Spectrum Considerations for Interplanetary SmallSat Missions

Presenter: William Notley
NASA ARC Spectrum Manager

Interplanetary Small Satellite Conference
Santa Clara, CA
April 2015

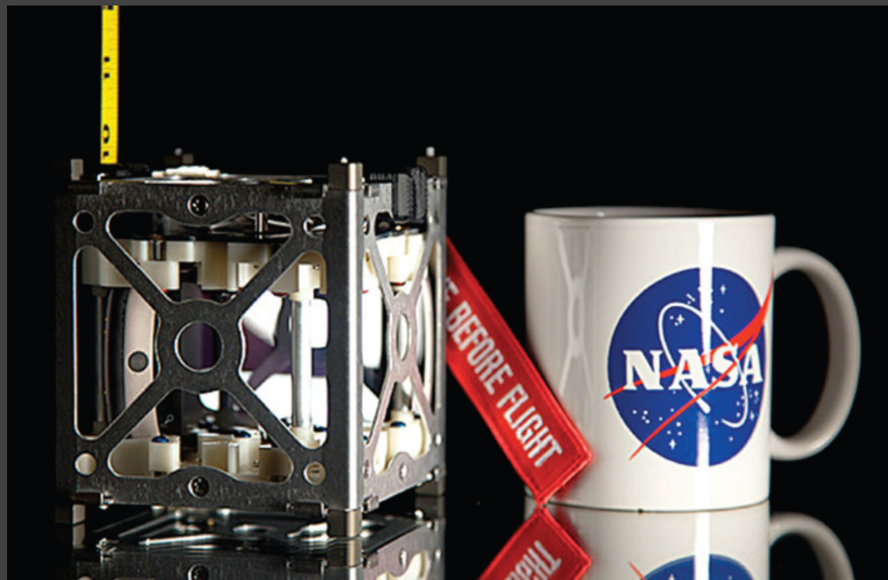
NASA Spectrum Management

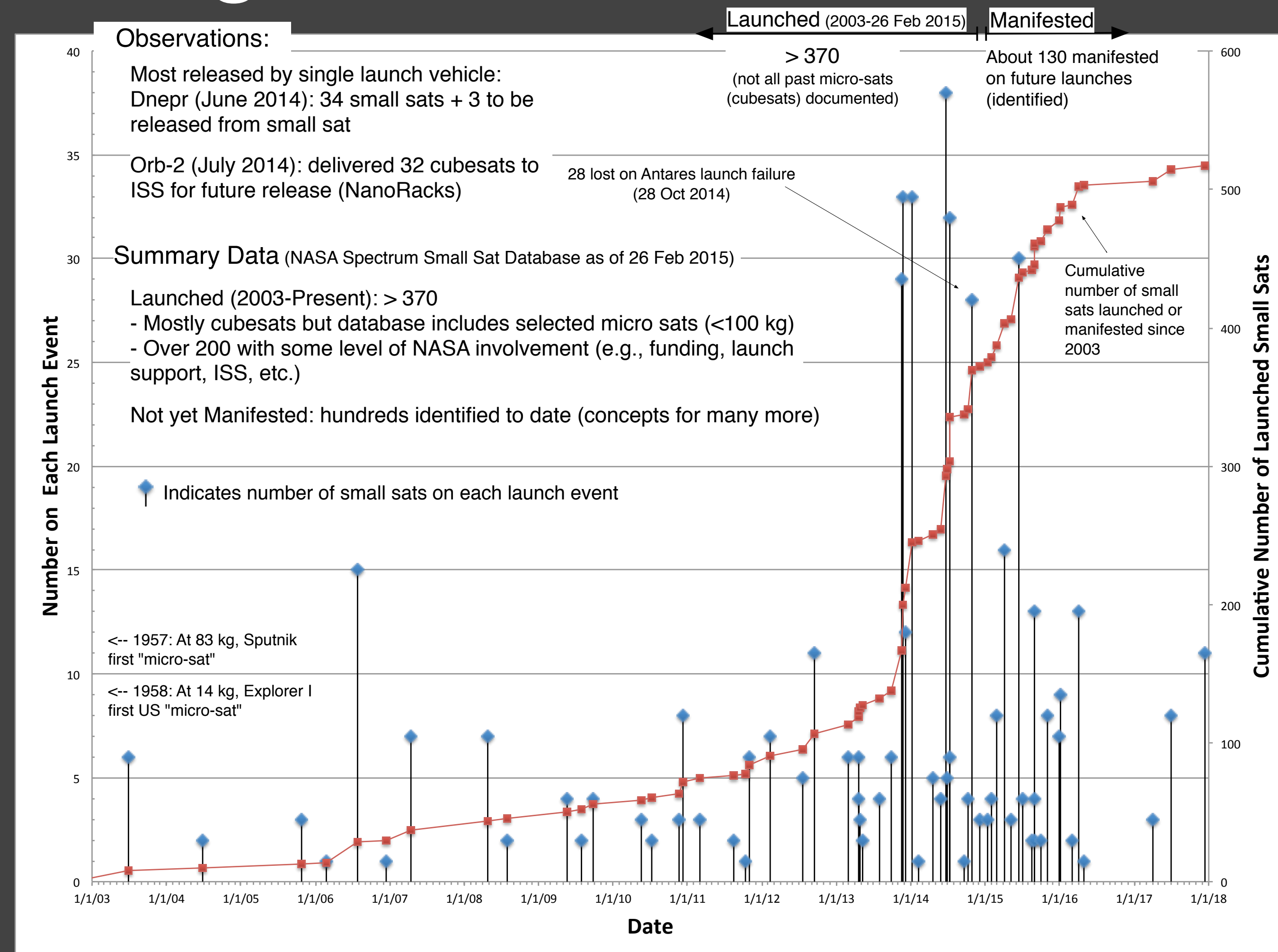
Small Sat Point of Contact:

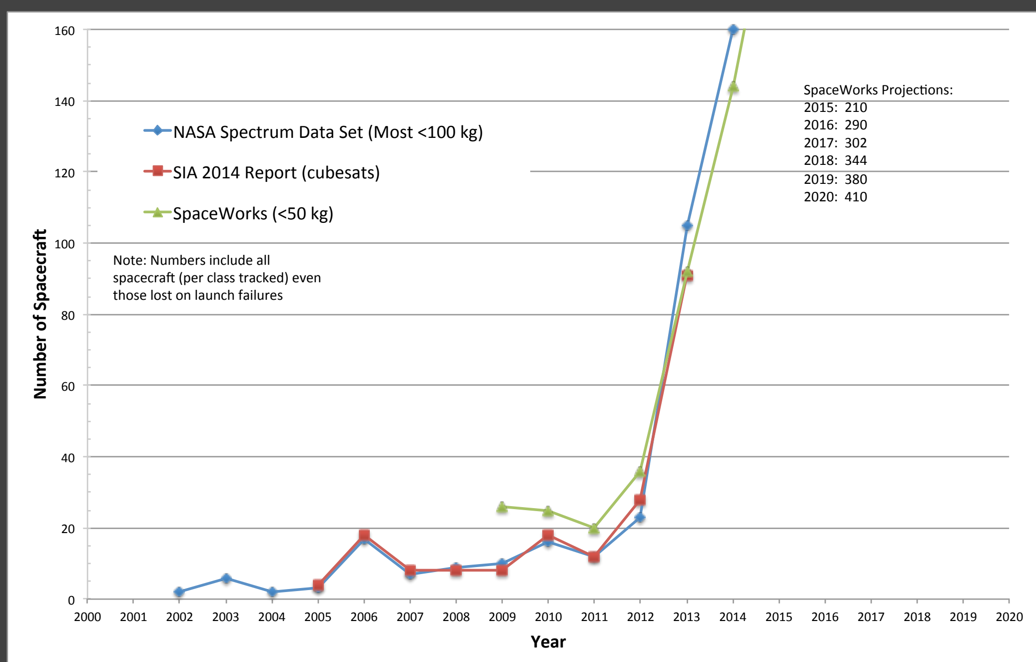
William Horne
NASA Headquarters
Washington, DC
william.horne@nasa.gov

William Notley
Center Spectrum Manager
NASA Ames Research Center
Moffett Field, CA
william.k.notley@nasa.gov

Small satellite use is growing . . .







