Nondestructive Testing to Identify Concrete Bridge Deck Deterioration

SHRP 2 R06-A

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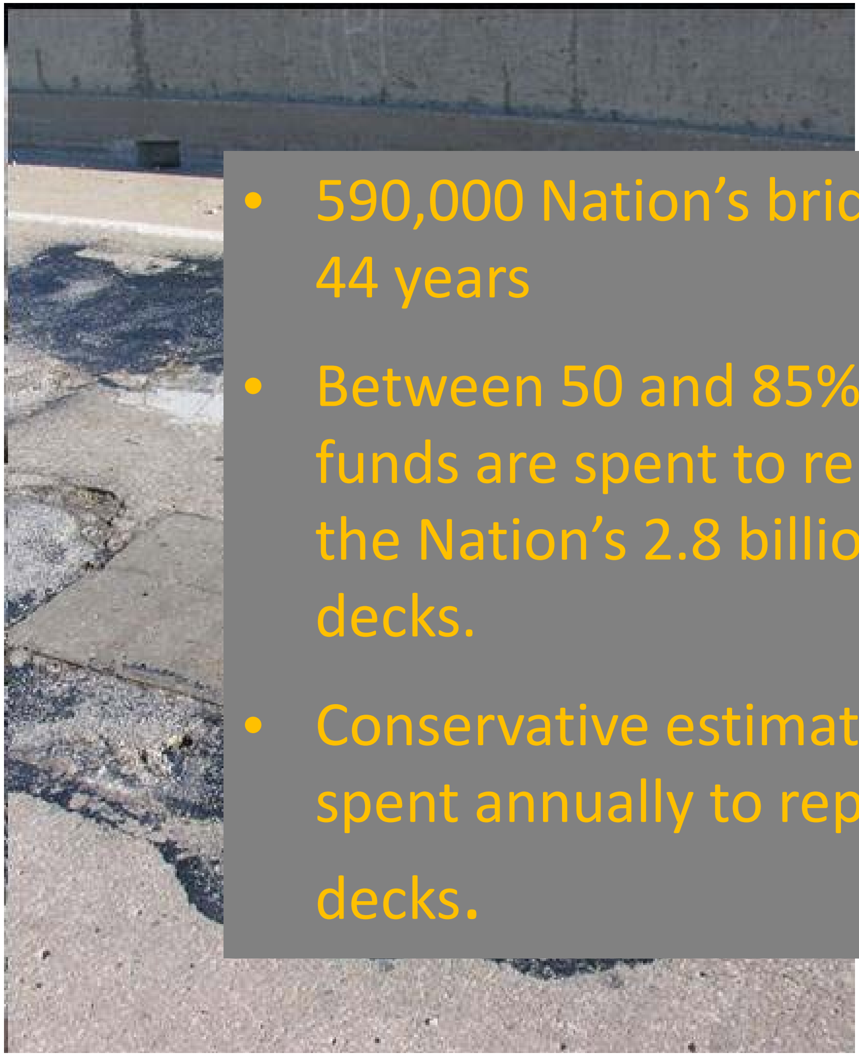
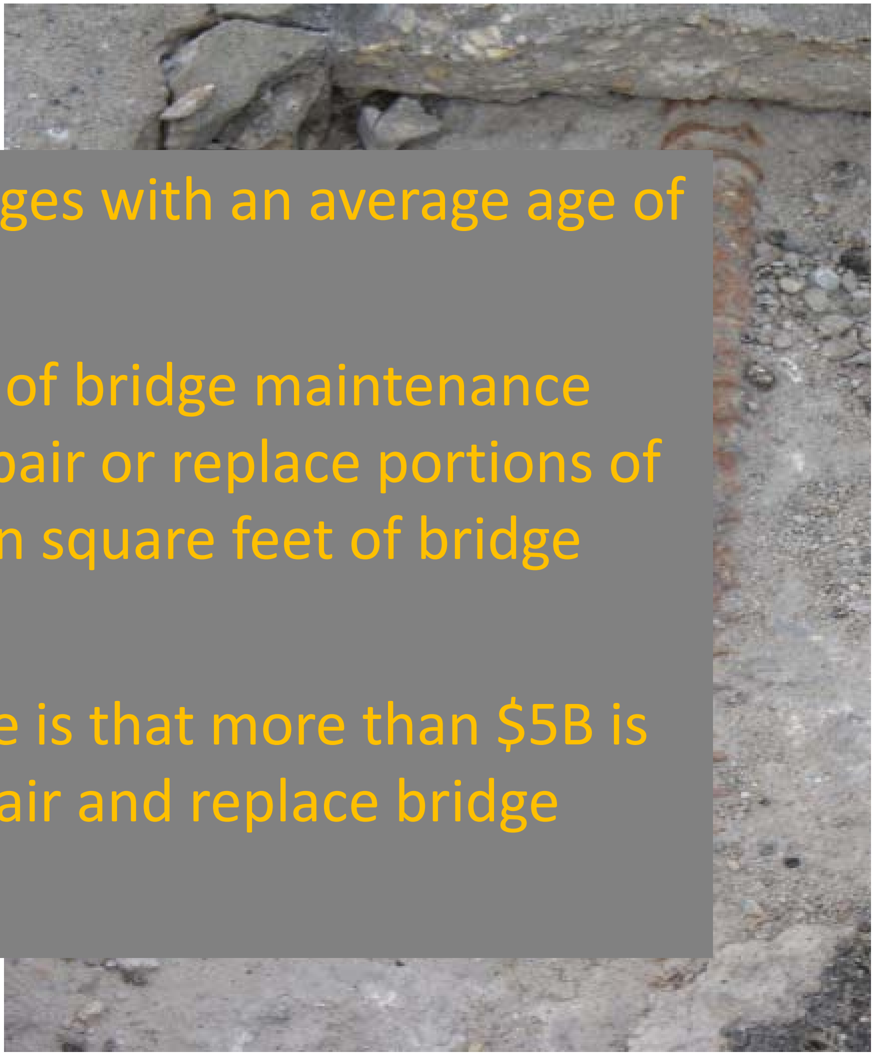
Bridge Deck Damage


enterprise





- 590,000 Nation's bridges with an average age of 44 years
- Between 50 and 85% of bridge maintenance funds are spent to repair or replace portions of the Nation's 2.8 billion square feet of bridge decks.
- Conservative estimate is that more than $5B is spent annually to repair and replace bridge decks.

