

Colorado Department of Transportation SHRP2 NDT for Concrete Tunnel Linings Update (R06G)

Pennsylvania DOT Tunnel Showcase Event

Pittsburg, PA
September 14, 2016



U.S. Department of Transportation
Federal Highway Administration

AMERICAN ASSOCIATION
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TRANSPORTATION OFFICIALS

AASHTO



Tunnel Inspection/ Asset Management & LiDAR/ IRT Scanning Evaluation Program

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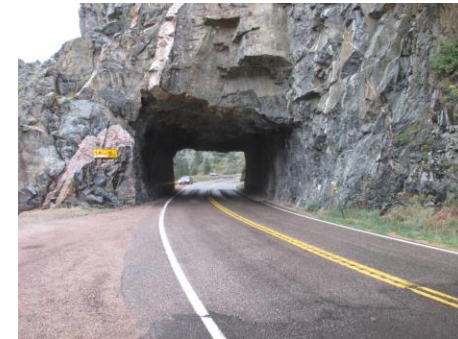
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CDOT Statement of Support



CDOT Tunnel Overview

- # of Vehicular Tunnels: 39 total
 - On-System 20 vehicular, 2 closed
 - Off- System 11 with 6 closed
- Types of Tunnels:
 - Rock Lined
 - Cast in Place Lined
 - Shotcrete Lined
- Max Elevation: 11,158 ft with avg snowfall of 380 inches
- Asset Valuation Efforts \$1.8B



Why Colorado?



- Number of tunnels
- Environment
- Past Research
- Olson Engineering
- FHWA

SHRP2 Plan of Action

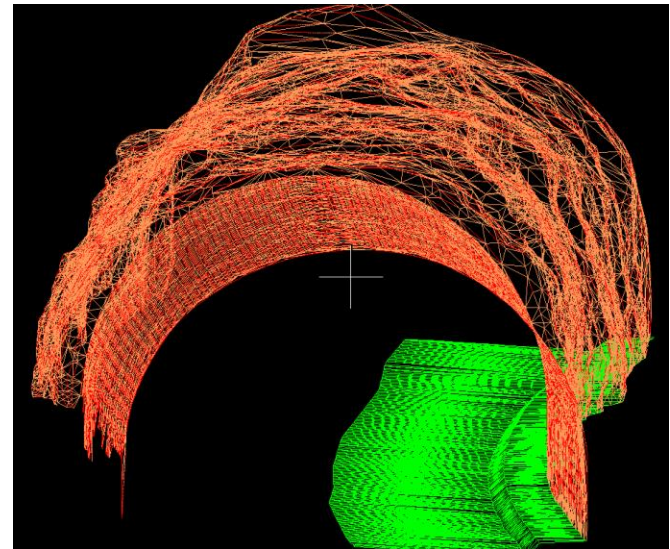
- Year 1

- Figure out program
- Implementation support meeting
- Analyze different options



