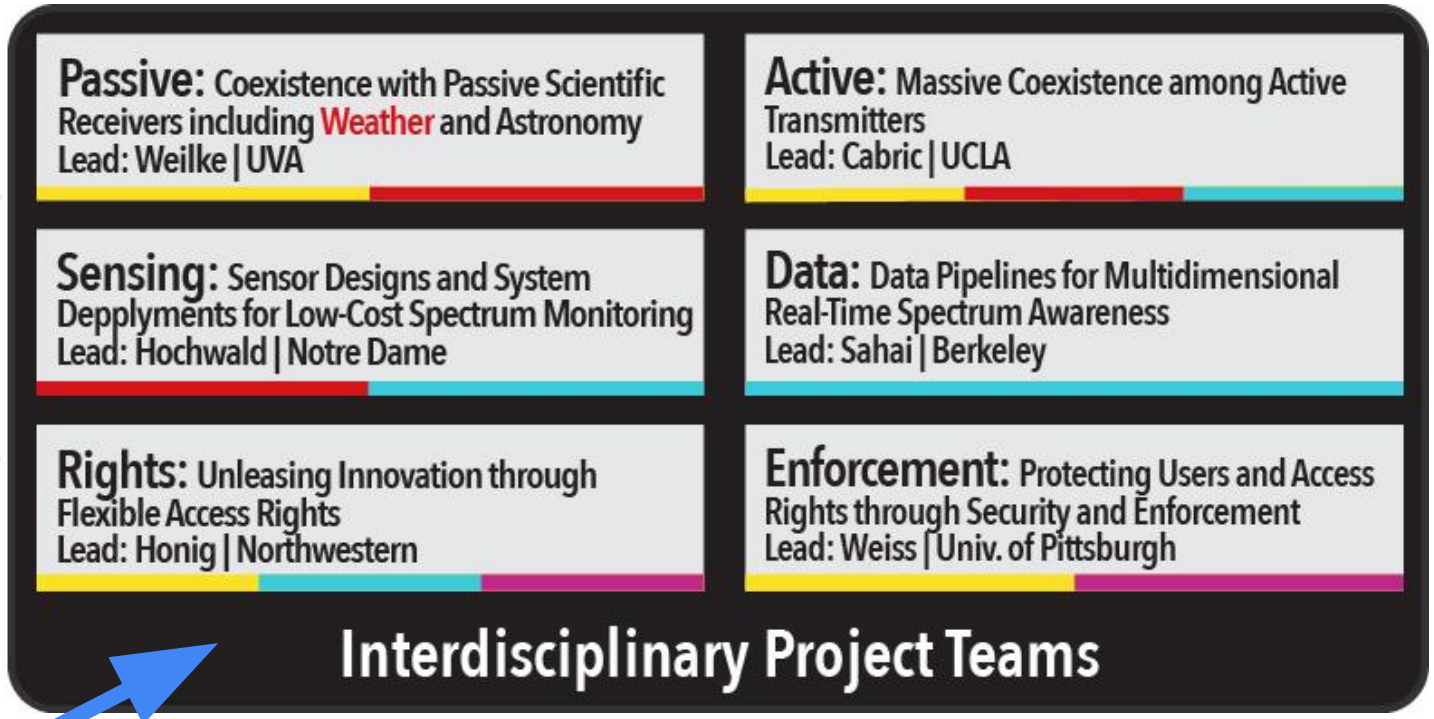
EWD Plan Timeline



- First cohort of middle- & high-school teachers beta-testing materials developed in Summer 2022
- RFP for MS course instructors out, deadline December 5, 2022
- RFP for UG course instructors coming soon

NSF | SPECTRUMX

Research: From Planning to Execution



- 6 Initial Project Teams from Planning Phase, Executing Now
- Plan is to evolve projects based upon CAB and EAB input, opportunities for supplemental funding, new priorities, and so forth
- RFP for Research Seed Funding out, deadline December 15, 2022