NASA spectrum is tracking small satellites to ensure appropriate use of the spectrum and licensing

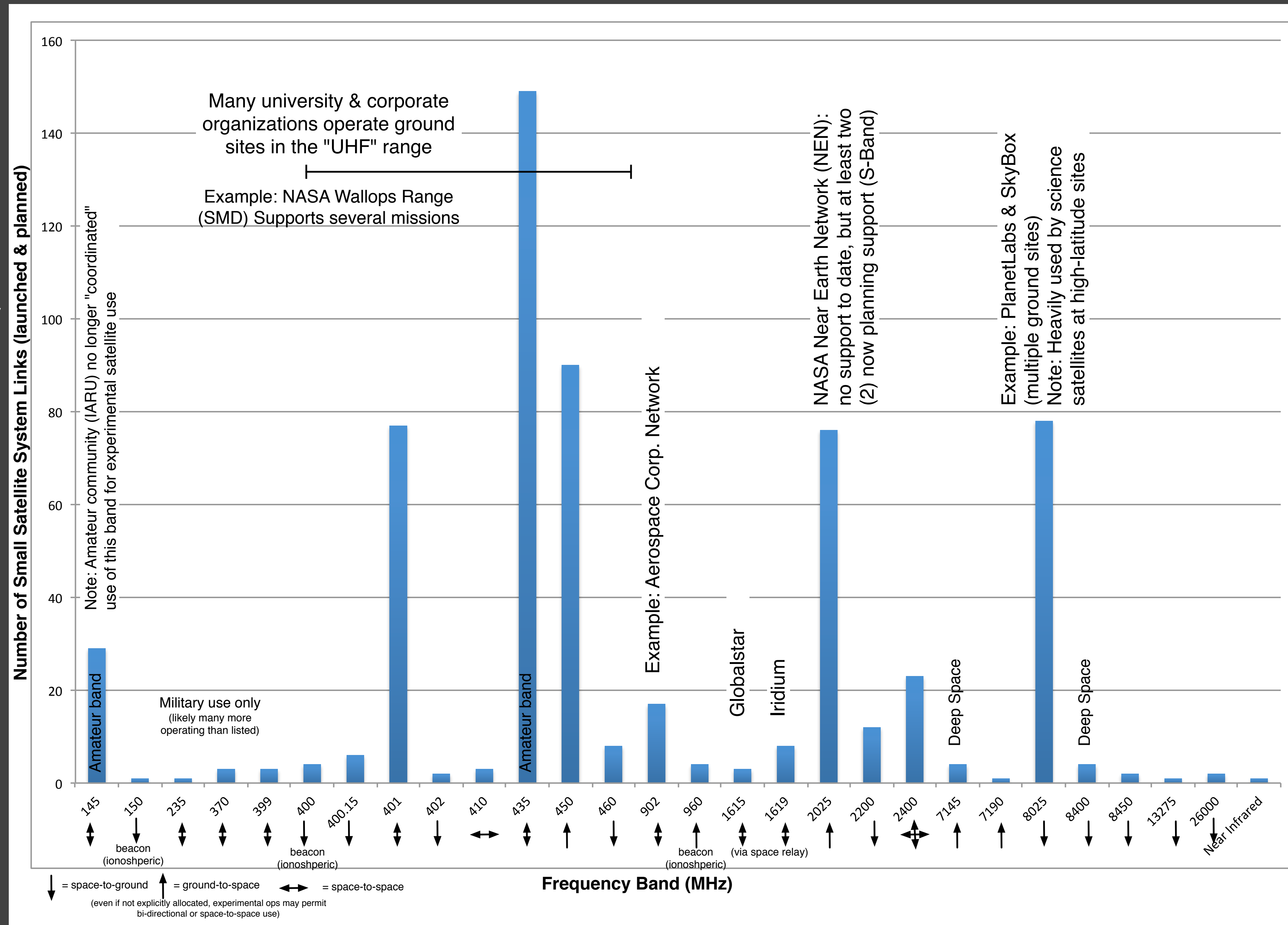
< Left: Studies show growth in cubesat/smallsats

^ Above: NASA/Spectrum data shows growth in smallsats

. . . and they use the electromagnetic spectrum . . .