- Year 2

- Implementation of NDT technique

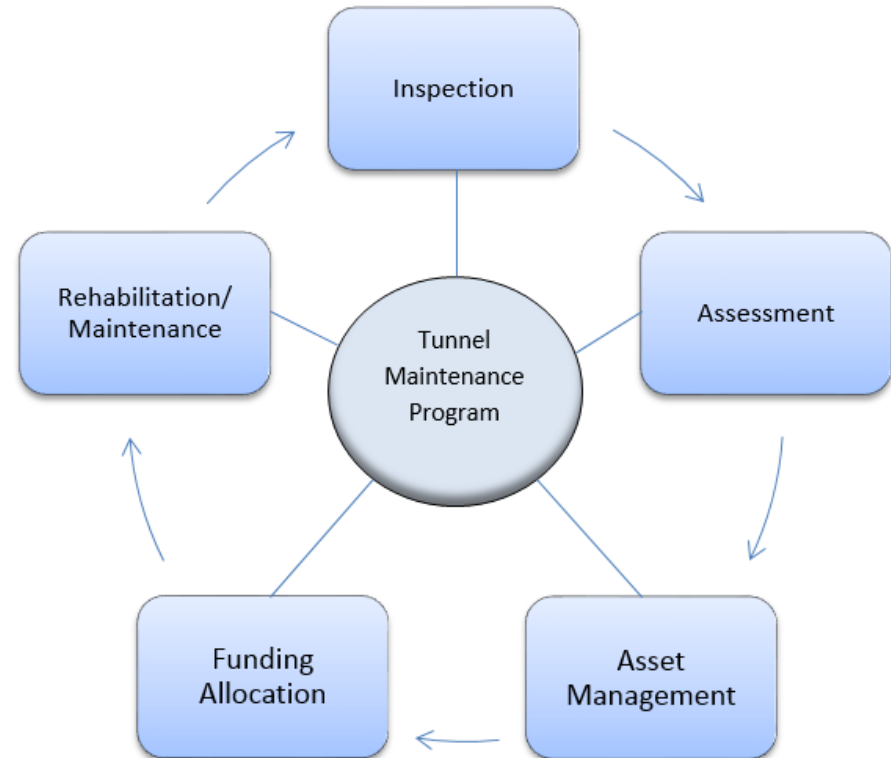


SHRP2 Plan of Action

Proof of Concept

Use in:

- Inspection
 - Asset Management
 - Design
 - Construction
- and integrate into cycle



Implementation

- Selected Method
 - Mobile LiDAR with Thermal Camera
 - Technology
- Service Provider:
 - Surveying and Mapping, Inc. (SAM)



Surveying and Mapping, Inc.

- How did we get to SAM?
 1. Application with inspection program
 2. Mobile
 3. Cost Effective
 4. Capabilities of Contractor



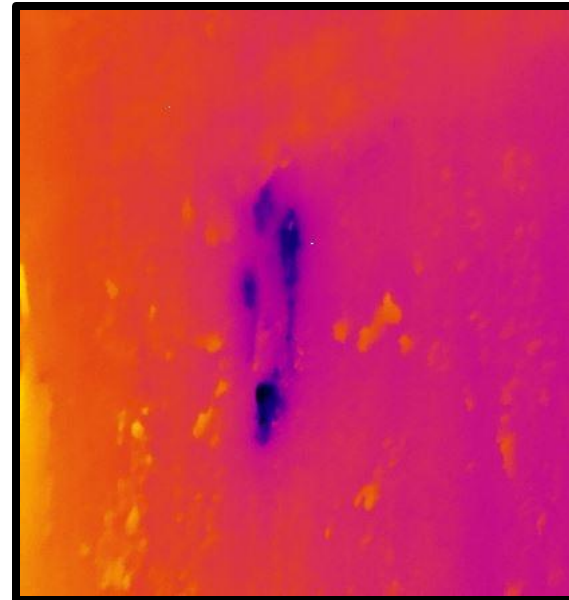
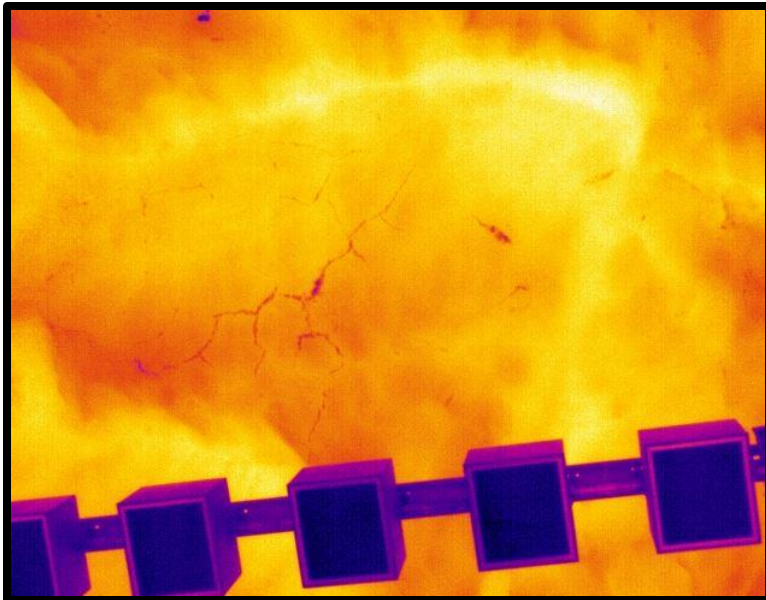
The Grass Roots

- CDOT attended a brownbag at a private firm
 - Brownbag topic was LiDAR, highlighting mobile acquisition and DOT experience
 - CDOT approached SAM with interest
 - Follow up meeting was set
 - CDOT pitched the concept (challenge)
 - SAM accepted and started investigating



