Status of V2X in the United States

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Toyota InfoTech Labs

Toyota Motor North America

Base: Mountain View Research Park (US Headquarters)

Location: Mountain View, California

Established: April 2001

Formerly known as Toyota InfoTechnology Center

Approx. 50 research staff

Outline

- Background
- Regulation Status
- Standards Status
- Deployment considerations

V2X is … Vehicle to Everything

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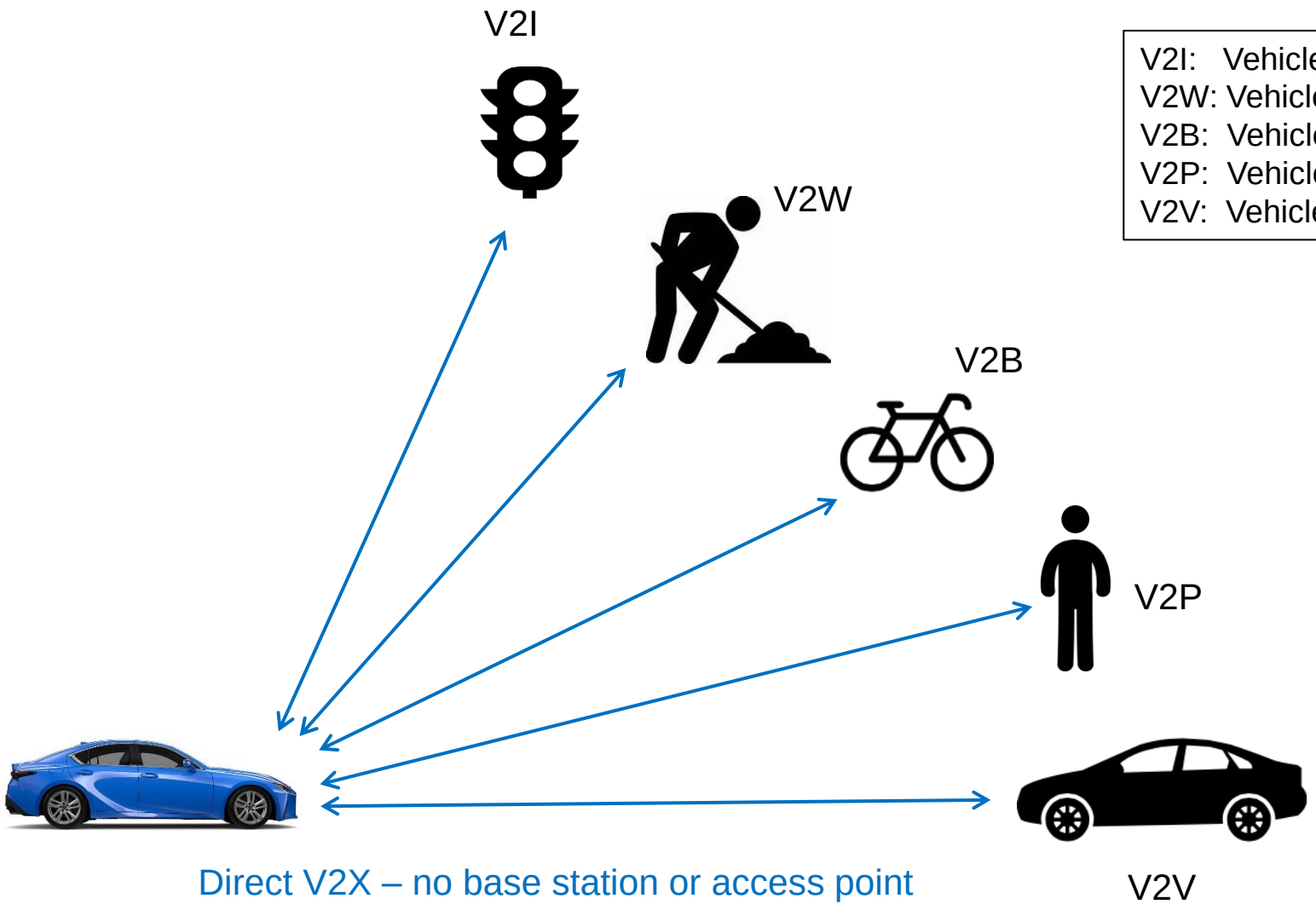
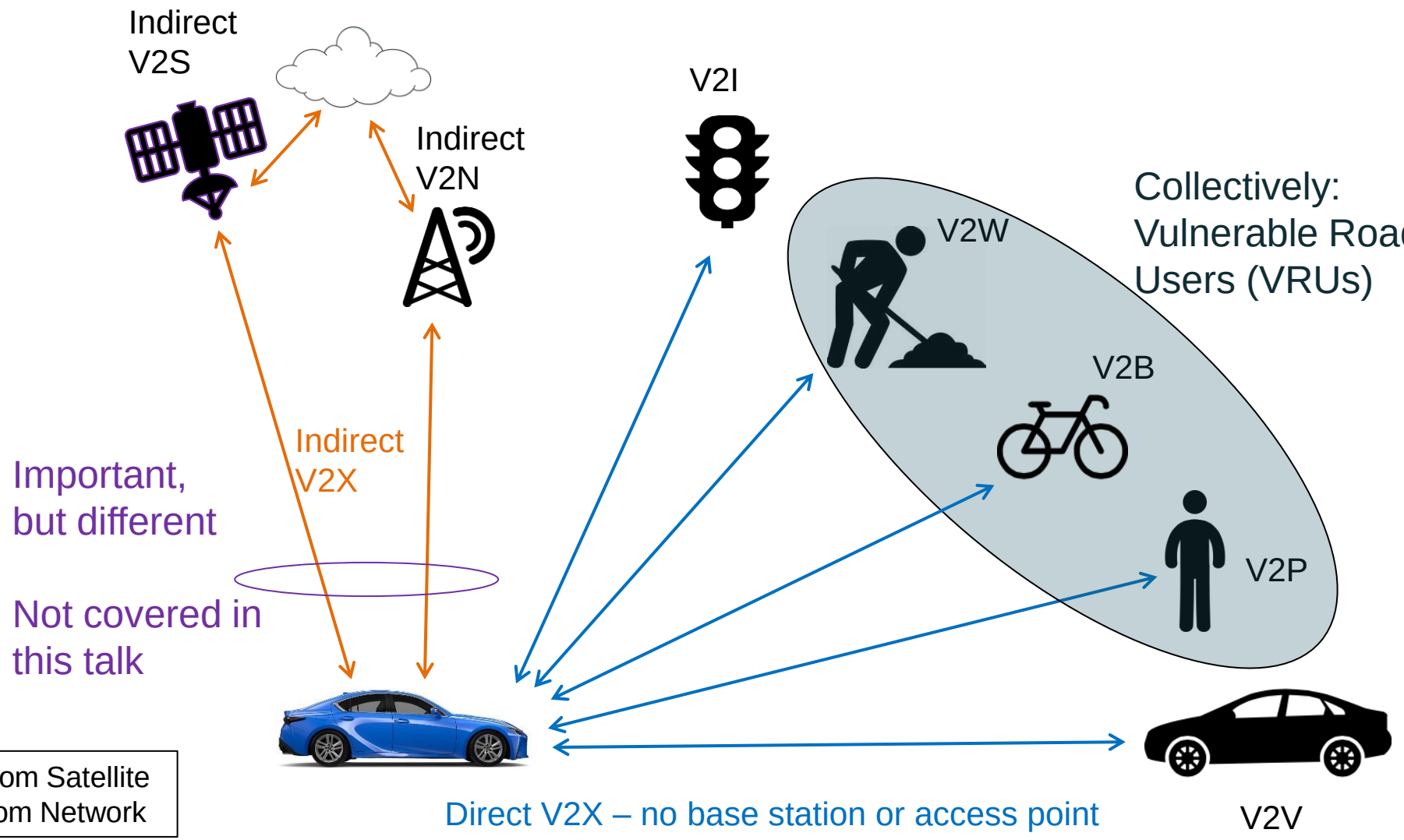


V2I: Vehicle to/from Infrastructure
V2W: Vehicle to/from Worker
V2B: Vehicle to/from Bicycle
V2P: Vehicle to/from Pedestrian
V2V: Vehicle to/from vehicle

Direct V2X – no base station or access point

What about indirect via a network?



