



U.S. Department of Transportation



ENHANCING THE SAFETY OF VULNERABLE ROAD USERS AT INTERSECTIONS

U.S. Department of Transportation

MARCH 17, 2023

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AGENDA

- Introduction
 - **Dr. Robert Hampshire**, Deputy Assistant Secretary for Research and Technology, United States Department of Transportation (U.S. DOT) Chief Science Officer.
- Summary of Request for Information (RFI) Responses
 - **Dr. Govind Vadakpat**, Program Manager, Smart Infrastructure, ITS Joint Program Office (JPO).
- Intersection Safety System (ISS) Concept
 - **Dr. Chris Atkinson**, Deputy Director for Advanced Research, Office of the Assistant Secretary for Research and Technology.
- USDOT Intersection Safety Activities
 - **Brian Cronin**, Director, Office of Safety and Operations Research and Development, Federal Highway Administration (FHWA).
- Q&A



INTRODUCTION

Dr. Robert Hampshire
Deputy Assistant Secretary for Research and Technology
U.S. DOT Chief Science Officer

SUMMARY OF RFI RESPONSES

**Dr. Govind Vadakpat
Program Manager, Smart Infrastructure
ITS Joint Program Office (JPO)**

INTERSECTION SAFETY

- **VISION: Transform intersection safety** through the innovative application of emerging technologies including machine vision, sensor fusion, and real-time decision-making to identify and mitigate unsafe conditions involving vehicles and vulnerable road users.
- **PROBLEM: Intersection safety is a growing issue, especially for vulnerable road users.**
 - **Dangerous Intersections** – Each year roughly one–quarter of traffic fatalities and about one–half of all traffic injuries in the United States are attributed to intersections ([FHWA Safety](#)).
 - **Rising Vulnerable Road User Deaths and Injuries** – Vulnerable road user fatalities are on the rise with pedestrian fatalities up 13% and pedalcyclist fatalities up 5% since 2020¹.
- **ALIGNMENT WITH DOT PRIORITIES:**
 - The concept aligns with the **National Roadway Safety Strategy (NRSS)** and supplements current and existing U.S. DOT **safety** and **equity** efforts (e.g., FHWA Complete Streets, Proven Safety Countermeasures, etc.).

¹<https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813298>



REQUEST FOR INFORMATION (RFI) OVERVIEW

■ Purpose of the RFI:

- To better understand the feasibility and potential application of technologies that could enhance intersection safety.
- U. S. DOT published the “Enhancing the Safety of Vulnerable Road Users at Intersections” RFI on 9/16/2022 and closed on 11/15/2022.
- <https://www.regulations.gov/docket/DOT-OST-2022-0096>

■ RFI Questions:

- (A) General Technical Considerations – 7 questions.
- (B) System Installation and Deployment – 8 questions.
- (C) Human Factors and Performance Measurement – 7 questions.
- (D) Development Costs and Time to Deployment – 5 questions.
- (E) Other Comments – open ended.



RFI RESPONSES OVERVIEW

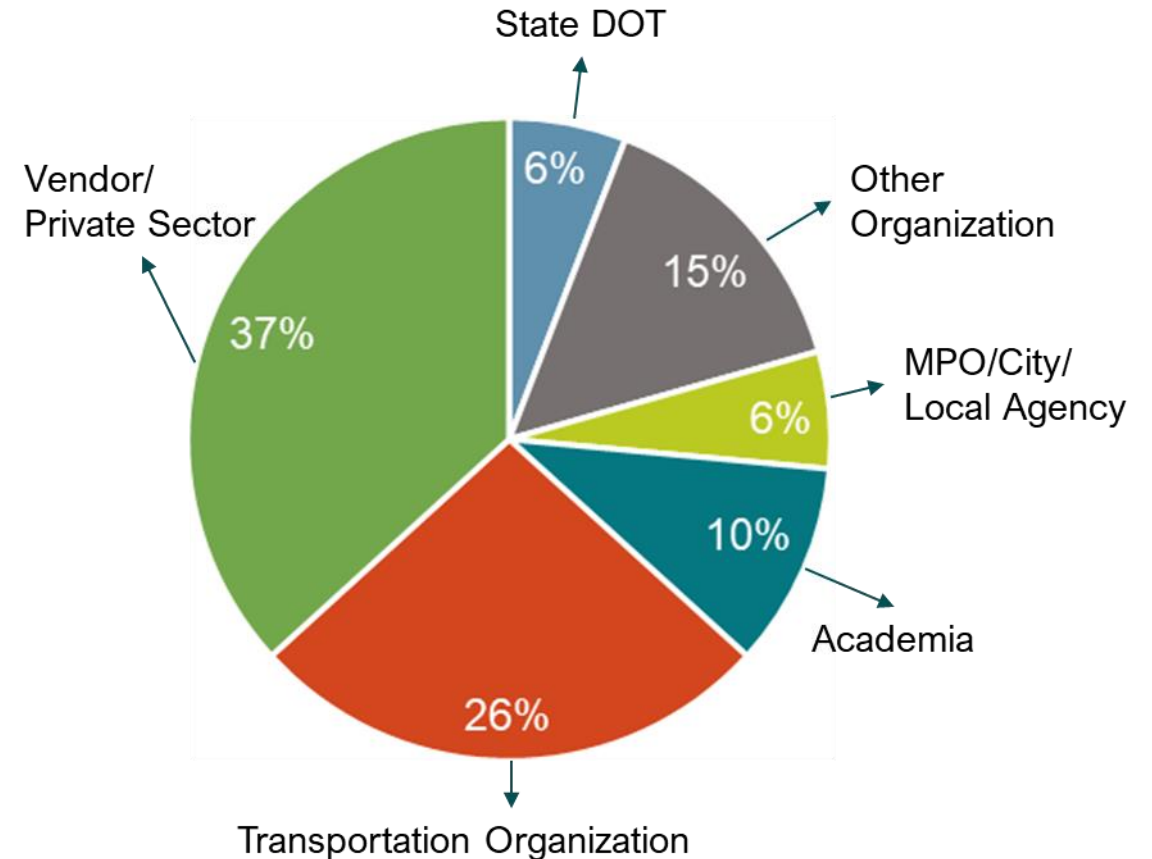
■ Number of Responses:

- A total of 221 RFI responses were received.
 - 1/3 technical responses (70 responses).
 - 2/3 non-technical responses.

■ RFI Responses Summary Report:

- <https://rosap.ntl.bts.gov/view/dot/66622>
- Inform U. S. DOT efforts for intersection safety and other departmental safety initiatives.
- Confirmed industry interests and technical feasibility.

Technical Responses by Organization Type



* MPO: Metropolitan Planning Organization Image Source: U.S. DOT.



KEY TAKEAWAYS – OVERALL

- **Overall Feasibility:**

- It is feasible to develop an intersection safety system for vulnerable road users based on the technologies mentioned in the RFI, including machine vision and sensor fusion.
- Several non-trivial challenges remain to near-term, widespread implementation.

- **Challenges:**

- While the system building blocks or components of the proposed intersection safety system concept mostly exist, important challenges remain.
 - Technical challenges include the need for improved position accuracy and latency concerns for real-time safety applications.
 - Other challenges include the need for standards development and adoption, communications/spectrum uncertainty, and sustainability of a public-private partnership model.



KEY TAKEAWAYS – SAFETY

- **Broader Safety Context:**

- Many responses emphasized the criticality of vulnerable road user safety within a holistic context combining technology with policy measures and traffic calming.
- Warnings alone may not bring sizeable safety benefits. Control actions (e.g., automatic emergency braking, signal changes) can better protect vulnerable road users and drivers.

- **Real-Time Operations:**

- Low latency is critical for real-time safety applications, with tradeoffs between latency, detection accuracy, and cost.
- There may be a need for direct communications for safety applications.
- Edge computing offers promise to reduce latency, protect privacy, and scale readily.



KEY TAKEAWAYS – TECHNICAL CONSIDERATIONS

- **Sensors and Detection :**

- Cameras, radar, and Light Detection and Ranging (LiDAR) were the most frequently mentioned perception technologies.
- Using existing sensors at intersections can help save on costs but could require additional calibration.
- Simple forms of vulnerable road user classification may be cost-effective and represent an important first step.

- **Key Technologies:**

- Artificial Intelligence (AI) and machine vision, multi-access edge computing (MEC), 5G, and vehicle to everything (V2X) could be important emerging technologies for enhancing safety.

- **Alert Types:**

- It is important to have multiple alert types for different vulnerable road users and drivers but be wary of overly distracting them.



KEY TAKEAWAYS – VULNERABLE ROAD USERS

- **Vulnerable Road User Behavior:**

- Predicting the pace, direction, and path of vulnerable road users with high precision may be difficult.
- Obtaining road users' attention is a challenge, especially since different road users have different communication needs.

- **Vulnerable Road User Groups:**

- It is important to consider high-risk vulnerable road user groups and occupations (lower socio-economic groups, first responders, law enforcement, etc.) in system development and testing.
- The technical approach does not necessarily have to be able to classify each individual vulnerable road user group to bring safety impacts, so long as it can classify them all as vulnerable.



KEY TAKEAWAYS – DESIGN AND TESTING

- **Use Cases:**

- Need strategies for identifying use cases as well as specific use cases that could benefit from an intersection safety system.
- Signalized intersections (permissive left turns and long cycle lengths), intersections with a high incidence of red-light violations, right turns on red, unsignalized intersections, and roundabouts.

- **Testing and Validation:**

- A phased approach is key for system testing and validation to ensure safety:
 - Virtual lab environment → controlled environment → limited deployment testing.
- A systems engineering process (i.e., V-model) can be a useful approach for validation.
- It is important to test the system in various conditions (rain, snow, shadow, darkness, etc.) to ensure it behaves as intended.



KEY TAKEAWAYS – PERFORMANCE MEASUREMENT

- **Key Performance Measures:**

- Performance in perception (e.g., accuracy, number of false positives) is the critical first step for overall performance.
- Key safety performance measures: the number/frequency of crashes, conflicts, near-misses, injuries, fatalities, and red-light violations, as well as smoothness of driving metrics, such as speeding, sudden acceleration, and hard braking.
- Many of these safety measures require a before and after period of study.