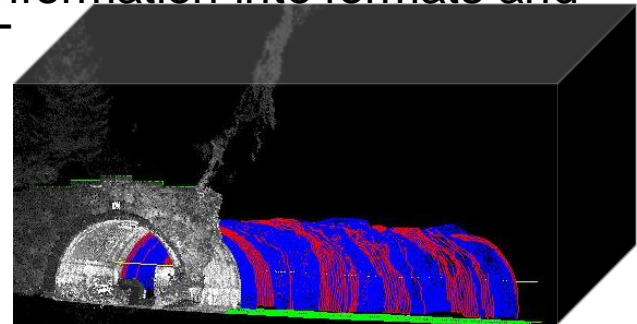
First Steps

- Moving to the “The Laboratory” (Tunnel 4)
 - 1) Tunnel 4 is an abandoned highway tunnel
 - 2) Worked with Flir’s Scientific Division
 - 3) Tested multiple cameras and lenses



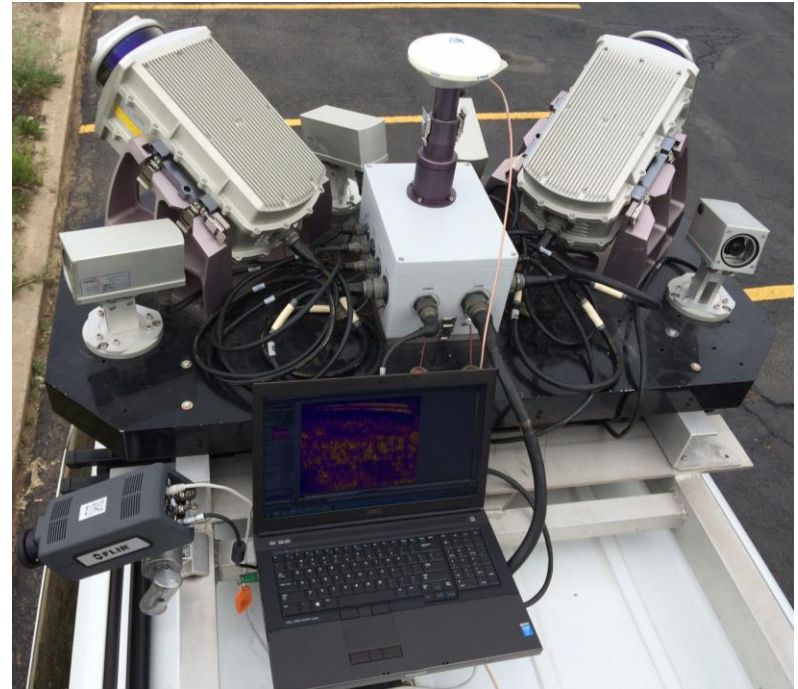
Contracting

- Funding
 - SAM, LLC. had multiple existing NPS contracts with CDOT
- Scoping
 - Approached as a Research and Development Project
 - Defined CDOT's Goals within and around SHPR2 strategic goals
 - Broke out Deliverables into 2 groups
 - Existing
 - » SAM's standard DOT compliant formats
 - Goals
 - » Incorporating the thermal information into formats and usable platforms for a DOT



The Foundation

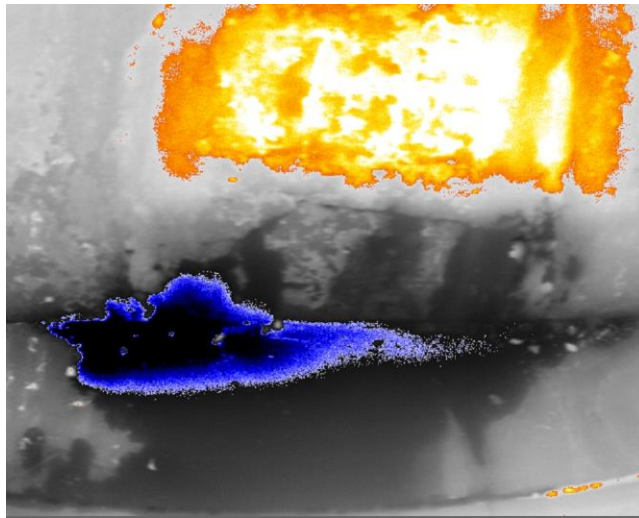
- Mobile LiDAR
 - Survey Grade Accuracy
 - Up to 1,000,000 pts per second
 - Military grade IMU
- Thermal Camera
 - Flir A6700sc series
 - Cooled camera
 - High frame rate
 - Fast integration time
 - Exports suitable for integration with our mobile system



Validation

Finding areas of interest and comparing to confirm effectiveness.

