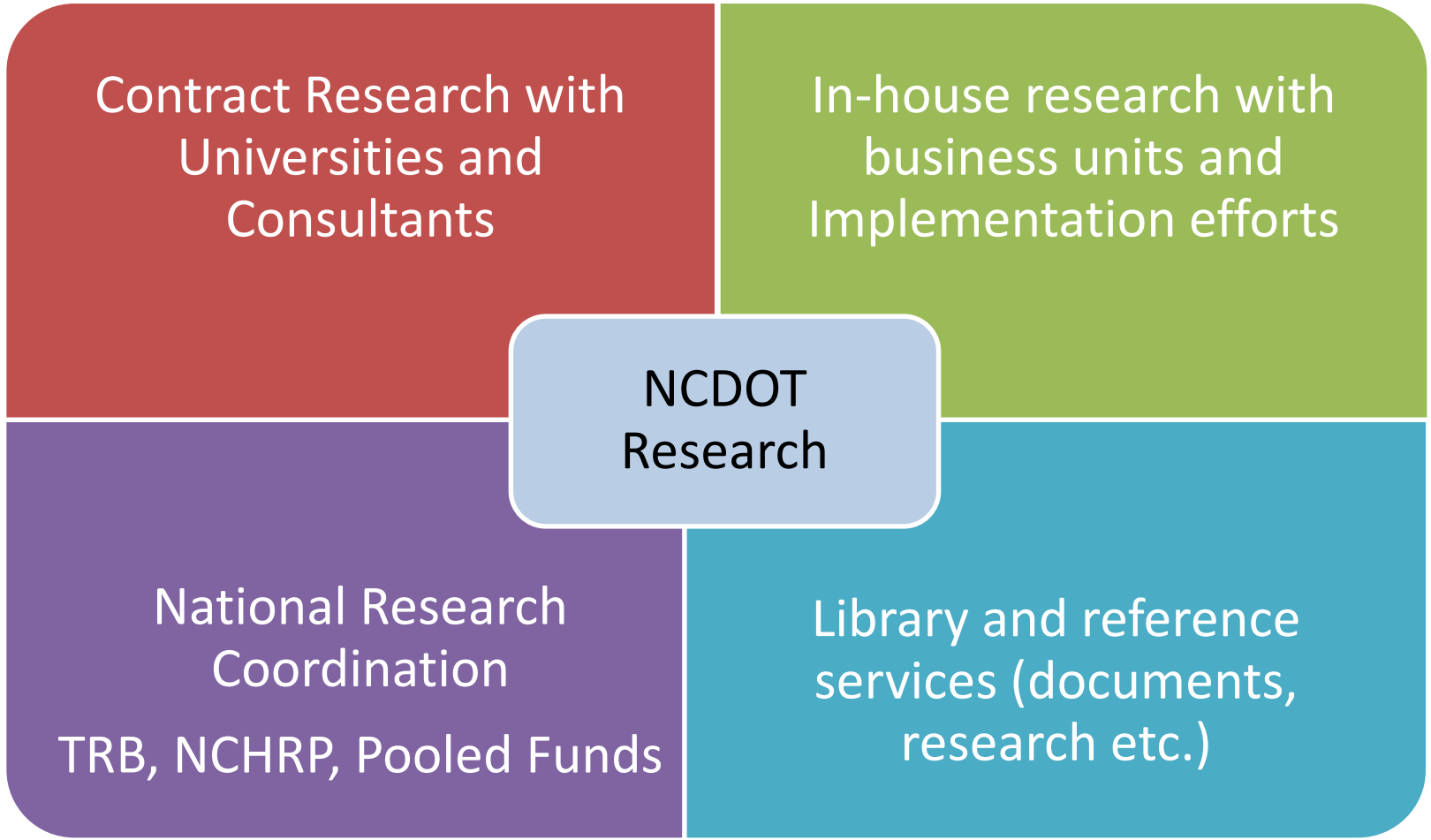
NORTH CAROLINA
Department of Transportation

NCDOT Research & Implementation Program / Grant Writing

Neil Mastin, PE – R&D Manager

Spring 2019

What do we do?


Contract Research with Universities and Consultants
In-house research with business units and Implementation efforts
NCDOT Research
National Research Coordination
TRB, NCHRP, Pooled Funds
Library and reference services (documents, research etc.)

Program Goals

Improve NCDOT Planning, Engineering and Business Practices

Support NCDOT Operations and Maintenance Activities

Conduct research that can be implemented

Develop relationships between Academia & NCDOT

Annual Program FAQ

Who typically submits Research Needs?

- Anyone at NCDOT, with manager approval
- University researchers in coordination with DOT business units
- Outside groups in coordination with NCDOT Subject Matter Experts

How are projects selected?

- Internal, multi-step committee process that includes review input by idea submitters

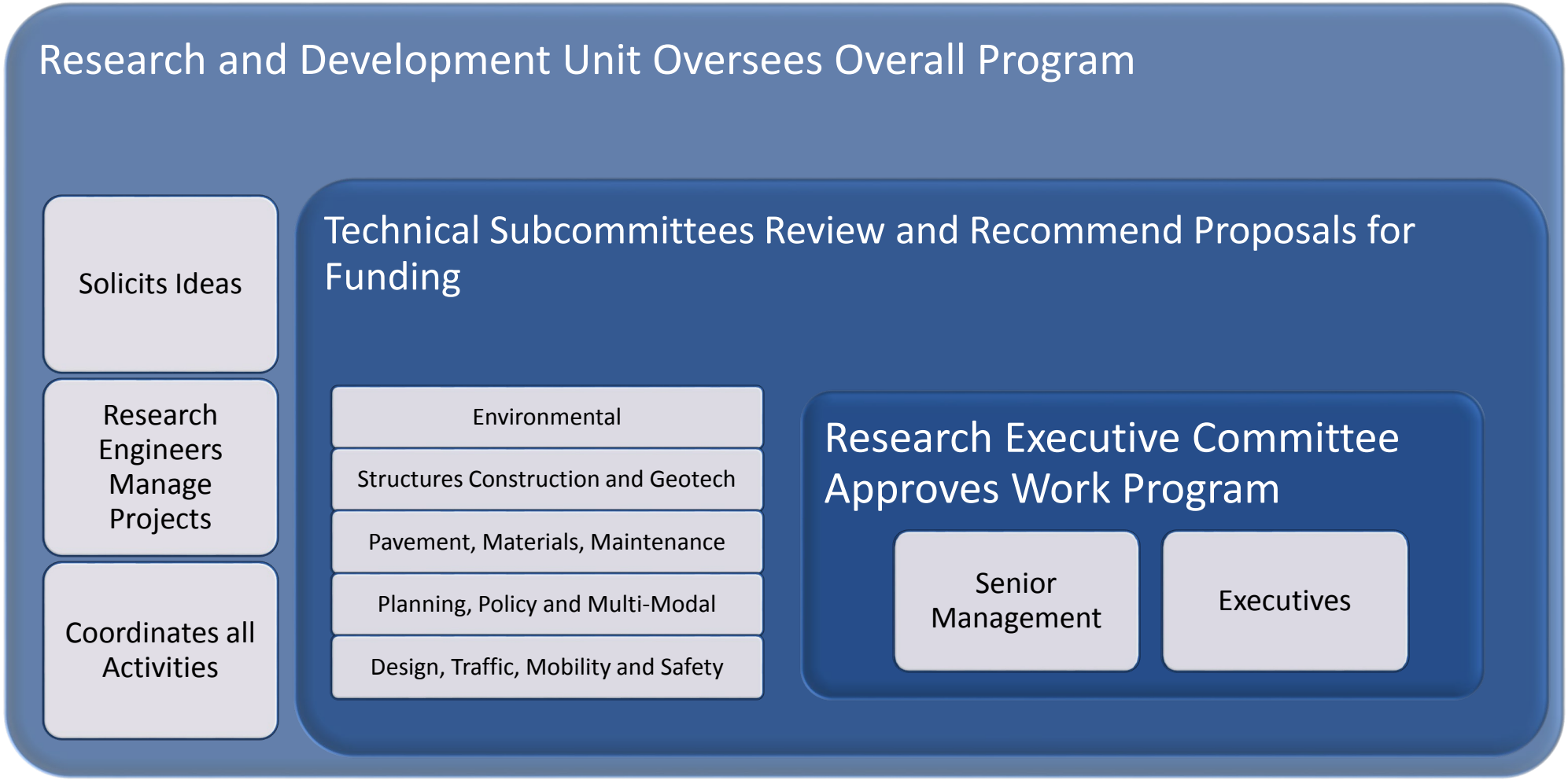
How long does it take for an Idea to become a project?

- 1 year from close of solicitation period
- Contingency funds for off cycle needs.
- When using alternative funds, can be less than 1 month

How long do Research Projects Last?

- *Varies*
- 2 years is typical
- Can be as short as 6 months or as long as 3 years

Project Selection / Oversight



Annual Research Program is not the only opportunity

Remain on the lookout for other opportunities during the year!

- Business units may have other, off-cycle needs
- Those opportunities will be advertised as well

Other research opportunities are as follows

- Technical Assistance Program
- Technology Transfer Program
- Other state funded opportunities

Technical Assistance Program (~ $150k per year of state funds)

Quick hit projects for NCDOT

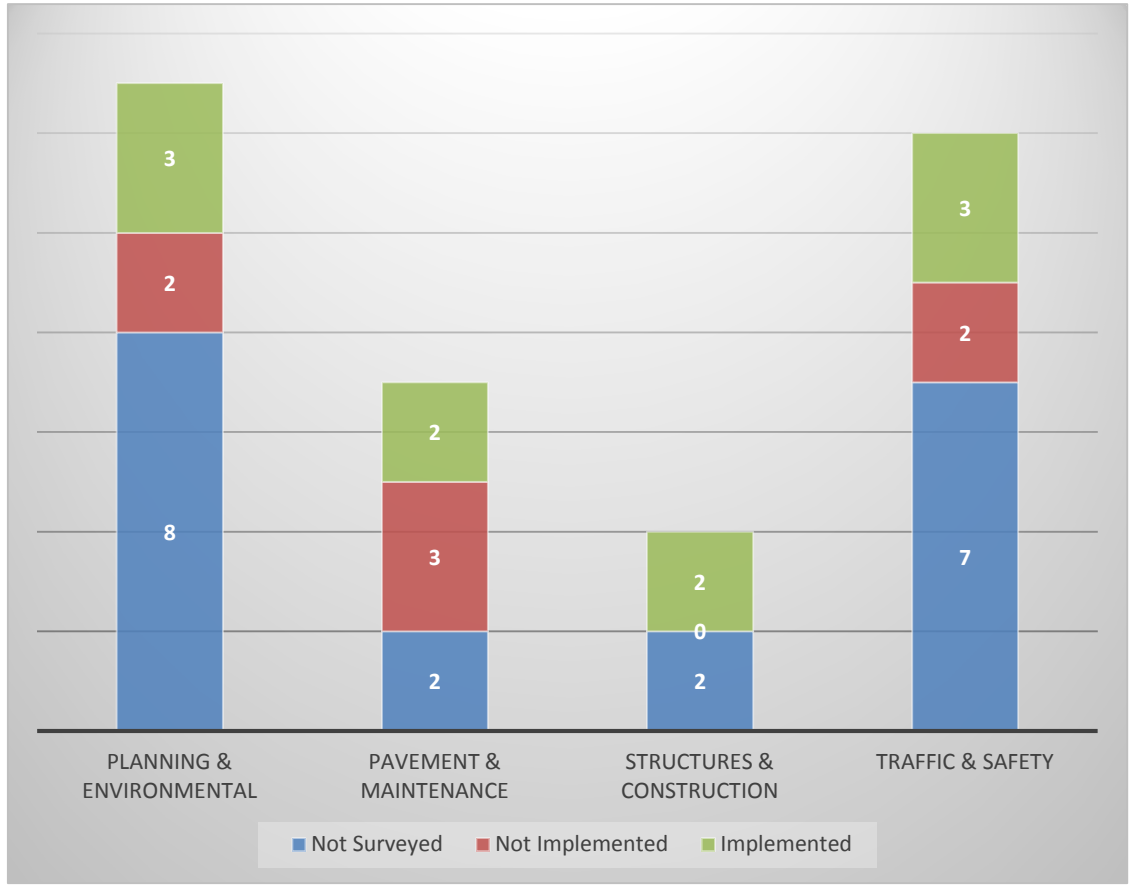
Lab testing?	White paper writing?	Survey conducted?

Technical Assistance Program

Managed by NCSU-ITRE	Easily contract with expertise across the state	Limited to 120 hours of investigator time

Implementation / Technology Transfer (T^2) (~$250k of SP&R funds per year)

- RP 2019-44: Spatial and Temporal Distribution of Major Beltway Project Impacts.
- RP 2019-50: Ped. Incident Detection using Artificial Intelligence.
- RP 2019-46: NCDOT Research & Innovation Summit



What Makes a Good Research Idea / Proposal?

Work with NCDOT Subject Matter Experts (SME) to clearly articulate idea and understand need

Lines up with ongoing initiatives and fits DOTs current mission and goals

Clearly articulated methodology: Needs to be useable for NCDOT

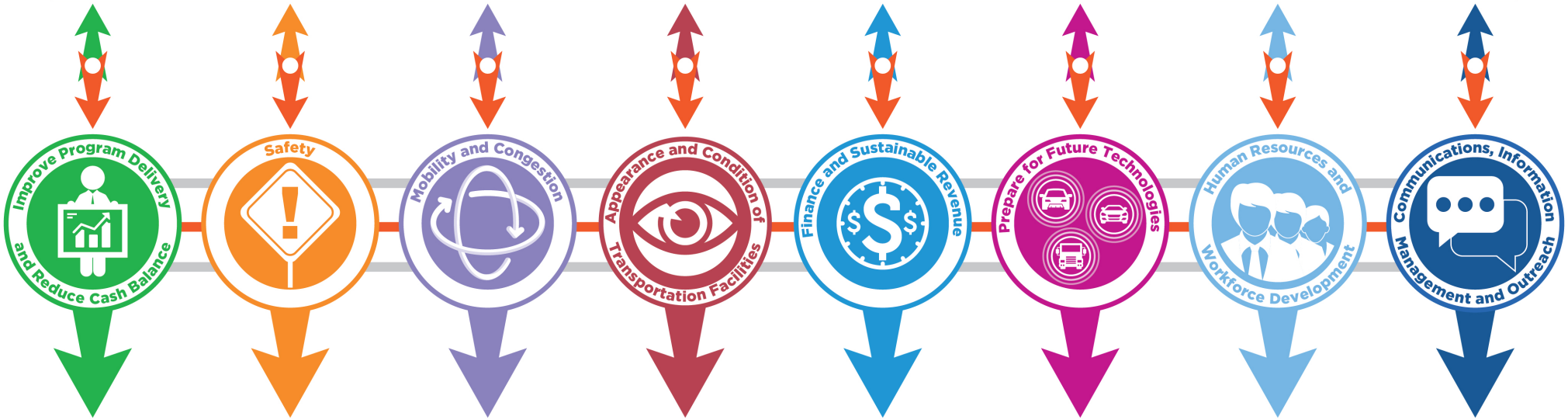
Tangible / Useable deliverables (Implementation)

NCDOT Priorities and Work Groups

10/16/17

Better Transportation Service for North Carolina

Our Mission: Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina.



Improve Program Delivery and Reduce Cash Balance

- ☑ Prioritization/Programming
- ☑ Scoping, Scheduling
- ☑ Project Development
- ☑ Procurements
- ☑ Right-of-Way
- ☑ Operations and Maintenance
- ☑ Revenue and Cash Model

Executive: Bobby Lewis

Safety

- ☑ Executive Committee for Highway Safety
- ☑ Vision Zero
- ☑ Technology Pilots
- ☑ Planning and Policy

Executive: Jim Trogdon

Mobility and Congestion

- ☑ State Mobility Models and Analytics
- ☑ Rural Mobility and Economic Development
- ☑ Mobility Modernization Fund Implementation
- ☑ Mobility Performance Data

Executives: David Howard, Bobby Lewis

Appearance and Condition of Transportation Facilities

- ☑ Roadside Appearance
- ☑ Bridge and Structures
- ☑ Pavements; Signals/ITS
- ☑ Transportation Facilities
- ☑ Budgeting and Performance Plans

Executive: Bobby Lewis

Finance and Sustainable Revenue

- ☑ Future Revenue Options for Sustained Transportation Delivery
- ☑ Debt Capacity Instruments

Executive: Jim Trogdon

Prepare for Future Technologies

- ☑ Unmanned Aerial Systems
- ☑ Connected and Automated Vehicle Policy
- ☑ Connected and Automated Vehicle Infrastructure and Data
- ☑ Industry Technology Advisory Group
- ☑ University Center for Transportation Innovation
- ☑ Decision Support and Operations Control Data, Integration, Infrastructure, and Analysis Systems Technology

Executives: David Howard, Beau Memory

Human Resources and Workforce Development

- ☑ Recruiting
- ☑ Small Business Development
- ☑ Benefits/Compensation Reform and Modernization
- ☑ Scholarships/Internships/ Apprenticeships

Executives: David Howard, Anne Lasley

Communications, Information Management and Outreach

- ☑ Real Time Internal Performance Measures and Dashboarding
- ☑ Real Time External Performance Measure and Dashboarding
- ☑ External Communications and Outreach of DOT Services—Planning, Project Development, Construction, Operation, All Hazard Response, Transportation Permits, Vehicle and Driver Services
- ☑ Real Time Data Collection, Analysis, Storage, and Reporting Across all Modes, Units, Facilities and Operations to Obtain and Sustain Full Time Situational Awareness

Executive: Greer Beaty

How to be engaged

Reach out to NCDOT Research & Development Unit

- Send Resume / CV
- Send one pager outlining research interests
- NCDOT R&D Unit will connect you with appropriate Subject Matter Experts (SME's)

Contact w/ Subject Matter Experts

- Meet w/ SME to discuss personal research and SME research needs
- START EARLY: This should happen prior to, or early in, the Research Idea solicitation period
- It would be good to show completed research to identify how your research is related to the need of SME (Note: It is also good to identify the gaps).

Developing Research Ideas / Proposals

Research Ideas (RI)

- Communicate with SME
- Meet / call multiple times to focus research idea.
- Make sure to connect the results w/ need and deliverable for SME.
- Note: University RI's are treated as proprietary.