NSF | SPECTRUMX

PT-Passive: Coexistence with Passive Scientific Receivers

- **Challenge**: Develop technologies to permit coexistence of emerging wireless services with passive scientific receivers operating at sensitivities that approach physical limits
- **Main Directions:**

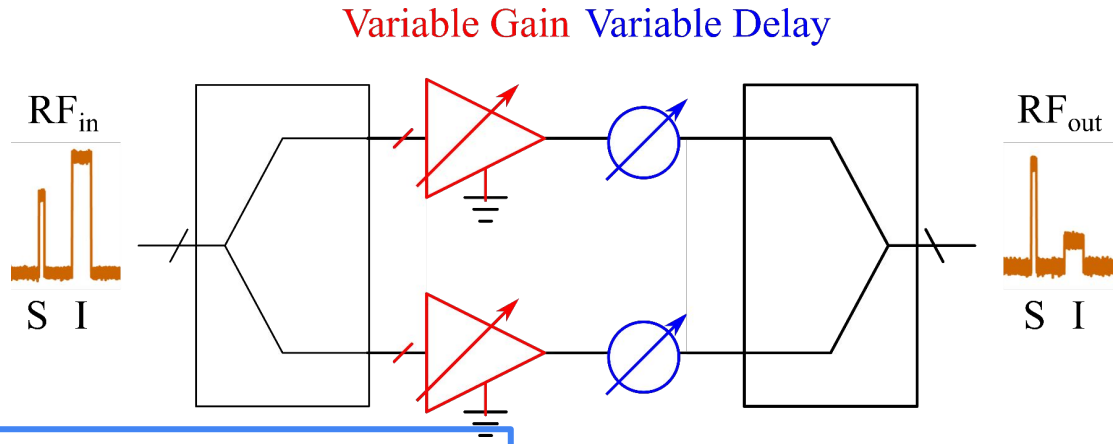
Advanced scientific receivers with interference mitigation / cancellation	Weikle, UVA; Gasiewski and Popovic, CU; Pamarti, UCLA; Lind, MIT Haystack
Dynamic scheduling for interference management across disparate systems	Honig and Berry, NWU; Palo, CU; Lohmeyer, Olin
Scientific sensing enhancements in the presence of radio frequency inter	Lind and Akiyama, MIT Haystack; Sidiropoulos and Shen, UVA
Low-cost millimeter-wave sensing for scientific spectrum monitoring	Bowers, UVA; Lind, MIT Haystack

- **Use Cases:** Earth Remote Sensing, Radio Astronomy, Terrestrial Communications (Cellular/WiFi), Satellite Constellations
- **Lead:** Steven Bowers, UVA

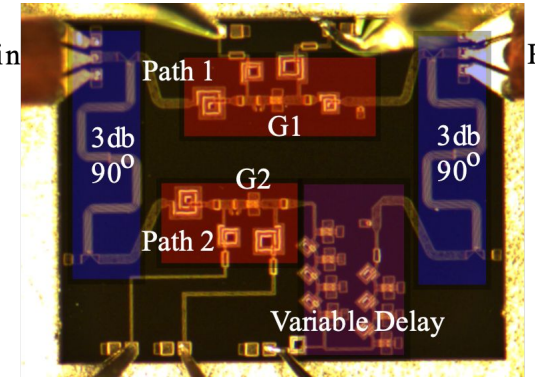
NSF | SPECTRUMX

Result: Broadband Analog Interference Suppression

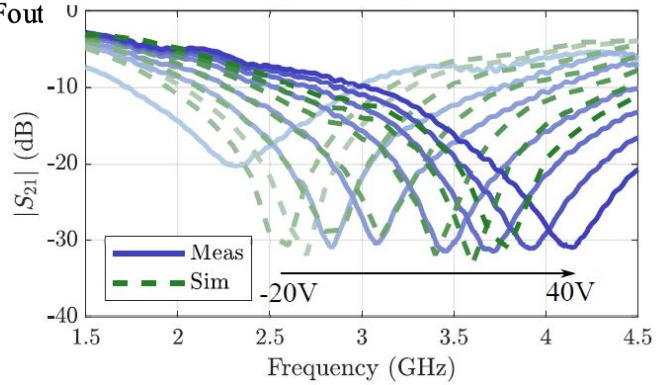
GOAL: Develop a broadband analog front-end for radio astronomy receivers to suppress interferers for improved ADC dynamic range.

