Operational Data Sharing (ODS) Framework

A coexistence strategy for radio observatories in the broadband era

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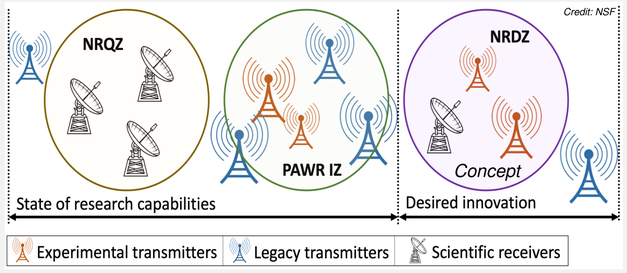
Introduction

National Radio Quiet Zone (NRQZ)

Established by
- FCC ***Docket No. 11745*** (November 19, 1958)
- Interdepartment Radio Advisory Committee (IRAC) in ***Document 3867/2*** (March 26, 1958)
- NRQZ ~ 13,000 sq-mile
  ~ 34,000 sq-km

National Radio Dynamic Zones (NRDZ)



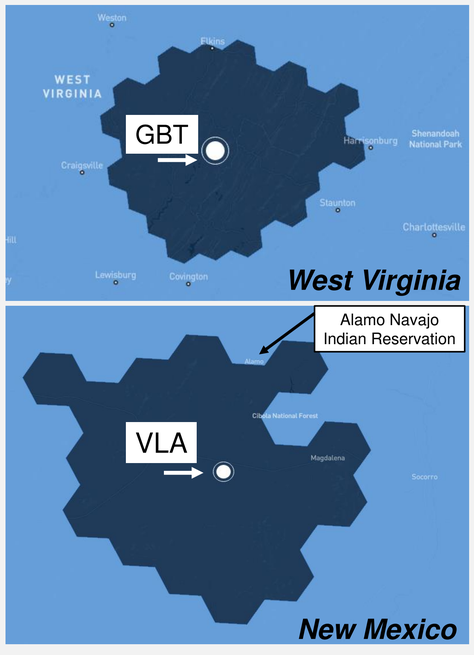
PAWR = NSF's Platforms for Advanced Wireless Research

Dynamic spectrum sharing (DSS)
- Independent & dynamic access methods

Radio Dynamic Zone (RDZ)
- Control RF energy entering & escaping the zone
- Need a zone management framework

SpaceX Voluntary Coordination

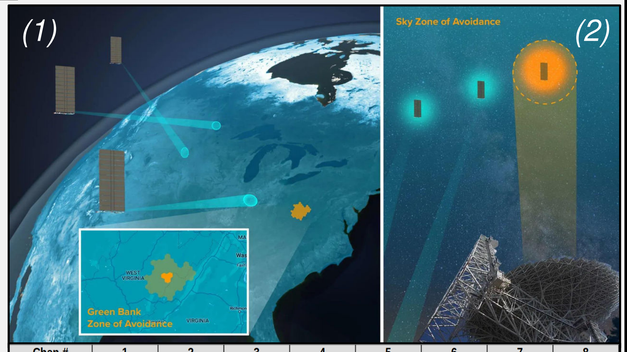
https://www.starlink.com/map



Fixed address user-terminal request are unavailable for dark blue service cells

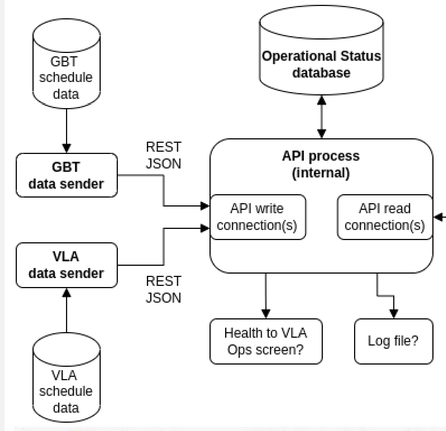
Possible Avoidance Schemes

1. ***Zone avoidance [1,2,3]***
   - Adaptive beam placement
   - When not close to telescope boresight
2. ***Boresight avoidance [5]***
   - Momentarily disabling downlink when close to telescope boresight
3. ***Frequency Multiplexing***
   - Downlink only in bands not being used



Chan #	1	2	3	4	5	6	7	8
Band Name	X							Ku
Freq (GHz)	10.7-10.95	10.95-11.2	11.2-11.45	11.45-11.7	11.7-11.95	11.95-12.2	12.2-12.45	12.45-12.7
RA Telescopes	In-use					Available		
LEO	No downlink					Downlink		
RA Telescopes	Available				In-use			
LEO	Downlink				No downlink			

Operational Data Sharing (ODS) Frameworks



- Autonomous avoidance informer (REST API)
- Standardized JSON data format
- Queryable by satellite operators
- Telescopes self-report & satellite operators adjust tasking in real-time