- **Performance Tradeoffs:**

- There are performance tradeoffs between detection accuracy and system latency.
 - While fusing inputs from multiple sensors is likely to improve detection accuracy, a system dependent on multi-sensor fusion may also have increased latency.



KEY TAKEAWAYS – COST, TIMELINE, AND PARTNERS

- **Costs:**

- Costs are highly dependent on the solution proposed and the availability of supporting infrastructure in actual deployments.
- Reducing costs will be an important factor in driving deployment of these systems at scale.

- **Deployment Timeline and Partners:**

- Responses were mixed on the timeline for deploying intersection safety systems.
- Intersection safety system deployments tend to follow a public-private partnership model involving a variety of partners.
 - E.g., technology vendors, consultants and engineering groups, traffic system distributors, system integrators, original equipment manufacturers (OEMs), agencies, universities or research centers, and possibly wireless service providers.



INTERSECTION SAFETY SYSTEM (ISS) CONCEPT

Dr. Chris Atkinson
Deputy Director for Advanced Research
Office of the Assistant Secretary for Research and
Technology

CONFLUENCE OF FACTORS LEADING TO AN OPPORTUNITY TO IMPROVE INTERSECTION SAFETY AT SCALE

- Integrate emerging technologies to improve intersection safety at scale in a new way.

Data Fusion Utilizing Existing and Emerging Sensors	+ AI/Machine Learning	= Low-Cost, High-Value Opportunity for Integration at Scale
Emerging, low-cost vision sensors can be deployed at intersections for improved sensing of vulnerable road users . Data from these sensors can be fused and used in new ways by AI.	AI/ML can fuse data from multiple machine vision sensing modalities rapidly to improve situational awareness and anticipate safety threats .	These existing technologies have not been deployed together at intersections broadly, offering an opportunity ripe for innovative collaboration .

* AI: Artificial intelligence

INTERSECTION SAFETY SYSTEM (ISS) CONCEPT

- Emerging, low-cost sensors (e.g., cameras, LiDAR, infrared) deployed at intersections to improve sensing.
- Multi-sensor data fusion/analytics to improve situational awareness and anticipate safety threats.
- System issues warnings or modifies control settings to improve safety.



Concept Illustration: Intersection Safety System

Safety systems informed by data fused from multiple sensors may anticipate unsafe conditions, e.g., a vehicle turning right in potential conflict with pedestrian pushing a stroller (lower right).

Image Source: U.S. DOT.