Thermal Image



Actual Photo



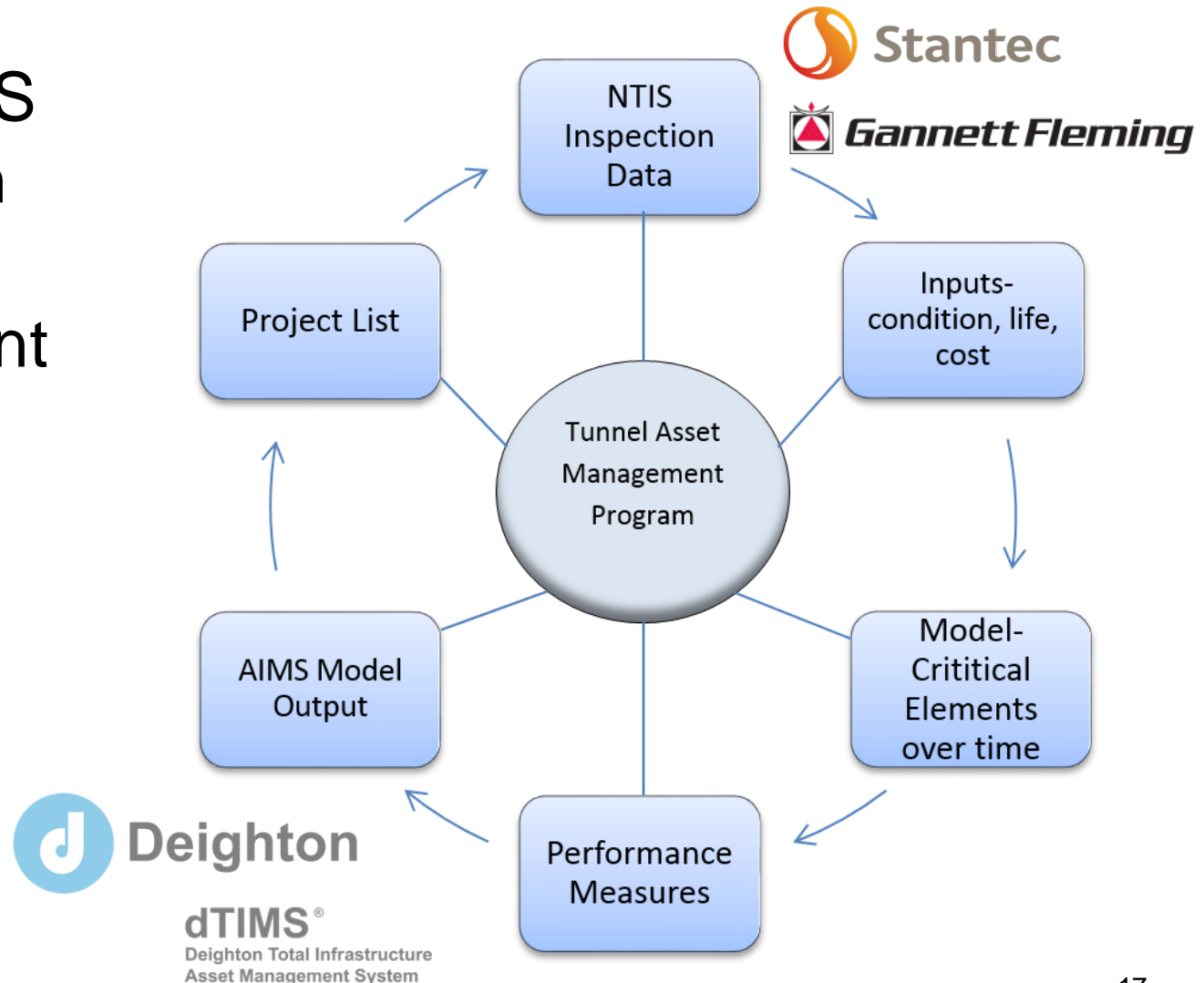
Lessons

- Entry level thermal cameras will not meet expectations
- Artificial warming at portals from sun during daytime collection
- Hard permanent reference markers installed for future monitoring
- Don't walk away from the raw thermal data collected



Tunnel Asset Management

- Tunnel NTIS Data Driven Asset Management Cycle



Tunnel Asset Management

- Tunnel Data – Update with NTIS
 - Initially using past inspection data.