Based on partial insight into mission designs, at least 25 different frequency bands have been or are planned to be used by small satellites for communications . . . Not all are appropriate for sustained operations

Other frequency bands have been used for observations (e.g., passive sensors) and other mission objectives (e.g., asset monitoring (e.g., AIS))



. . . and small satellites must follow all applicable spectrum regulations and processes!

From a spectrum requirements and frequency coordination perspective, small satellites (e.g., nanosatellites, picosatellites, etc.) can not be defined as a distinct satellite class . . .

An emitter is an emitter no matter what size the platform (spacecraft)

(per ITU studies completed per ITU WRC-12 request)

Existing spectrum regulations apply to ALL spacecraft no matter what size . . .

- Authorization/licensing required
- Must follow regulations including technical parameters (e.g., power flux density limits)
- Must follow satellite notification and coordination processes

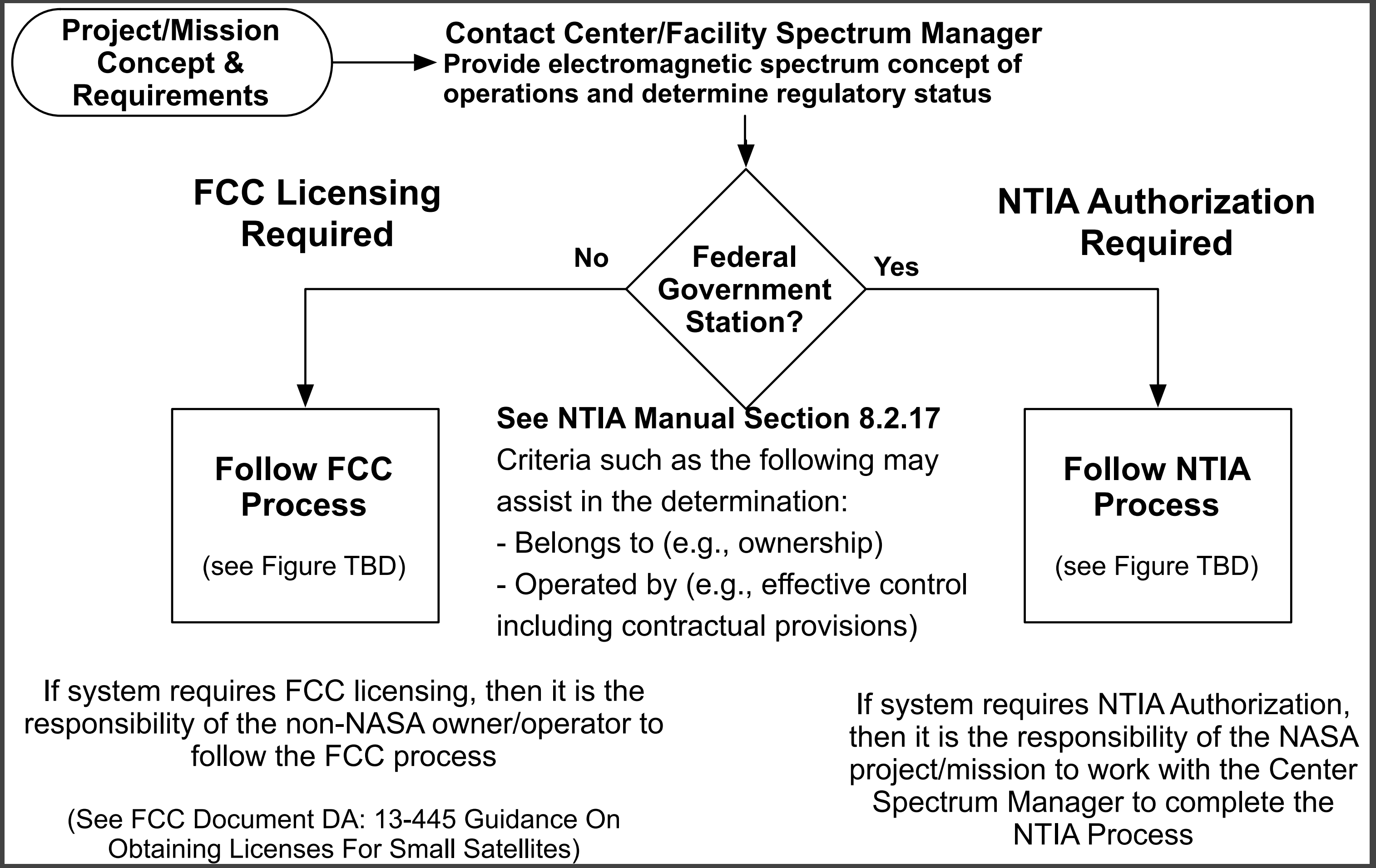
Key Considerations for any small satellite developer:

Seek spectrum guidance and Prepare a mission operations plan to guide and define needed access to the electromagnetic spectrum BEFORE designing or procuring any spectrum dependent sub-systems (e.g., transmitters, antennas, etc.)

- For NASA or NASA-affiliated missions, contact the appropriate NASA Center Spectrum Manager or NASA/HQ Spectrum, see: http://www.nasa.gov/content/spectrum-points-of-contact/

For US systems, determine the Federal or Non-Federal status since the status defines which regulatory agency and rules are involved for frequency authorization

- Note: A single spacecraft may host both Federal and Non-Federal communication systems depending upon the operations and contractual arrangements (e.g., hosted payloads)



Key Considerations for any small satellite developer:

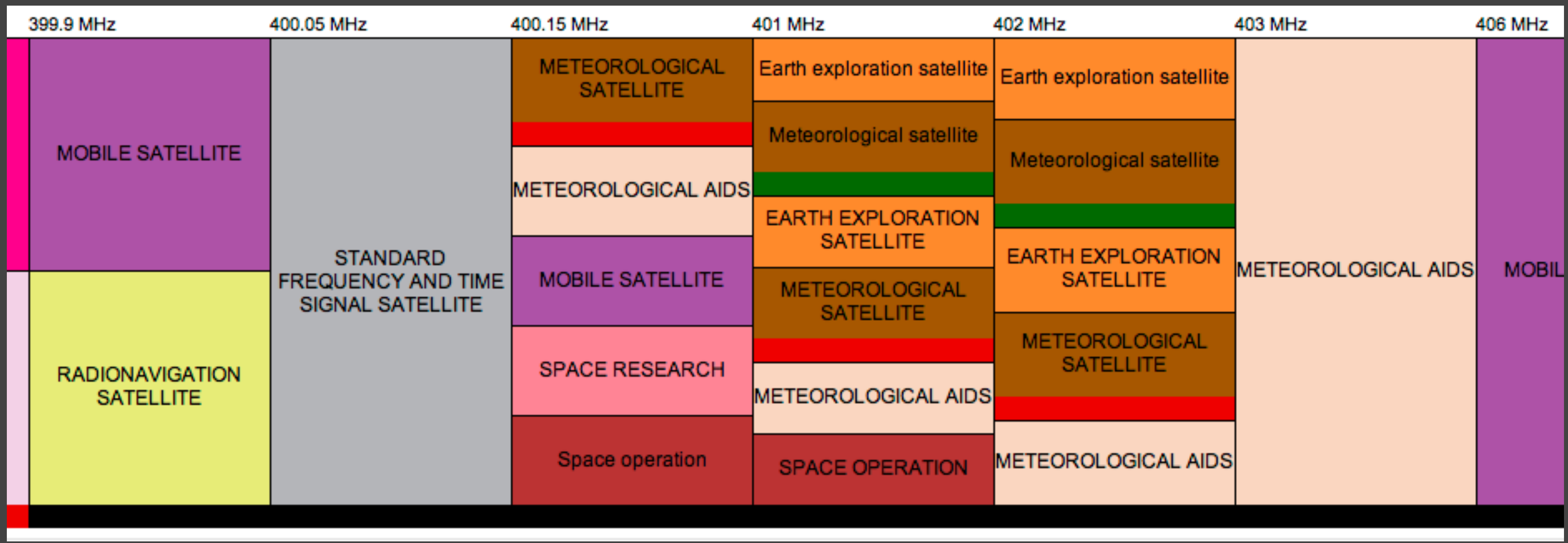
Select network support and frequency bands based on the mission needs (e.g., location, data transport (data volume, latency)) and type of mission (e.g., space research, Earth exploration):