CONCEPTUAL ISS CONTEXT DIAGRAM

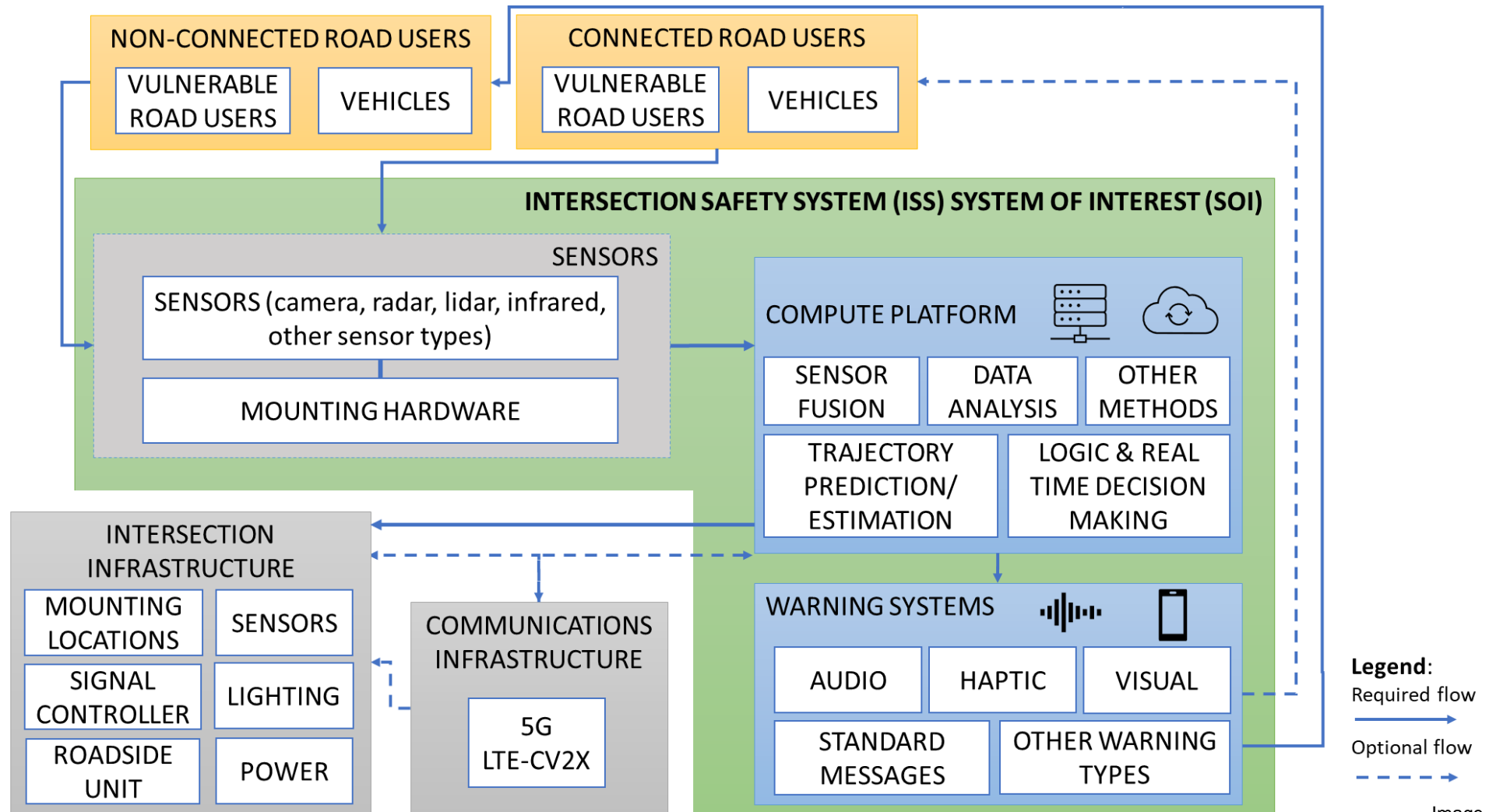
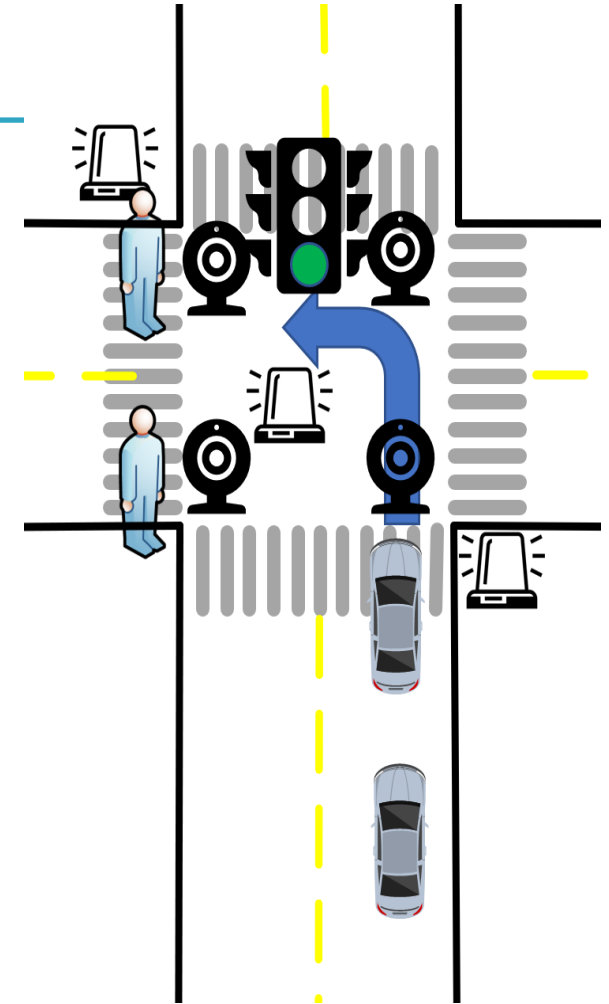


Image Source: U.S. DOT.

THE ISS CONCEPT IN ACTION: PERMISSIVE LEFT-HAND TURN USE CASE

1. **Detect, localize and classify** vehicles and vulnerable road users simultaneously in real-time.
2. **Predict** the movements or trajectories of all vehicles and vulnerable road users in or near the intersection in real-time.
3. **Identify** potential conflicts and unsafe conditions (current or future).
4. **Warn** vulnerable road users and vehicles (where possible).
5. **Adapt** intersection controls to mitigate unsafe conditions.

E.g., change from permissive to protected left-turn to reduce vehicle-pedestrian conflicts – implemented when the volume of turning vehicles and/or pedestrian densities are too large.