Clear Creek #1		F-15-AY		Length: 883 ft						
Structural			Condition				Life			
Element			Criticality	Eq Pct	WCI	Adj Score	Year Instl	Age	Exp Life	Eq Pct
Liner			5.00	71%	2.17	1.552				
Element	Total Quantity	CS1	CS2	CS3	CS4					
10001	Cast-in-Place Concrete Tunnel Liner	18422	0	18422	0	0	1951	64	75	14.67%
10003	Shotcrete Tunnel Liner	32730	0	23893	8837	0	1951	64	50	-28.00%
10006	Unlined Rock Tunnel	0								
Ceiling Panels			0.00	0%	0.00	0.000				
Element	Total Quantity	CS1	CS2	CS3	CS4					
10090	Steel Ceiling Panels	0								
10091	Concrete Ceiling Panels	0								
Hangers and Anchorages			0.00	0%	0.00	0.000				
Element	Total Quantity	CS1	CS2	CS3	CS4					
10080	Steel Hangers and Anchorages	0								
Wall Panels			0.00	0%	0.00	0.000				
Element	Total Quantity	CS1	CS2	CS3	CS4					
10042	Tile Lined Concrete Panels	0								
Portal			2.00	29%	2.00	0.571				
Element	Total Quantity	CS1	CS2	CS3	CS4					
10051	Concrete Portal	0								
10055	Masonry Portal	1775	0	1775	0	0	1951	64	100	36.00%
10059	Other Portal	0								
						WCI	2.123		Life (Min) -28.00%	
						WCI (%)	63%		Life (%) -28.00%	

Tunnel Asset Management

- Age/Life Transition per Condition State

				<i>Final</i>					
				Median Years				Age	Expected Life
				CS1-CS2	CS2-CS3	CS3-CS4	CS4		
Structural Elements	Liner	10001	<i>Cast-in-Place Concrete Tunnel Liner</i>	30	15	15	0		75
		10003	<i>Shotcrete Tunnel Liner</i>	15	15	10	0		50
		10006	<i>Unlined Rock Tunnel</i>	35	25	20	0		100
	Ceiling	10090	<i>Steel Ceiling Panels</i>	50	30	15	0		100
		10091	<i>Concrete Ceiling Panels</i>	35	25	10	0		75
	Steel Hangers and Anchors	10080	<i>Steel Hangers and Anchorages</i>	35	25	20	0		85
	Wall Panels	10042	<i>Tile Lined Concrete Panels</i>	35	25	10	0		75
	Portals	10051	<i>Concrete Portal</i>	20	25	15	0		75
		10055	<i>Masonry Portal</i>	30	45	15	0		100
		10059	<i>Other Portal</i>	35	25	20	0		100

Figure 4: Median Years Sample

Tunnel Asset Management

- Treatment Types Minor, Major, Replace
- Unit Costs – Important!

CDOT Tunnels Maintenance/Benefit Worksheet

Element	Type	Unit Cost	Unit	Trigger(s) of Available Funding Options
10001, 10003, 10006	Liner	Minor	\$ 250.00 SF	Liner WCI \geq 2.2 and $<$ 2.5
10001, 10003, 10006	Liner	Major	\$ 500.00 SF	Liner WCI \geq 2.5 or %CS4 \geq 0%
10001, 10003, 10006	Liner	Replace	\$ 670.00 SF	Life $<$ 0% and WCI \geq 2.5 or %CS4 $>$ 30%
10090, 10091	Ceiling Panels	Minor	\$ 370.00 SF	Ceiling Panels WCI \geq 2.2 and $<$ 2.5
10090, 10091	Ceiling Panels	Major	\$ 300.00 SF	Ceiling Panels WCI \geq 2.5 or %CS4 $>$ 0%
10090, 10091	Ceiling Panels	Replace	\$ 200.00 SF	Life $<$ 0% and WCI \geq 2.5 or %CS4 $>$ 30%
10080	Steel Hangers and Anchorages	Minor	\$ 150.00 EA	H&A WCI \geq 2.2 and $<$ 2.5
10080	Steel Hangers and Anchorages	Major	\$ 300.00 EA	H&A WCI \geq 2.5 or %CS4 $>$ 0%
10080	Steel Hangers and Anchorages	Replace	\$ 1,300.00 EA	Life $<$ 0% and WCI \geq 2.5 or %CS4 $>$ 25%
10042	Tile Lined Concrete Panels	Minor	\$ 15.00 SF	Wall Panels WCI \geq 2.2 and $<$ 2.5
10042	Tile Lined Concrete Panels	Major	\$ 80.00 SF	Wall Panels WCI \geq 2.5
10042	Tile Lined Concrete Panels	Replace	\$ 65.00 SF	Life $<$ 0% and WCI \geq 2.5 or %CS4 $>$ 40%