High Priority Performance Issue Ranking

Category	Issue	Importance	Urgency	EWG	Rank
Decks	Performance of Untreated Concrete Bridge Decks	2.9	2.8	5.6	1
Decks	Performance of Bridge Deck Treatments (Membranes, Overlays, Coatings, Sealers)	2.8	2.9	5.6	2
Joints	Performance, Maintenance and Repair of Bridge Deck Joints	2.8	2.5	5.3	3
Steel Bridges	Performance of Coatings for Steel Superstructure Elements	2.4	2.1	4.5	4
Concrete Bridges	Performance of Bare or Coated/Sealed Concrete Superstructures and Substructures (splash zone, soils, or exposed to deicer run-off)	2.5	2.0	4.5	5

Traditional Methods of Deck Evaluation

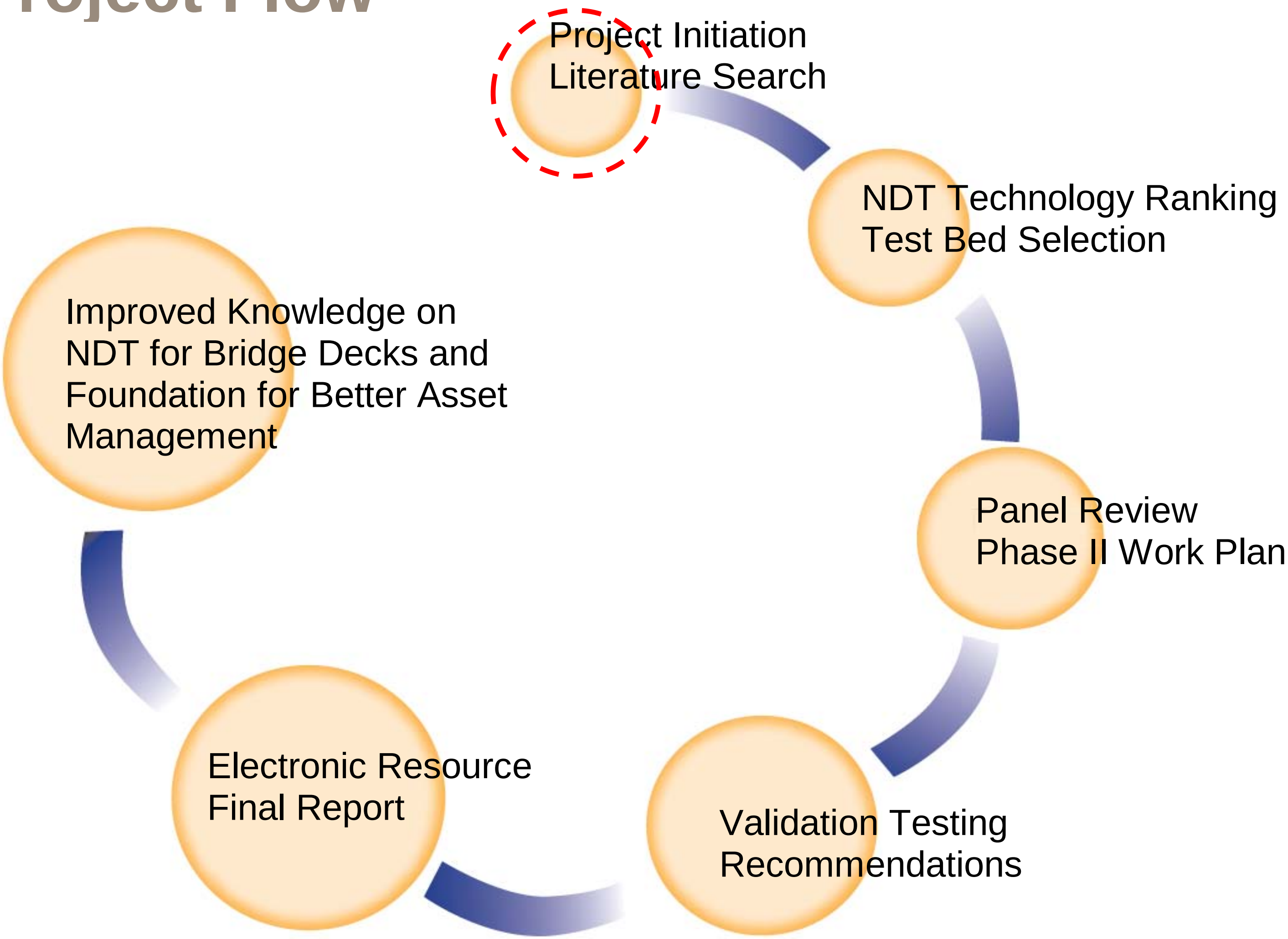
Outline

- Project objectives
- Completed project tasks
- Future project tasks
- Project products and anticipated impacts

Project Objectives

1. To identify and characterize rapid NDT technologies for concrete deck deterioration;
2. To evaluate the strengths and limitations of applicable NDT technologies from the perspective of speed, accuracy, precision, and ease of use; to validate the promising technologies;
3. To recommend test procedures and protocols for the most effective application of the bridge deck NDT methods evaluated, and;
4. To develop an NDT repository for practitioners.

Project Flow



Task 1 – Literature Search

To conduct an international literature search to identify applicable NDT technologies and techniques for different concrete deck types (i.e. slab, voided slab, and deck/girder with and without AC or PCC overlays) and different concrete deterioration, including delamination, cracking, etc.