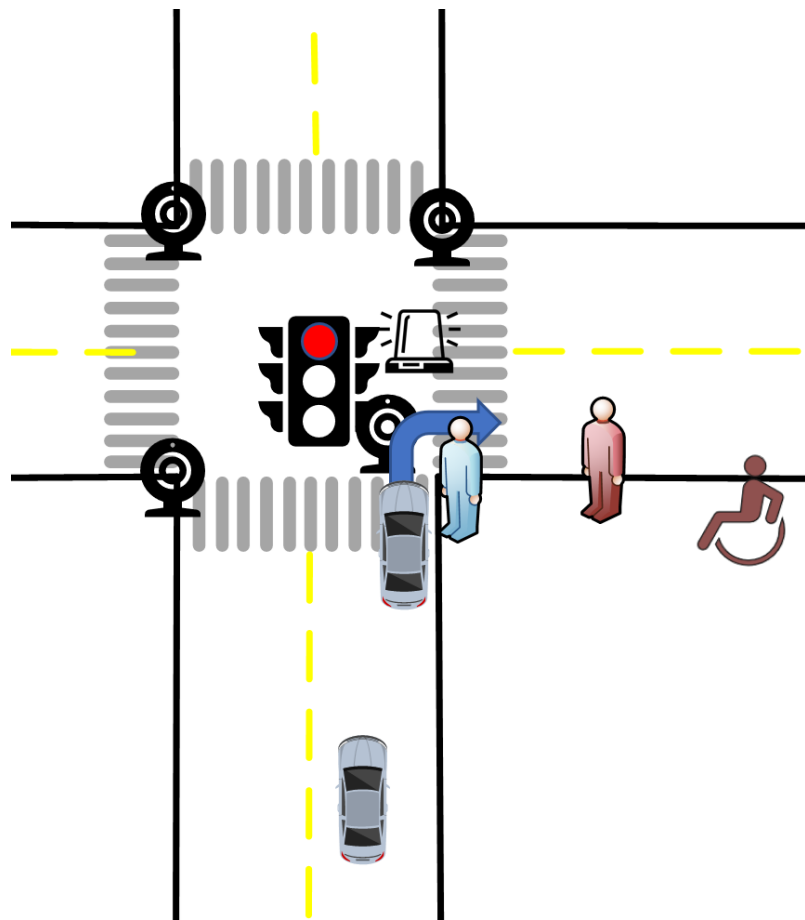


Example Use Case: Permissive left-Turn at a Signalized Intersection.

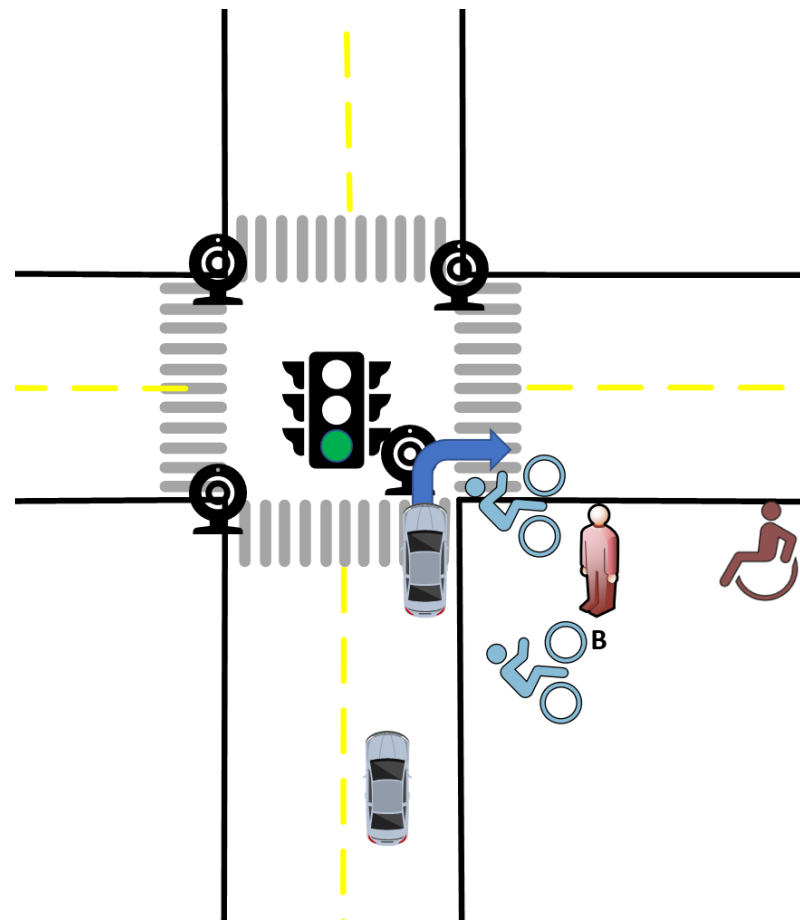
Image Source: U.S. DOT.



OTHER EXAMPLE USE CASES



Example Use Case: Right Turn on Red at a Signalized Intersection.



Example Use Case: Permissive Right Turn at a Signalized Intersection.

Image Source: U.S. DOT.



USDOT INTERSECTION SAFETY ACTIVITIES

Brian Cronin

**Director, Office of Safety and Operations Research and
Development
Federal Highway Administration (FHWA)**

NATIONAL ROADWAY SAFETY STRATEGY (NRSS): A HOLISTIC APPROACH TO SIGNIFICANTLY IMPROVE SAFETY

- Outlines the Department's comprehensive approach to significantly reducing serious injuries and deaths on our Nation's highways, roads, and streets.
- Commits U.S. DOT to a national vision of zero roadway fatalities and identifies priority actions in pursuit of five Safe System objectives:
 - Safer people.
 - Safer vehicles.
 - Safer speeds.
 - Safer roads.
 - Post-crash care.