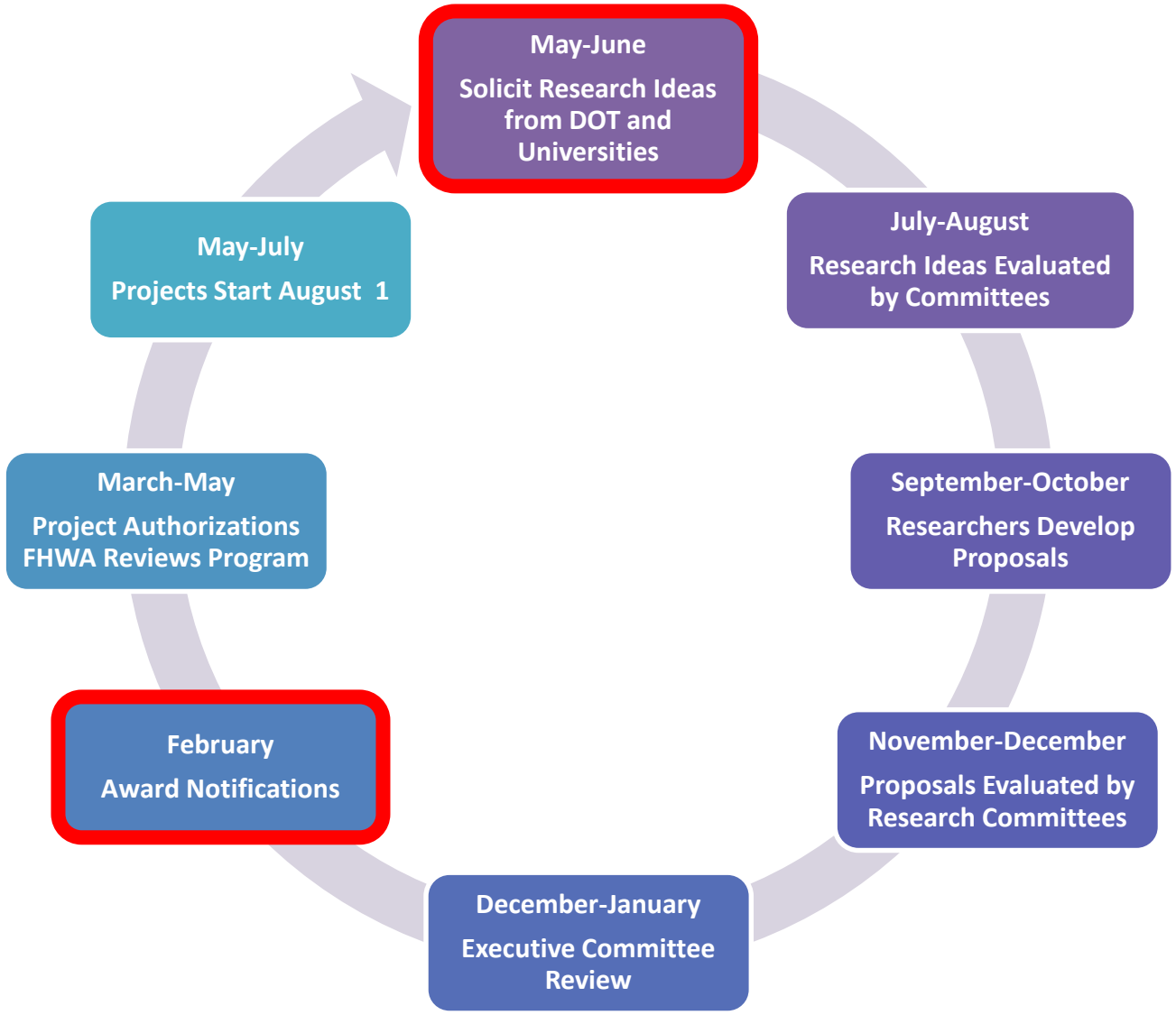
Proposals

- Reach out to RI Author (NCDOT R&D Unit can assist with this process) to gain a good understanding of their needs
- It is critical to clearly articulate the following: How does the proposal address the problem? Are the deliverables what the SME needs? How can the SME implement the Research Product?

Off-Cycle Projects

- This process is like the proposal process.
- It is very important to communicate with SME's.
  - Time is typically limited for the SME's (Efficiency and clarity are very important).

Research Program Annual Timeline



We accept research ideas year-round!

Annual due date is typically in July

R&D can help develop and refine Research Ideas
(or find someone that can)

Research Idea Guidelines

Research Idea Online Form (being upgraded)

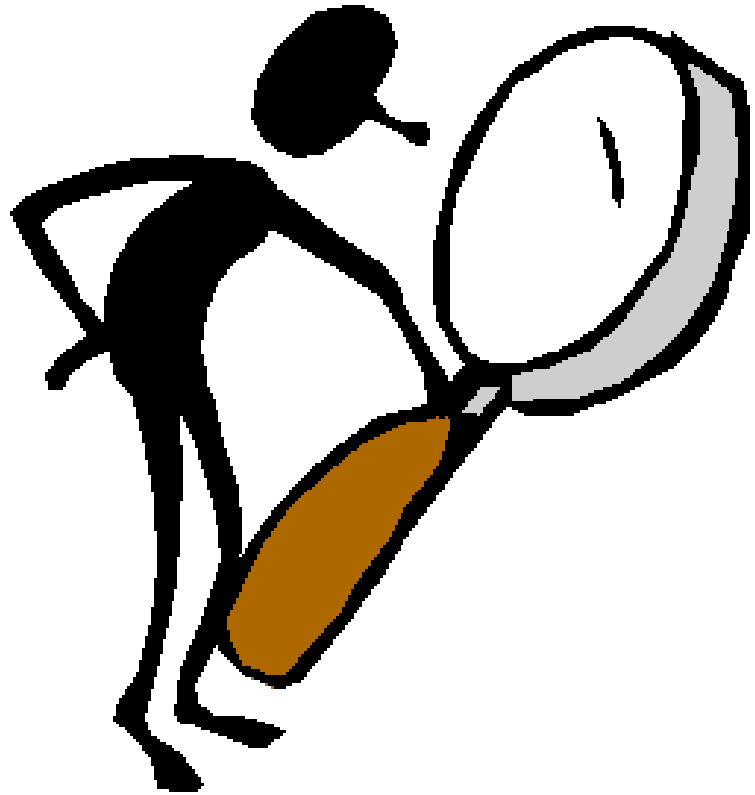
https://connect.ncdot.gov/projects/research/Pages/RNS-Form.aspx

Contact Info

Neil Mastin	**Research Manager**	**919-707-6661**	**jmastin@ncdot.gov**
Steve Bolyard	Mobility, Safety, Roadway Design, etc.	919-707-6663	sjbolyard@ncdot.gov
John Kirby	Stormwater, Environment, Planning	919-707-6662	jkirby@ncdot.gov
Mustan Kadibhai	Pavement, Materials, Maintenance, Structures, Construction, Geotech	919-707-6667	mkadibhai@ncdot.gov
Curtis Bradley	Implementation Manager, Planning, Policy, Multi-modal	919-707-6664	cbradley8@ncdot.gov
Lamara Williams-Jones	Research Librarian	919-707-6665	lcwilliams2@ncdot.gov
General Contact		919-707-6660	research@ncdot.gov

Research Connect Page (for Forms, completed and active projects and more):
https://connect.ncdot.gov/projects/research/Pages/default.aspx

Research Directory Page:
https://apps.ncdot.gov/dot/directory/authenticated/UnitPage.aspx?id=8781



Thank You

Capturing and Communicating the Value of NCDOT Research

Thomas Nicholas, PhD, PE

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Agenda

1. Applied research process
2. Project success
3. CBA to define value
4. Future work

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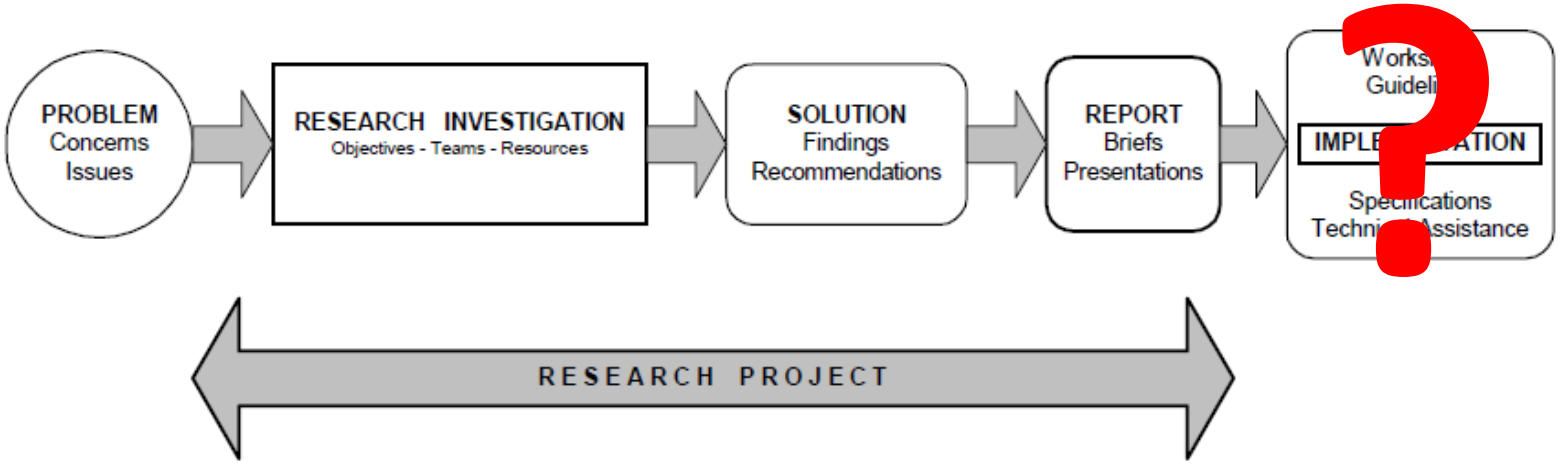
Applied Research Process

- Can the research process help ensure “value” is obtained for stakeholders?

- What opportunities exist in research process where success be impacted positively?
  - At the beginning of the project, implementation was the prime candidate.

The Applied Research Process

- The applied research process (cradle to grave), is often described as identification, investigation, formulation, reporting and implementation.



Applied Research Process, (Hartman, et al., 2001)

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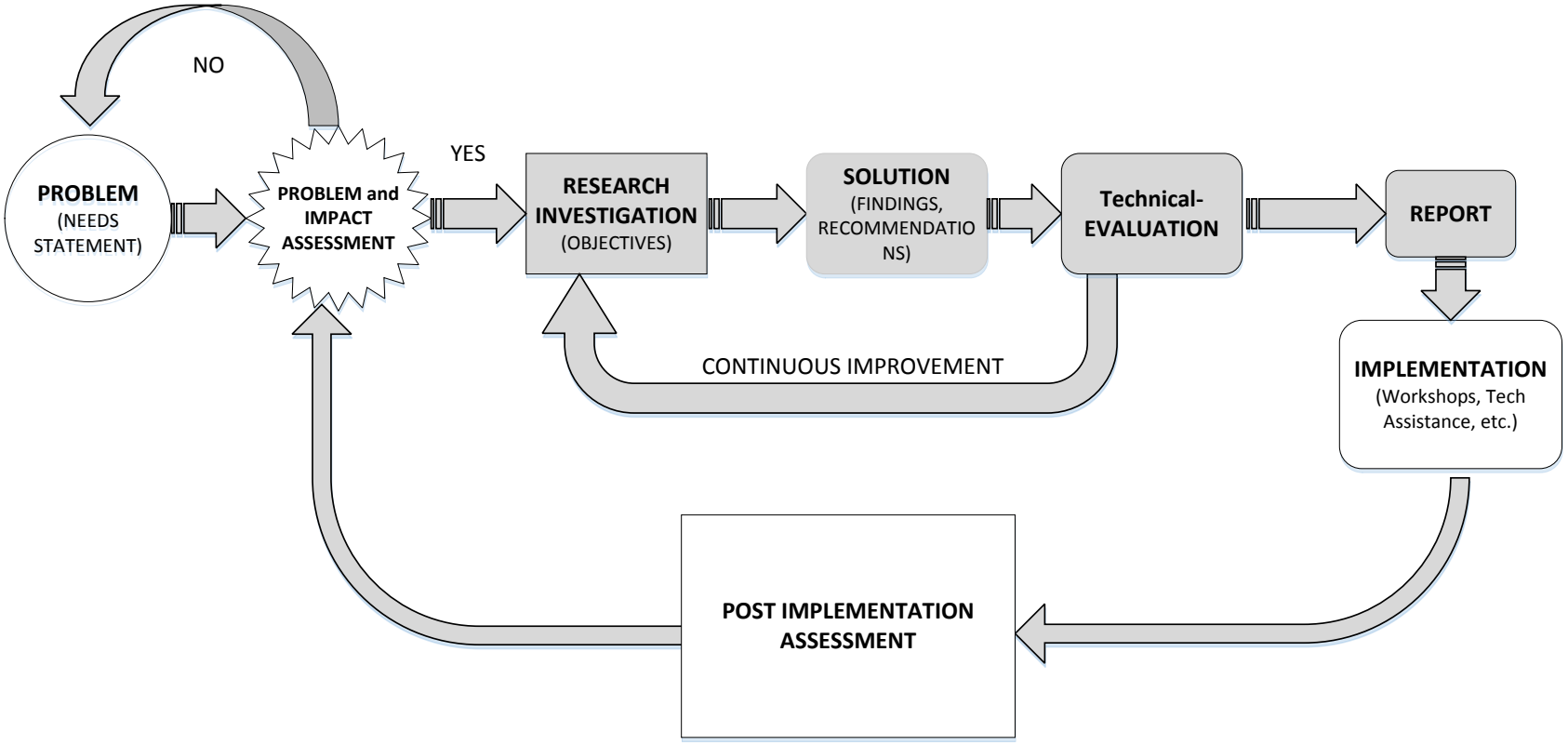
Continuous Improvement

- Continuous Improvement is a methodology that allows us to take a break, assess, correct and move forward in a direction that adds value and improves chances of a successful project.

Improving the Applied Research Process

- The new Applied Research Model:



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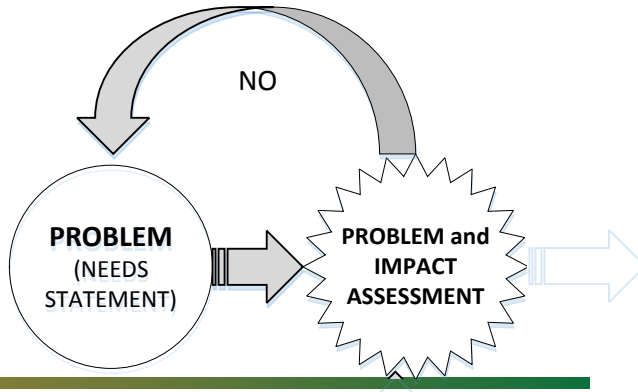
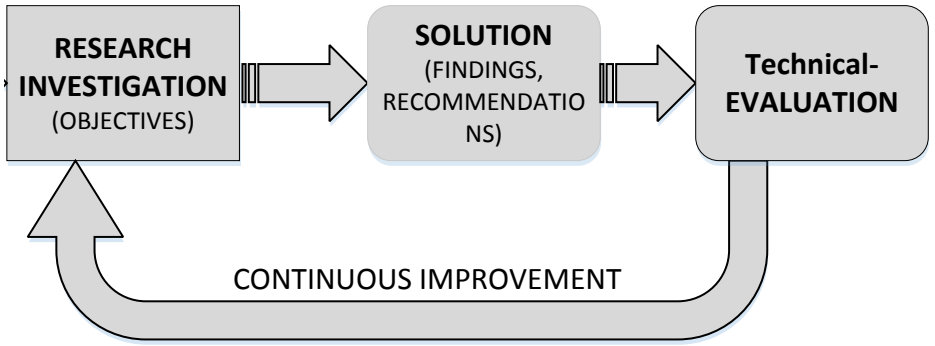
Recommendations: Applied Research Process

- Probability of Success is impacted primarily at the proposal selection stage:
  - Research Champion, PI-Exp, and Project Need
  - Problem statement/scope of work
  - Determining value and definition of success for each project at the needs assessment stage.
    - This is an area for future investigation.



Recommendations: Applied Research Process

- Communication is still key to insure final research products meet the needs of the NCDOT.
- During the project, opportunity to improve research projects should be provided.
- Historically, this is occurring informally in highly successful projects, it is recommended that the process be formalized to insure ALL projects are meeting the level of communication required for success.



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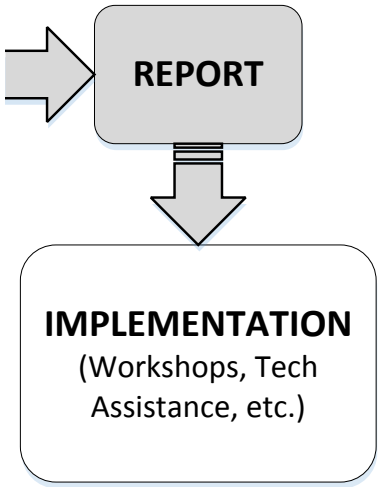
Recommendations: Applied Research Process

- Executives, Politicians, Public – Money is the communication medium for Value
  - Realized through implementing research results and products.
  - Implementation plan needs to be a unified effort between the researcher and the StIC.



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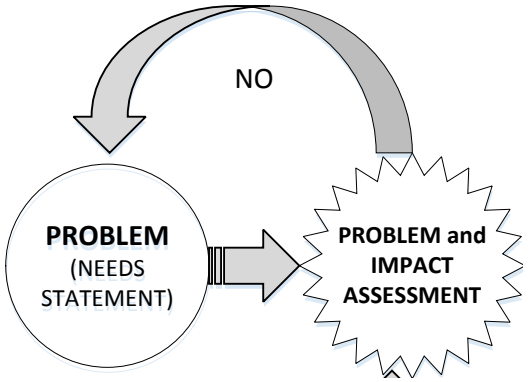
Recommendations: Applied Research Process

- CBA is performed once implementation of the research products has concluded.
- Evaluation of project in terms of performance and identification of improvements for the next research cycle.
- Communication of Results

Probability of Project Success

- What is success and how can we impact it at the proposal stage?
  - First, we have to define project success and then what drives it.



Definition of a successful Research Project	
Knowledge Gained	77.14%
Detailed Implementation Plan	17.14%
Quality Final Report	5.71%

Note: We will revisit Knowledge Gained later in the presentation

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Project Performance

- Success Indicators – Interview Identified

1	Active NCDOT Research Champion
2	Active StIC Participation
3	Detailed Implementation Plan
4	Graduate Student Participation
5	NCDOT Management Support
6	Performing Organization/University
7	Proposal Quality
8	Regular Communication from the PI
9	Research Need Priority
10	Researcher Experience with NCDOT
11	Resulting Publications
12	Routine Engagement with Research Team

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Survey – Final Hierarchal Ranking of Performance Indicators

HIERARCHAL RANK	RESEARCH SUCCESS INDICATORS
1	Regular Communication from the PI
2	Researcher Experience with NCDOT
3	NCDOT Research Project Champion
4	Research Need
5	Proposal Quality

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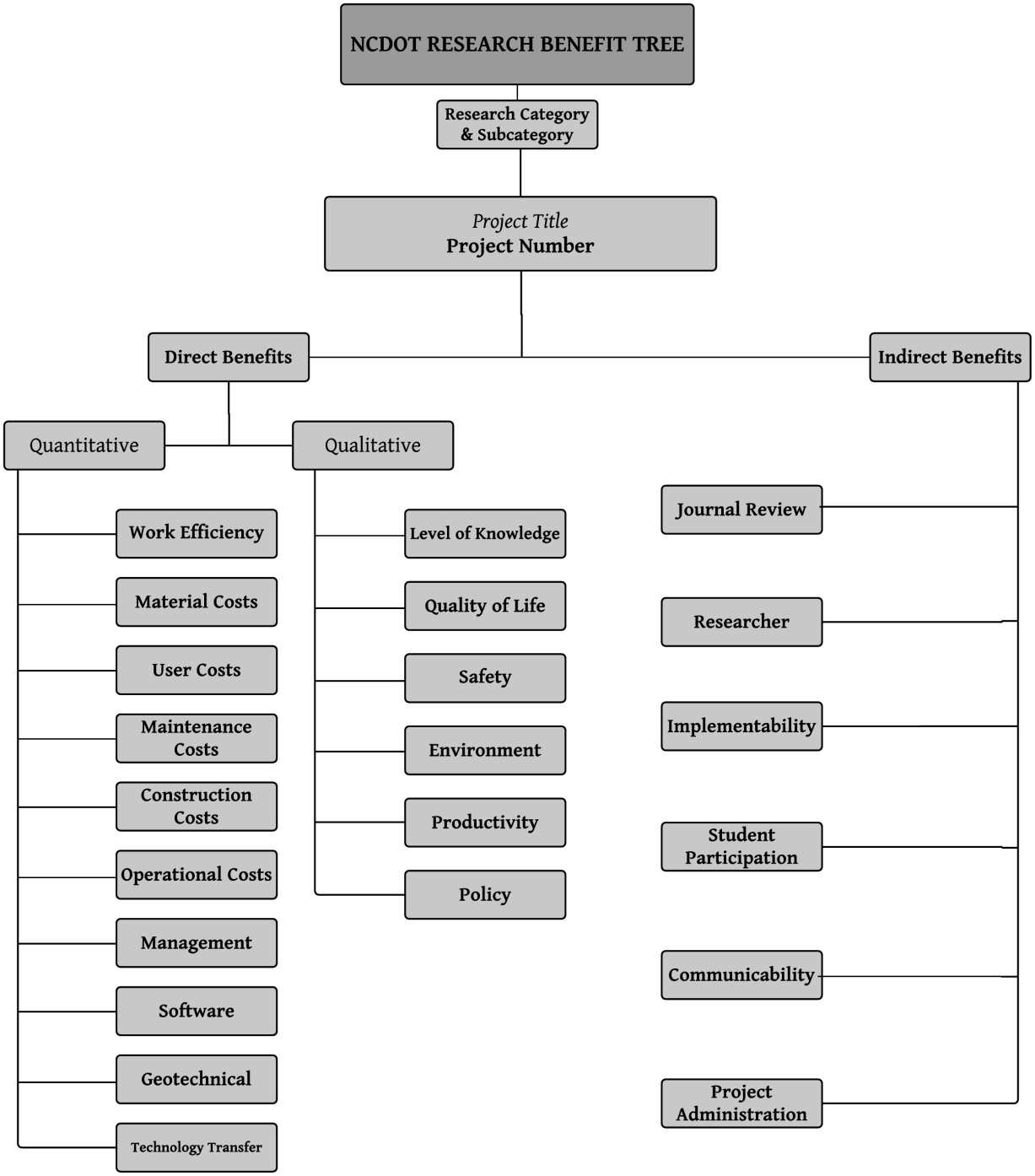
Cost Benefit Analysis

- If monetary benefit is to be used as a communication focus, a methodology must be developed to calculate both hard costs (quantitative) and soft (qualitative) costs to capture the true value of the research project.