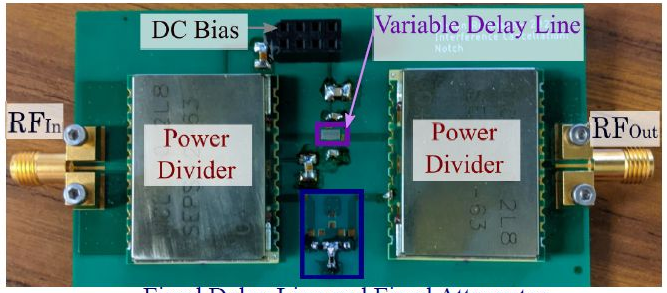


- Demonstrated 2-4 GHz hybrid version: Suppresses 1 interferer 20 dB
- Demonstrated 6-12 GHz version in a GaAs and GaN MMIC to validate approach
- Designed GaN circuit for radio astronomy, 60-110 GHz (HRL T3 GaN), high IP3, in fab
- Next Step: Expand circuit to multiple interferers with more suppression



2.5mmx
2mm





Fixed Delay Line and Fixed Attenuator

Zoya Popovic

University of Colorado Boulder

P. Danielson, M. Robinson, G. Lasser and Z. Popovic, "GaAs MMIC Interferometer for Broadband Interference Suppression," *2022 17th European Microwave Integrated Circuits Conference (EuMIC)*, 2022, pp. 17-20, doi: 10.23919/EuMIC54520.2022.9923535.

NSF | SPECTRUMX

PT-Active: Coexistence among Active Transmitters

- **Challenge**: Harnessing spectrum opportunities for broadband access and spectrum sharing in mid-band spectrum band (< 10 GHz)
- **Main Directions:**

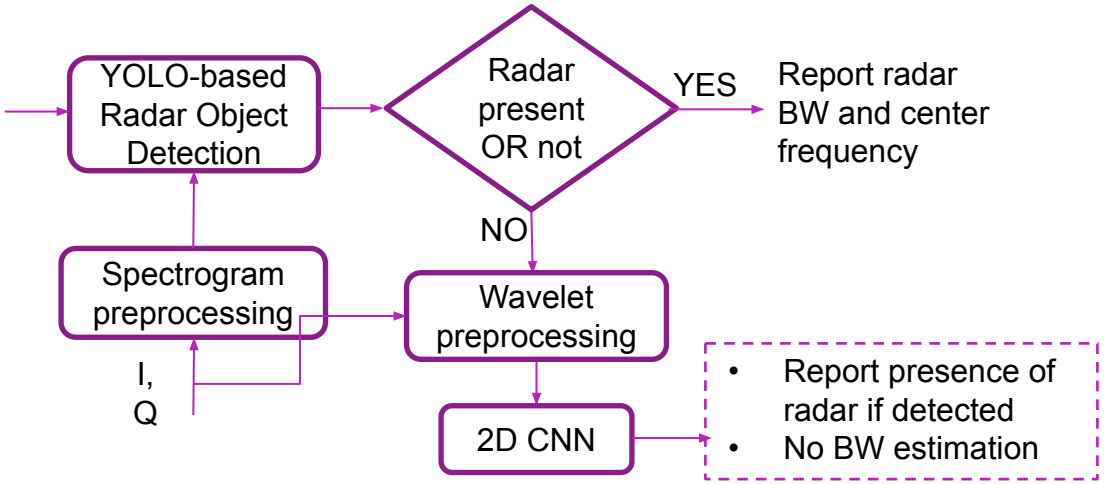
Measurement-enhanced centralized databases for interference management	Cabric, UCLA; Zheleva, Albany
Distributed coordination mechanisms that exploit abundant Degrees of Freedom (frequency/space/time)	Honig, NWU; Cabric, UCLA; Zheleva, Albany
Machine Learning for interference detection and spectrum management	Cabric, UCLA; Zheleva, Albany; Guo, NWU
Hardware advances for spectral confinement, circuit efficiency, large antenna arrays.	Popovic and Barton, CU; Rodriguez Solis, UPRM