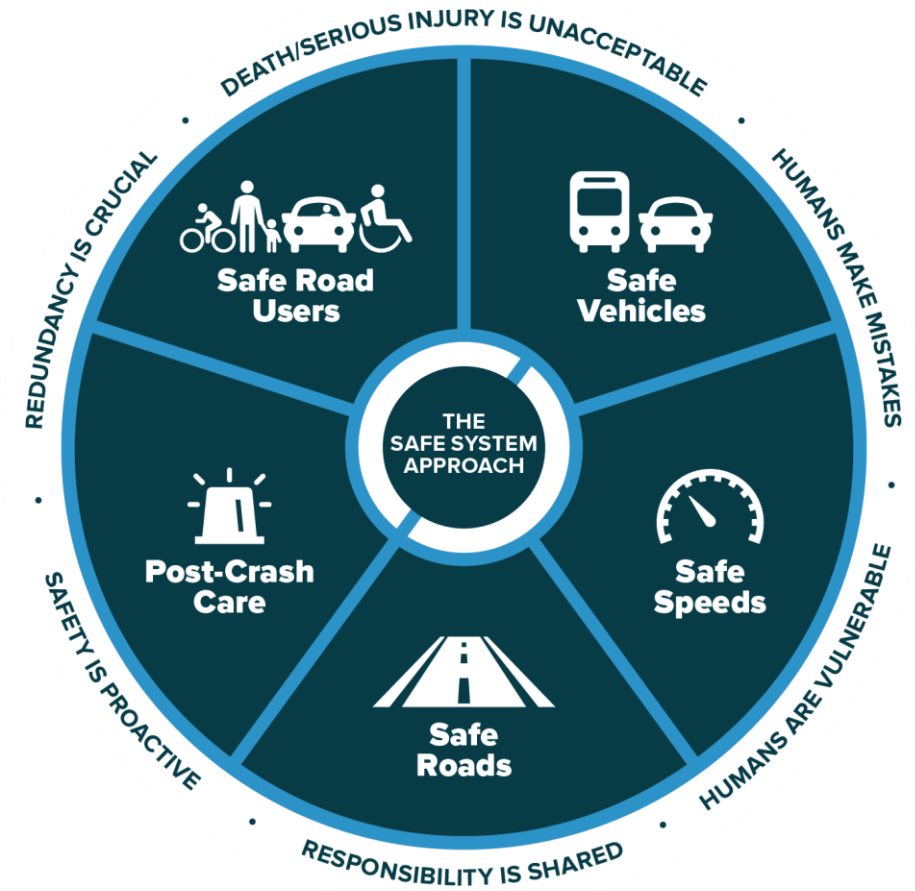


Image Source: FHWA.