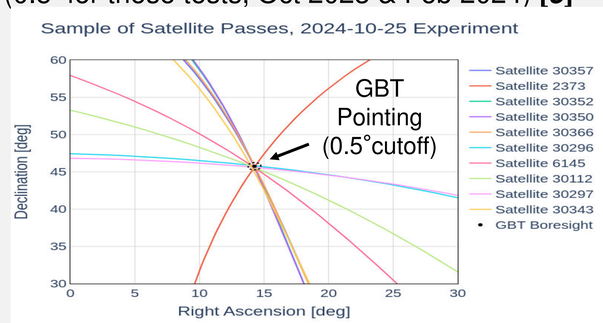
- Ongoing development & testing with SpaceX
- Implementing for NRAO's Very Large Array (VLA) and Green Bank Telescope (GBT)

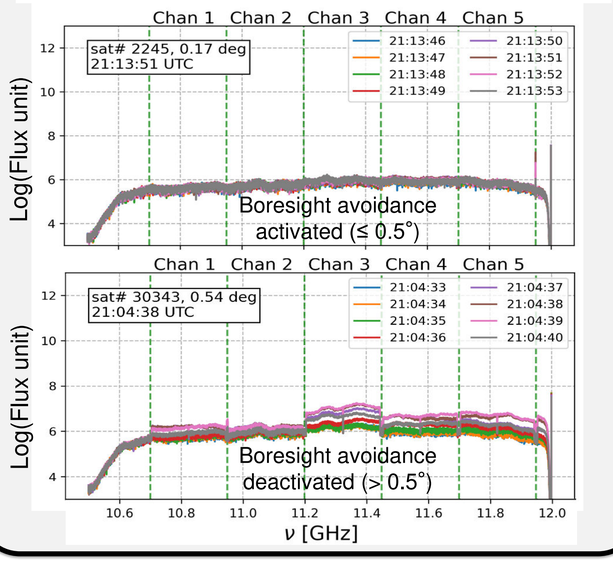
Successful Operation - Returns array of JSON objects with these attributes:

Attribute	Type	Format	Example	Description
site_id	string		vla_D	Identifier of the observatory/instrument. In the example '_D' indicates VLA 'D' configuration. The possible 'site_id's for the VLA are: vla_A, vla_A-to-D, vla_D, vla_D-to-C, vla_C, vla_C-to-B, vla_B, vla_B-to-BnA, vla_BnA, vla_BnA-to-A.
site_lat_deg	number	decimal-degrees +/- DD.D	34.07874917	the latitude of the observatory/instrument
site_lon_deg	number	decimal-degrees +/- DDD.D	-107.6177275	the longitude of the observatory/instrument
site_el_m	number	decimal-meters	2124	the elevation of the observatory/instrument
src_id	string		J1056+7011	identifier of source/target observed during time interval
src_is_pulsar_bool	boolean		false	true = src is a pulsar, false = src is not a pulsar
corr_integ_time_sec	number		3	correlator integration time in seconds (if 'src_is_pulsar_bool'=false)
src_ra_j2000_deg	number	decimal-degrees	70.88181332916666	right ascension of the source/target
src_dec_j2000_deg	number	decimal-degrees	34.685184469444444	declination of the source/target
src_radius	number	decimal-degrees	0.0034	radius of beam around the source/target
src_start_utc	string	date-time	2023-08-16T15:23:47.000541	start time of this observing interval
src_end_utc	string	date-time	2023-08-16T15:26:16.000723	end time of this observing interval
slew_sec	number		130.8	the time taken for the array to reach the source (counted from 'src_start_utc')
trk_rate_dec_deg_per_sec	number	decimal-degrees per second	0	declination tracking rate of src (if not sideral)
trk_rate_ra_deg_per_sec	number	decimal-degrees per second	0	right ascension tracking rate of src (if not sideral)
freq_lower_hz	number	decimal-Hz	26000000000	lower limit frequency used during this interval
freq_upper_hz	number	decimal-Hz	40000000000	upper limit frequency used during this interval
notes	string		inAdv:True	notes that add context to the data

Precursor Tests with SpaceX

Boresight Avoidance tests:
Scheduled GBT observation at a fixed sky pointing, with and without Starlink's onboard boresight avoidance tasking activated within a coordinated boresight angular separation cutoff (0.5° for these tests, Oct 2023 & Feb 2024) **[*5*]**





Current & Future Development

- Conduct initial autonomous system testing between SpaceX and VLA & GBT (Summer 2024)
- Continue collaborating with SpaceX & other satellite operators
- Eventually develop into a closed-loop system for mutual avoidance (possibly including dynamical scheduling to avoid crowded sky regions for obs)

Literature Cited

NRAO RFI memo series: **https://library.nrao.edu/rfi.shtml**

[1] RFI Memo #120 - *Coordinated Starlink User Terminal Testing Near the VLA*
[2] RFI Memo #121 - *SpaceX-VLA Alamo Pilot Testing*
[3] RFI Memo #154 - *Coordinated GBT-Starlink Tests (April-July 2023)*
[4] Nhan, B.; et al. (2024) – URSI-NRSM, Jan 2024,
DOI: 10.23919/USNC-URSINRSM60317.2024.10464916
[5] Nhan, B.; De Pree, C.; Iverson, M.; Gregory, B.; et al. (*In Prep*) – *Toward Spectrum Coexistence: First Demonstration of the Effectiveness of Boresight Avoidance between the NRAO Green Bank Telescope and Starlink Satellites*

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