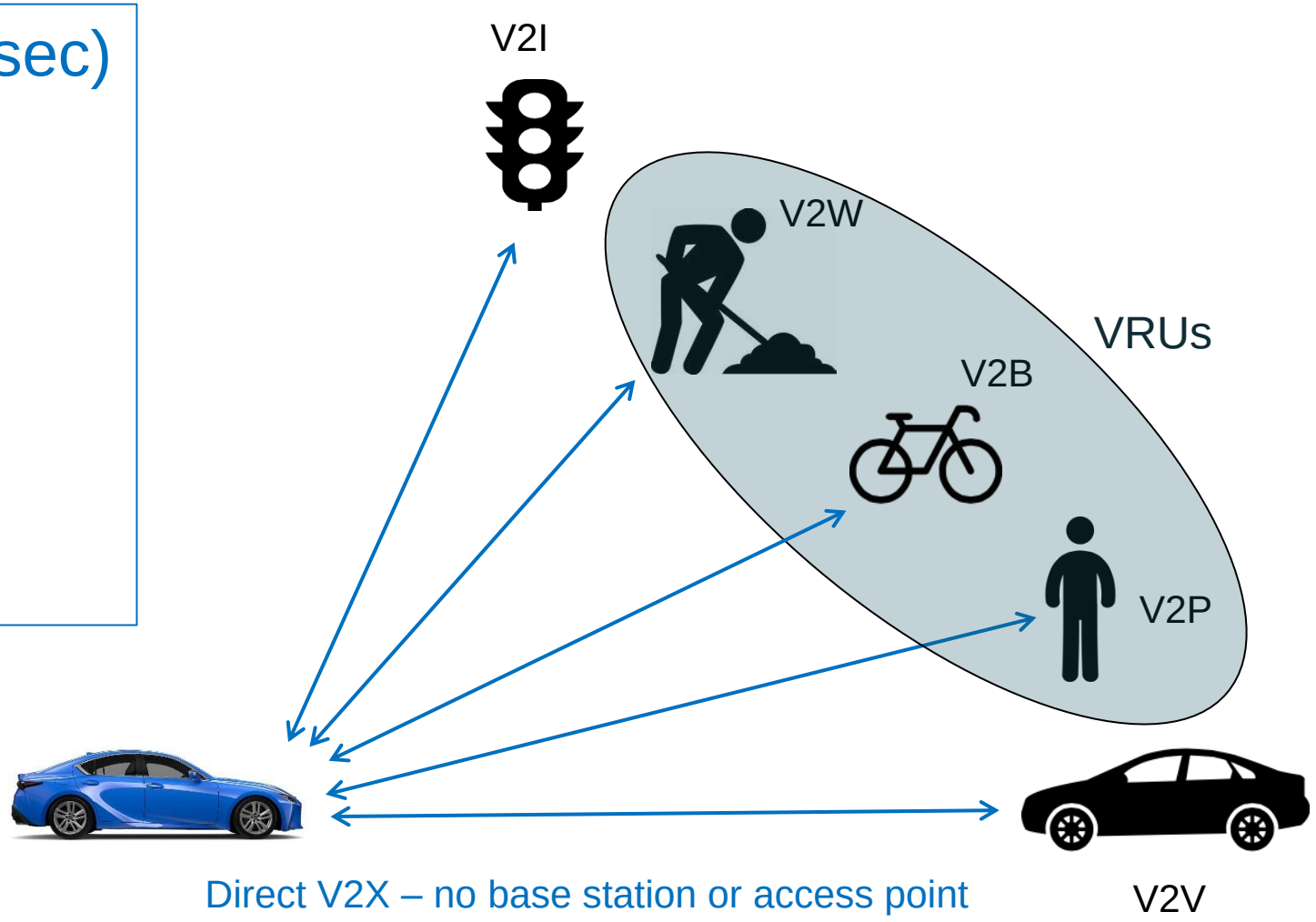
V2S: Vehicle to/from Satellite
V2N: Vehicle to/from Network