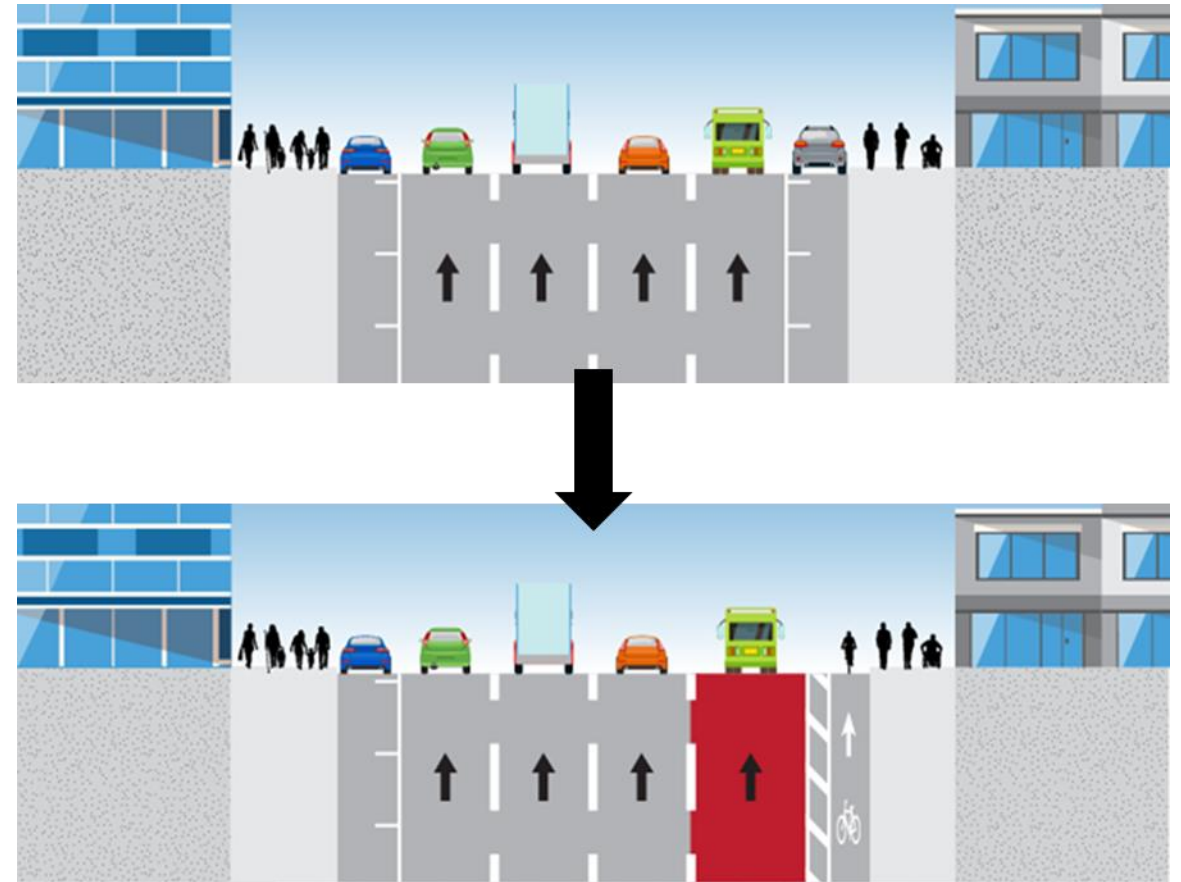
USDOT SAFETY PROGRAMS

- Complete Streets Program.
- Safe Streets and Roads for All (SS4A) Program.
- Proven Safety Countermeasures Initiatives (PSCi).
- Other Safety Research and Development research:
 - Innovative Intersection Designs.
 - Enhancing Vulnerable Road User Detection.
 - Vehicle-to-Everything (V2X) Communications.
- *The Intersection Safety System (ISS) concept builds from and supports the current portfolio of U.S. DOT safety programs and Office of Safety R&D research portfolio.*



COMPLETE STREETS PROGRAM

- Ensures that the entire right-of-way and transportation network is planned, designed, constructed, operated, and maintained to provide safe access for all users.
- Focuses on improving roadways with non-freeway arterial functional classification:
 - Urban areas: Speed limits < 55 mph.
 - Rural areas: Small-town main arterial street.
- Emphasizes:
 - Complete pedestrian networks.
 - Complete cycle networks.
 - Accessible transit.



All images Source: FHWA.



SAFE STREETS AND ROADS FOR ALL

- Key program that supports the National Roadway Safety Strategy (NRSS).
- For FY 2022, 510 communities were selected to receive more than \$800 million in funding¹:
 - Action Plan Grants: 473 recipients.
 - Implementation Grants: 37 recipients.
- Funds will improve roadway safety planning for over half the nation's population.