Rebar Corrosion

Deck Delamination

Deck Delamination/Overlay Debonding

Deck Delamination/Vertical Cracking

NDE Techniques for Bridge Decks

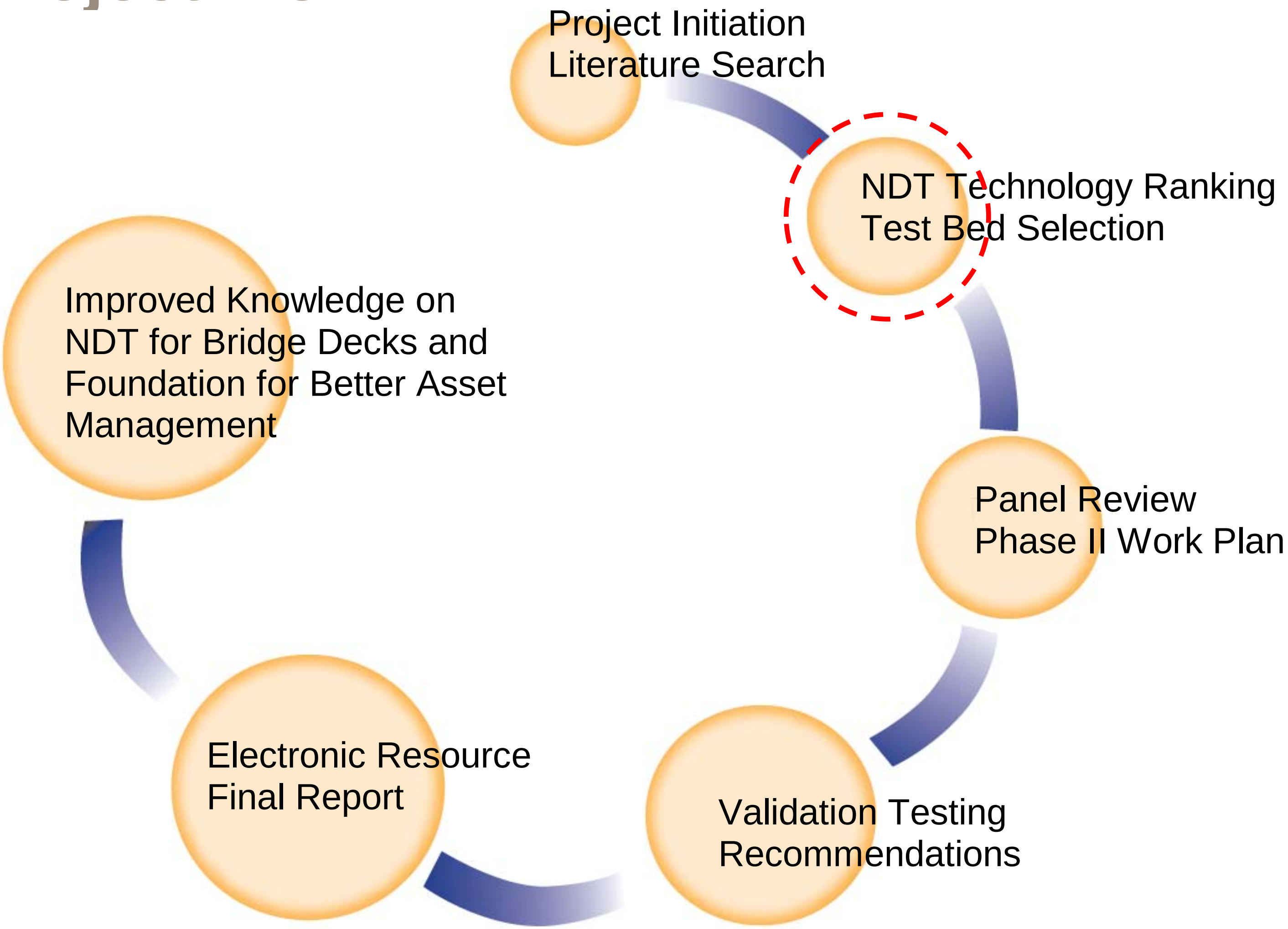
Results of Literature Survey

NDT Method	Advantages	Limitations
Impact Echo (IE)	•Reliable and comprehensive delamination detection and characterization. •Works on decks with PCC overlays and on decks with AC overlays at lower temperatures. •Delamination characterization can be automated and results presented in an intuitive way. •Method has strong potential for rapid data collection and interpretation. •Can be used for applications like evaluation of grouting conditions in ducts, element thickness measurement and surface crack characterization.	•Data collection conducted on a relatively sparse grid, relatively slow and requires lane closure. •Delamination surveys cannot be conducted on decks with AC overlays at higher ambient temperatures. •When there is debonding between the overlay and deck, no information about the deck condition can be provided. •Rebar and duct detection, and duct grouting condition evaluation, limited to relatively shallow ones. •Evaluation can be affected by boundary conditions.
Ultrasonic Pulse Echo (UPE) and Pulse Velocity (UPV)	•Reliable and comprehensive evaluation and imaging of voids, material changes, tendon ducts and rebars. •Provides evaluation of grouting conditions in ducts. •Data collection can be automated. •Enables detection of shallow, small delaminations. •UPV very simple.	•Requires a scanning mode data collection with small test point spacing that makes it slow. •Requires lane closure. •Problems with probe coupling on rough surfaces. •UPE requires well trained and experienced personnel.

Conclusions from Literature Search

1. A number of technologies can provide detailed and accurate information only about a certain type of deterioration or defect.
2. Comprehensive condition assessment of bridge decks, at this stage, can be achieved only through a complementary use of multiple technologies.
3. Speed remains a major limitation for most of the technologies, and is a main inhibitor for wide adoption by transportation agencies.
4. Most of the technologies require significant level of training and expertise, especially in data analysis and interpretation.

Project Flow



Task 2 – Categorization and Ranking of Most Promising Techniques

From the literature search, categorize and rank the most promising techniques from the perspective of speed, accuracy, precision, and ease of use.

Flowchart of the Categorization and Ranking Process

Idenitification of Most Important Deterioration Types and Corresponding Significance Factors

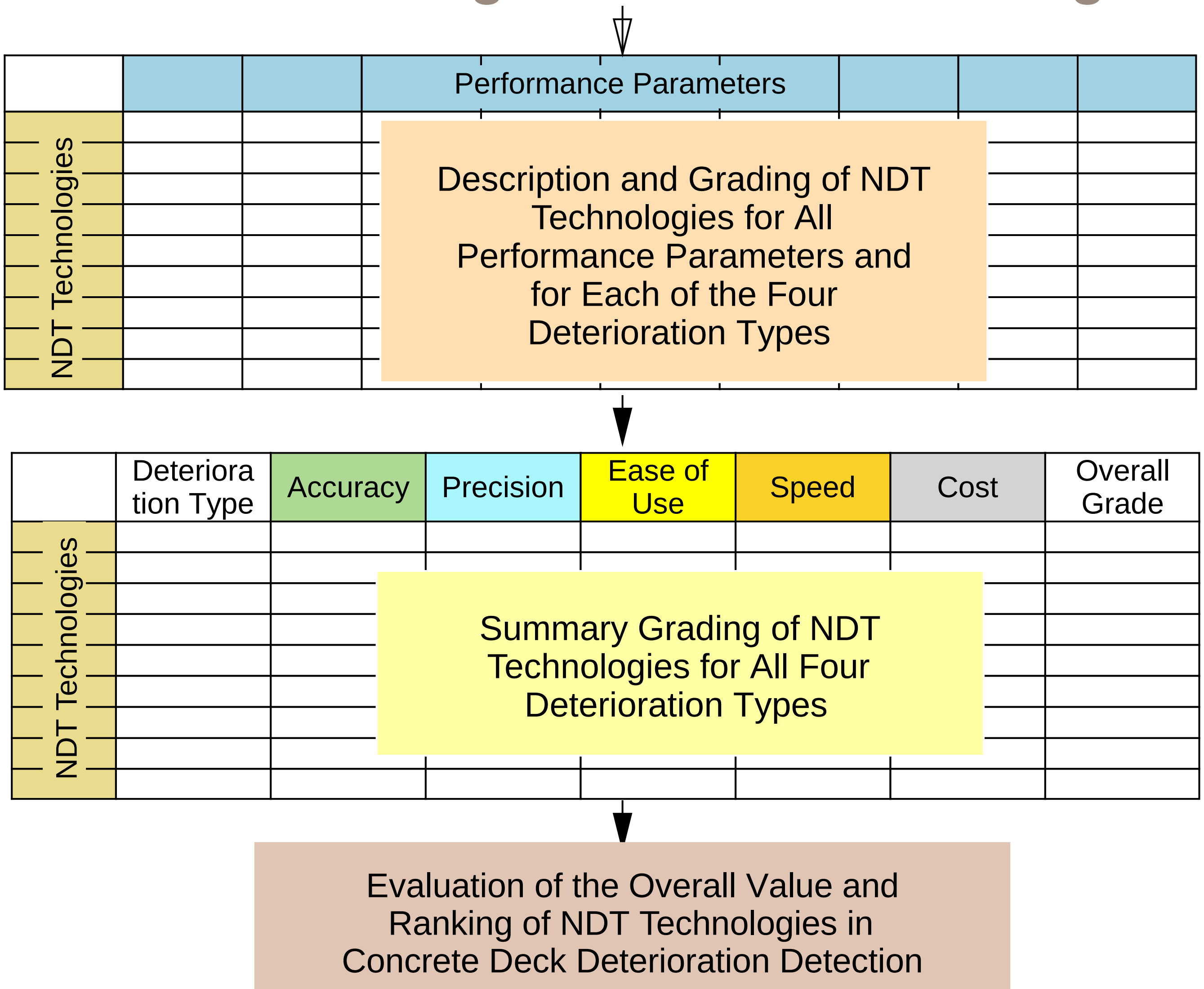
Performance measure	Delamination	Corrosion	Cracking	Concrete Deterioration
Accuracy				
Precision				
Ease of Use				
Speed				
Cost				