- *Radiocommunication service*: A service involving the transmission, emission and/or reception of radio waves for specific telecommunication purposes

- *space research service*: A radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes

Frequency bands around 400 MHz have been used by small sats for basic Telemetry, Tracking, and Command (TT&C) operations –

Many other frequency bands are allocated for services for space systems



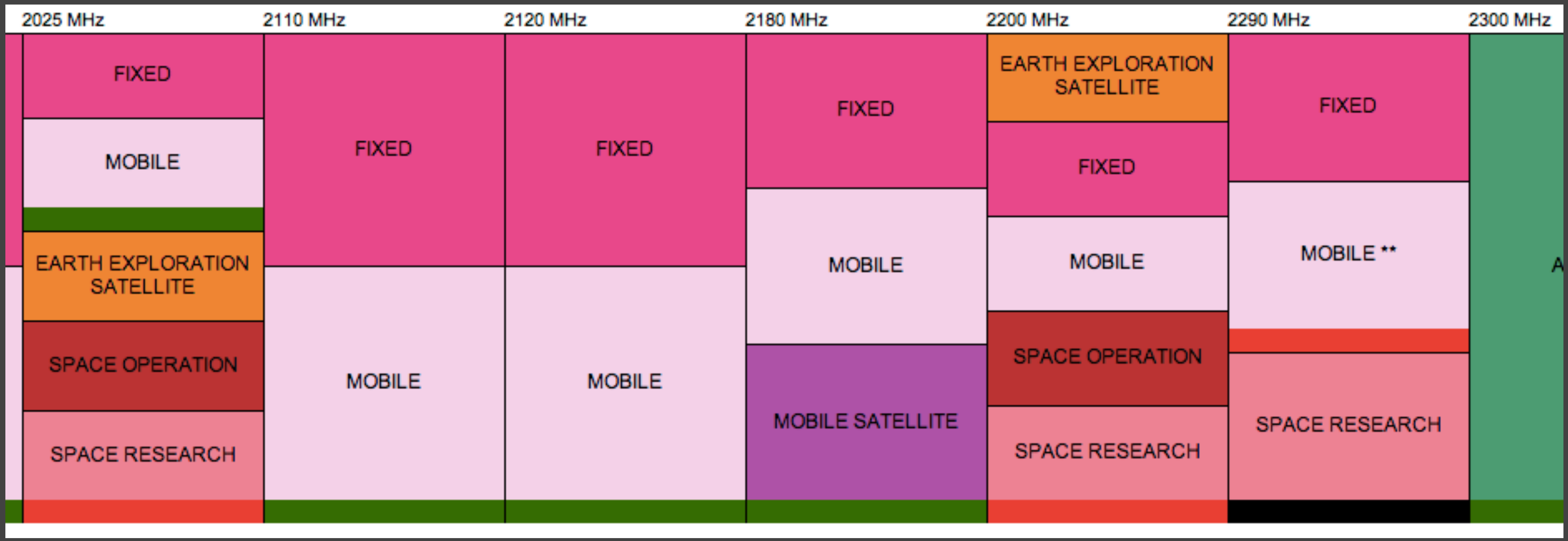
Key Considerations for any small satellite developer:

For non experimental science and exploration systems, selection of the frequency band should consider long-term network support and regulatory protection

- Several bands are supported by multiple networks and have full regulatory protection (see below)
- To date, many small sat systems operate under a temporary, experimental license and operate in frequency bands (e.g., amateur, ISM bands (902-928 MHz)) that are not designated for satellite communications and thus, while useful for experimentation, are not necessarily good for the long-term development of the community

Bands with significant support and regulatorily available for inter-planetary (both near-Earth and deep space) small sats include, but are not limited to:

- Bands around 400 MHz
- 2025-2120 MHz & 2200-2300 MHz
- 7145-7235 MHz & 8400-8500 MHz
- 25.5-27.0 GHz
- 31.8-32.3 GHz & 34.2-34.7 GHz



* US252 The band 2110-2120 MHz is also allocated to the space research service (deep space) (Earth-to-space) on a primary basis at Goldstone, CA (35° 20' N, 116° 53' W).