Key characteristics of direct V2X

- Low latency (msec)
- 100s meters
- Free spectrum
- Ad hoc

Base Station

Access Point

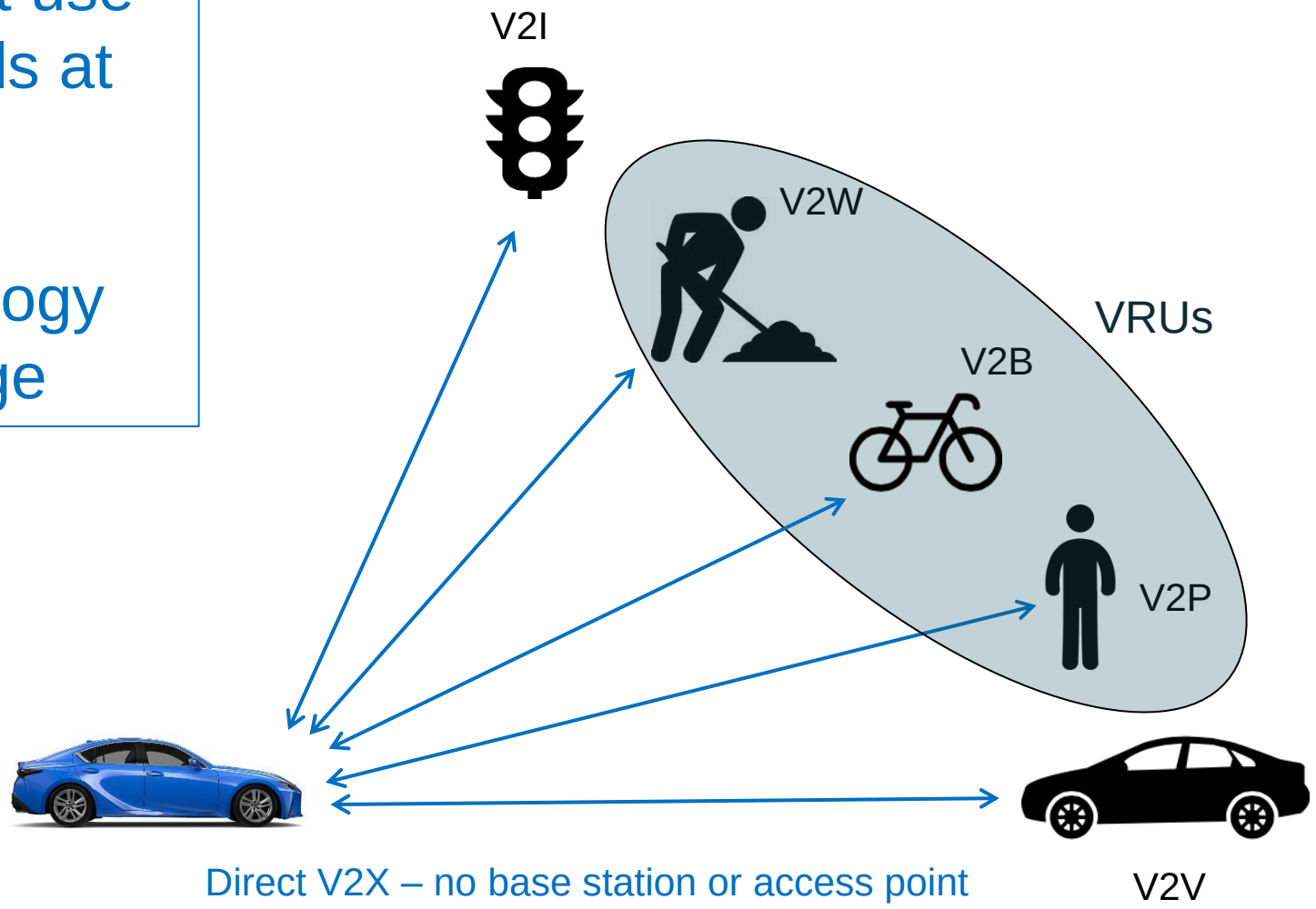


Direct V2X – no base station or access point

Key requirement: Interoperability

V2X devices must use the same protocols at every layer

Creates a technology evolution challenge



Direct V2X – no base station or access point

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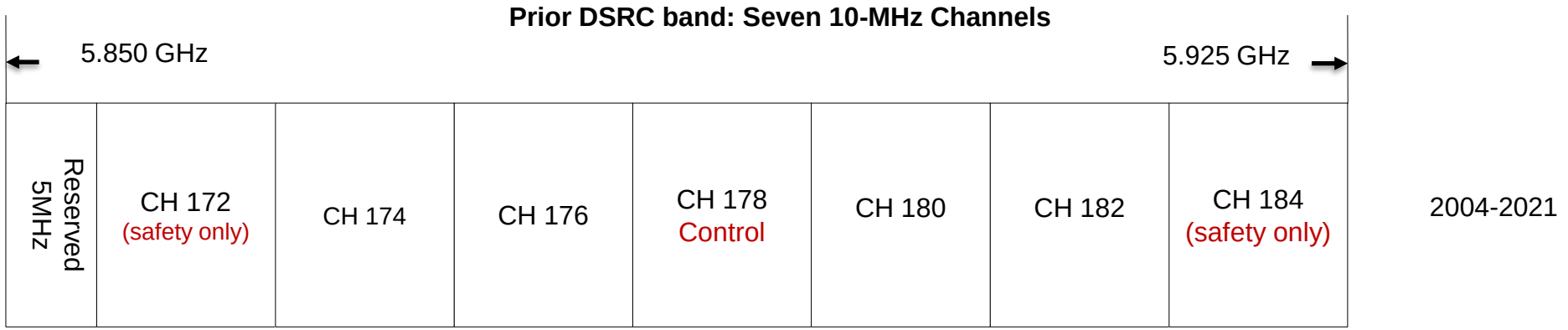
US ITS Spectrum: Background

- Federal Communications Commission (FCC) created ITS band rules in 2004:
- 75 MHz total spectrum, must use DSRC protocol:

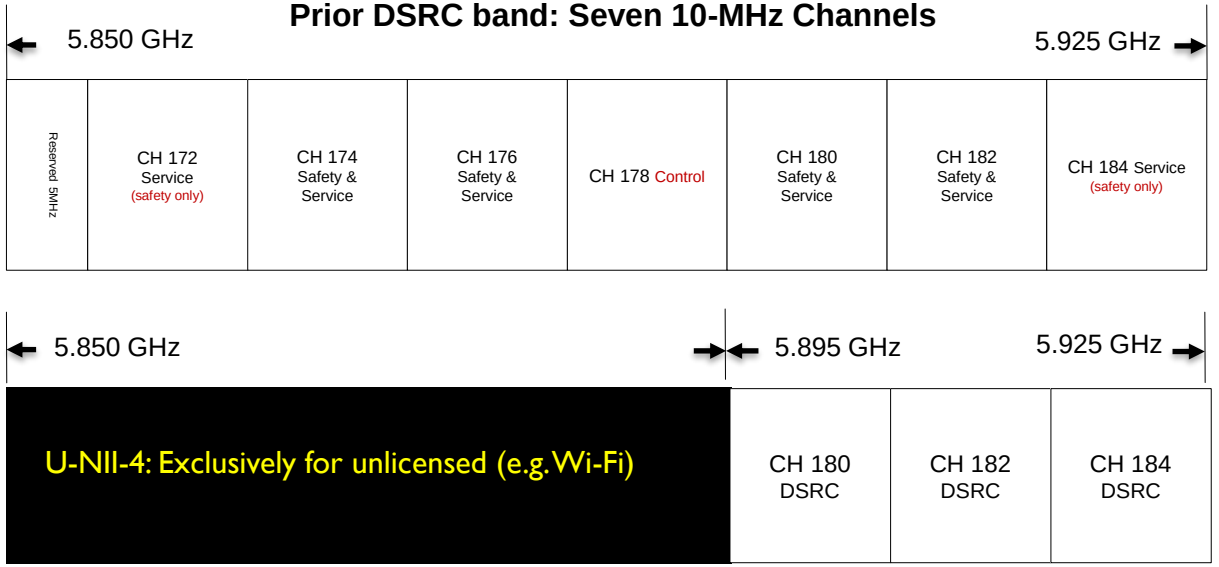


- 2013: FCC proposed allowing Wi-Fi to share lower 45 MHz (4 channels)
- 2018: Advocates of LTE V2X protocol seek to remove DSRC rules.
- 2020: FCC issued new 5.9 GHz rules (see next slide)

Spectrum: new 5.9 GHz rules from FCC

From this …

… to this



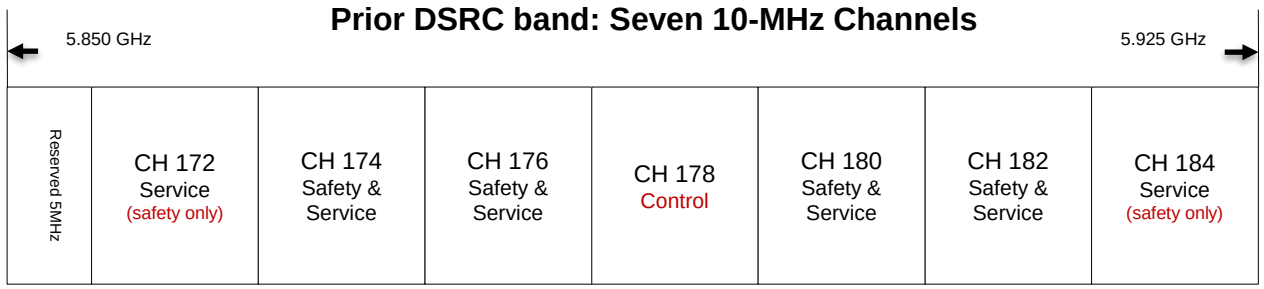
- 1st R&O took effect July 2021. Wi-Fi deployment started.
- DSRC below 5895 MHz moved or stopped by July 2022

First Report and Order (2021)

- 75 MHz → 30 MHz (3 original channels remain)
- Unlicensed band for Wi-Fi takes over lower 45 MHz (no sharing with V2X). Indoor use only
- Wi-Fi interference threatens remaining V2X
- FCC intends to switch from DSRC to "C-V2X" (but not yet)

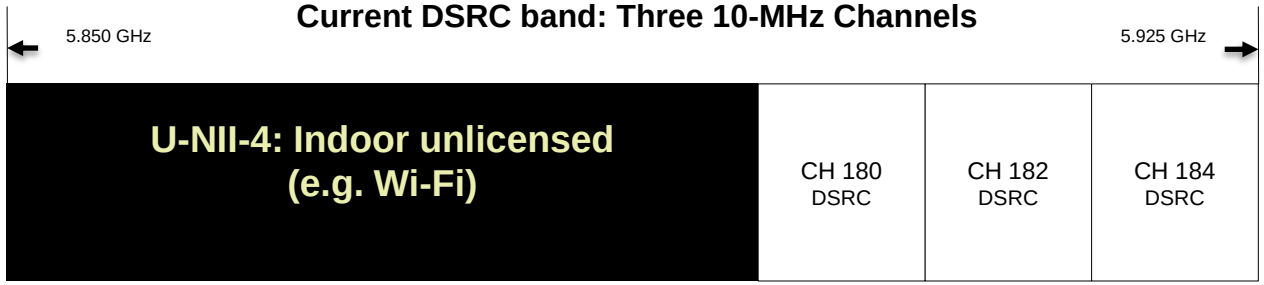
After future additional rule changes from FCC:

From this …



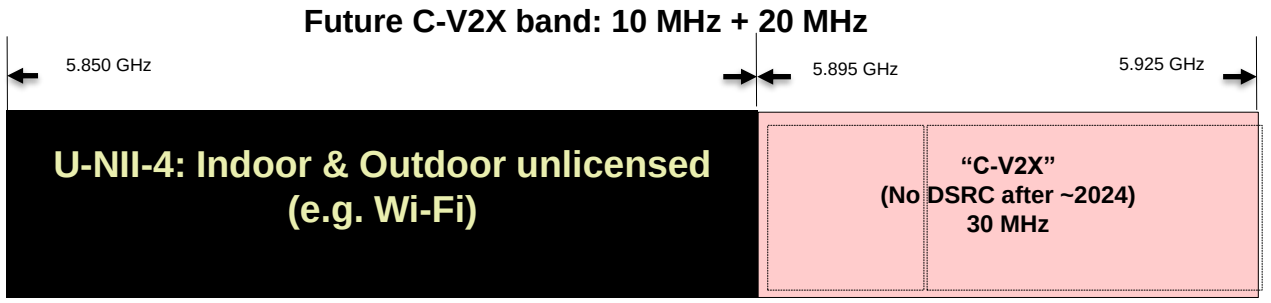
2004-2020

… to this



NOW
1st FCC R&O

… to this



Proposed
After 2nd R&O and transition

FCC will only permit LTE V2X in a few years

R&O = Report and Order

Spectrum (continued)

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FCC Proposal for 2nd Report & Order (2021)

- Propose to define "C-V2X" as Release 14 LTE V2X and establish detailed rules
- Propose transition timeline from DSRC to C-V2X (2 years from 2nd R&O)
- Propose to allow outdoor U-NII-4 (double-edged sword for V2X)
- 2nd R&O will not be issued before waivers are decided (see below). Likely not until 2024.

R&O = Report and Order

Waiver requests to deploy LTE V2X now

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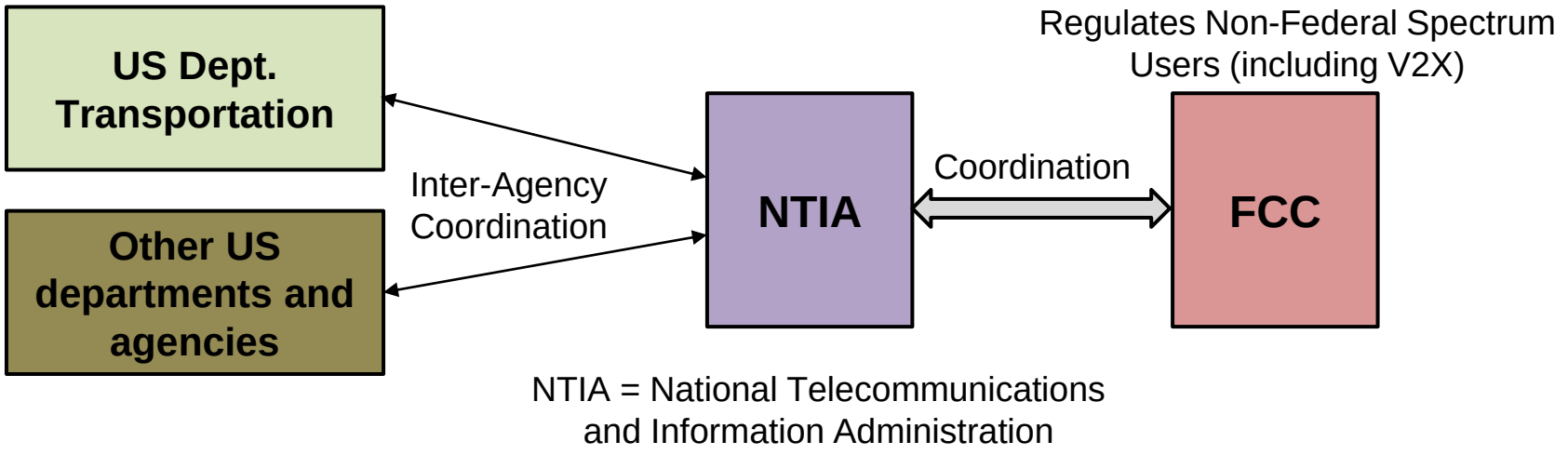
- Current FCC rules still require DSRC
- FCC says they will accept waiver petitions for early LTE V2X deployment
- Several waiver requests have been filed with FCC
- FCC has not decided on any waivers yet

“Joint” Waiver request

The largest waiver request was filed by 14 stakeholders: The “Joint” Waiver

- Filed in December 2021
- One large US automaker, two US states, other stakeholders
- Request permission to deploy LTE V2X now, with certain parameters including 33 dBm EIRP maximum transmit power
- FCC collected public comments in July 2022. Auto industry comments supported the waiver.
- FCC has not acted on this request yet.



- Expect waivers to be decided in 2023
- Regulatory summary: Eventually rules for widespread deployment will be in place

US Department of Transportation

- US DOT Strongly opposed FCC First Report and Order
- V2X Summit August 24-25, 2022 (Washington DC)
  - Strong consensus shown for V2X benefits
  - US DOT (Volpe) presented LTE V2X field test results
    - Focus on Wi-Fi Interference and high vehicle density
  - Funding available for V2X infrastructure
  - Attendees requested USDOT to set a national roadmap toward deployment
- Next US DOT V2X Public Meeting: April 28
- No indication that US DOT/NHTSA will renew V2X mandate initiated in 2017