Definition of Performance Measures for Different Deterioration Types

Performance measure	Performance Parameter	Weight Factor	Definition of Parameter	Definition of Grades
Accuracy				
Precision				
Ease of Use				
Speed				
Cost				

Definition of Performance Parameters Used in Forming Performance Measures and Corresponding Grades

Flowchart of the Categorization and Ranking Process



Selection of Deterioration Types

The evaluation of NDT technologies was carried out with respect to the following four deterioration types:

- Delamination,
- Corrosion,
- Cracking, and
- Concrete degradation.

Selection of Performance Measures

The following five performance measures were selected for categorizing and ranking of technologies:

- Accuracy,
- Repeatability,
- Ease of data collection, analysis and interpretation,
- Speed of data collection and analysis, and
- Cost of data collection and analysis.

Deterioration Types and Performance Measures of Highest Interest

Deterioration Type	Significance Factor	
	SHRP2 Team	DOT Bridge Engineers
Delamination	0.42	0.39
Corrosion	0.35	0.38
Cracking	0.10	0.12
Concrete Degradation	0.13	0.11

Performance Measure	Weight Factor	
	SHRP2 Team	DOT Bridge Engineers
Accuracy	0.25	0.24
Precision	0.30	0.34
Speed	0.25	0.14
Ease of Use	0.10	0.18
Cost	0.10	0.11