NCDOT RESEARCH BENEFIT TREE
Research Category & Subcategory
Project Title
Project Number
Direct Benefits
Indirect Benefits
Quantitative
Qualitative
Work Efficiency
Material Costs
User Costs
Maintenance Costs
Construction Costs
Operational Costs
Management
Software
Geotechnical
Technology Transfer
Level of Knowledge
Quality of Life
Safety
Environment
Productivity
Policy
Journal Review
Researcher
Implementability
Student Participation
Communicability
Project Administration

Cost Benefit Analysis

- CBA for research projects:

$$B/C = \frac{K \times (HB + SB)}{RC + IC}$$

B/C = the benefit-cost ratio for a research and implementation effort

K = Impact Constant ($K = 1 + IF$)

HB = "Hard" Benefits based on per year calculation

SB = "Soft" Benefits based on per year calculation

RC = the cost of the research project

IC = the cost of implementing the results

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Impact Constant, *K*

Based on survey feedback from NCDOT research stakeholders the following qualitative benefits were identified as beneficial and deemed qualitative impact factors, *IF*:

- Level of Knowledge Gained – development of standards, policies, specifications, changes to operations, etc., K_i
- Implementation of Research Products, IR_i
- Experience Gained between the NCDOT and Researcher (PI), E_i
- Student Participation and Exposure, GS_i
- Positive Visibility of NCDOT, V_i
- Publications, Peer Reviewed (conferences, journals), PC_i

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Impact Constant, K

- K is calculated as:

$$(K = 1 + IF)$$

Where:

$$IF = w_K(K_i) + w_{IR}(IR_i) + w_E(E_i) + w_{GS}(GS_i) + w_V(V_i) + w_{PC}(PC_i) \leq 1$$

Note: w_i is the weight factor for each qualitative impact factor.

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Development of Weight Factors, w_i

- Analytic Hierarchy Process (AHP) was used to develop weighting factors, w_i
- AHP requires the input (survey data) must elicit the respondent to compare variables. This requires that the pair wise comparisons have increasing and decreasing degrees of importance past the midpoint (average) assessment.

Strongly Disagree	1
Disagree	2
Undecided	3
Agree	4
Strongly Agree	5

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Impact Factor Equation

- The Impact Factor equation can then be written as follows:

$$IF = 0.19(K_i) + 0.18(IR_i) + 0.17(E_i) + 0.15(GS_i) + 0.16(V_i) + 0.15(PC_i) \leq 1$$

- Individual Impact Factor Values

None	Low Impact	Impacted	High Impact
0	0.33	0.67	1

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Cost – Benefit Analysis Example

- Cost Benefit Example:

  RP 2015-11. Preventive Maintenance Program

- Good example that contains both hard and soft benefits.

- Research Budget: $243,000

Cost – Benefit Analysis Example

- Current Cost of Oil Changes

For Regular Interval				
Threshold		Oil Changes per Machine	Annual Cost per vehicle	Annual Cost
value	units			
5,000	miles	2	$ 700.00	$ 114,800.00
5,000	miles	6	$ 900.00	$ 19,800.00
5,000	miles	6	$ 840.00	$ 46,200.00
200	hours	1	$ 270.00	$ 17,280.00
200	hours	2	$ 400.00	$ 21,600.00
200	hours	2	$ 560.00	$ 24,080.00
200	hours	3	$ 750.00	$ 15,000.00
200	hours	2	$ 420.00	$ 23,100.00
			Cost	**$ 281,860.00**
			Benefits	0
			Benefit / Cost Ratio	0

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Cost – Benefit Analysis Example

- Costs of Oil Changes based on Project

from Extended Oil Drain Intervals				
Threshold		Oil Changes per Machine	Annual Cost per vehicle	Annual Cost
value	units			
10,000	miles	1	$ 350.00	$ 57,400.00
5,000	miles	6	$ 900.00	$ 19,800.00
10,000	miles	3	$ 420.00	$ 23,100.00
500	hours	1	$ 270.00	$ 17,280.00
500	hours	1	$ 200.00	$ 10,800.00
500	hours	1	$ 280.00	$ 12,040.00
500	hours	1	$ 250.00	$ 5,000.00
500	hours	1	$ 210.00	$ 11,550.00
			Cost	**$ 156,970.00**

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Cost – Benefit Analysis Example

- Estimated Savings per Year

Estimated savings		
Oil Changes per Machine	**Annual Cost**	**Oil (Gallon)**
1	$ 57,400.00	1230
0	$ -	0
3	$ 23,100.00	537
0	$ -	0
1	$ 10,800.00	216
1	$ 12,040.00	258
2	$ 10,000.00	210
1	$ 11,550.00	220
	$ 124,890.00	**2671**

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Cost – Benefit Analysis Example

- Calculating the *IF* as:

Knowledge	= 1.0 (new knowledge)
Implementation	= 0.33 (has not been fully implemented)
Experience	= 0
Grad Students	= 0.67 (2 MS students funded)
Publications	= 0.67 (3 presentations and a TRB paper)
Visibility	= 0.33 (Small communication about the project)

IF = 0.19(1) + 0.18(0.33) + 0.17(0) + 0.15(0.67) + 0.15(0.67) + 0.16(0.33) = 0.50

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Cost – Benefit Analysis Example

- And the CBA can be calculated as follows:

$$B/C = \frac{K \times (HB + SB)}{RC + IC}$$

$$= \frac{1.50 \times (124{,}890 + 1{,}823)}{121{,}500} = 1.56$$

- In this instance, the yearly savings would be better communicated as the project is saving North Carolina taxpayers $187,500/year based on the current implementation level.

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Future Work – Knowledge Gained

- Knowledge Gained defined as a product – measurable, quantifiable result of research.
  - standards,
  - policies,
  - specifications,
  - changes to operations,
  - Safety procedures

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Capturing and Communicating the Value of NCDOT Research

Thomas Nicholas II, P.E., Ph.D.

tnichola@uncc.edu

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Protecting Bridge Maintenance Workers:

Evaluating Fall Protection Supplementary Devices using Virtual Prototyping and Wearable Technology

Alex Albert, Ph.D.
Assistant Professor

Carlos Zuluaga, Ph.D.
Project Engineer – Harkins Builders, MD

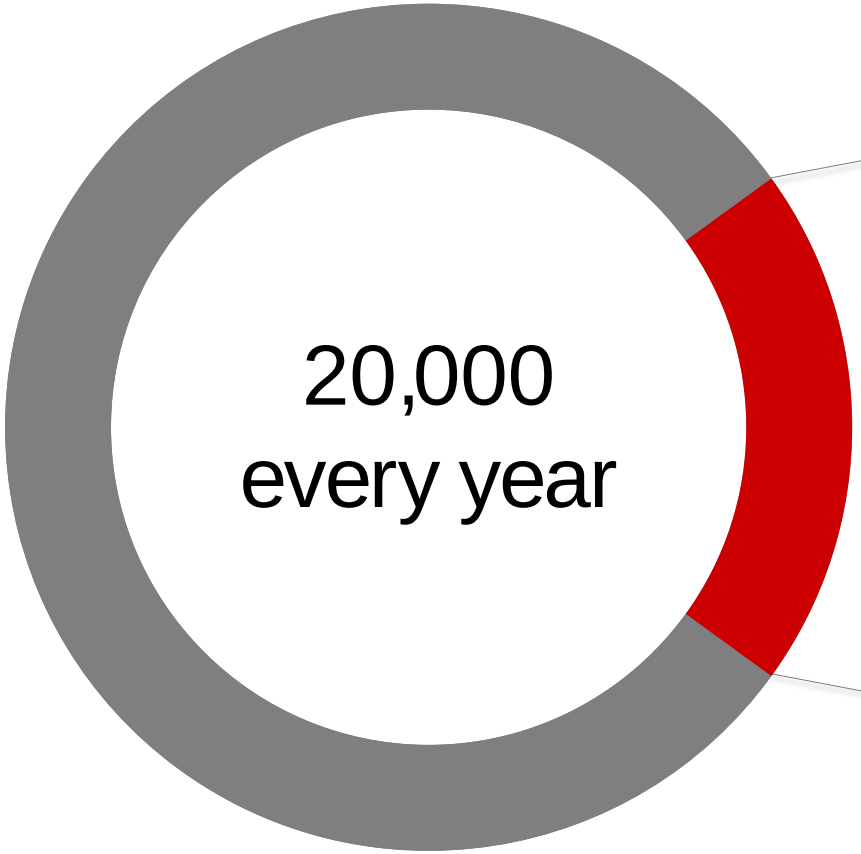
NC STATE UNIVERSITY

Department of Civil, Construction, and Environmental Engineering

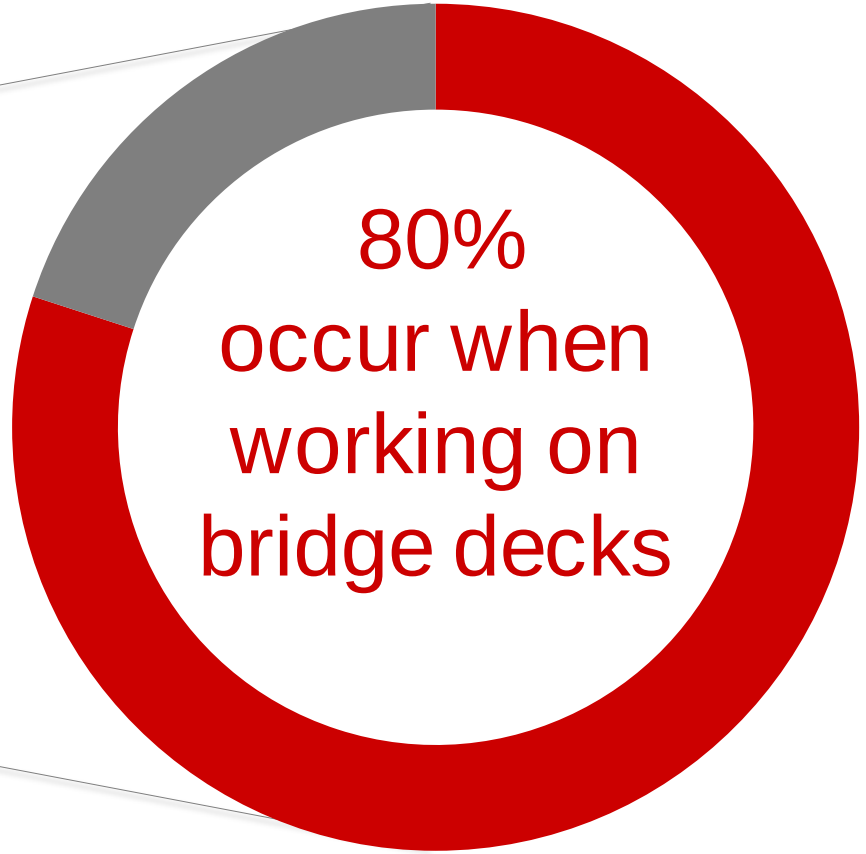
Introduction

The proportion of fall-related injuries is unacceptable

Transportation workers injuries



Bridge workers' fatal injuries



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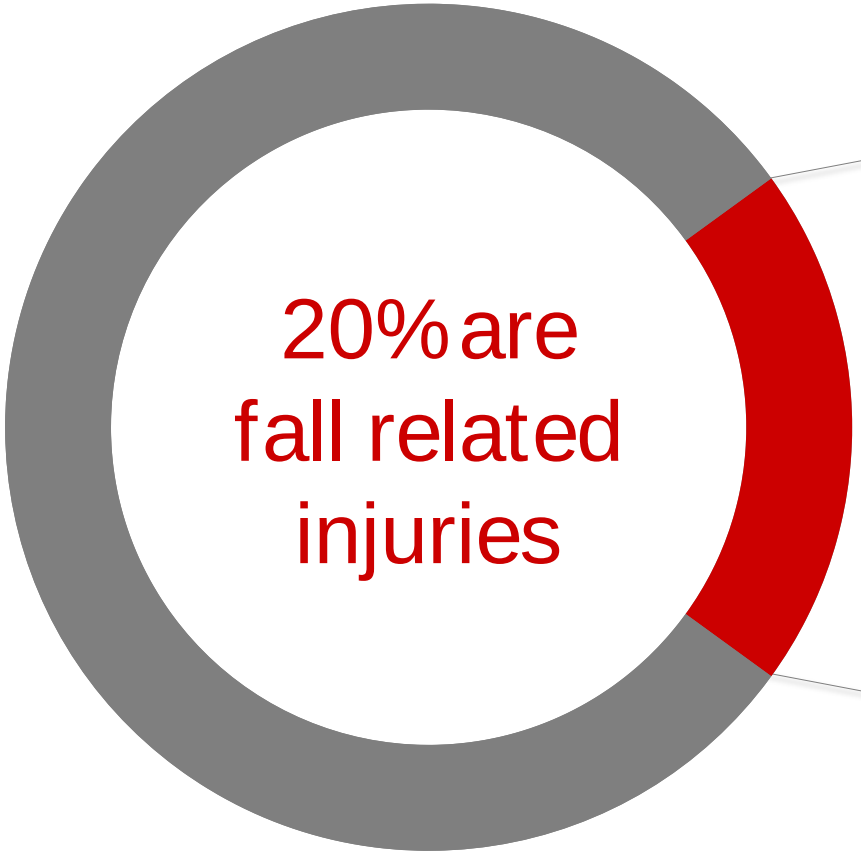
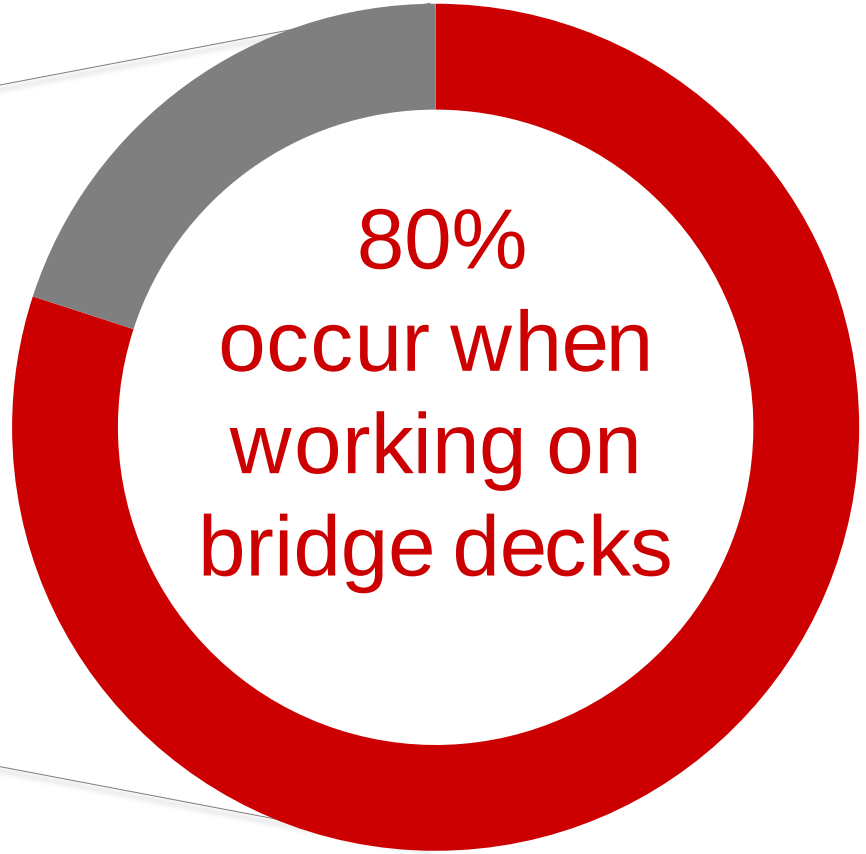
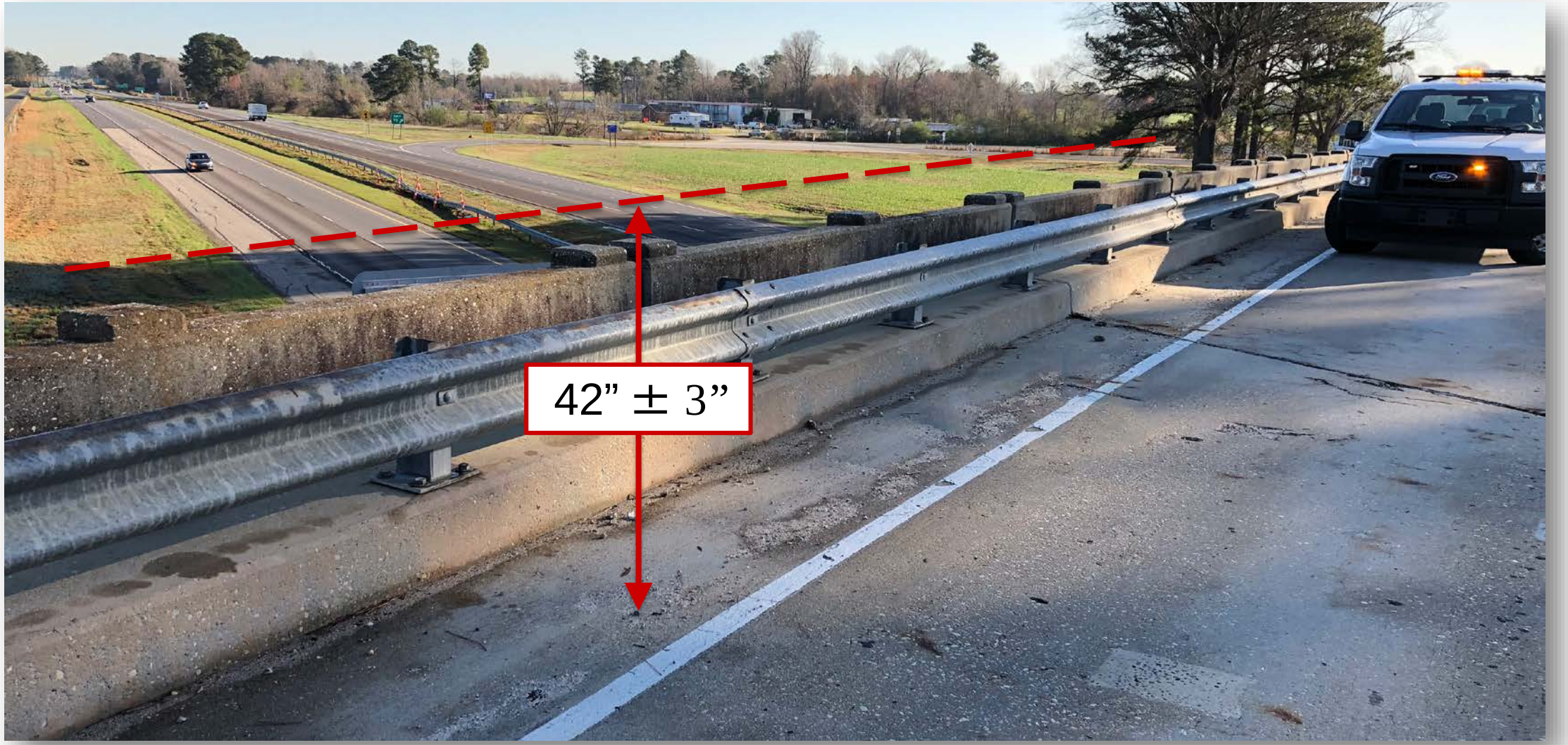
Transportation workers injuries