¹<https://www.transportation.gov/grants/SS4A>

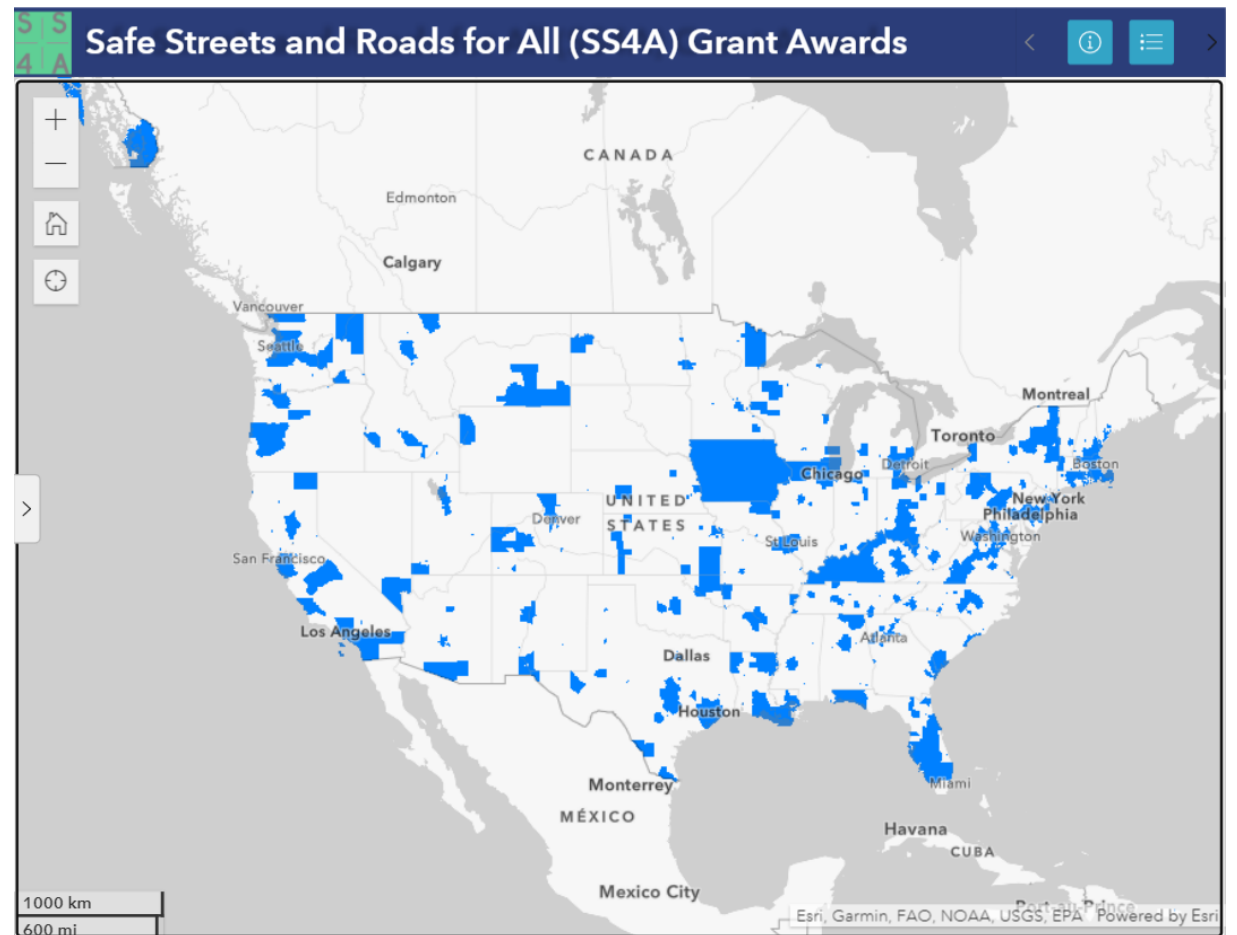


Image Source: FHWA.



PROVEN SAFETY COUNTERMEASURES INITIATIVES (PSCI)

- Identified 28 Proven Safety Countermeasures that can offer significant, measurable impacts as part of any agency's data-driven, systemic approach to improving safety.
- Designed to enhance safety on all kinds of roads.
- Organized around five focus areas:
 - Speed management.
 - Roadway departure.
 - Intersections.
 - Pedestrians/Bicyclists.
 - Crosscutting (address all four safety focus areas).

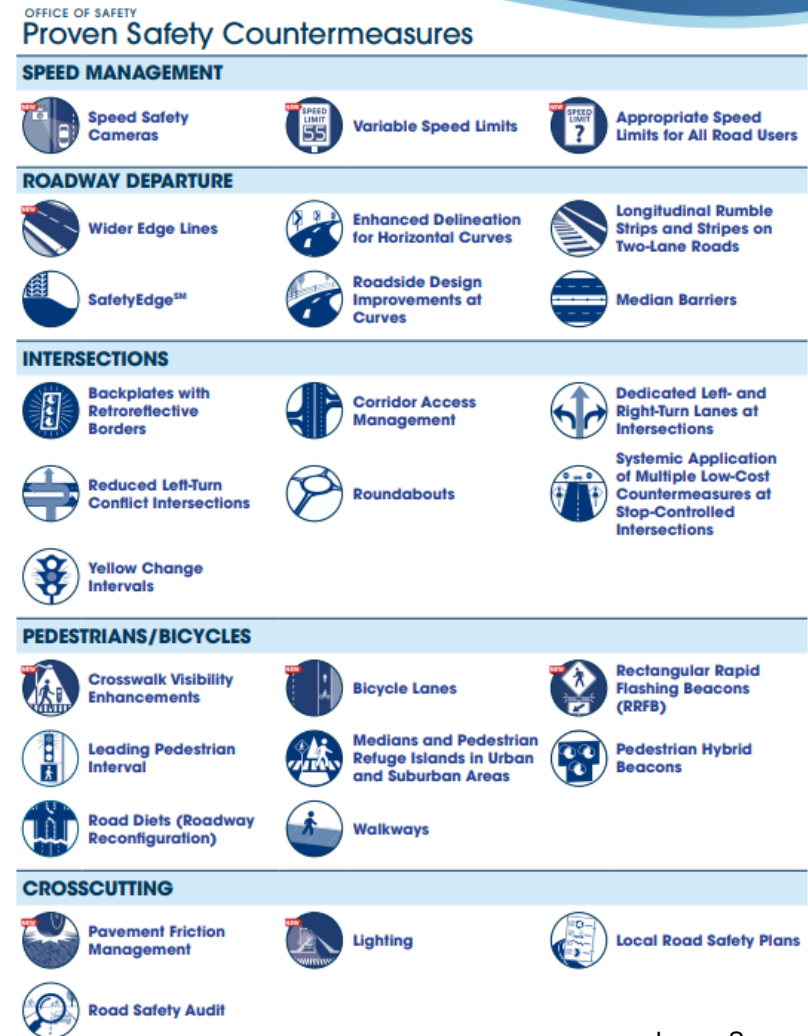


Image Source: U.S. DOT.

THE INTERSECTION SAFETY SYSTEM (ISS) CONCEPT IN CONTEXT

- A technology-based approach is one of many potentially cost-effective approaches for improving safety at intersections.
 - Cost-effective approaches are *critical* to support equity and accessibility considerations.
- Intersection Safety System (ISS) research would augment (but does not substitute for) a comprehensive suite of intersection safety considerations.
 - Data from an ISS can support designing tailored improvements to intersection geometry and local intersection safety policy.
- An ISS would support current and future U.S. DOT safety and equity efforts.



Q&A

Dr. Govind Vadakpat, Dr. Chris Atkinson, and Brian Cronin

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