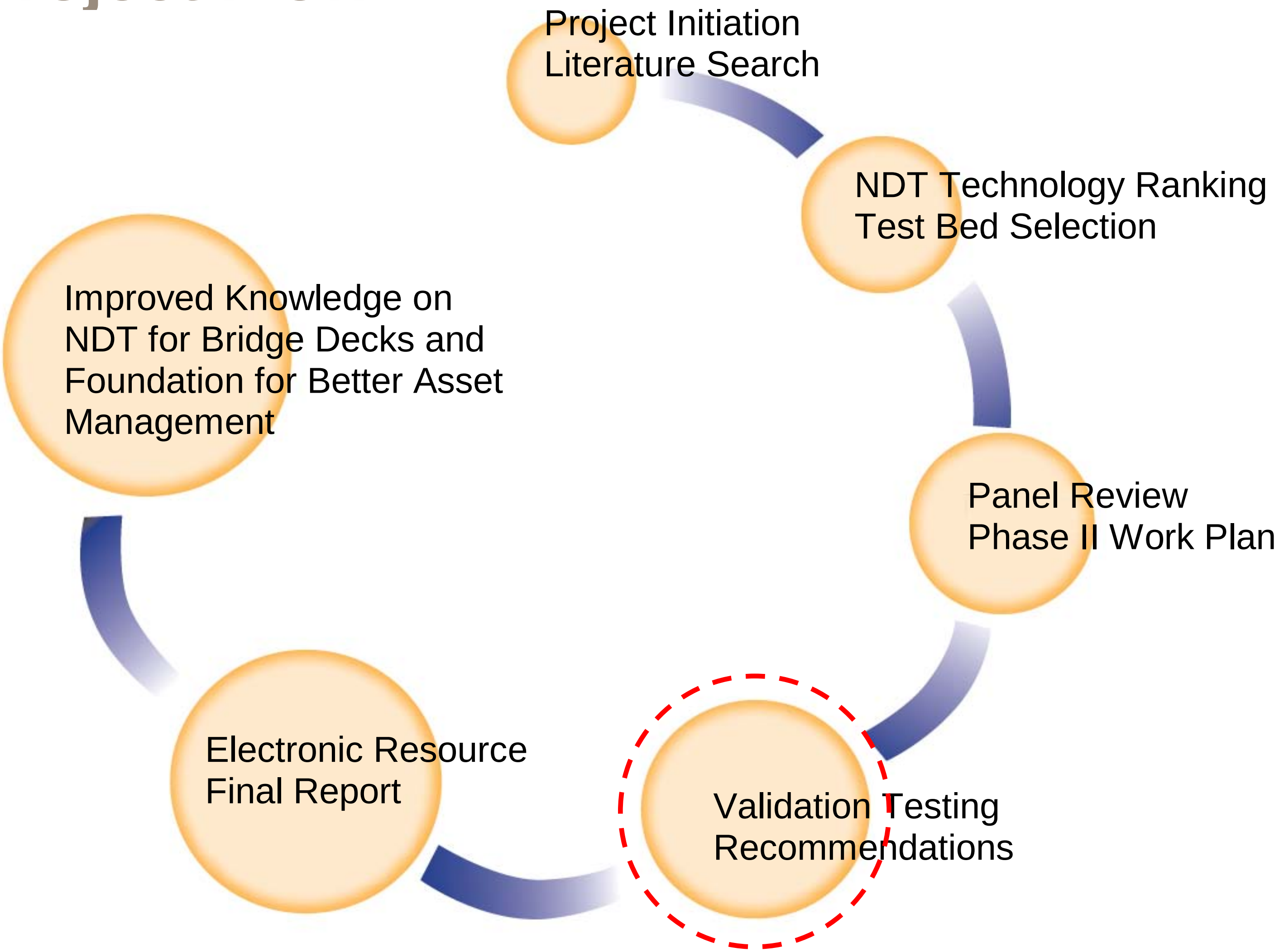
Summary of Grading

NDT Method	Deterioration Type	Accuracy	Precision (Repeatability of Measurements)	Speed of Data Collection and Analysis	Ease of Data Collection and Analysis	Cost of Data Collection and Analysis	Overall Deterioration Type Grade
		WF-1	WF-2	WF-3	WF-4	WF-5	
Impact Echo (IE)	Delamination	5	5	5	4	3	4.70
	Corrosion	N/A	N/A	N/A	N/A	N/A	1.00
	Cracking	3	3	1	2.8	3	2.48
	Concrete Det.	3	3	3	4	3	3.10
Ultrasonic Pulse Echo (UPE) and Pulse Velocity (UPV)	Delamination	4.4	5	1.8	4	2	3.65
	Corrosion	N/A	N/A	N/A	N/A	N/A	1.00
	Cracking	4.4	3	1	1.8	2	2.63
	Concrete Det.	5	3	2.6	4	2	3.40
Ultrasonic Surace Waves (USW)	Delamination	1	3	3	3.4	3	2.54
	Corrosion	N/A	N/A	N/A	N/A	N/A	1.00
	Cracking	3	3	3	2.8	3	2.98
	Concrete Det.	4.2	3	3	4	3	3.40
Impulse Response (IR)	Delamination	2.2	5	3	4	4	3.60
	Corrosion	N/A	N/A	N/A	N/A	N/A	1.00
	Cracking	N/A	N/A	N/A	N/A	N/A	0.00
	Concrete Det.	1	3	3	4	4	2.70
Ground Penetrating Radar (GPR)	Delamination	2.2	3	4.2	2	3	3.00
	Corrosion	N/A	N/A	N/A	N/A	N/A	1.00
	Cracking	N/A	N/A	N/A	N/A	N/A	1.00
	Concrete Det.	2.4	3	4.2	2	3	3.05

Overall Value and Ranking

Deterioration Type	Delamination	Corrosion	Cracking	Concrete Det	Overall Value	Ranking
	WF-1 =0.42	WF-2 = 0.35	WF-3 = 0.10	WF-4 = 0.13		
Impact Echo (IE)	4.7	1.0	2.5	3.1	3.0	1
Ultrasonic Pulse Echo (UPE)	3.6	1.0	2.6	3.4	2.6	1
Half-Cell Potential	1.0	4.9	0.0	1.0	2.3	2
Impulse Response (IR)	3.6	1.0	0.0	2.6	2.2	2
Ultrasonic Surface Waves (USW)	2.5	1.0	3.0	3.4	2.2	2
Ground Penetrating Radar (GPR)	3.0	1.0	1.0	3.1	2.1	2
Chain Drag/ Hammer Sounding	3.7	1.0	0.0	1.0	2.1	2
Electrical Resistivity (ER)	1.0	3.9	0.0	1.0	1.9	3
Infrared (IR) Thermography	3.2	1.0	0.0	1.0	1.8	3
Galvanostatic Pulse Measurement(GPM)	1.0	3.0	0.0	1.0	1.6	3
Visual Inspection	1.0	1.0	3.7	1.0	1.3	3
Microwave Moisture Technique	0.0	1.0	1.0	1.0	0.6	4
Chloride Concentration	0.0	1.0	0.0	1.0	0.5	4
Eddy Current	0.0	1.0	1.0	0.0	0.5	4

Project Flow



Tasks 5, 7 and 8 – Validation Testing

Recommend the technologies to be evaluated in subsequent tasks, prepare a work plan for validation testing and conduct validation testing. Document generic features of NDT technologies.

Validation Testing Flowchart

Invitation of vendors to the validation testing with clearly described conduct of testing and results interpretation and presentation

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Laboratory validation testing

- Vendor data collection, analysis and reporting
- Research team autopsies, ground truth data collection and evaluation of vendor results
- Selection of technologies for field validation testing

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Field validation testing

- Vendor data collection, analysis and reporting
- Research team ground truth data collection and evaluation of vendor results

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Summary of the performance of the evaluated NDT technologies, reporting to the vendors and incorporation of the results in the electronic repository

Tasks 5 and 7 – Validation Testing

Two main components:

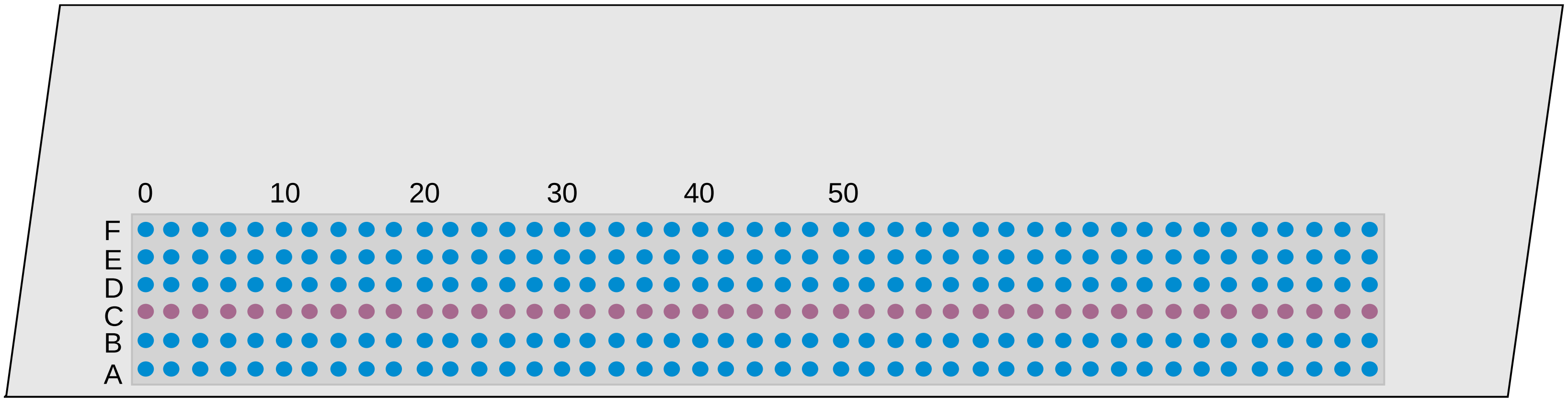
1. Laboratory component (conducted at UTEP)
    a. Testing on a prepared 20x8 ft bare deck slab with a series of defects/deteriorations (delaminations, vertical cracks, corrosion).
    b. Testing on a section of a real bridge where deterioration and defects will be determined after the validation testing through autopsies.
    c. Concentrates on accuracy and repeatability of NDT technologies.