Bridge workers' fatal injuries



The majority of bridge guardrails do not offer sufficient fall protection to workers



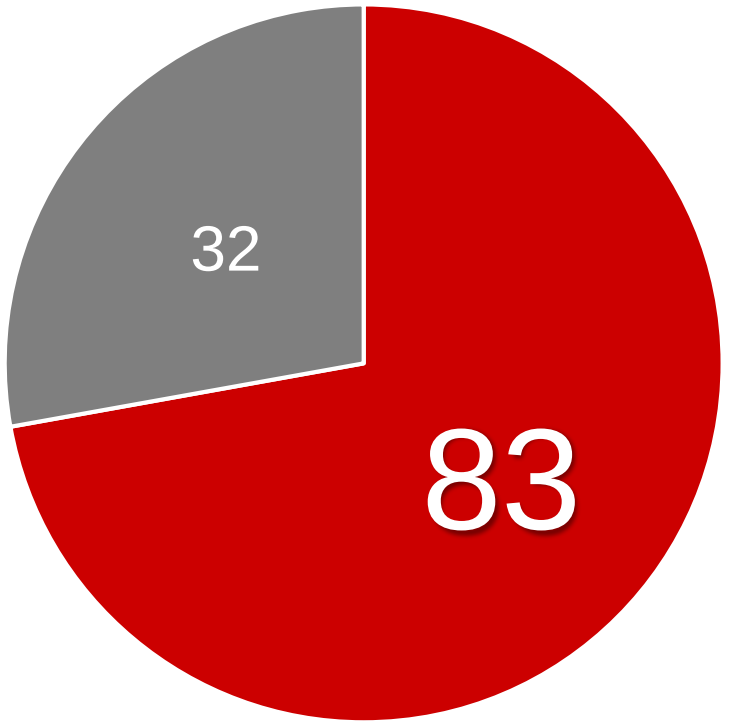
The majority of bridge guardrails do not offer sufficient fall protection to workers

800+ bridge structures inspected by worker-crews per day

The majority of bridge guardrails do not offer sufficient fall protection to workers

- Many workers exposed to fall-related hazards
- Nationwide issue in most bridges
- North Carolina is no exception

Guardrail designs approved for use in the National Highway System



Lower than 39 inches

The majority of bridge guardrails do not offer sufficient fall protection to workers

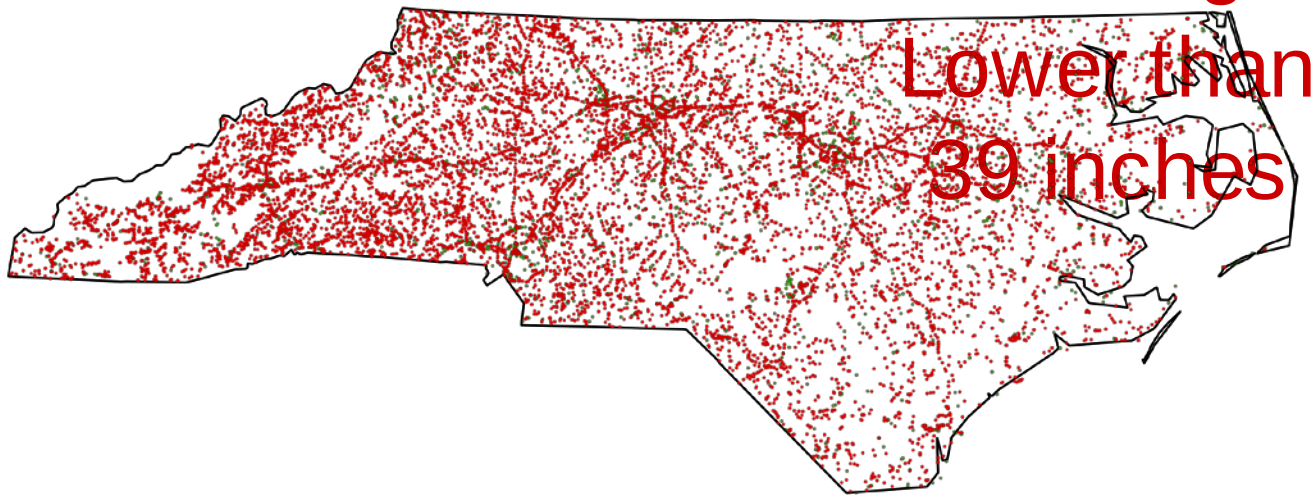
- Many workers exposed to fall-related hazards
- Nationwide issue in most bridges
- North Carolina is no exception

88%

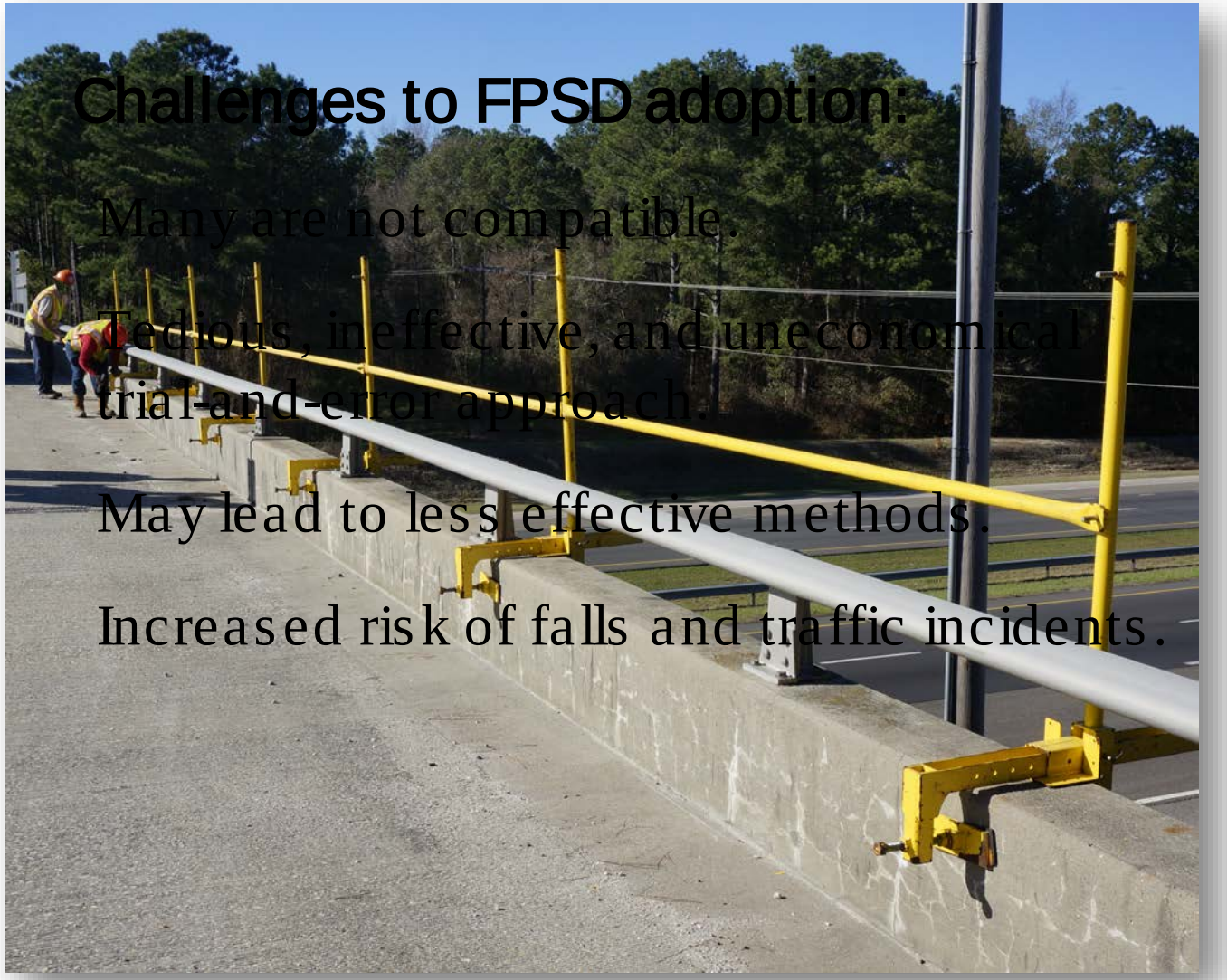
guardrails below 39 inches in height

12%

Compliant guardrails



Fall Protection Supplementary Devices (FPSD) are an effective solution



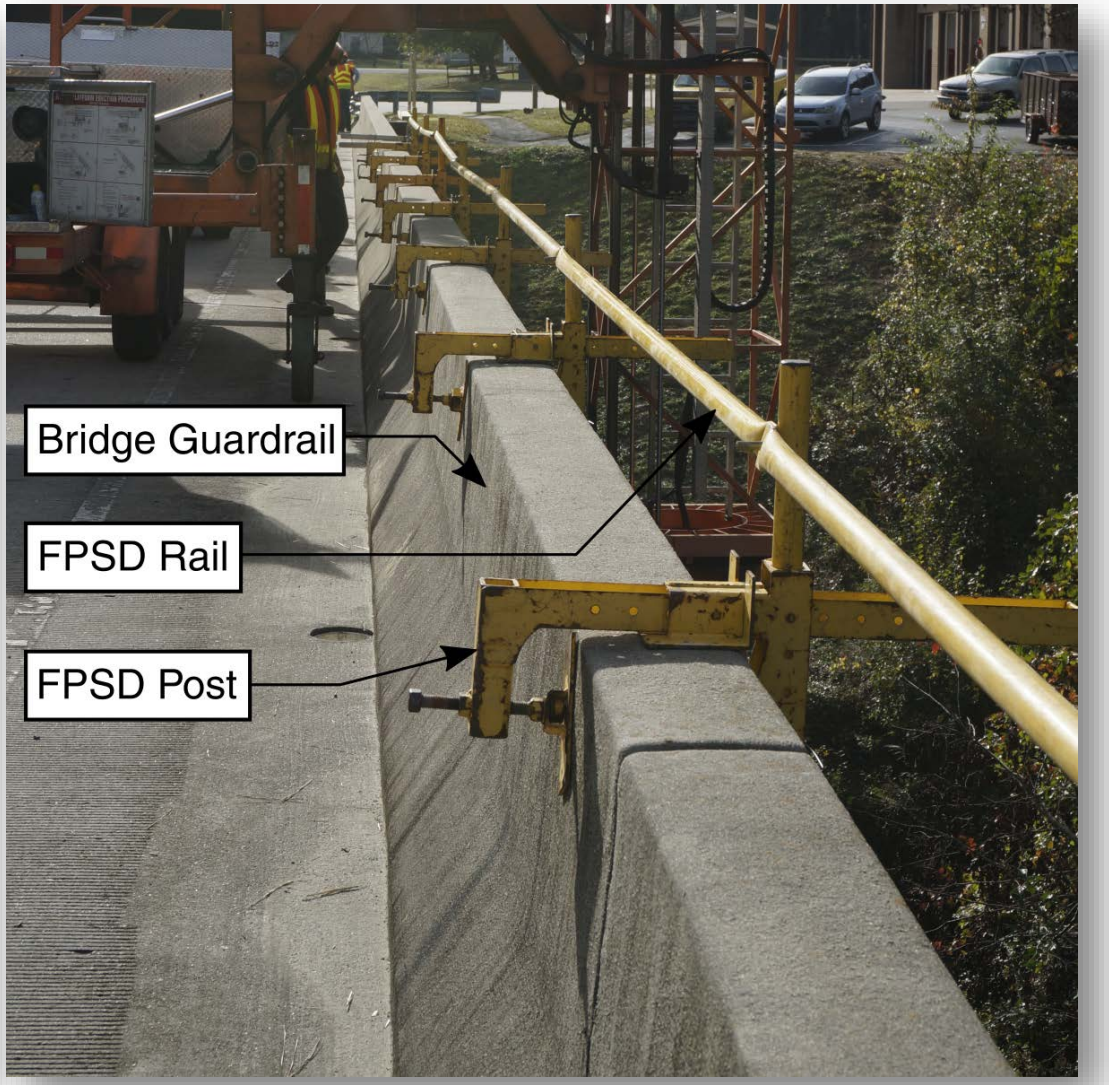
Challenges to FPSD adoption:

Many are not compatible.

Tedious, ineffective, and uneconomical trial-and-error approach.

May lead to less effective methods.

Increased risk of falls and traffic incidents.



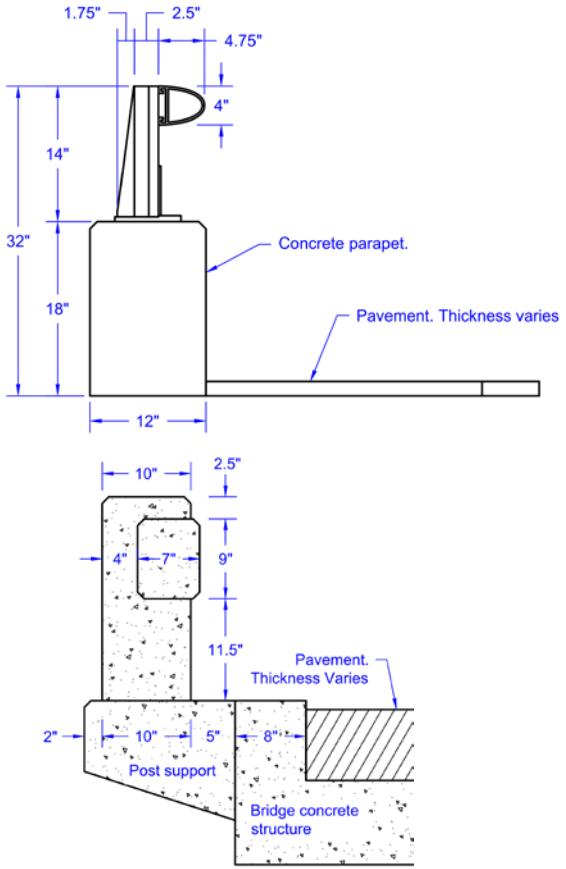
Research Objectives

Objective 1 Propose a safe, economic, and efficient method for the completion of compatibility testing between FPSDs and bridge guardrails using virtual prototyping techniques.

Objective 2 Conduct field-level studies to objectively compare and evaluate FPSDs adopted by bridge workers using physiological, postural, productivity, and utility measures.

Identification of Non-Compliant Bridge Guardrails

Primary Source



Secondary Source

AASHTO
THE VOICE OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

NC DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
STRUCTURE MANAGEMENT UNIT

ATTENTION: TEMPORARY REPAIRS / PM ISSUED

Structure Safety Report
Routine Element Inspection

COUNTY: BLADEN STRUCTURE NUMBER: 080032 FREQUENCY: 24 MONTHS
FACILITY CARRIED: SR1700 MILE POST:
LOCATION: 0.2 MI N JCT SR1708
FEATURE INTERSECTED: HAMMOND CREEK
LATITUDE: 34° 34' 43.41" LONGITUDE: 78° 35' 30.81"
SUPERSTRUCTURE: PRESTRESSED CONCRETE CHANNELS, STD.BMD-13
SUBSTRUCTURE: E.BTS&BTS:PRESTR.CONC.CAPS ON TIM.PILES@5'6CTS
SPANS: 1@30'6,1@30',1@30'6
FRACTURE CRITICAL TEMPORARY SHORING SCOUR CRITICAL SCOUR PLAN OF ACTION
PRESENT CONDITION: Fair INSPECTION DATE: 06/02/2015
POSTED SV: 22 POSTED TTST: 25
OTHER SIGNS PRESENT: 3 DELINEATORS

Sign noticed issued for		Number Required
NO	WEIGHT LIMIT	0
YES	DELINEATORS	1
NO	NARROW BRIDGE	0
NO	ONE LANE BRIDGE	0
NO	LOW CLEARANCE	0

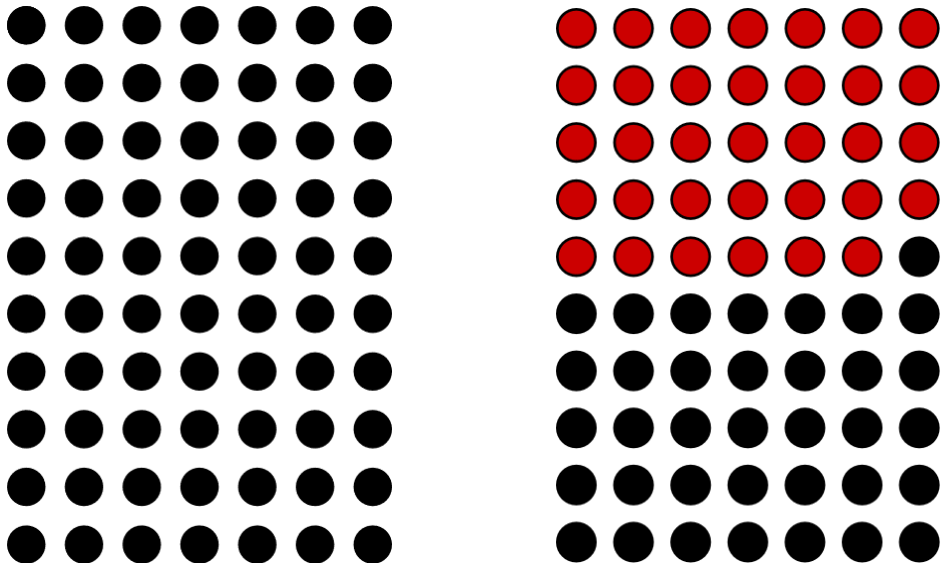
LOOKING NORTH (MERCER MILL / BROWN MARSH ROAD)

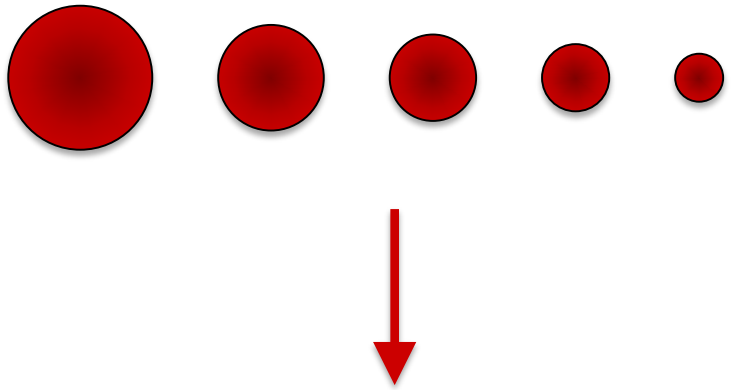
INSPECTED BY Ray L. Kisner SIGNATURE ASSISTED BY R.D. Heath