- **Use Cases:** Terrestrial Communications (Cellular/WiFi), Radar Systems, Microwave Links
- **Priority Frequencies / Bands:** 3.5 GHz CBRS, 5 GHz-7 GHz, 28 GHz mmWave
- **Lead:** Danijela Cabric, UCLA

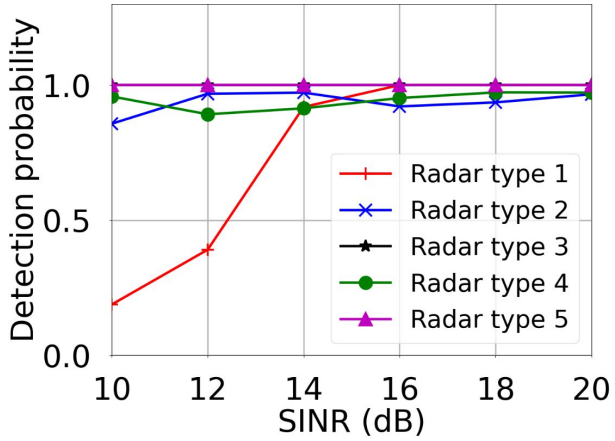
Result: Eliminating Whisper Zones of ESCs in CBRS

GOAL: Robust spectrum sensing for detecting radar in interference.

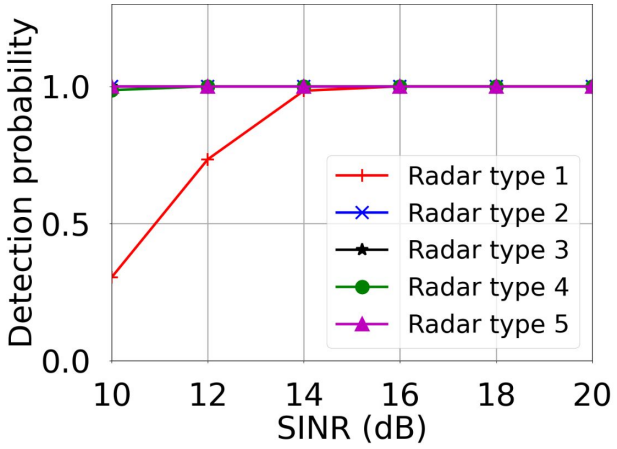
- Machine Learning for Low SNR Radar Defection
- Specifically “You Only Look Once” (YOLO) objection recognition as well as Wavelet pre-processing with Cellular Neural Networks, and combinations
- NIST radar dataset, 10 MHz signals, all five radar types, only AWGN interference
- YOLO + Wavelet-CNN improves radar detection accuracy by 6 dB, can reduce whisper zone radius by half



YOLO Only



YOLO + Wavelet / CNN



Danijela Cabric

UCLA

P. Danielson, M. Robinson, G. Lasser and Z. Popovic, "GaAs MMIC Interferometer for Broadband Interference Suppression," *2022 17th European Microwave Integrated Circuits Conference (EuMIC)*, 2022, pp. 17-20, doi: 10.23919/EuMIC54520.2022.9923535.