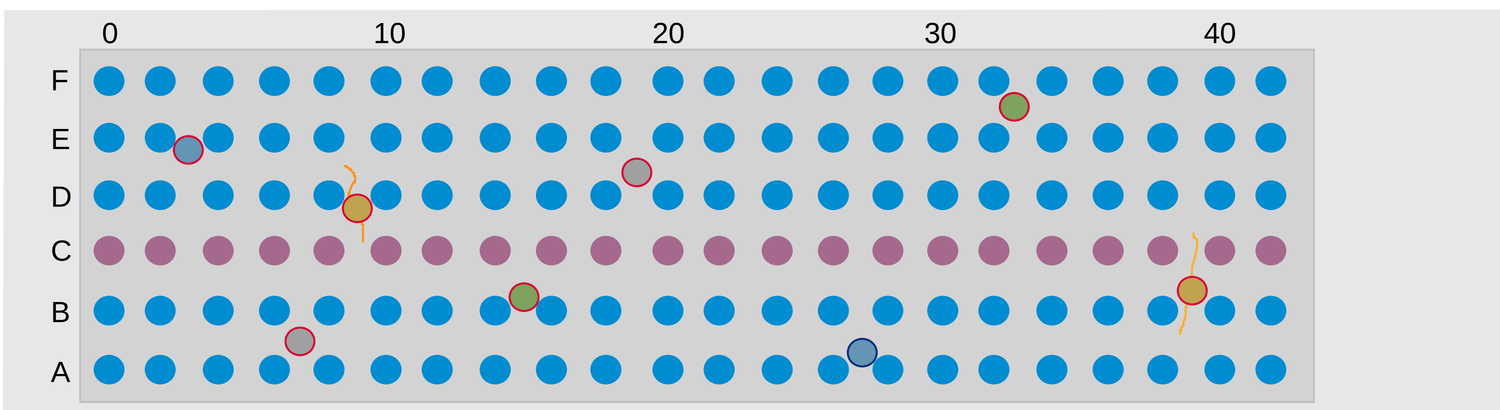
Recovered Bridge Deck Section (with Overlay)

Tasks 5 and 7 – Validation Testing

2. Field component
   a. Testing conducted on one of the LTBPP bridges, on a section approximately 100 x 20 ft. (Leveraging of the available “ground truth” data.)
   b. Concentrates on repeatability, speed, ease of use of NDT technologies.
   c. Information regarding the cost associated with the testing will be collected too.