Tertiary Source

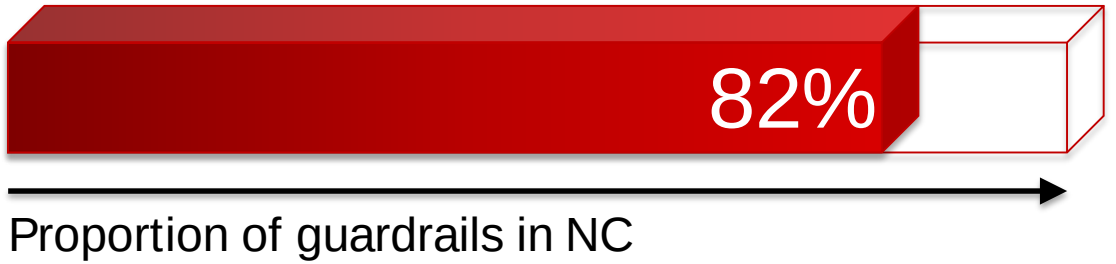
Identification of Non-Compliant Bridge Guardrails

70 Guardrail Designs → 34 guardrails than lower 39 inches → Ranking according to the quantity





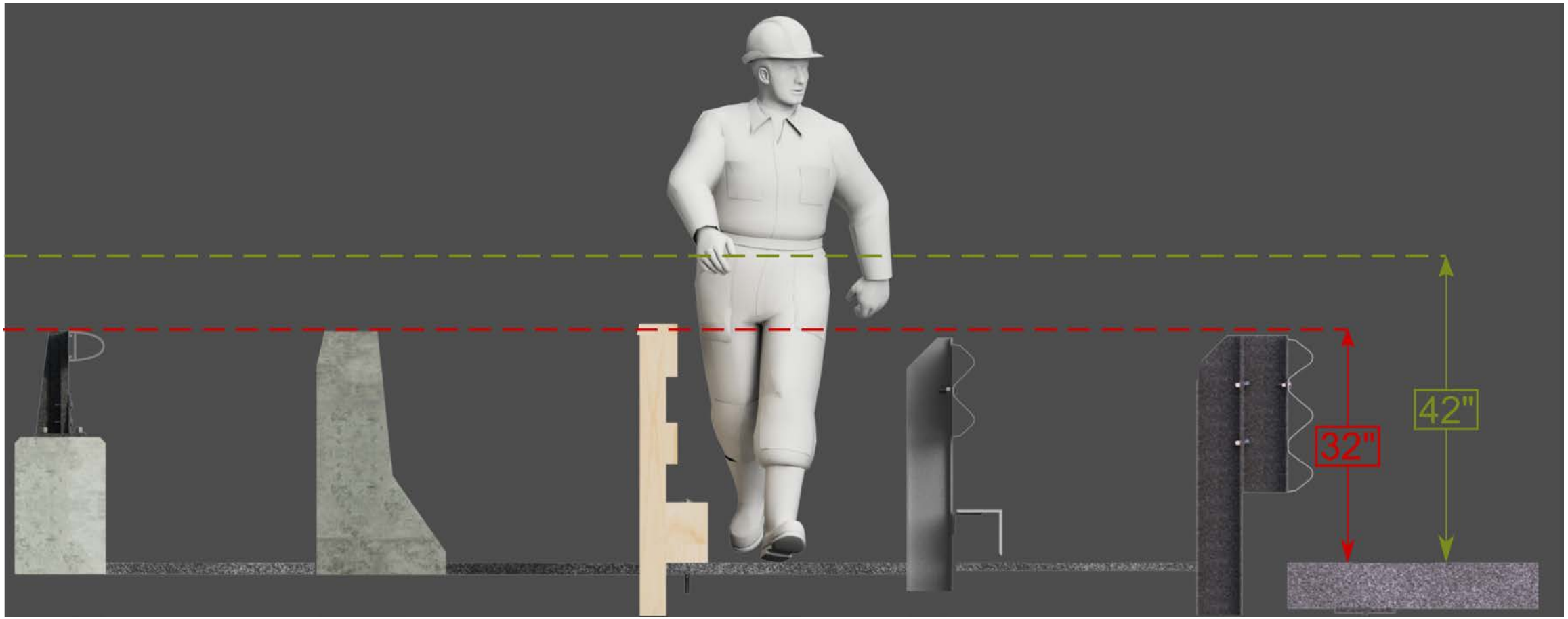
12 Most Common Low-height Guardrails



> 22,000 guardrails

Identification of Non-Compliant Bridge Guardrails

5 most common bridge guardrails in NC



Identification of FPSDs

Parapet Clamp

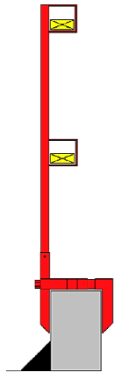
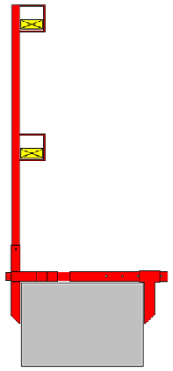
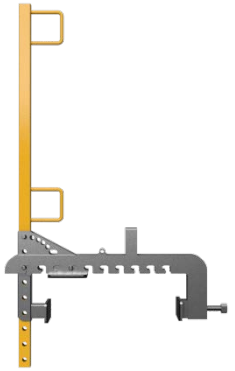
Slab Clamp

Freestanding guardrails

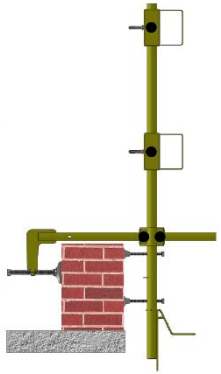
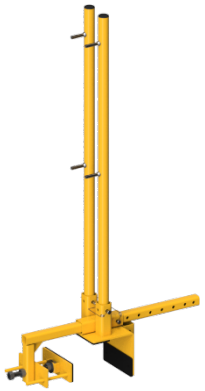
Barrier Supplements