NSF | SPECTRUMX

PT-Sensing: Sensor Designs and Deployments for Low-Cost Spectrum Monitoring

- **Challenge**: Low-cost spectrum sensors today have limited fragmented capabilities, and lack a universal deployment imperative
- **Main Directions:**

Survey low-cost RF spectrum sensors	Palo and Morton, CU; Hochwald and Laneman, ND
Develop hardware prototypes; emphasis on low-cost high frequency (10s of GHz)	Hochwald, ND; Pamarti, UCLA; Rodriguez Solis, UPRM
Develop simple API for interfacing large numbers of sensors	Lind and Erickson, MIT Haystack
Mapping, storage, learning systems that fuse outputs of large numbers of sensors	Hochwald and Laneman, ND

- **Use Cases:** Spectrum Monitoring, Dynamic Spectrum Management
- **Priority Frequencies / Bands:** 100 MHz - 6 GHz (next version to 18 GHz)
- **Lead:** Bertrand Hochwald, ND

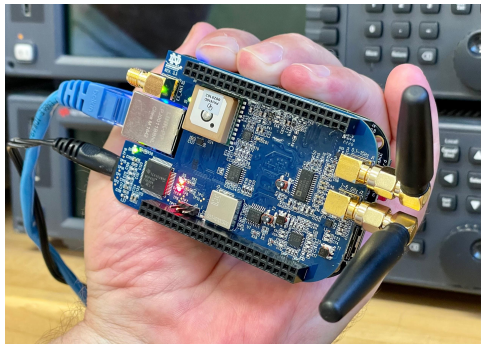
NSF | SPECTRUMX

Result: RadioHound Iteration and Dissemination

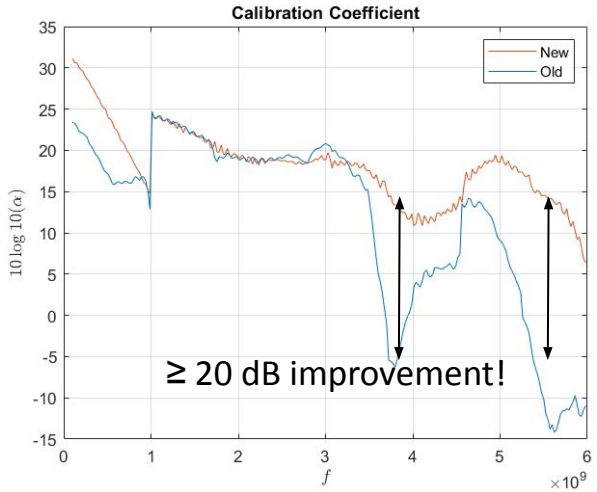
GOAL: Evolve low-cost spectrum sensing platform, including sensor designs as well as software for sensor management, visualization, and data analysis

- Updated ND RadioHound V3.4 PCB layout for better RF performance up to 6 GHz; added real-time clock, calibration fixes
- Shipped 2-3 sensors to collaborators at MIT Haystack, CU Boulder, UPRM, Stanford, and NIST to beta test deployment, collections, and provide feedback
- Next Step: Collect requirements for next version, targeting tuning up to 18 GHz and 100 MHz bandwidth
- V3.5 being fabricated - improved low-band RF performance (Dec. 2022)

RadioHound
ND WIRELESS INSTITUTE



- Low-cost, low-power custom sensor for 100 MHz-6 GHz
- Built upon BeagleBone Black host computing platform
- Third version of sensor design
- Used in ARL & FCC Field Trials



Bert Hochwald

UNIVERSITY OF NOTRE DAME

MIT HAYSTACK OBSERVATORY

University of Colorado Boulder

Recinto Universitario de Mayagüez – Universidad de Puerto Rico – CAAM

Stanford University

NIST

NSF | SPECTRUMX

PT-Data: Scalable Architecture for Open Spectrum Data Analytics

- **Challenge**: Support and promote the use of diverse empirical data and machine learning approaches for spectrum monitoring and decision making
- **Main Directions:**