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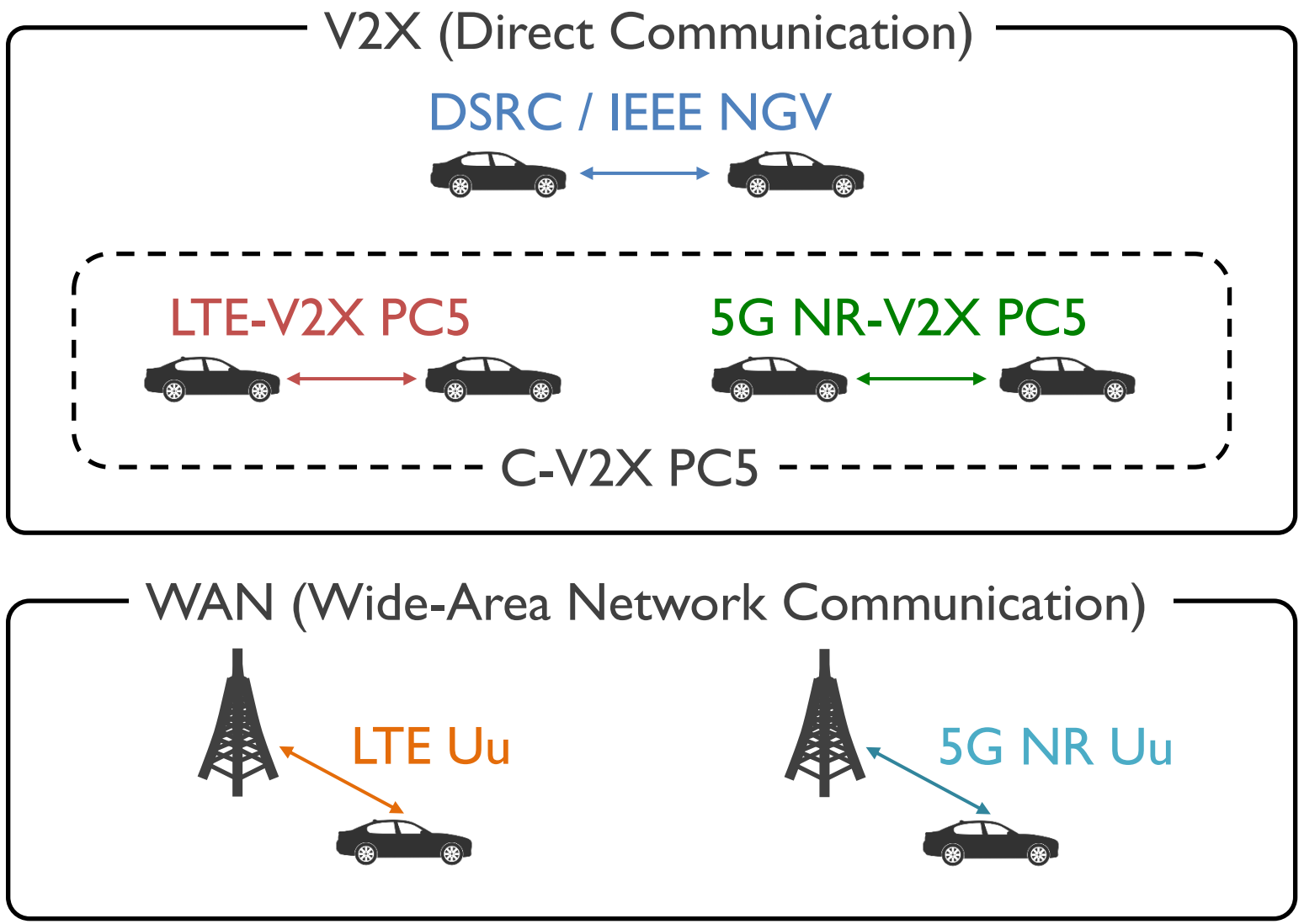
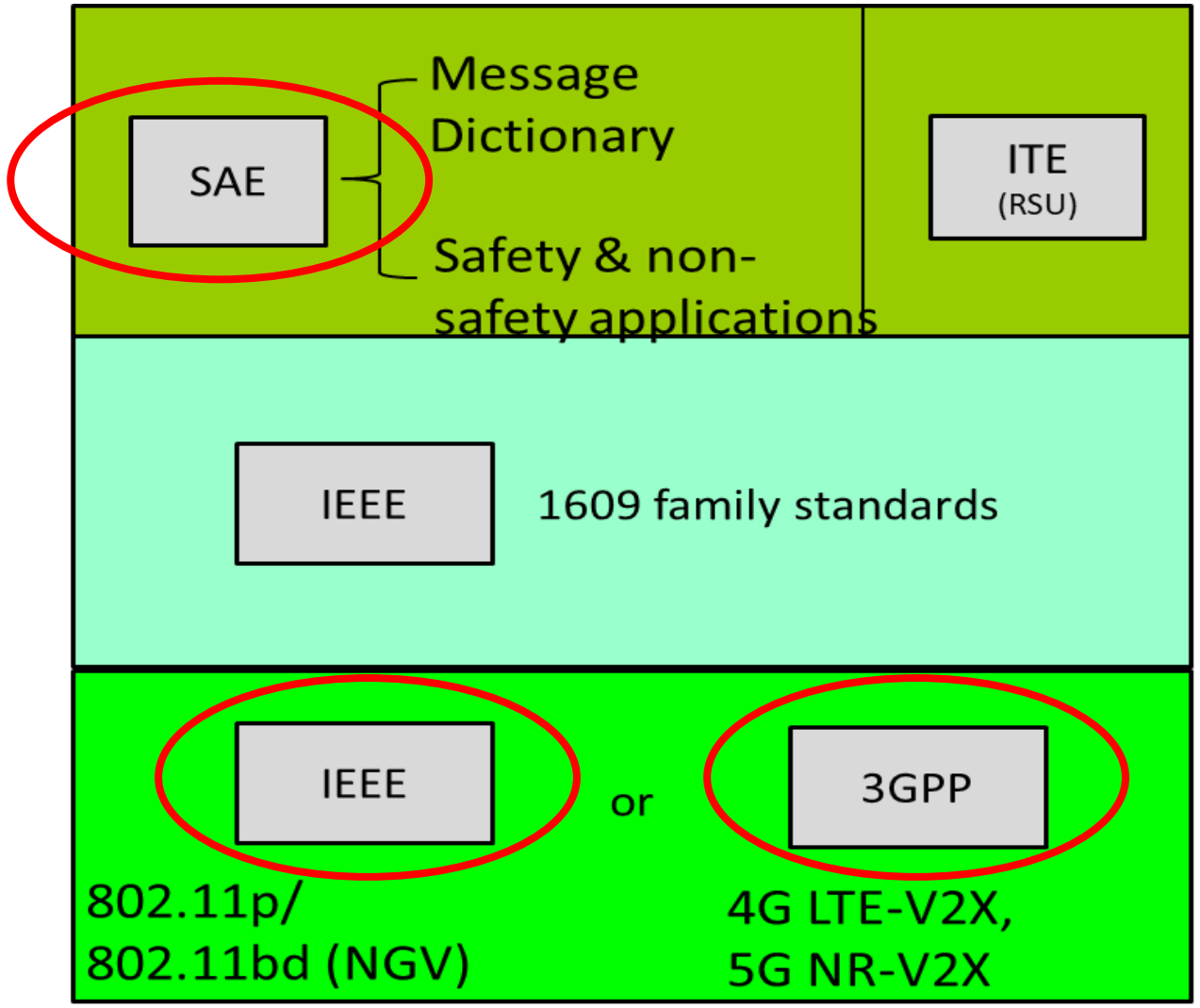
Standards: Taxonomy of V2X Technologies



PC5 interface is also called "Sidelink" in 3GPP

V2X Standards for the US

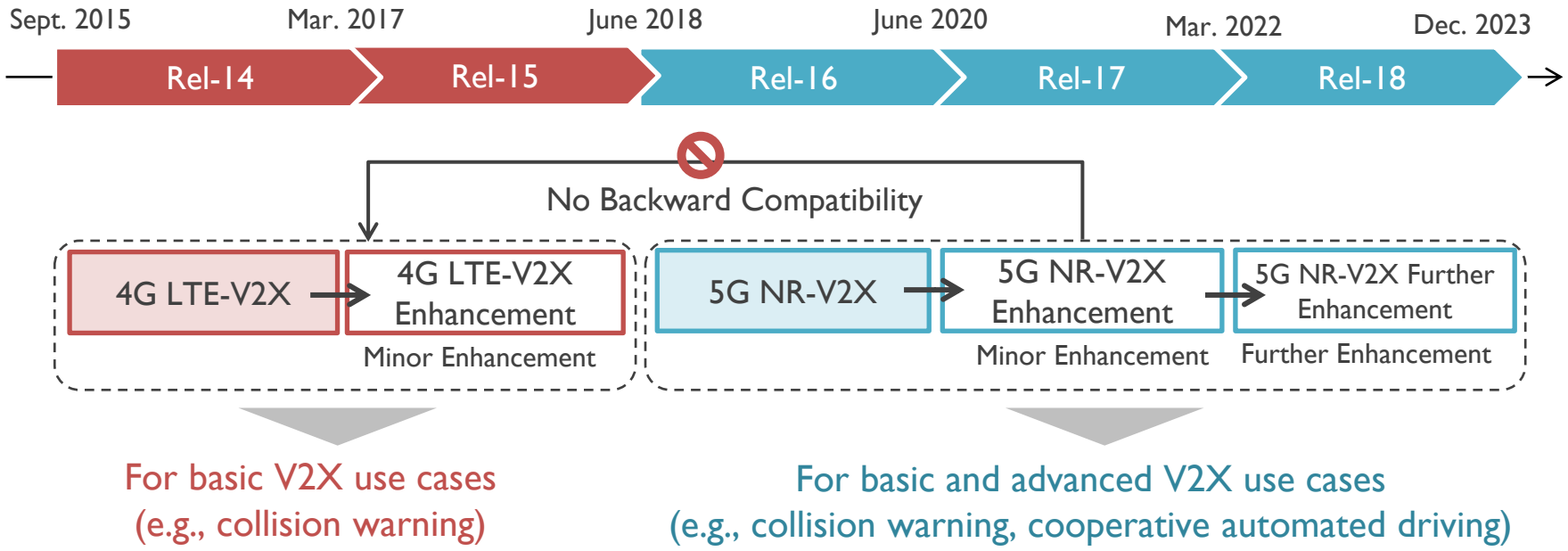


Standards: 3GPP

3GPP is working on Rel-18 5G NR-V2X Further Enhancement.