Identification of FPSDs

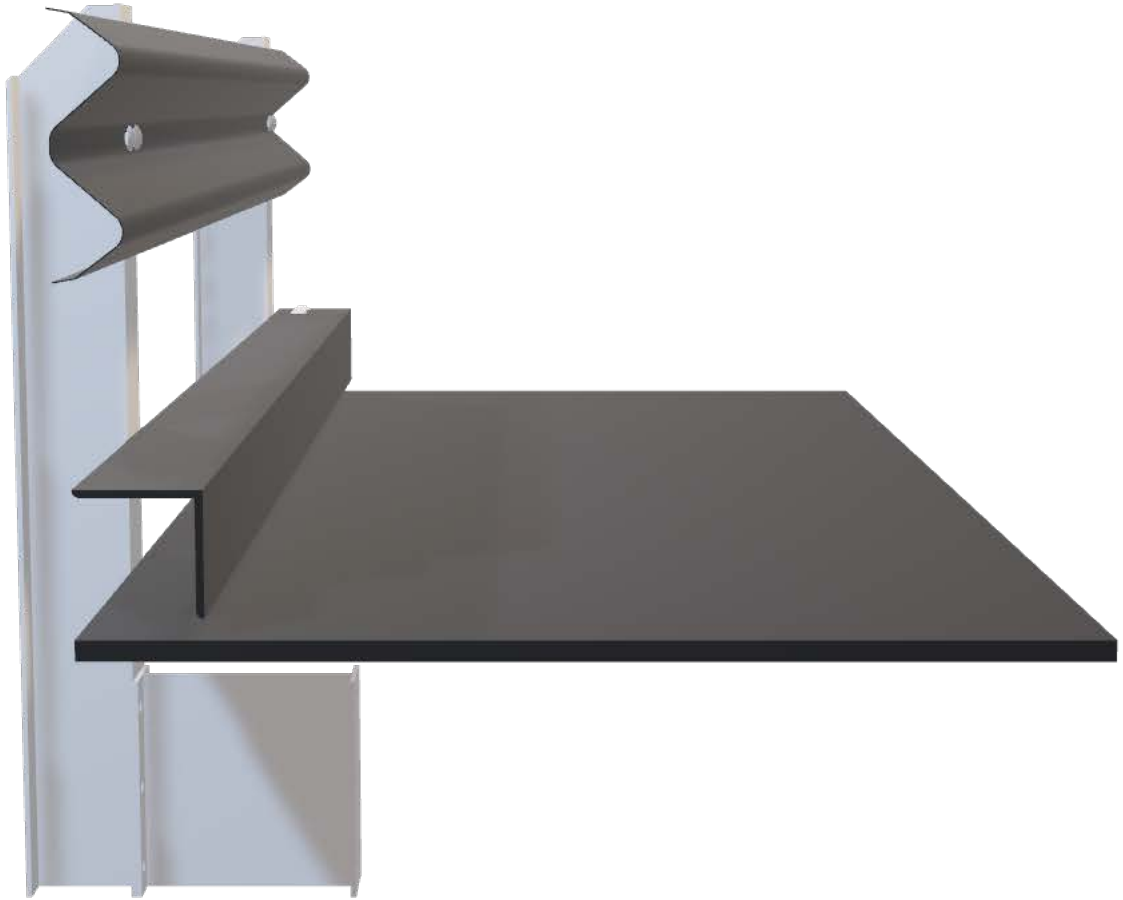
23 candidate FPSD were identified

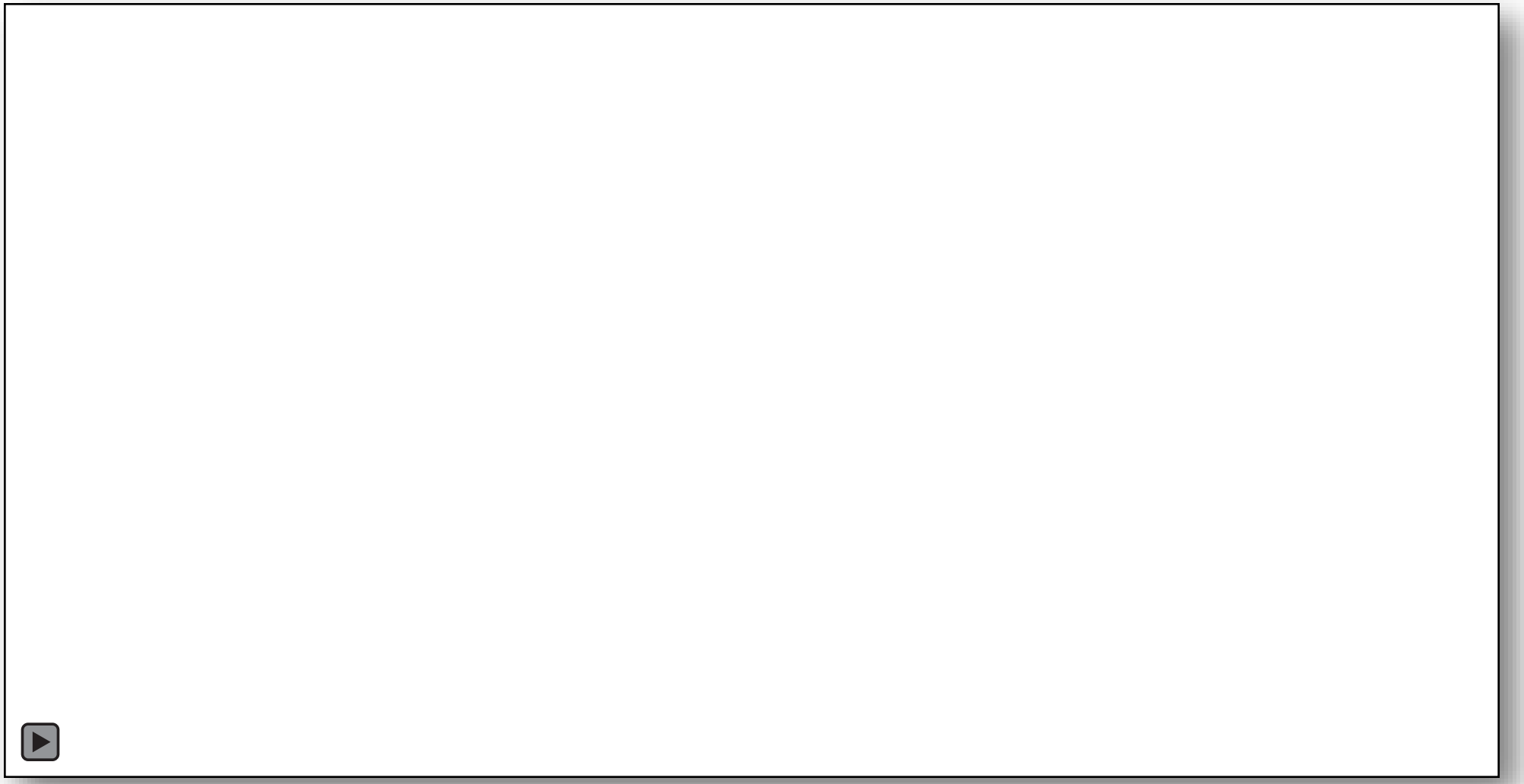


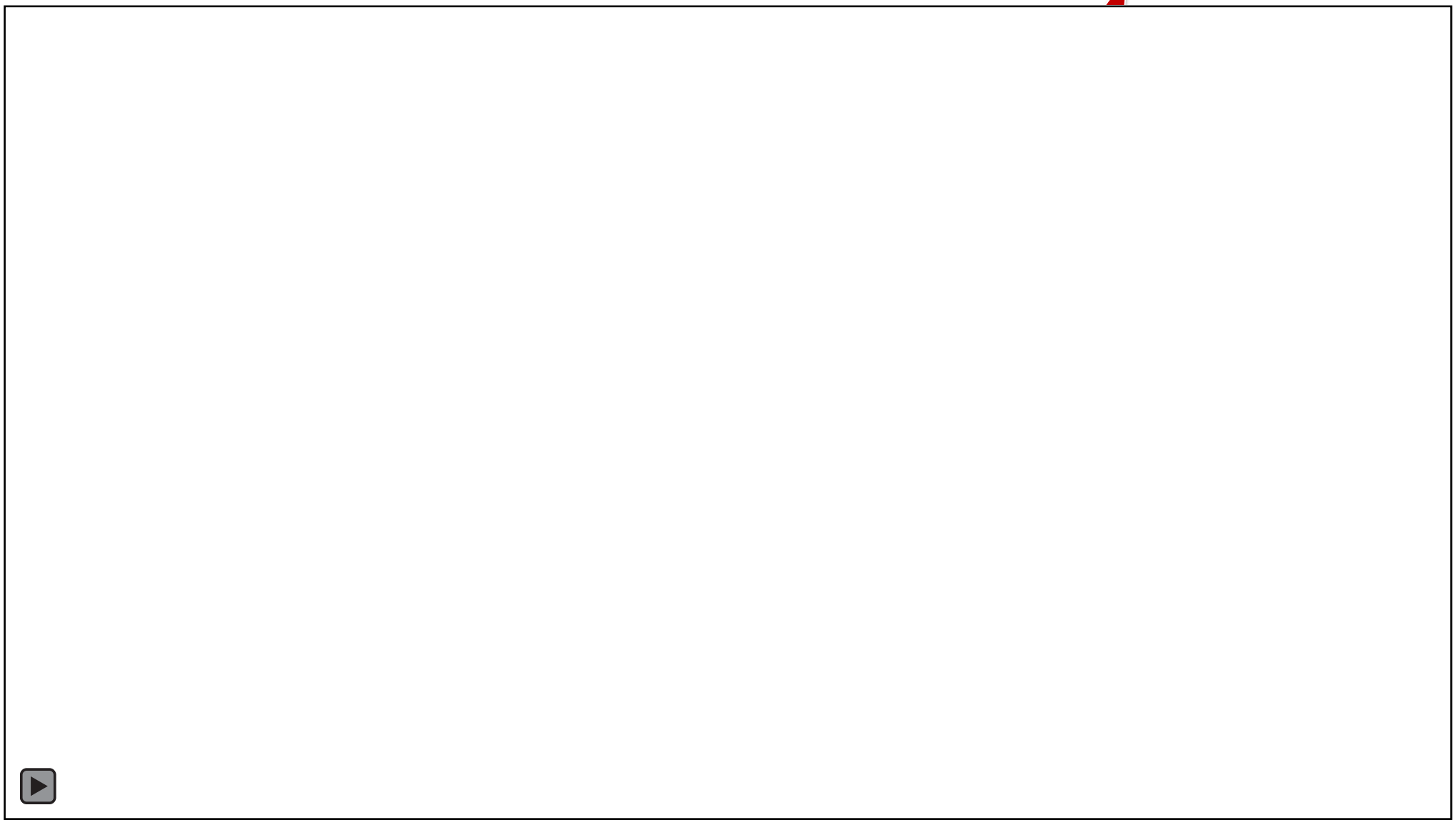
Construction of Virtual Prototypes



Construction of Virtual Prototypes



Virtual Compatibility Testing



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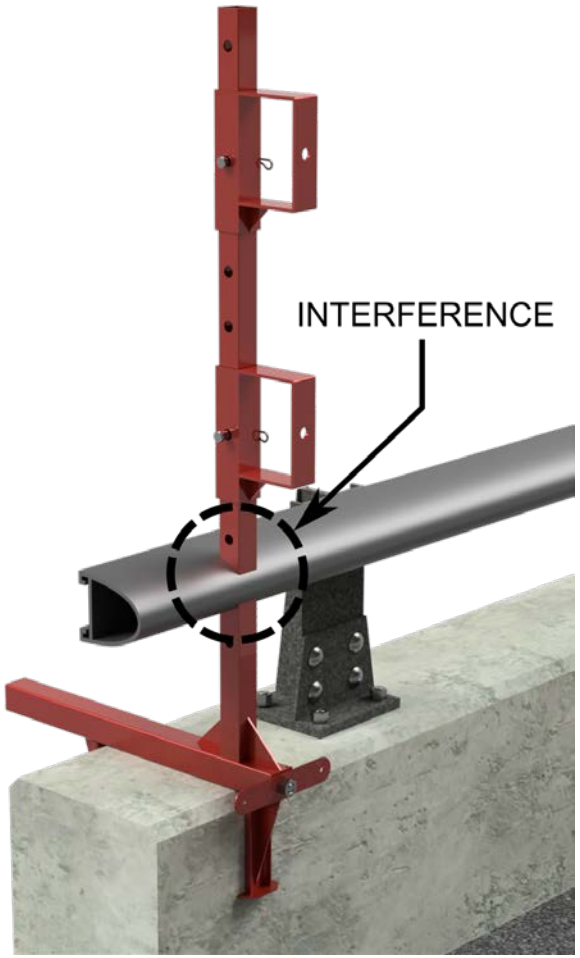
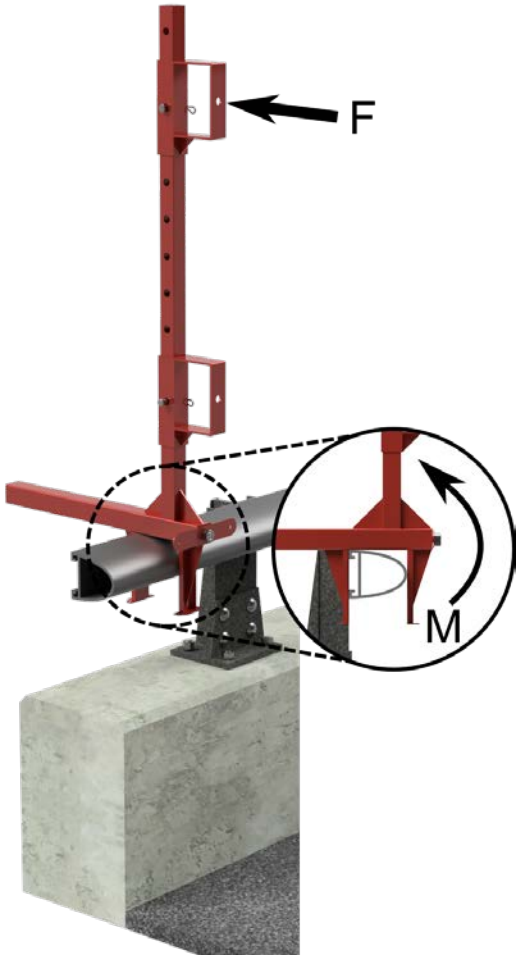
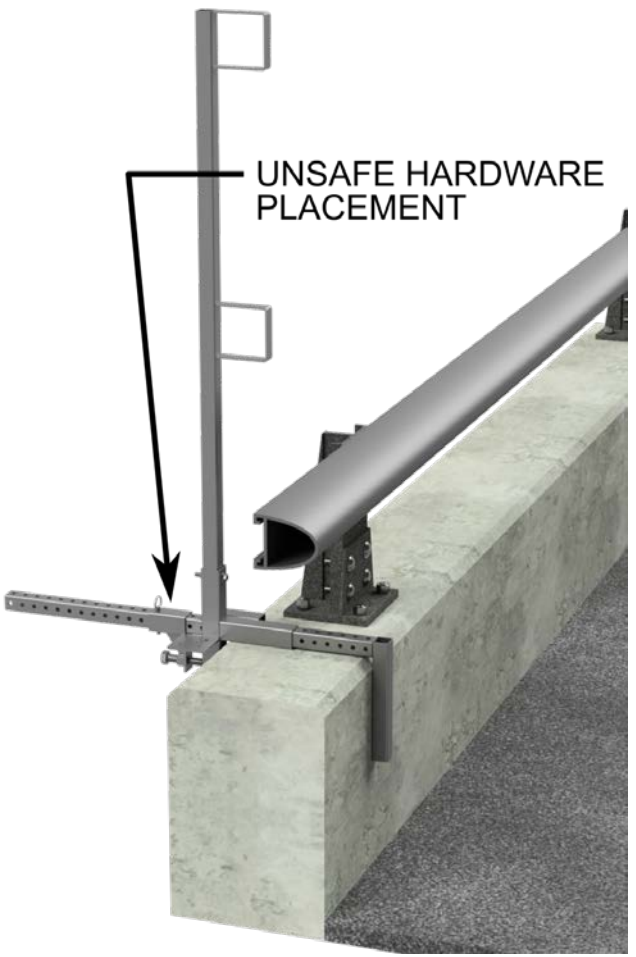
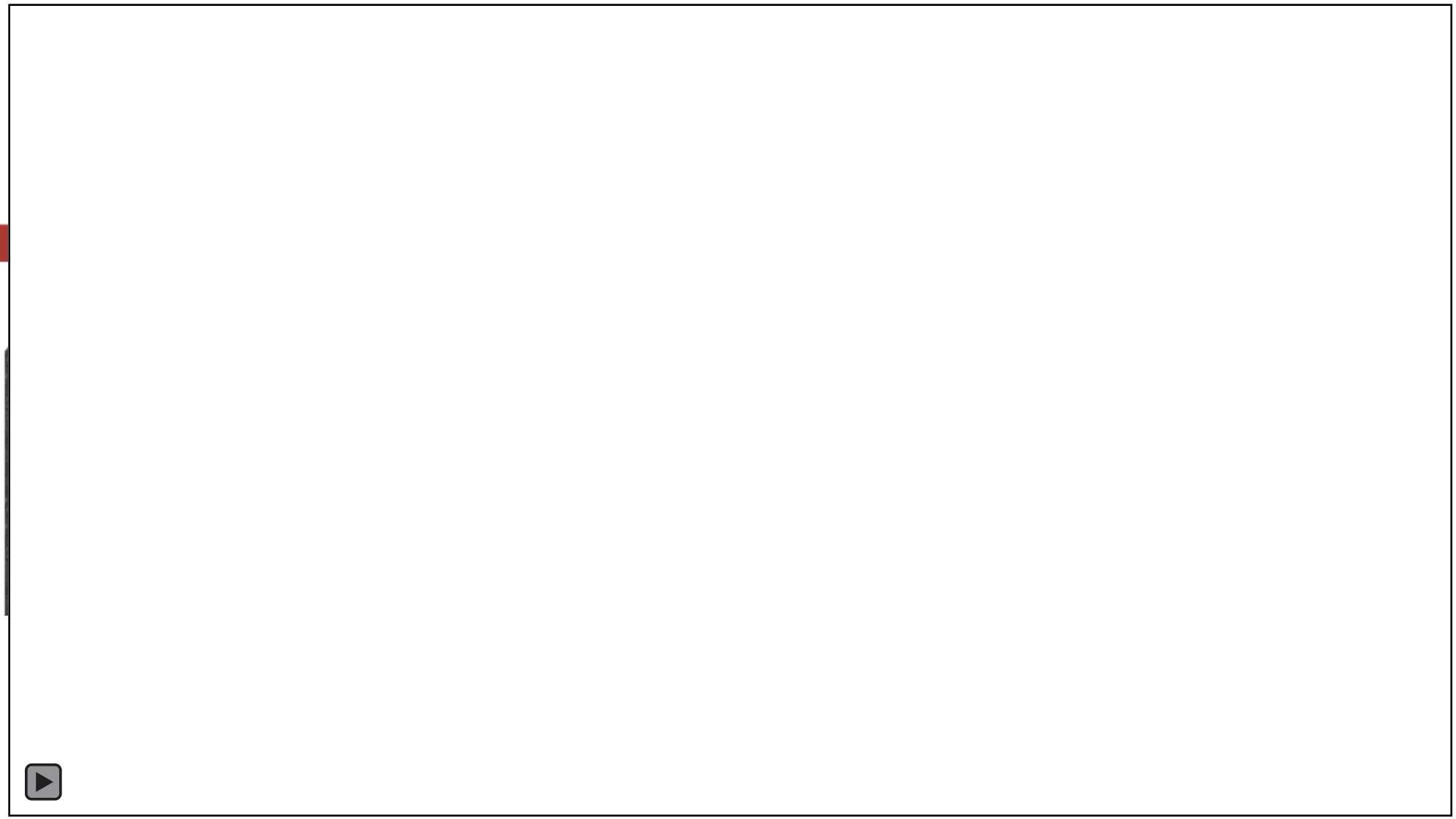




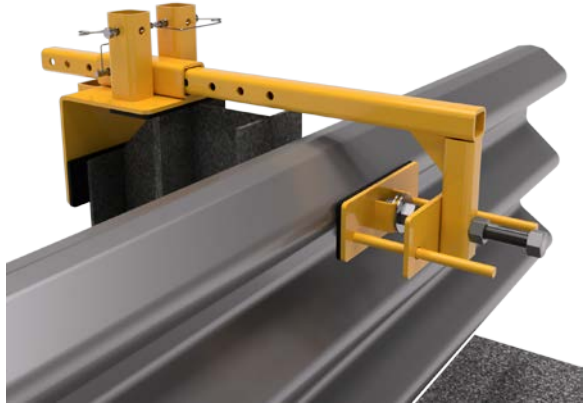


Virtual Compatibility Testing



Virtual Compatibility Testing

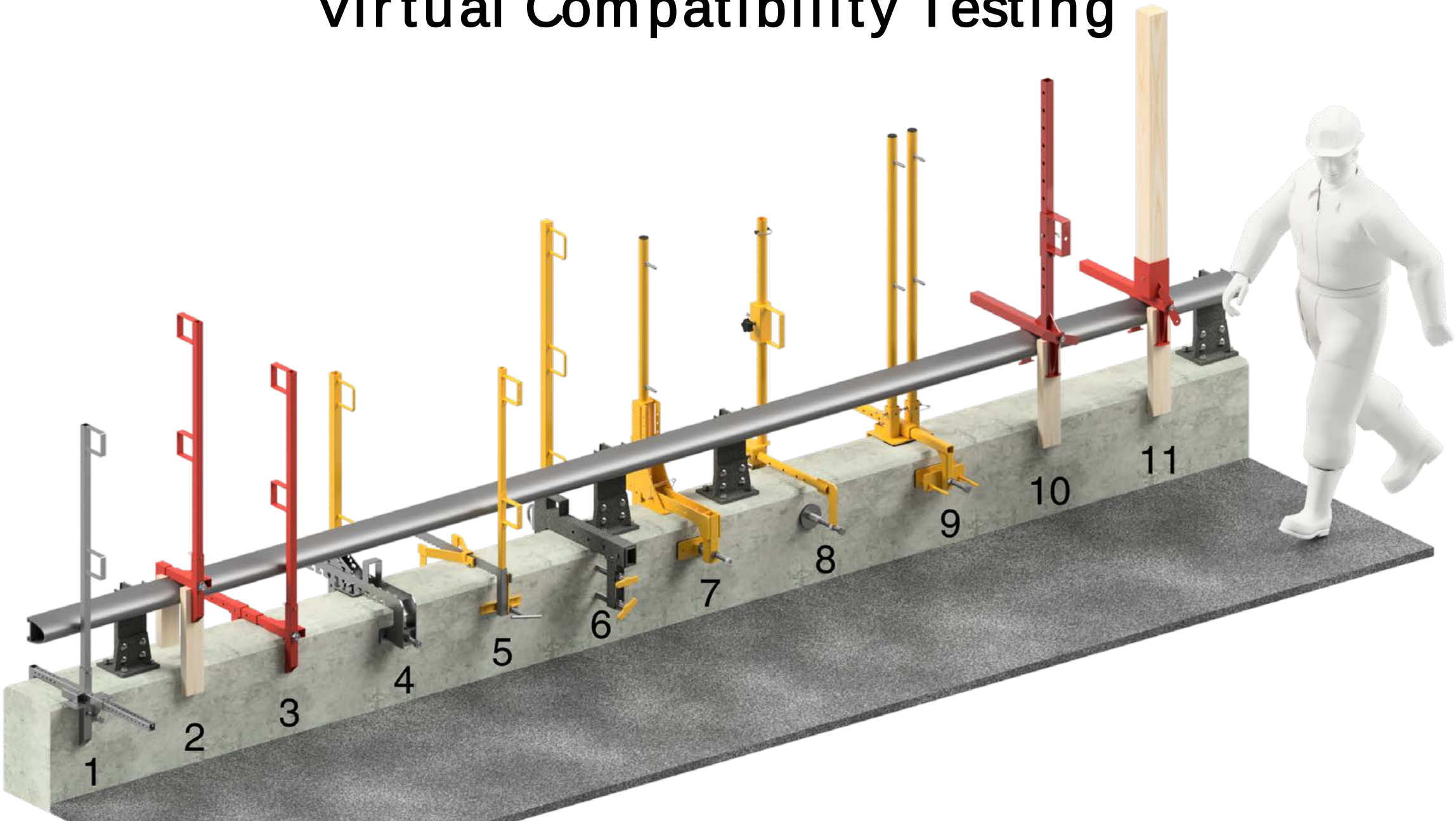
Virtual Prototypes




Photographs




Virtual Compatibility Testing

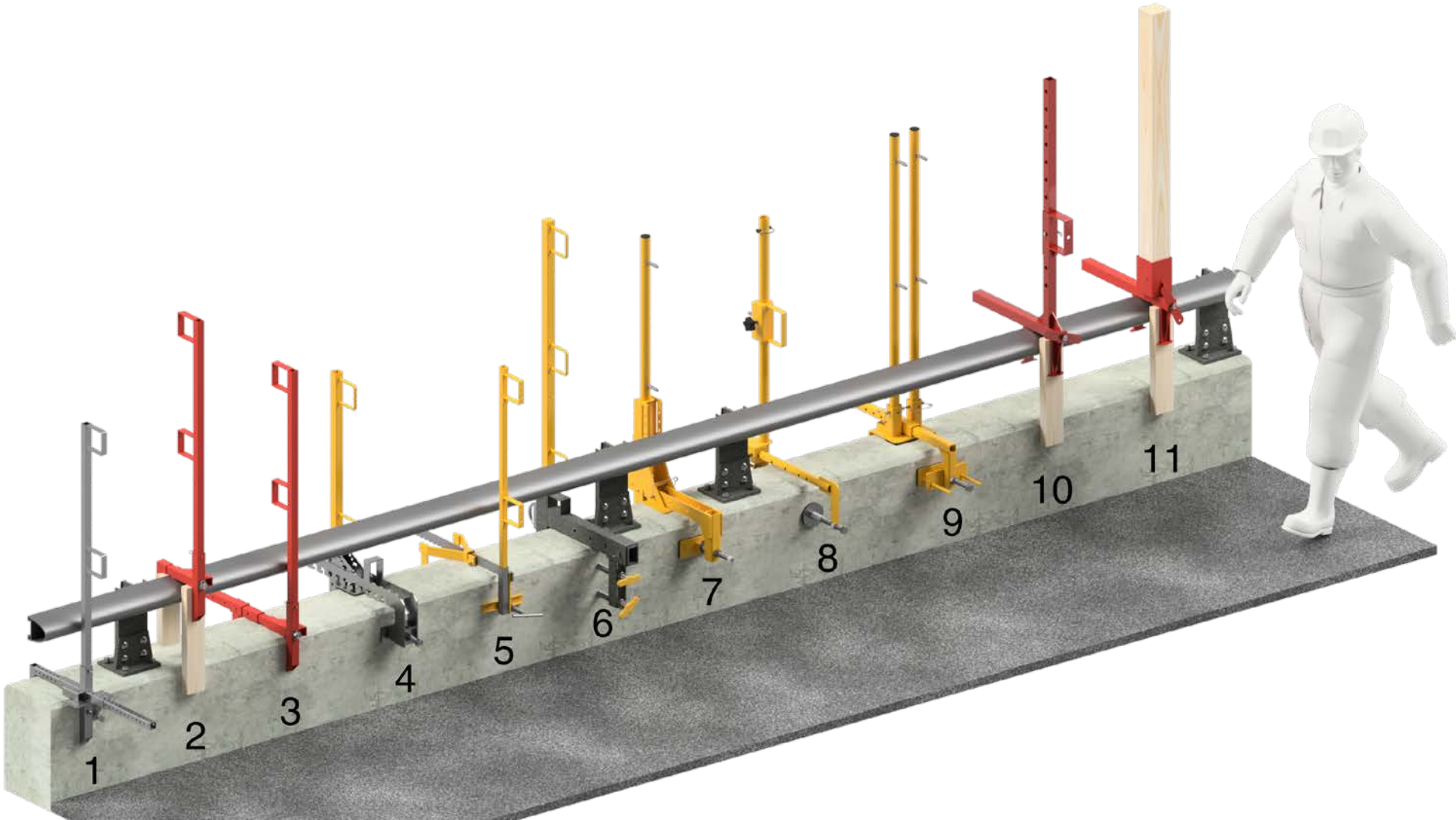


Virtual Compatibility Testing

Safe

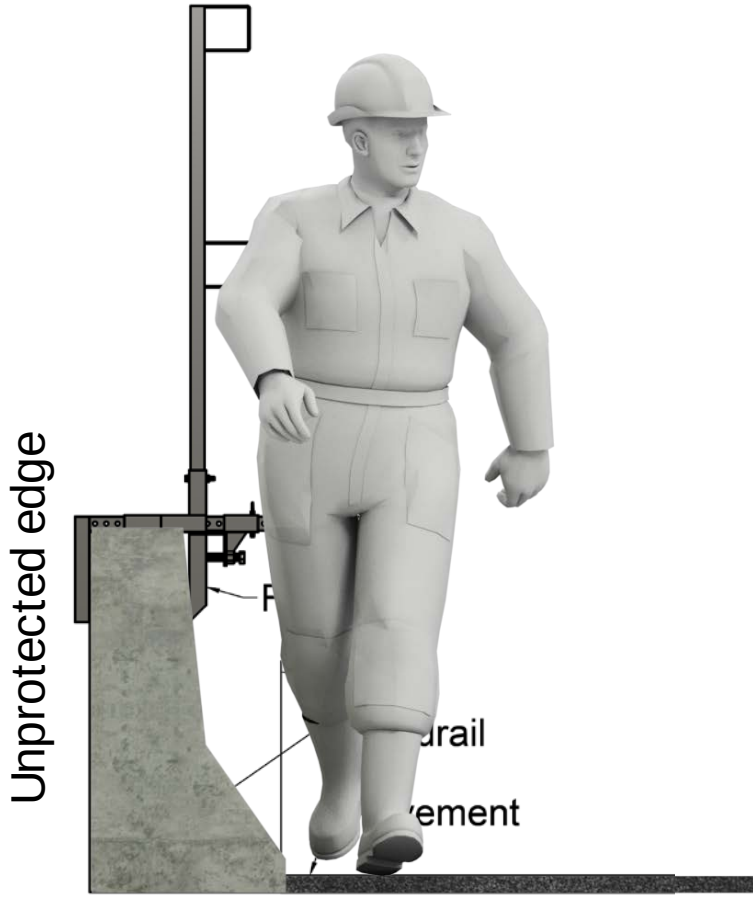
Economical

Efficient



Identification of Desirable Characteristics and Relevant Selection Criteria

Want Factors	Criteria
1. Ease of transportation and installation.	**Easier is better.** Scale 1 – 10 with 1 being the easiest.
2. Exposure to the unprotected edge.	**Lesser is better.** Scale 1 – 10 with 1 not extending beyond the barrier.
3. Protrusion into the work area.	**Lesser is better.** Measured in inches.
4. Self-weight of the FPSD.	**Lesser is better.** Measured in pounds.
5. # of components and movable parts required for complete installation.	**Lesser is better.** Count.



Objective

Evaluate and objectively compare FPSDs in terms of the advantages they provide to the safety, efficiency, and productivity of the workforce.

CC120

MCC130

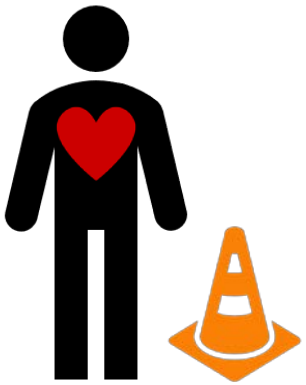
ParaClamp

RaptorRail

Objective

Evaluate and objectively compare FPSDs in terms of the advantages they provide to the safety, efficiency, and productivity of the workforce.