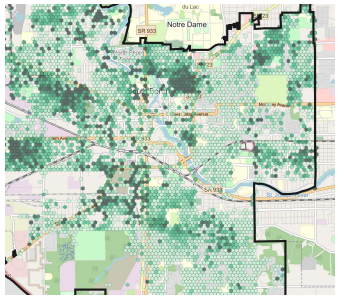
Build a core data pipeline for diverse data sources with an accessible interface	Katti, Stanford; Sahai, Berkeley; Zheleva, Albany
Develop a unified machine-learning framework for back-end processing	Sahai, Berkeley; Guo, NWU; Shen, UVA
Identify case studies that exploit potential (e.g., cloud-based propagation modeling, broadband mapping)	Gremban and Grunwald, CU; Ghosh, ND
Explore mechanisms for RFI detection	Lind and Erickson, MIT Haystack; Morton, CU

- **Use Cases:** Spectrum Monitoring, RFI Detection, Propagation Measurements/Modeling
- **Priority Frequencies / Bands:** CBRS, 3.3 GHz, 4.8 GHz
- **Lead:** Keith Gremban, CU Boulder (newly appointed)

NSF | SPECTRUMX

New: Broadband Mapping Using Smartphones (Broadband MAP US)

- Backdrop
  - FCC requests cellular providers to submit coverage data and data rates—data is notoriously inaccurate
  - Congress directing FCC to verify broadband maps
  - Capabilities and pilot projects have been developed by Monisha Ghosh in Chicago (University of Chicago) and South Bend, Indiana (University of Notre Dame)
- Four Minority-Serving Institutions (MSI) partners recruited by Tanya Ennis
  - Partners will conduct broadband mapping for 3 major carriers in their geographic areas
  - Faculty leads identified & students being recruited
  - Phones being ordered & kickoff being planned



Morgan State

Florida A&M

FIU FLORIDA INTERNATIONAL UNIVERSITY

Virgin Islands

Monisha Ghosh

Tanya Ennis

Google NSF | SPECTRUMX

PT-Rights: Innovation through Flexible Access Rights

- **Challenge**: Designing innovative spectrum access across scientific, defense & commercial applications to enhance efficiency
- **Main Directions:**

Comparative study of access rights regimes accounting for all transaction costs, regulatory overhead, and future adjustments	Hazlett, Clemson; Berry and Honig, NWU; Weiss and Murtazashvili, Pitt
Data collection for econometric studies, empirical welfare analysis.	Hazlett, Clemson
Tribal Lands studies	Murtazashvili and Weiss, Pitt

- **Use Cases:** Terrestrial Communications (Cellular/WiFi), Satellite Constellations, Government Users
- **Priority Frequencies / Bands:** 3.5 GHz, 6-7 GHz, mmWave satellite bands
- **Lead:** Michael Honig, NWU

Result: Spectrum Rights in Outer Space

GOAL: Examine the satellite spectrum rights regime proposed by the FCC and, guided by empirical evidence, propose alternatives that may better resolve the challenges confronted

- Reviewed FCC NRPM FCC 21-123
  - NGSO satellites constellations are licensed in rounds, with priority for earlier rounds
  - "1/n rule" for interference mitigation - Licensees in the same round that cannot reach an agreement must split the bandwidth equally
- Identified Implications
  - Potential disincentive to invest in these services given the insecurity of existing rights
  - Opportunities to force fragmentation, hobbling competitors' bandwidth access
- Explored Alternatives
  - Open Access
  - Database-Drive Sharing
  - Tradeable Access Rights

Whitney Lohmeyer

Olin College of Engineering

R. Berry, and P. Bustamante, D. Guo, T. Hazlett, M. Honig, W. Lohmeyer, I. Murtazashvili, S. Palo, M Weiss, Spectrum Rights in Outer Space: Interference Management for Mega-constellations, TPRC 2022. https://ssrn.com/abstract=4178793 or http://dx.doi.org/10.2139/ssrn.4178793

NSF | SPECTRUMX

PT-Enforcement: Securing Users and Access Rights

- **Challenge**: Promote coexistence by developing efficient and effective mechanisms to secure and protect spectrum rights
- **Main Directions:**