Key Considerations for any small satellite developer:

Spectrum service allocations to specific frequency bands make a distinction for deep space (to afford additional protection), so missions need to consider where they operate when selecting frequencies and defining operational scenarios

Deep Space: Space at distances from the Earth equal to or greater than 2×10^6 kilometers (ITU)

Space Research (Deep Space) allocations supported by NASA's Deep Space Network (DSN):

- 2110-2120 MHz (Earth-to-space) & 2290-2300 MHz (space-to-Earth)
- 7145-7190 MHz (Earth-to-space) & 8400-8450 MHz (space-to-Earth)
- 31.8-32.3 GHz (space-to-Earth) & 34.2-34.7 GHz (Earth-to-space)

To coordinate deep space support with the DSN or other deep space networks, missions are encouraged to coordinate with the NASA JPL Center Spectrum Manager (contact info on title chart)

Key Considerations for any small satellite developer:

Besides basic regulatory service allocations, Earth and space systems must also follow applicable technical parameters to protect other systems operating in the frequency band or neighboring bands Example technical criteria include, but are not limited to:

- Earth Station Power Limits: To protect other systems, some bands limit an Earth station's equivalent isotropically radiated power (EIRP) toward the horizon and specified antenna elevation angles above the horizontal plane
- Power flux density (pfd) limits: To protect terrestrial system operations, many frequency bands have limits on the power incident on the Earth for a reference bandwidth
  - Example: For 460-470 MHz, the power flux density produced at the Earth's surface by any space station in this band shall not exceed -152 dBW/m²/4 kHz
- Out of band emissions (spectral masks): To protect systems operating in adjacent bands, many system types and frequency bands have limits on out of band emissions
  - Filtering and other signal shaping techniques may be required
- Bandwidth constraints: some frequency bands constrain transmission bandwidths or follow channel plans
  - Example: Per US policy, signals in the 2200-2290 MHz band are limited to 5 MHz or less

Case Study: A recent cubesat mission was required to implement a software change to comply with pfd limits only one week prior to integration in its deployment system; full testing was not possible thus increasing mission risk – Don't let this happen to your mission!

Work with the appropriate NASA Center Spectrum Manager or spectrum advisor to ensure compliance with regulatory constraints!

Other spectrum-related items developers need to know:

Launch-related requirements may include:

- Frequency Licensing/Authorization: The mission must obtain frequency licensing/authorization prior to integration on the launch vehicle; the integration date prior to launch will be set for each event (may be 3 months or more before launch)
- Inhibit and Delayed Communications: The small satellite shall not generate or transmit any signal from the time of integration into the launch container/deployer (e.g., PPOD) through a specified time period (e.g., 45 minutes) after on-orbit deployment (Note: time period depends on launch vehicle or system)
- Permissible Exposure Limit (PEL) & Electromagnetic Interference (EMI): Some launch systems and ranges may require compliance with PEL and EMI standards

Orbital Debris: NASA systems and non-Federal systems, as part of the FCC licensing process, must follow standards and provide information and analysis concerning orbital debris mitigation;
see http://orbitaldebris.jsc.nasa.gov/index.html