NR: New Radio

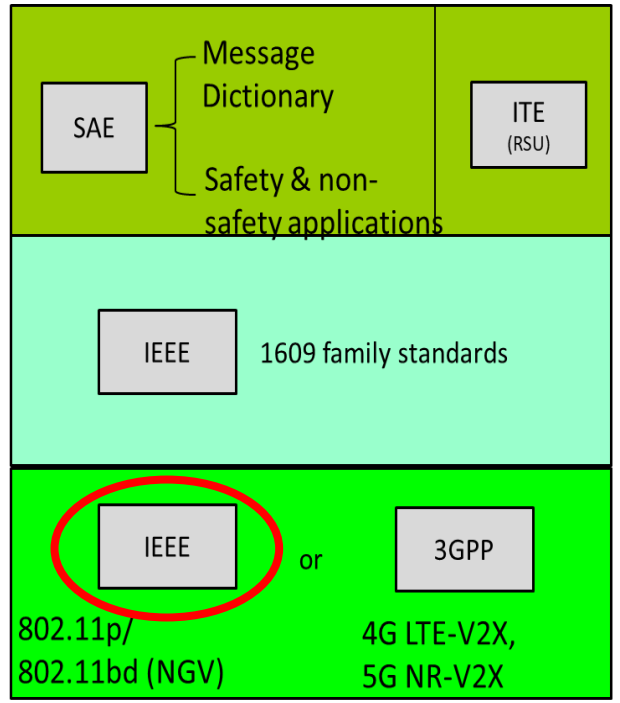
3GPP standardization timeline

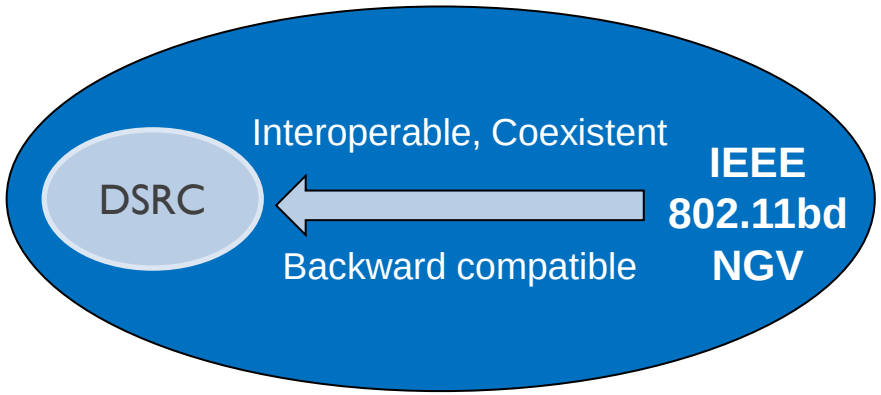


NR = New Radio

Standards: IEEE 802.11bd NGV

- NGV = Next Generation V2X = "DSRC+"
- Amendment to IEEE 802.11 standard
- Will be published very soon (work is complete)
- State of the art PHY, higher data rates & reliability
- 802.11bd is a superset of DSRC, so
  - It is same-channel coexistent, backward compatible, and interoperable with DSRC (802.11p)
  - Seamless evolution for those using DSRC (e.g. JP, EU)

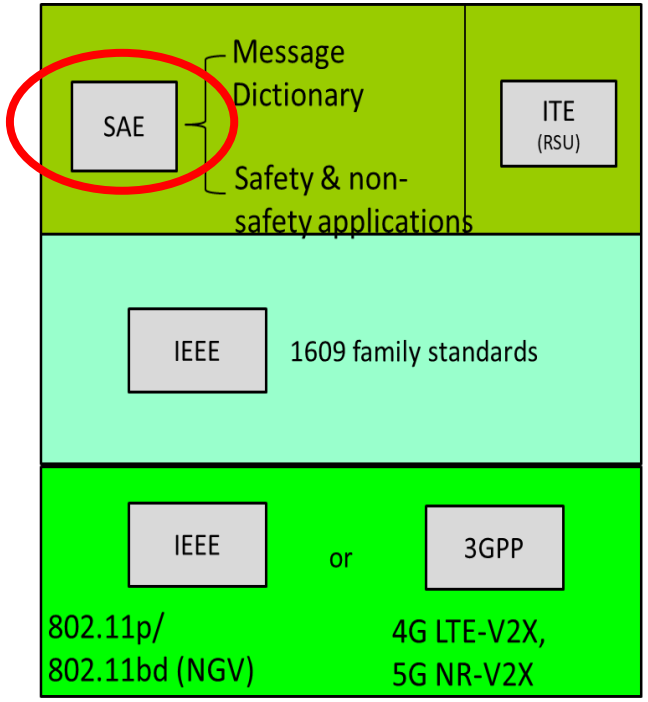




Standards: SAE V2X

Many standards published recently, including:

- J2945/3 V2I Weather
- J2945/5 Security
- J2945/C Traffic Probe Data
- J2735 Message Dictionary (updated)
- J3224 Sensor Sharing
- J3217 Toll Collection
- J3161 LTE V2X profile for Channel 183
- Many others are in progress: V2I Road Safety, Platooning, Signal preemption/priority, …