Machine Learning for RF fingerprinting	Cabric, UCLA; Zheleva, Albany
Data standards for documenting interference events	Zheleva, Albany; Cabric, UCLA
Automated methods for ex post adjudication (smart contracts, blockchains)	Guo, NWU; Weiss and Murtazashvili, Pitt

- **Lead:** Martin Weiss, Pittsburgh (likely transitioning to IPA)

Policy Outreach - Goals

- Arranging meetings and workshops between member institutions and collaborating organizations to explore synergies and approaches to enhance and accelerate the spectrum management process.
- Moderating conversations with the Federal stakeholders involved (e.g. FCC, NTIA, Federal Users, Congressional Committee Staff, OSTP, State Department) about best practices and communication bottlenecks affecting both spectrum use and coexistence.
- Summarizing upcoming ITU meetings, NTIA initiatives, and FCC NPRMs for monitoring and strategic planning by SpectrumX members.
- Delivering white papers and formal comments summarizing the challenges and opportunities as well as the technical and policy options developed by SpectrumX.

NSF | SPECTRUMX

Policy Outreach - Progress

- Biweekly meetings since January 2022.
- In-depth policy and technical discussions on recent policy issues:
  - Past: C-band/ radar altimeter, NGSO NPRM, Receiver Standards NOI.
  - Recent: Draft NOI on 12.7 – 13.25 GHz, to be adopted on Oct. 27, 2022.
- Facilitated presentations in the Radio Shop Chat Forum from EU policy makers and Keysight on next generation wireless spectrum needs.
- Facilitated presentations to the FCC Technological Advisory Council (TAC) by SpectrumX members: Phil Erickson, Dale Hatfield, Tom Hazlett.
- Discussions with APCO (Association of Public Safety Communications Officials) on 6 GHz interference concerns and how SpectrumX can help.
- Participated in Spectrum Policy panels at the 11th Americas Spectrum Management Conference, Brooklyn 6G Summit and Silicon Flatirons.

Policy Outreach - Future Plans

- Create a policy blog with contributions from SpectrumX team as well as outside experts on current topics of interest.
- Extract policy deliverables from ongoing research projects and make them available to policy makers, e.g. via comments to the FCC.
- Leverage the work being done in the FCC TAC groups to inform ongoing projects in SpectrumX, e.g. the focus on 7 – 24 GHz for next generation wireless.
- Incubate new projects with the specific purpose of addressing ongoing and future policy debates: e.g. 5G/mmWave, 5G/RadAlt

Tracking Bands / Systems / Issues

Midband (3.1-3.45, 3.55-3.7, 3.7-3.98 GHz)	Sharing with Radars (IIC) Secondary Coexistence (GAA) Power Levels at Band Boundaries TDD Uplink/Downlink Config. Mismatch
Unlicensed (6-7.2 GHz)	Indoor / Outdoor determination Aggregate Interference to Incumbents Automatic Frequency Control (AFC)
Satellites + Terrestrial (12.2-13.25 GHz)	Sharing rules with in-band incumbents Passives in adjacent bands (NOI on 12.7 - 13.25 GHz)
6G Vision (7-24 GHz)	Limited information on Federal uses Expand SpectrumWiki

Wrap Up

SPECTRUM X

Discussion

- What do WInnForum members want to see SpectrumX achieve?
- How might SpectrumX shift current projects and / or create new projects to address WInnForum member concerns?
- What systems / bands / interference issues are on the horizon?
- UG research project ideas and internship opportunities?
- Opportunities for faculty visits / liaison / IPAs?
- Topics / skills / tools to include in curriculum developments?
- How can WInnForum members collaborate with SpectrumX?
- Broader feedback and suggestions?

Get Involved in SpectrumX!!

Share Interests & Contact Info

https://www.spectrumx.org/get-involved/

Follow on LinkedIn

www.linkedin.com/company/spectrumx-center

Bookmark the Website

spectrumx.org