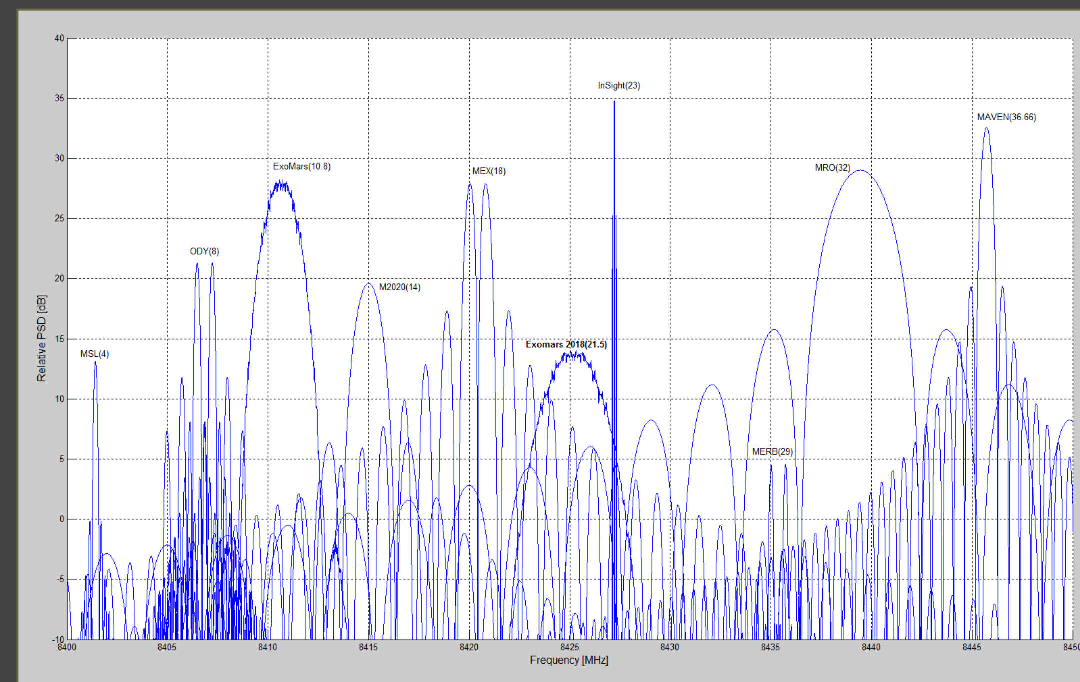
Note: Planetary protection criteria may also be required for interplanetary spacecraft

Coordination and future prospects:

A key consideration for interplanetary (beyond GEO) small sats is how to support increasing numbers recognizing the likely limited number of ground stations and key operational scenarios . . .

- Asset contention: Deployment of multiple spacecraft during a launch or operations clustered in key regions of space (e.g., Mars) will co-locate systems increasing chance for interference
- Tracking: Interplanetary smallsats may need to use the spectrum for significant amounts of time to support long tracking passes (2-way) necessary for trajectory and location determination

Case Study: On more than one launch event, small sats have had difficulty determining which one of the multiple "tracked" systems (from the published orbital elements ("TLEs")) is theirs and have requested unplanned support from networks (e.g., NASA's networks) – such support could not be provided due to incompatibilities



Congested Area: Mars Frequency Assignments in the Deep Space 8400-8450 MHz Frequency Band

Coordination and future prospects:

When defining operations and selecting spectrum parameters, coordinate with others:

- Follow ITU and domestic satellite notification and coordination processes
  Note: Small sats are not exempt from FCC or NASA processes for notifying systems
- Work with service provider to develop appropriate support plan and service scheduling mechanism
- Use standard signal interfaces and protocols to increase inter-operability across ground networks
- Exploit all dimensions of the spectrum space (e.g., frequency, time, polarization, location, directionality, signal format) to avoid interference
- Just “pick up the phone” and coordinate

Case Study: NASA did not support (and thus the FCC rejected) use of ground assets at a high latitude site useful for polar sun-synch orbits because of possible radiofrequency interference due to potential overlap in services between NASA and the licensee spacecraft–the licensee did not communicate with NASA and did not attempt to coordinate use so the licensee was limited to other ground station support

Future: Establishing processes for spectrum planning, operational coordination, and developing new technologies (e.g., space internetworking, protocols for shared assets (e.g., shared control channels (uplinks), etc.) may be useful to ensure successful operations and to avoid radiofrequency interference

Work with the appropriate NASA Center Spectrum Manager or spectrum advisor to ensure compliance with regulatory constraints and successful operations!