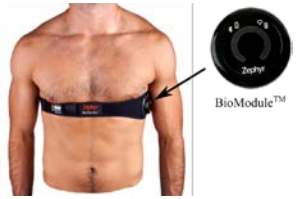
Physiological Demands



Postural Demands

Activity Rates

Data Collection Methods



Wearable Devices

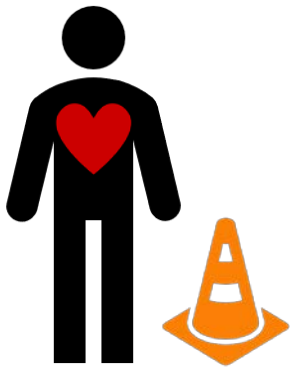
Physiological Demands

Postural Demands

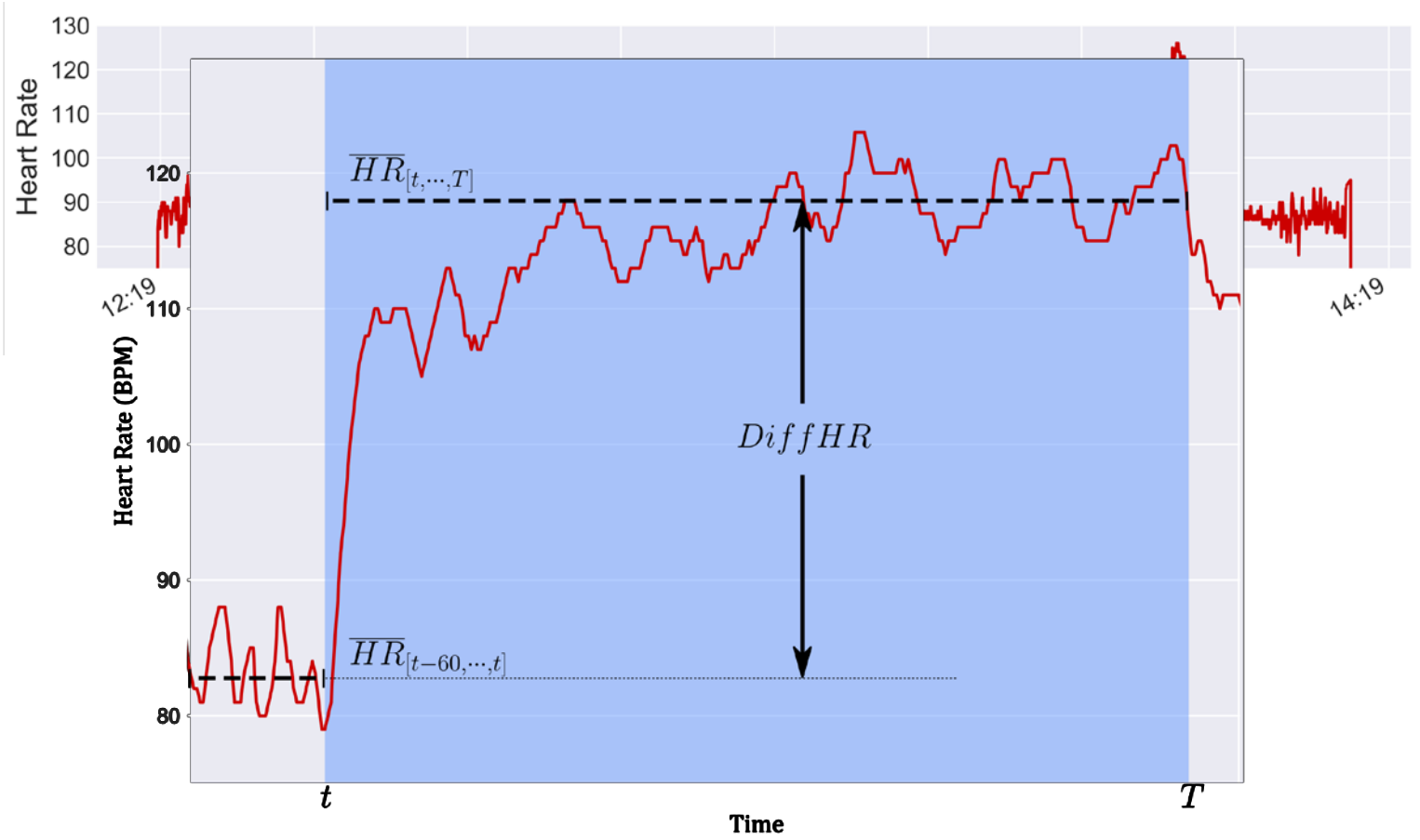
Activity Rates

Data Collection Methods

Physiological Demands

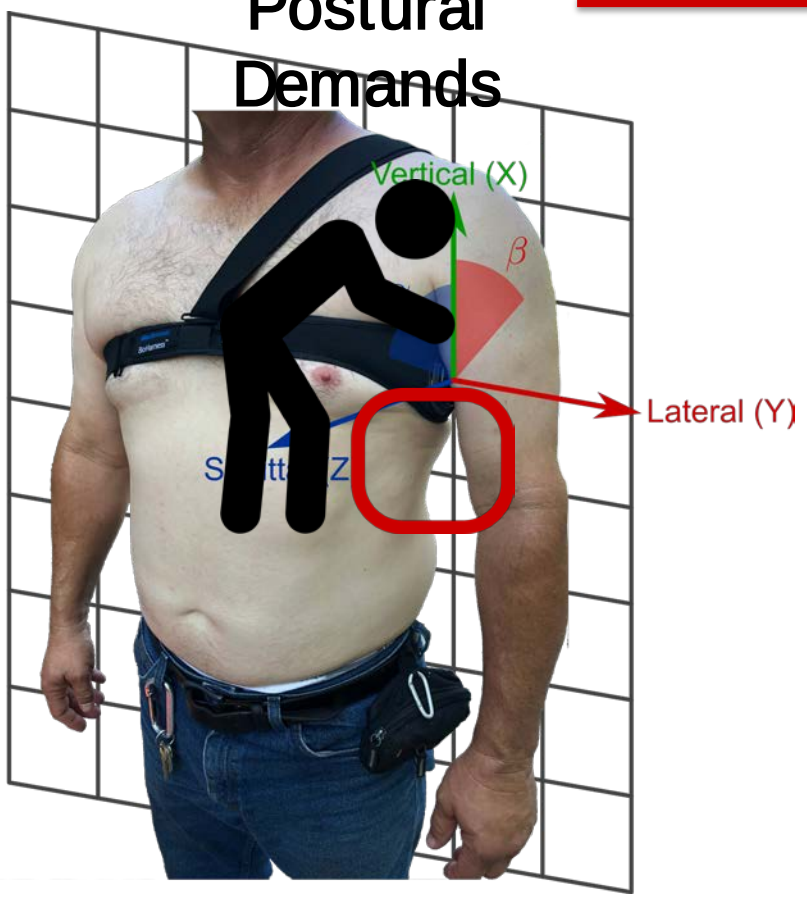


→ Differential Heart Rate

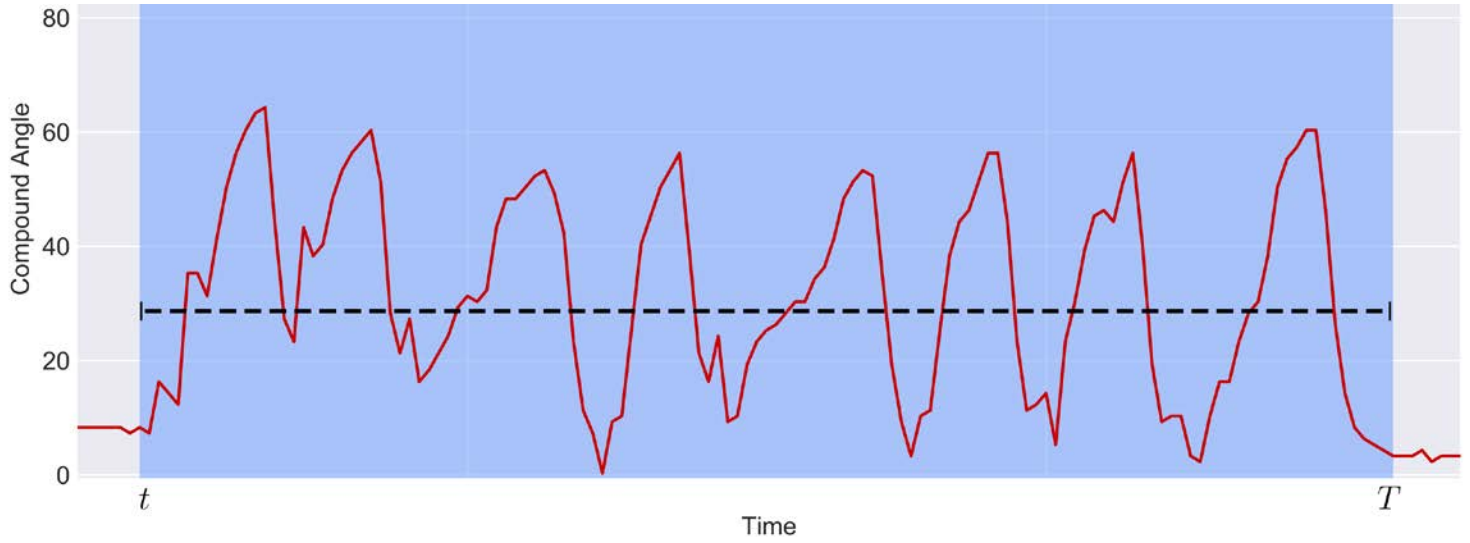


Data Collection Methods

Postural Demands → Average Compound Angle



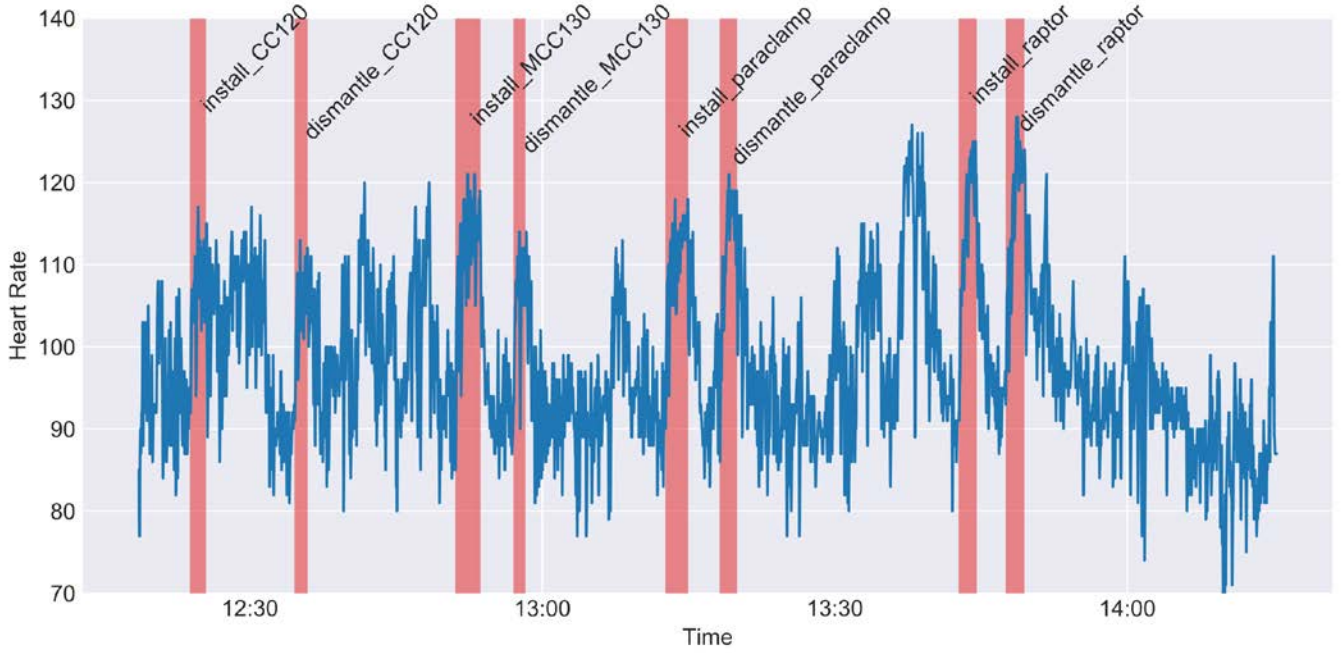
$$Compound\ Angle\ (\gamma)° = |\alpha°| + |\beta°|$$



Data Collection Methods

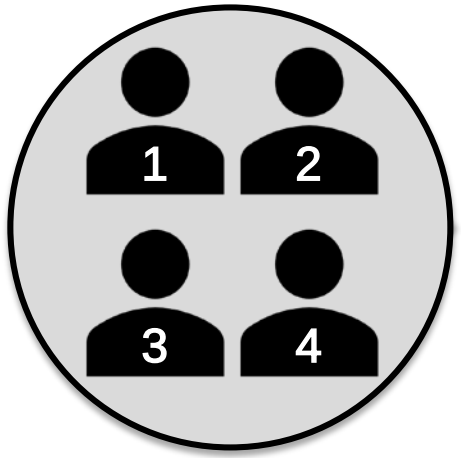
Activity Rates

Average Activity Rate

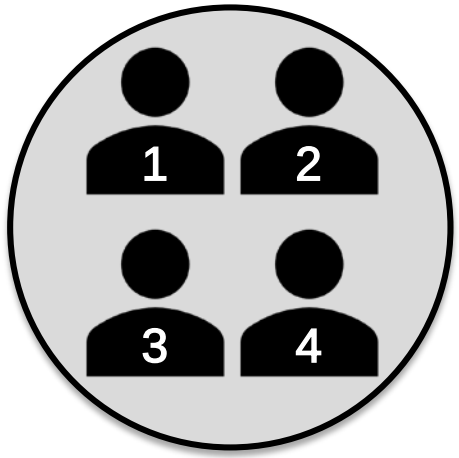


$$Average\ Activity\ Rate = \frac{Total\ activity\ duration}{\#\ of\ FPSD\ posts\ used}$$

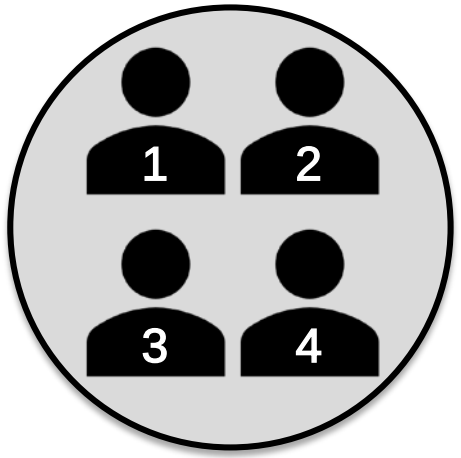
Repeated Measures Experimental Design



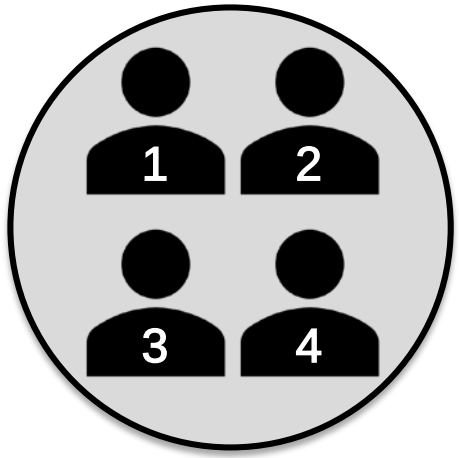
Treatment 1



Treatment 2



Treatment 3



Treatment 4

Repeated Measures Experimental Design

Subjects	Treatments	Activities
	CC-120	Load
	MCC-130	Unload
	ParaClamp	Install
	RaptorRail	Dismantle

Repeated Measures Experimental Design

Subjects	Treatments	Activities
	RaptorRail	Install
	ParaClamp	Dismantle
	CC-120	Load
	MCC-130	Unload

Experimental Procedures

Part 1

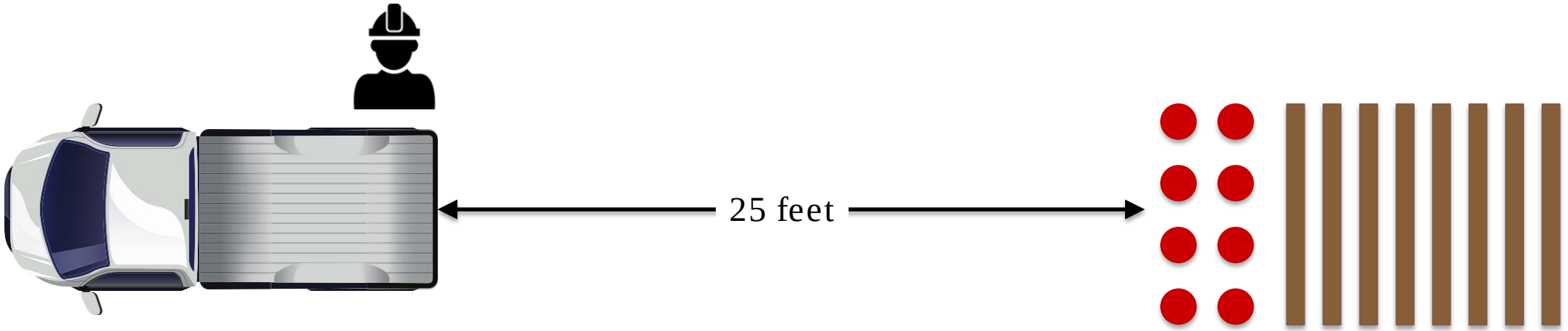
Storage, Preparation, and Transportation Activities

Part 2

Installation and Dismantling Activities

Experimental Procedures – Part 1
Storage, Preparation, and Transportation Activities

Truck Loading

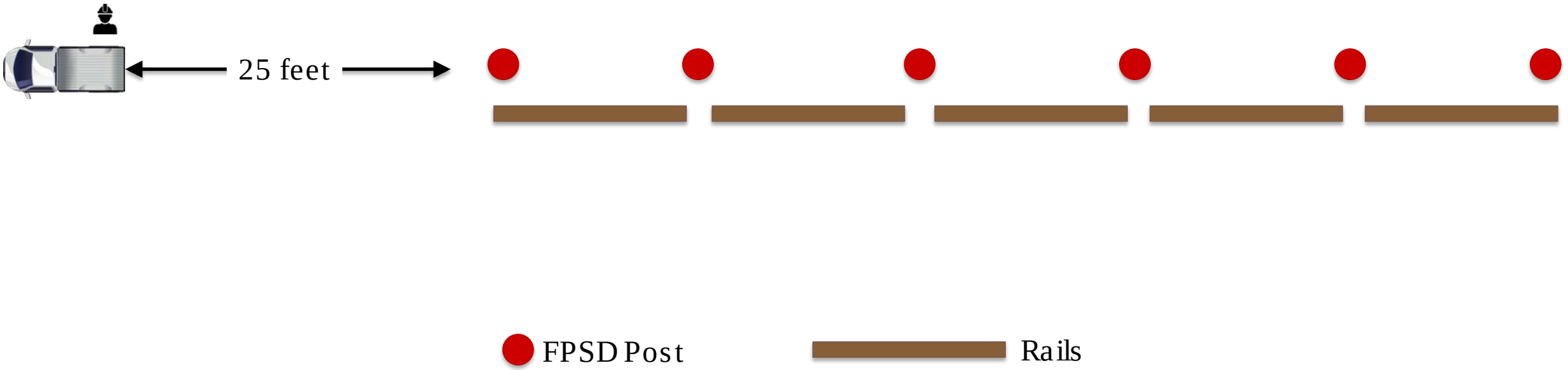


Experimental Procedures – Part 1
Storage, Preparation, and Transportation Activities

Truck Loading

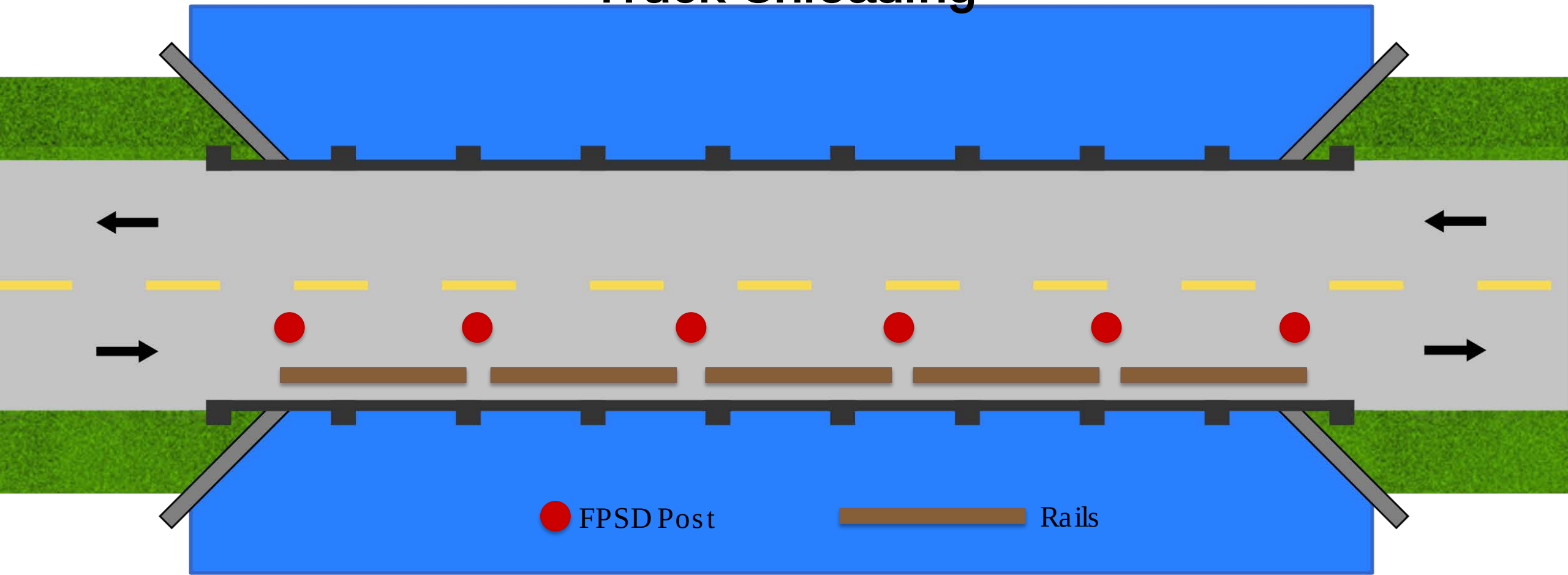
Experimental Procedures – Part 1
Storage, Preparation, and Transportation Activities