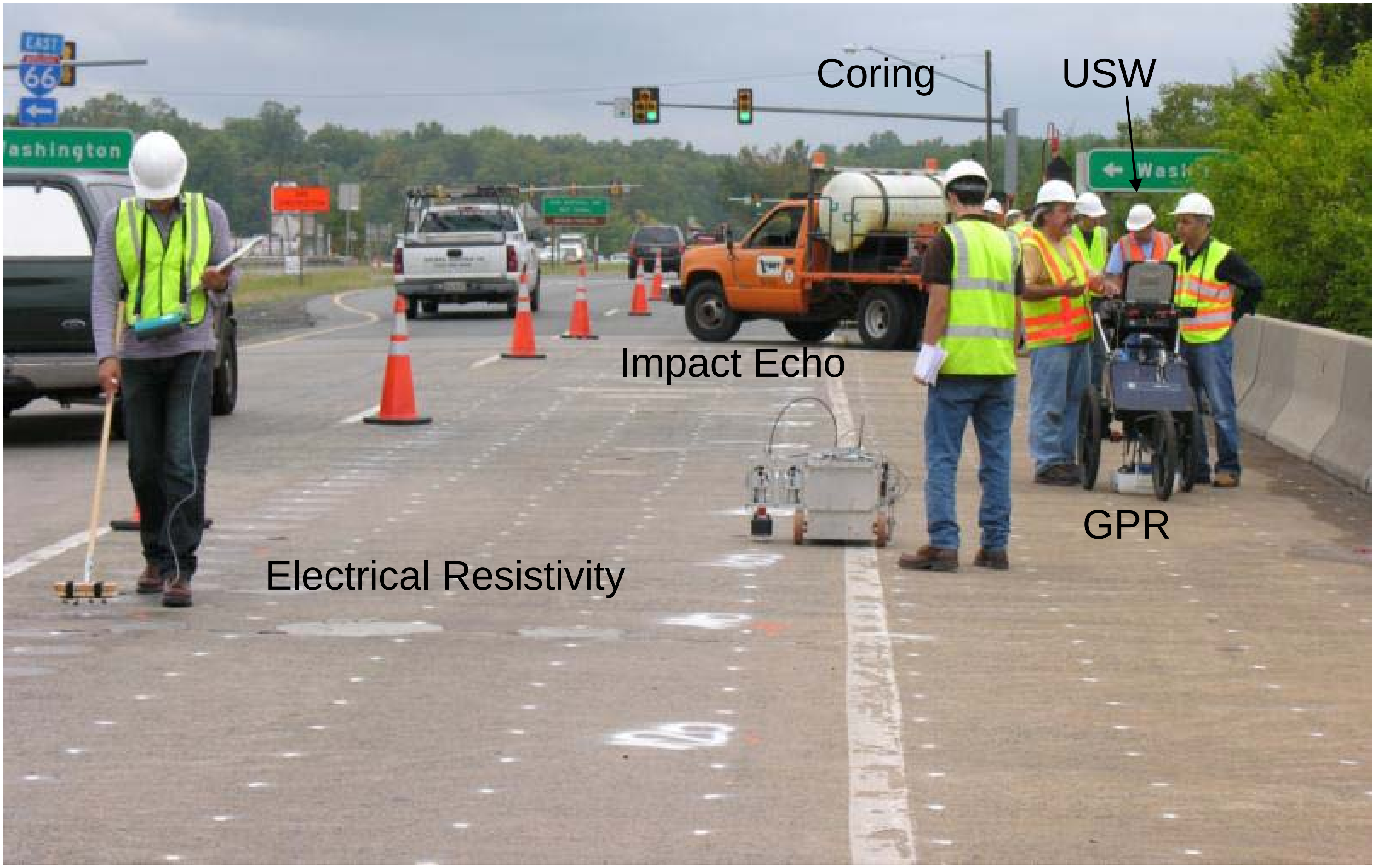
Field Validation Testing



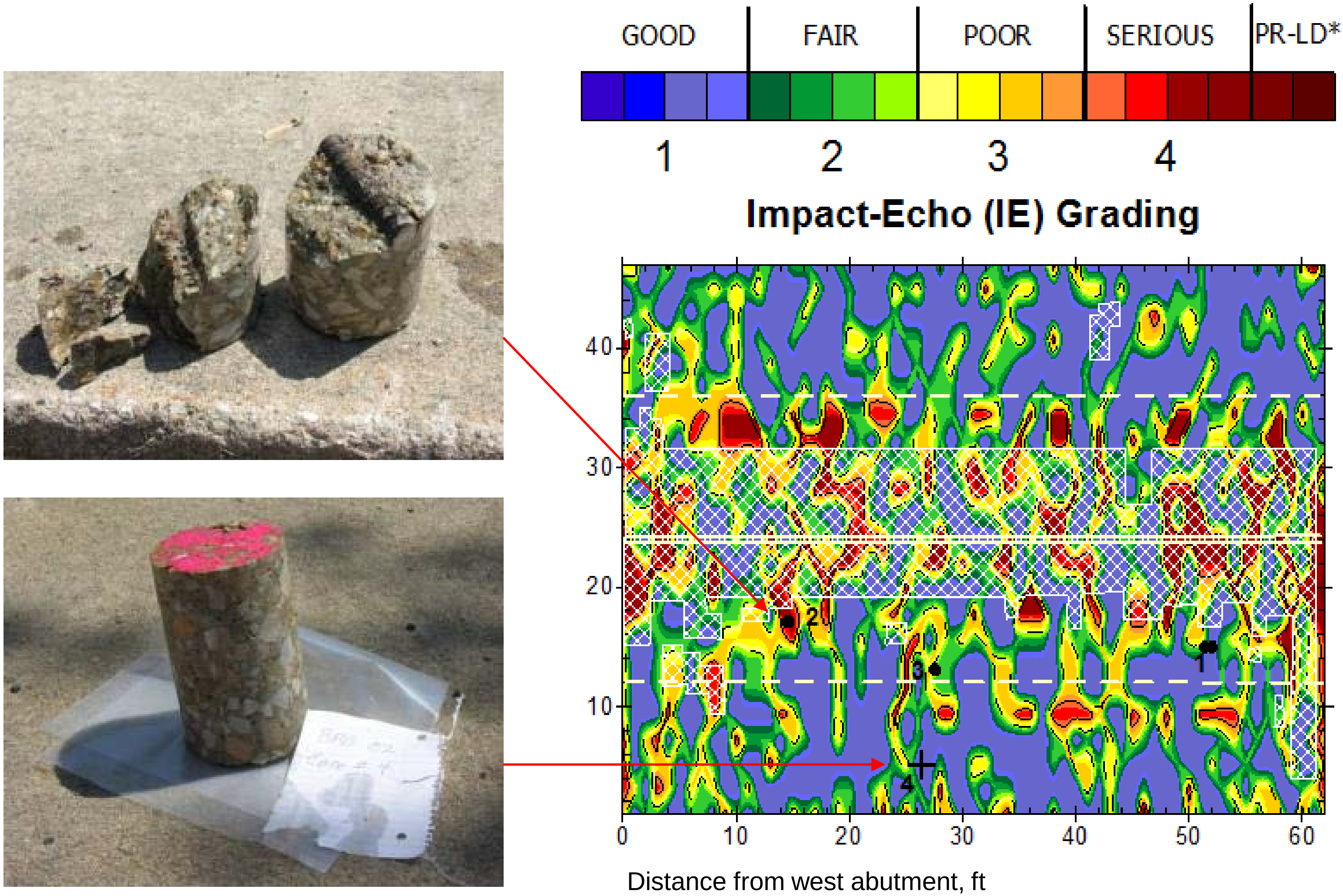


- Test line for repeatability testing
- Test lines and points for the result reporting
- Core locations for corrosion validation
- Core locations for vertical crack validation
- Core locations for delamination validation
- Core locations for concrete deterioration validation

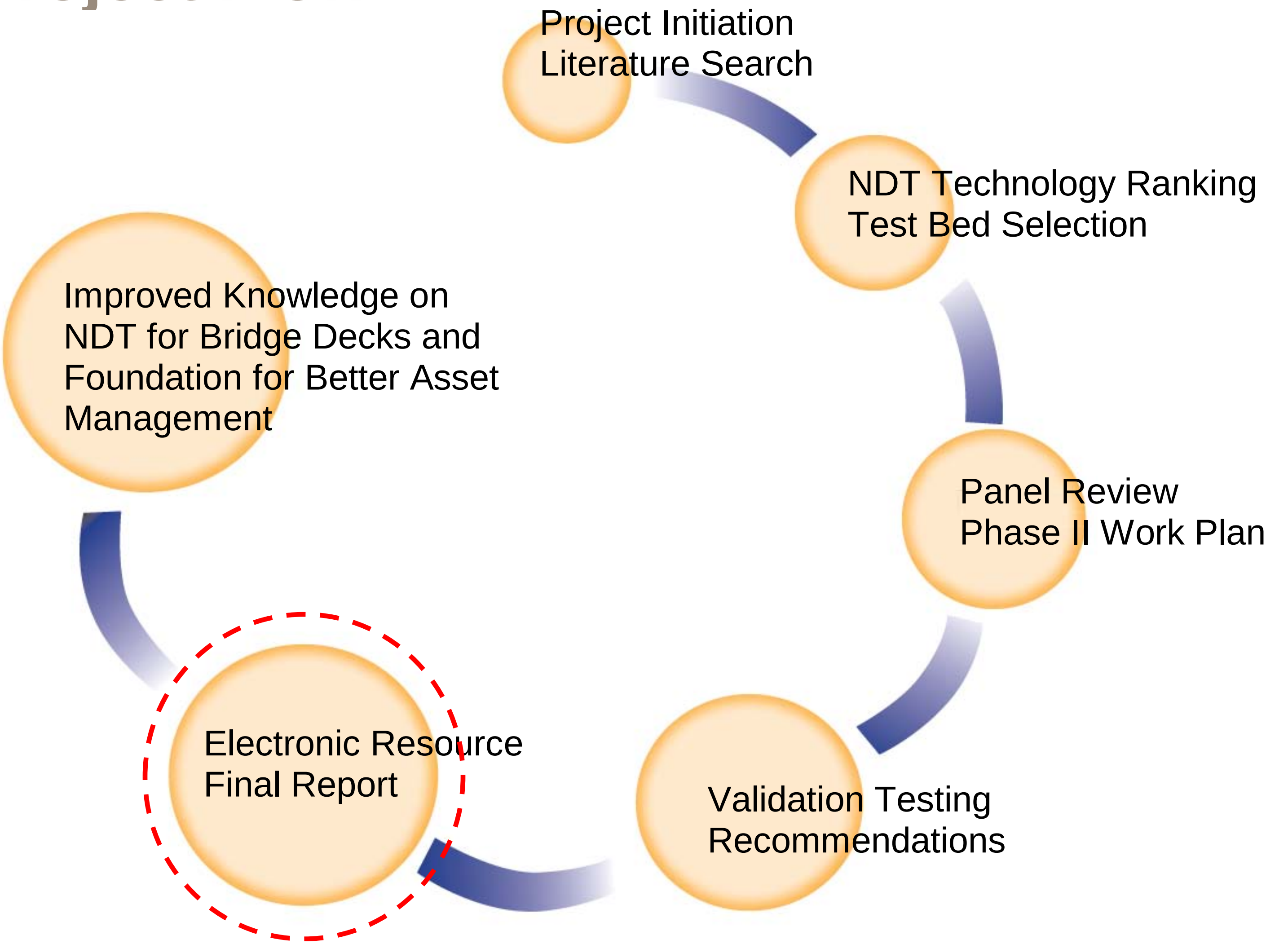
Field Validation Testing



Impact Echo Delamination Assessment



Project Flow



Task 10 – Development of Electronic NDT Repository (Tool-Box)

To develop an electronic repository (tool-box) of NDT techniques for identification of bridge deck deterioration that could be incorporated into transportation agencies' inspection manuals and/or management systems. The repository should include documentation for test procedures, protocols, photos, sample data output, equipment features, advantages, and limitations.