Summary:
V2X Standards are in place, not holding back deployment

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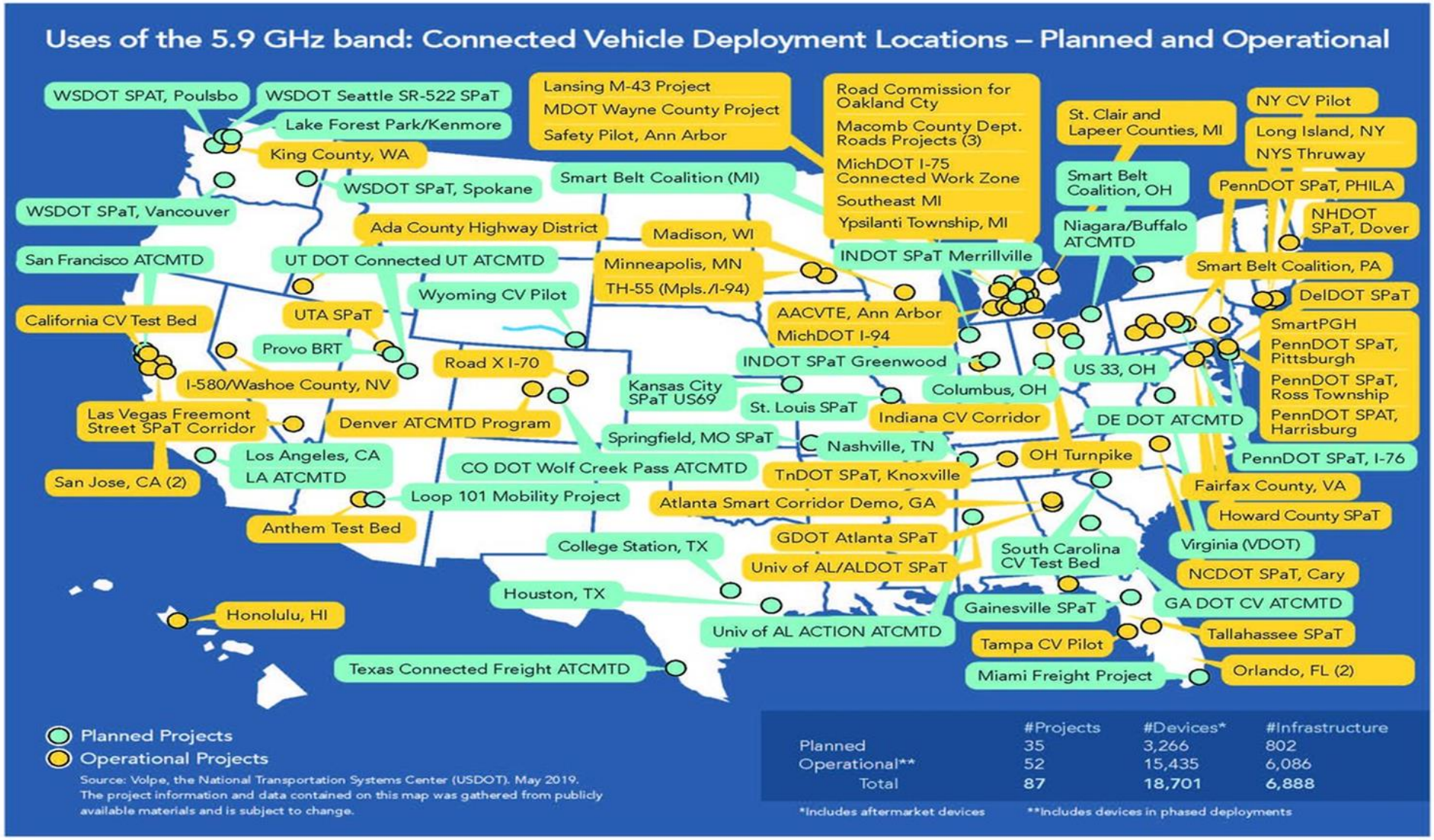
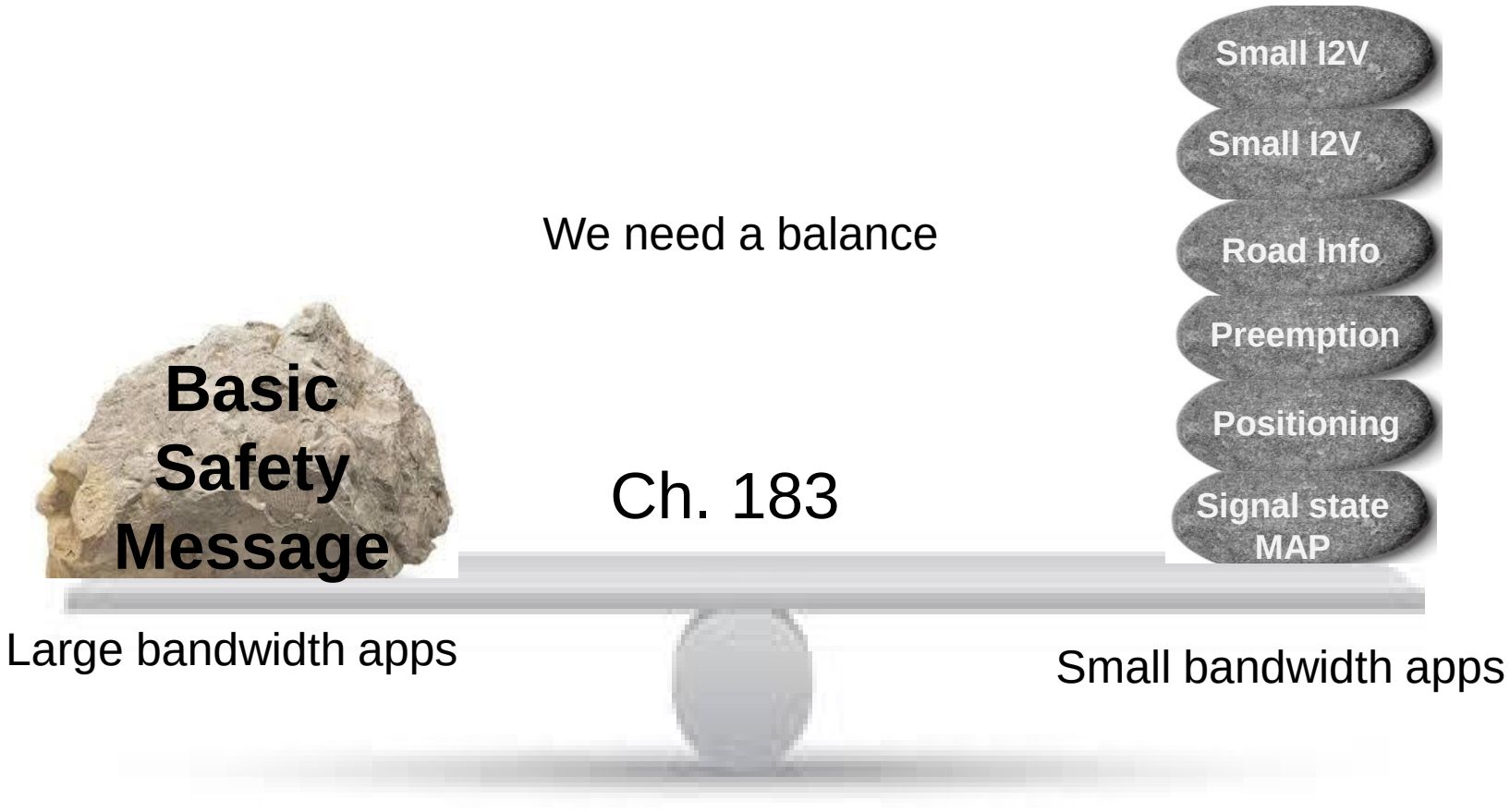
Snapshot of V2X (DSRC) pre-FCC R&O



- 15000 operational devices, not including commercial DSRC deployments started in 2017
- Almost all of these were disabled by 2022

Source USDOT

Deployment: What applications fit in 20 MHz Channel 183?



We need more spectrum beyond 30 MHz

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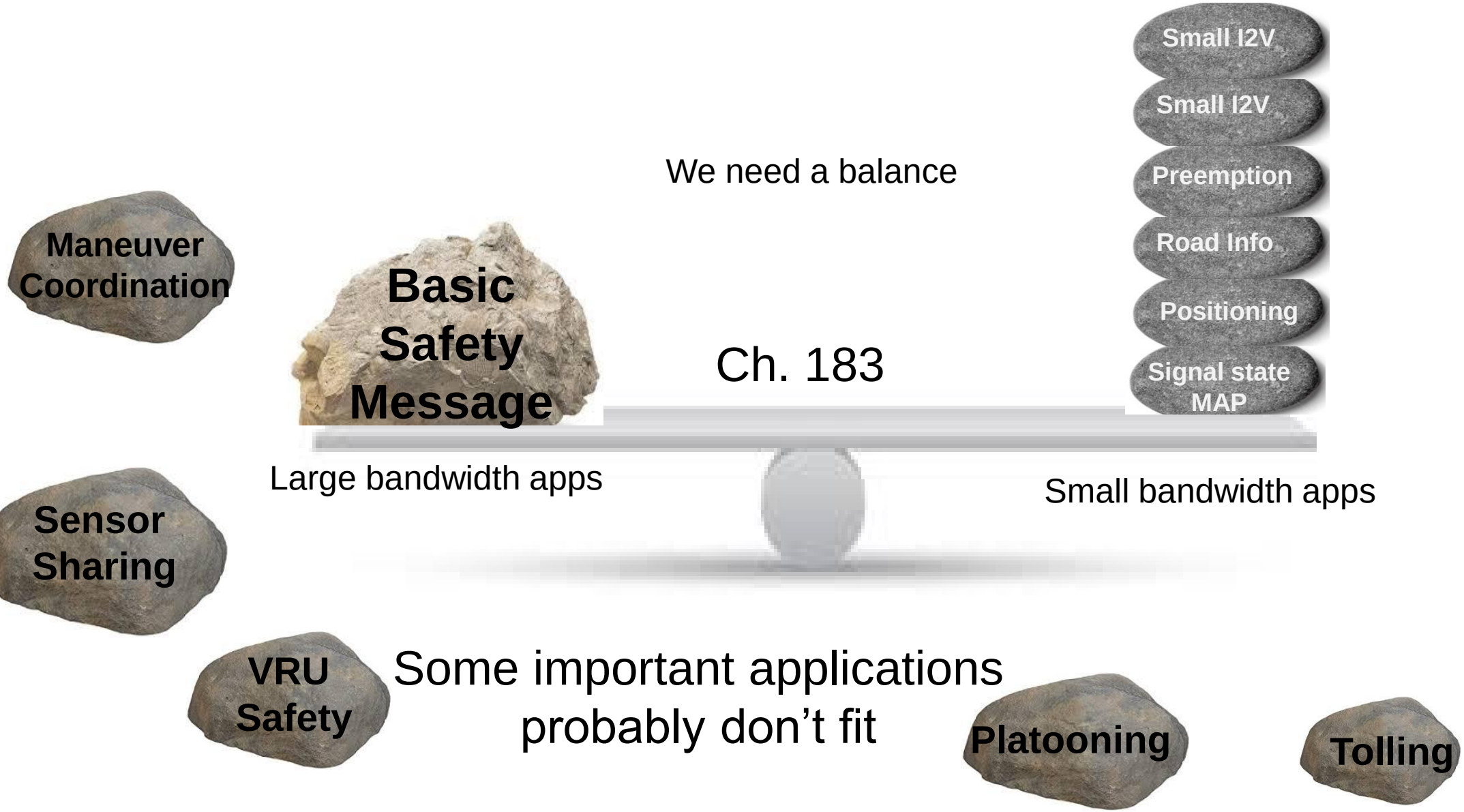