Truck Unloading



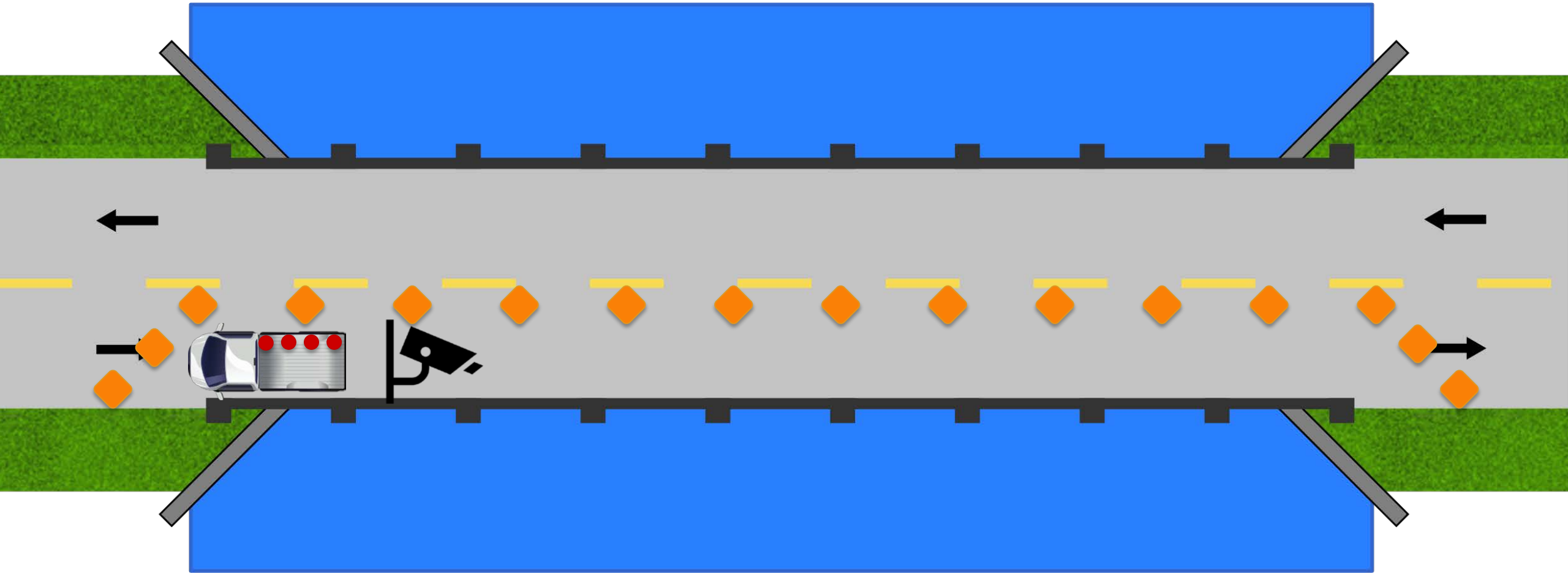
Experimental Procedures – Part 1
Storage, Preparation, and Transportation Activities

Truck Unloading



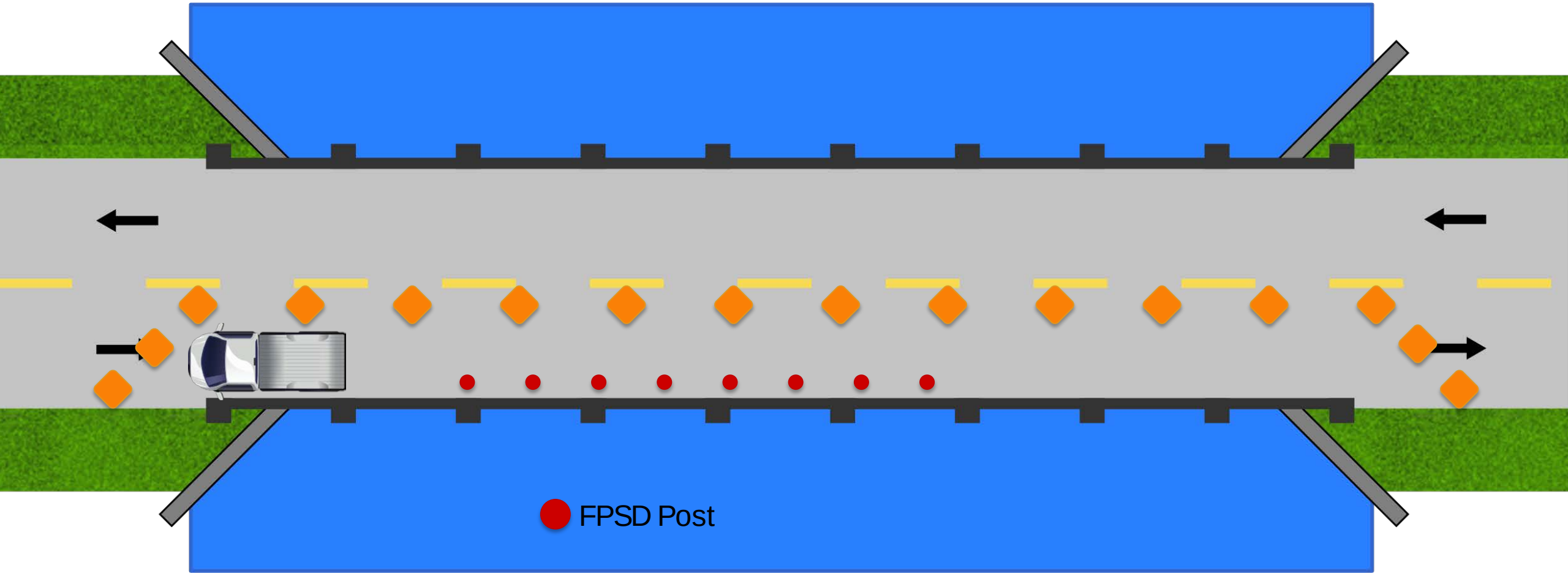
Experimental Procedures – Part 2
Installation and Dismantling Activities

Work Zone Safety → Data Collection



Experimental Procedures – Part 2
Installation and Dismantling Activities

Work Zone Safety → Data Collection → Initial Placement of FPSDs



Experimental Procedures – Part 2
Installation and Dismantling Activities

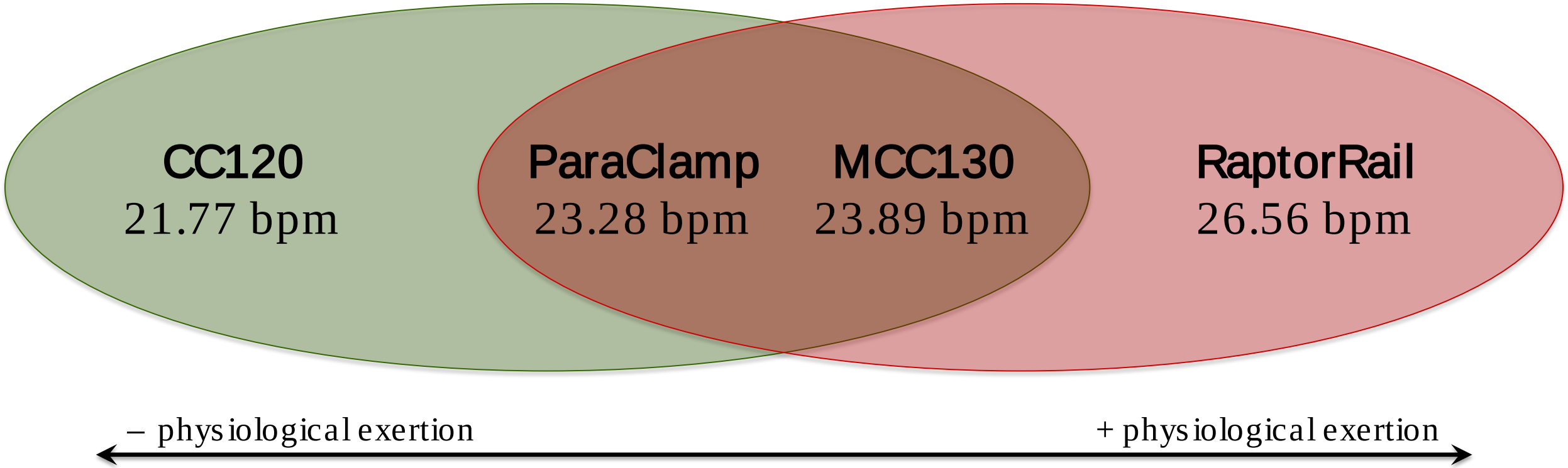
Installation

Experimental Procedures – Part 2
Installation and Dismantling Activities

Dismantle

Results – Physiological Demands

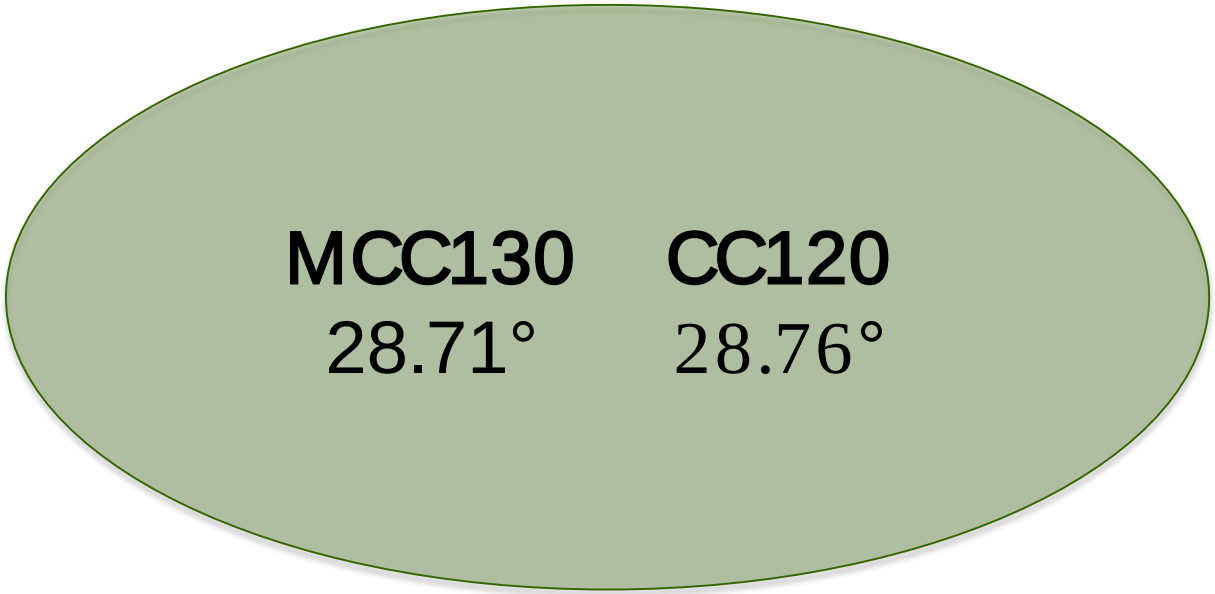
Differential Heart Rate

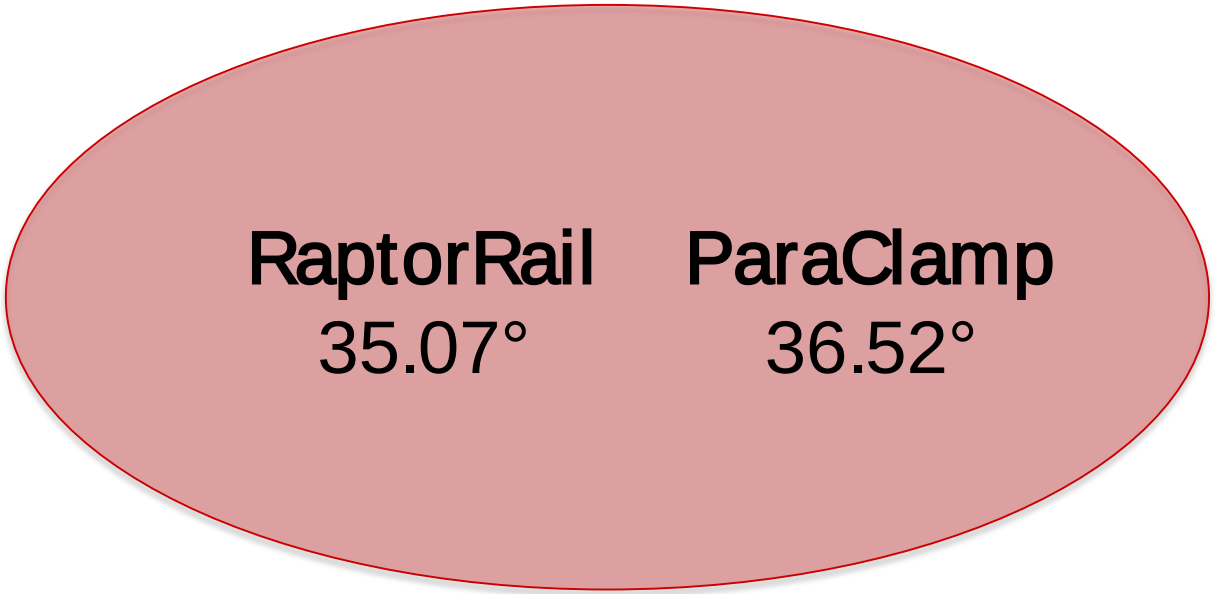


CC120 has significantly lower differential HR compared to the RaptorRail

Results – Postural Demands

Average Compound Angle



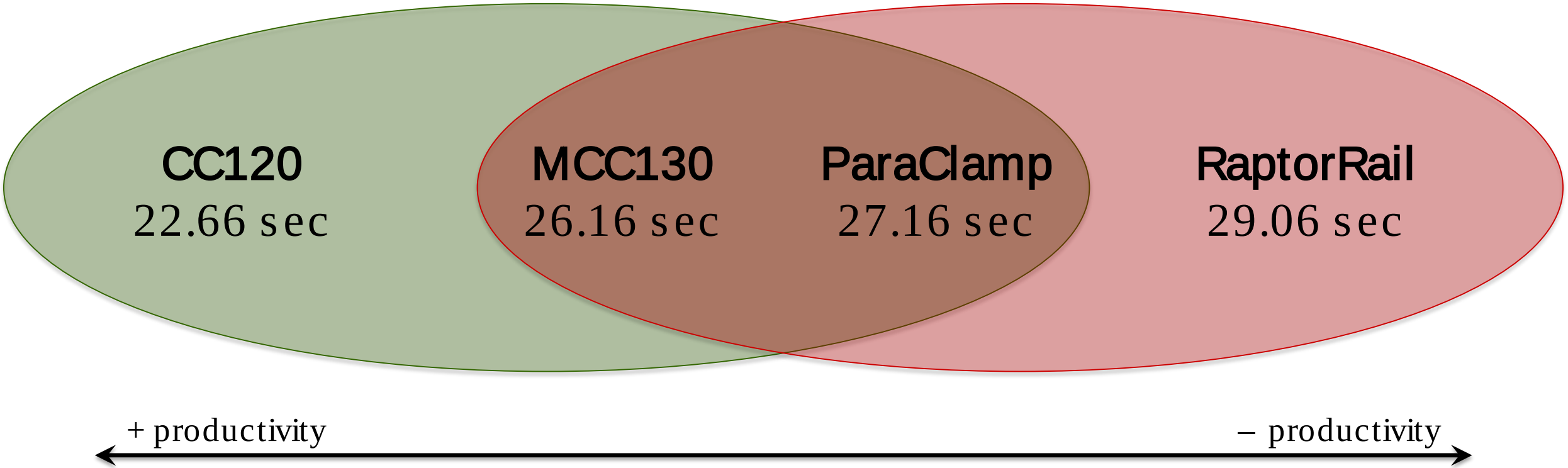


– postural demand + postural demand

CC120 & MCC130 have significantly lower mean compound angles compared to the RaptorRail & ParaClamp

Results – Activity Rates

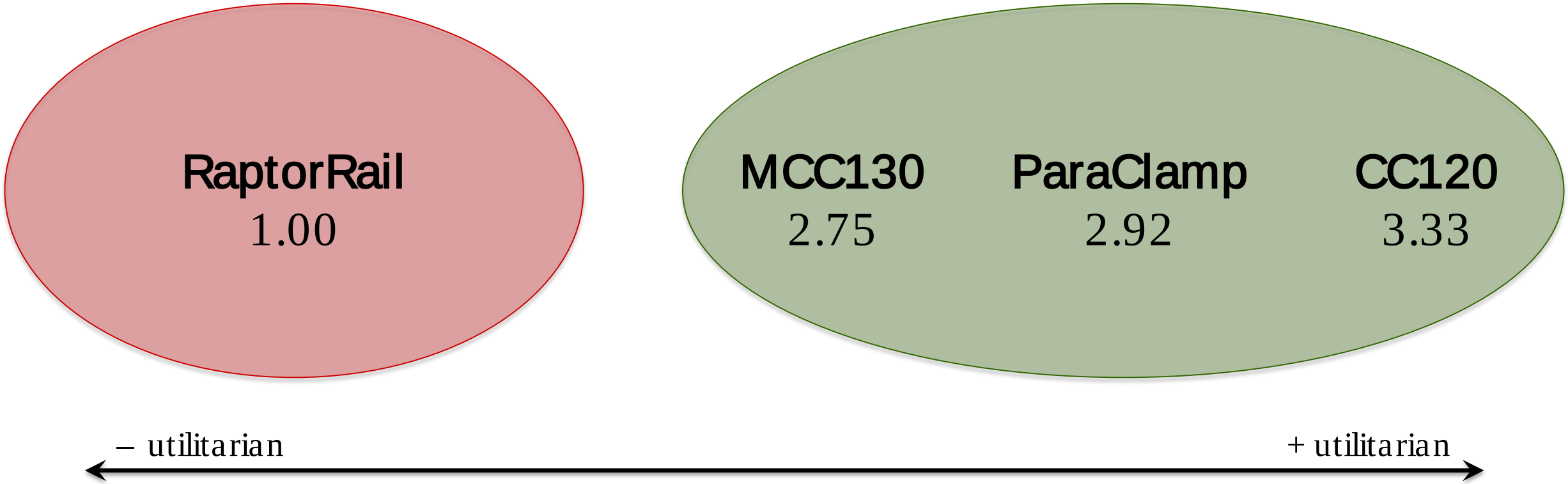
Average Activity Rates



CC120 has significantly lower duration of activities compared to the RaptorRail

Results – Utility Analysis

Friedman's ANOVA



RaptorRail has significantly lower ranking compared to the other FPSDs

Summary of Results

	Diff. Heart Rate	Torso Posture	Activity Rates
CC120	Most Desirable	Most Desirable	Most Desirable
MCC130	Desirable	Most Desirable	Desirable
ParaClamp	Desirable	Least Desirable	Desirable
RaptorRail	Least Desirable	Least Desirable	Least Desirable

1. **CC120 is preferable:** Lesser physical exertion, better posture, lesser duration, and better utility.

1. **MCC130:** Also the preferred alternative.

3. **ParaClamp:** Well perceived by workers. However, required higher postural demands.

4. **RaptorRail:** Least desired in all metrics. Not recommended

Concluding Remarks

Study Summary

Phase I

Virtual compatibility testing an efficient, cost-effective, and safe approach.

Validation of the proposed virtual compatibility process using physical tests in actual bridge guardrails

Phase II

Evaluated candidate FPSDs in field studies to gather physiological, postural, productivity, and utility data.

Recommended FPSDs that provided the most benefits to maximize safety, efficiency, and productivity.