NDT Tool-Box

NDT Method	Application 1	Application 2	Application 3
GPR	corrosion det.	delamination	water penetrat.
IE	delamination		
Ultrasonic Echo	voids detection	rebar localizat.	
......	....	....	

GPR	
Description	....
Physical principle	....
Applications	corrosion det. delamination water penetration
Limitations	....
Accuracy	....
Equipment	....
Data output, presentation	....
Protocols	....

Deterioration /Defect	Technique 1	Technique 2	Technique 3
Delamination	IE	GPR	IR
Concrete deterior.	GPR	USW	UE
Voids	UE	....	.....
Modulus degrad.			....
....			

GPR 2.6 GHz ground coupled antenna

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Deterioration assessment through attenuation measurement

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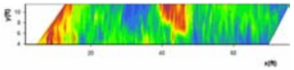

Test Procedure for

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Anticipated Contributions

Deliverables:

1. Comprehensive review and documentation of existing NDT procedures and equipment used for identifying deterioration and discontinuities in bridge decks;
2. Documentation of recommended rapid, economical tests to be used to determine the presence of defects and deterioration in bridge decks; and
3. Documented laboratory and field verification of recommended nondestructive testing procedures/ equipment.

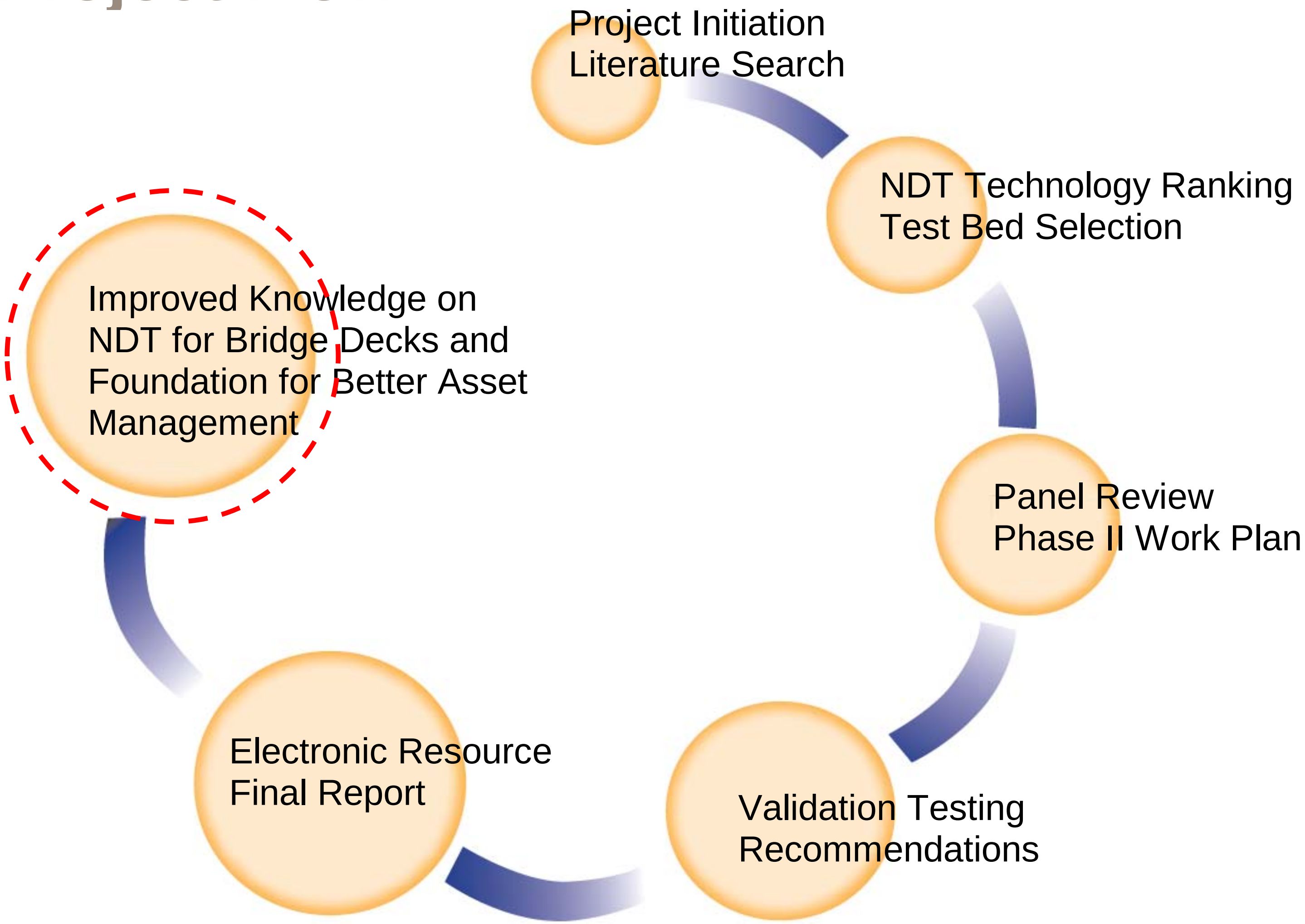
Anticipated Contributions

The final product of this research will be:

- Complete in the subject matter (detailed in descriptions and discussions, fully illustrated, etc.)
- Practical in the manner it conveys guidance to engineers and maintenance managers, incorporating a number of itemized checklists of important activities and actions associated with selecting and executing NDT to identify the deterioration of bridge decks.

Results of the study will both motivate and enable transportation agencies to incorporate NDT techniques into their daily operations.

Project Flow



- What is the prevailing practice of concrete bridge deck evaluation in Europe?
- Which deterioration types in concrete decks are of the highest concern?
- To which extent transportation agencies are implementing NDT technologies for bridge deck deterioration detection?
- Which technologies have found the highest acceptance by the transportation agencies and why?
- What are the main R&D initiatives in Europe to advance NDT technologies for bridge deck (concrete in general) deterioration detection?