We need more spectrum beyond 30 MHz

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See also ITS America webinar on topic of "What Fits"
https://itsa.org/event/the-future-of-v2x-30-mhz-application-map-webinar/

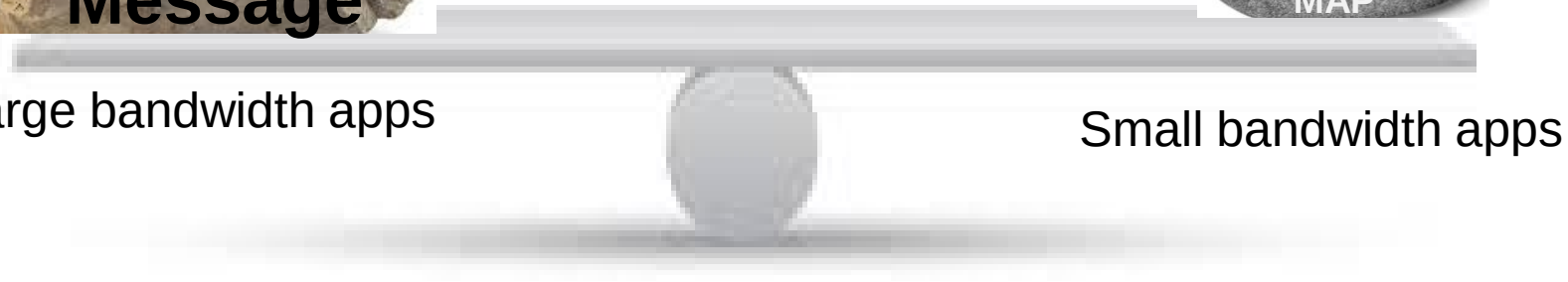
We need a balance

Maneuver Coordination

Basic Safety Message

Ch. 183

Small I2V
Small I2V
Preemption
Road Info
Positioning
Signal state MAP



Large bandwidth apps

Small bandwidth apps

Sensor Sharing

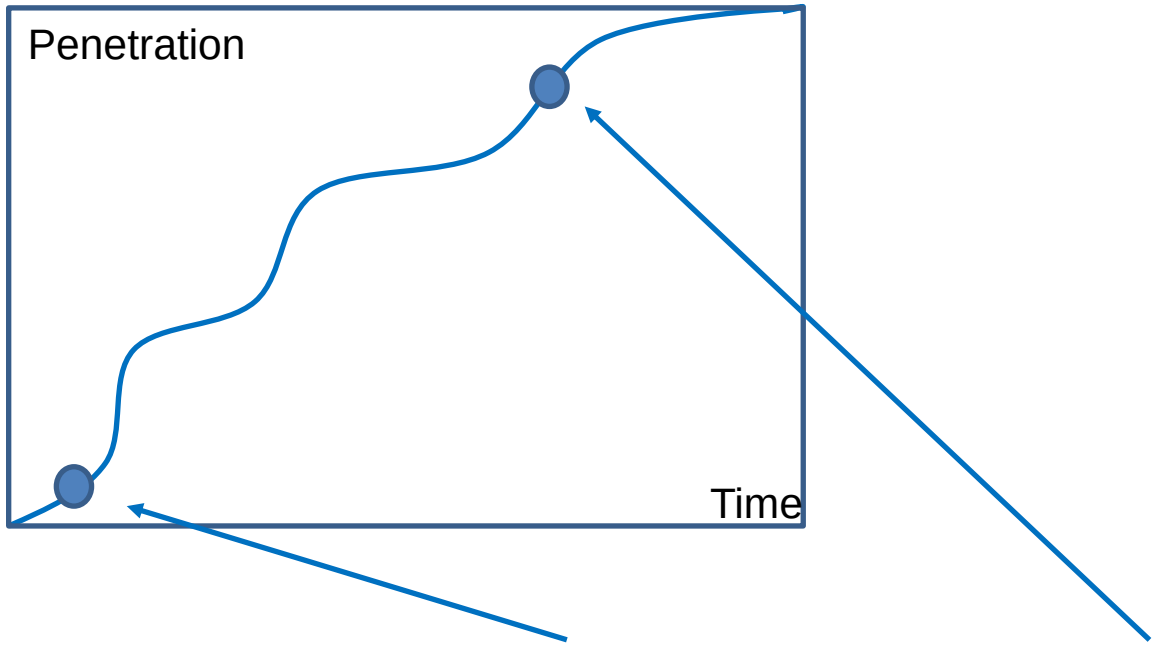
VRU Safety

Some important applications probably don't fit

Platooning

Tolling

Mass deployment is difficult



A deployment stakeholder might say “Why deploy early? If I wait until later my customers will have a higher and more consistent benefit?”

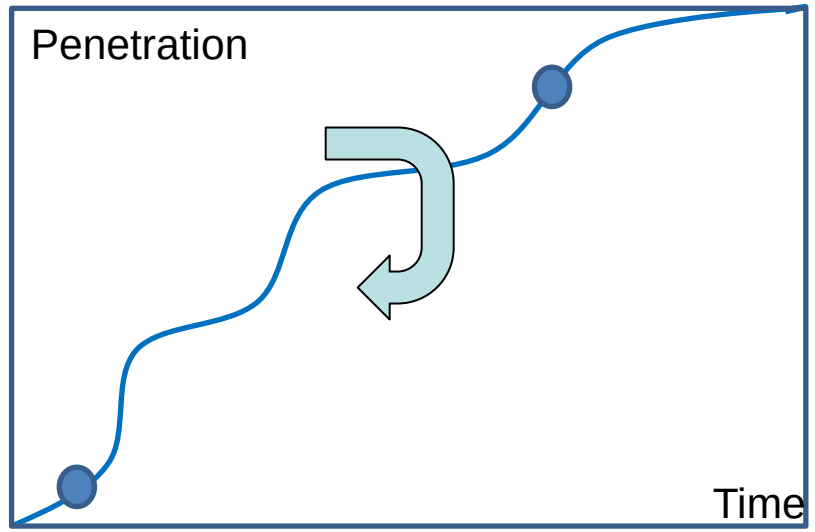
But …

My benefit depends on deployment decisions of other stakeholders

AND

Others' benefit depends on my deployment decision

So, penetration curve has a feedback loop in it



Very difficult to model or predict

US needs to restore momentum toward mass deployment

Deployment models

- **Mandate:** Government regulator requires V2X

- **Voluntary Leader:** Certain deployment stakeholders (i.e. automakers, state/local DOTs) begin deployment
  - Expect to stimulate others to follow
  - Typically, larger stakeholders can provide more leadership

- **Voluntary Group:** A group representing a significant portion of the market agrees to deploy together
  - Perhaps with a Memorandum of Understanding

- Combinations are also possible

For voluntary deployment models, what is the critical mass that will attract most of the others?

Conclusion

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- Regulations: FCC 1st R&O (2021) and 2nd R&O (maybe 2024)
  - Waiver requests to start LTE V2X deployment soon
- Regulations: US DOT V2X Summit (August 2022)
  - Test results LTE V2X
  - V2X Roadmap to be developed jointly with industry
- Standards: 3GPP working on 5G New Radio V2X
  - Release 16 (June 2020), Currently working on Release 18 enhancements
  - Incompatible with Release 14-15 LTE V2X
- Standards: IEEE 802.11bd Next Generation V2X
  - "DSRC+": backward compatible, coexistent, and interoperable
  - Publication expected March 2023
- Standards: SAE
  - Standards for Channel 183 published
  - Standards for many applications are in place
- Regulations (soon) and Standards (now) in place
- Deployment Status: After taking a step backward, ready to move forward again