Tunnel Asset Management

- Identify Critical Elements
- Tunnel NTIS Element #

The following tables describe the key elements of each component and the weight of the element in the overall component score.

Structural		
Element	NTIS/*CTIIM Number(s)	Criticality
Liner	10001, 10003, 10006	5
Ceiling Panels	10090, 10091	5
Steel Hangers and Anchorages	10080	5
Tile Lined Concrete Panels	10042	3
Portals	10051, 10055, 10059	2

Table 1: Structural Criticality

Mechanical Systems		
Element	NTIS/*CTIIM Number	Criticality
Ventilation System	10200	5
Fan Motors	*10202	3
Emergency Generator System	10400	3
Drainage and Pumping System	10300	3
Water Treatment System	*10310	2

Table 2: Mechanical System Criticality

Fire/Life Safety/Security Systems		
Element	NTIS/*CTIIM Number	Criticality
Fire Detection System	10650	5
Fire Detection System	10700	5
Water Line for Fire Protection	*10701	5
Tunnel Operations and Security	10800	5

Table 3: Fire Life Safety Criticality

Electrical Systems		
Element	NTIS/*CTIIM Number	Criticality
Electrical Distribution System	10500	5
Incoming Power Regulators	*10502	5
Transformers	*10503	5
Switchgear	*10504	5
Motor Control Centers	*10505	5

Table 4: Electrical Criticality

Lighting Systems		
Element	NTIS/*CTIIM Number	Criticality
Tunnel Lighting System	10600	5

Table 5: Lighting Criticality

Civil Elements		
Element	NTIS/*CTIIM Number	Criticality
Traffic Barrier	10161	5

Table 6: Civil Criticality

Sign Elements		
Element	NTIS/*CTIIM Number	Criticality
Variable Message Board	10890	5
Lane Signal	10910	5

Table 7: Sign Criticality

Tunnel Asset Management

- Performance Metric Evolution
 - 2014-15
 - ***Key components of fire/life safety must not exceed 100% of useful life, based on manufacturer's specifications, condition inspections and maintenance history.***
 - 2015-16
 - ***Percentage of tunnels with all elements in equal or better condition than 2.5.***
 - 2016-Future
 - ***Percentage of network tunnel length with all elements in equal or better condition than 2.5 weighted condition index.***

Tunnel Asset Management

	Name	AAD	Age	Expected Life	CS1	CS2	CS3	CS4	ELEMENT_NUMBER	Element Name	Tunnel_Name
1	H-03-BT_LIG_L_10600	17400	29	20	0	0	1	0	LIG_L_10600	Tunnel Lighting System	Beavertail WB
2	F-13-Y_MEC_E_10400	31000	42	40	0	0	0	1	MEC_E_10400	Emergency Generator	Eisenhower (EJMT WB)
3	F-15-AY_STR_L_10003	13300	64	50	0	23893	8837	0	STR_L_10003	Shotcrete Liner	Clear Creek #1
4	F-08-AT-	8000	26	75	30687	13087	1354	0	STR_L_10001	Cast-in-place Liner	Reverse Curve
5	F-13-X_SIG_V_10890	31000	14	15	0	0	12	0	SIG_V_10890	Variable Message Boards	Johnson (EJMT EB)
6	F-13-X_SAF_O_10800	31000	20	15	0	0	1	0	SAF_O_10800	Tunnel Ops and Security	Johnson (EJMT EB)
7	F-13-Y_SAF_O_10800	31000	12	15	0	0	1	0	SAF_O_10800	Tunnel Ops and Security	Eisenhower (EJMT WB)

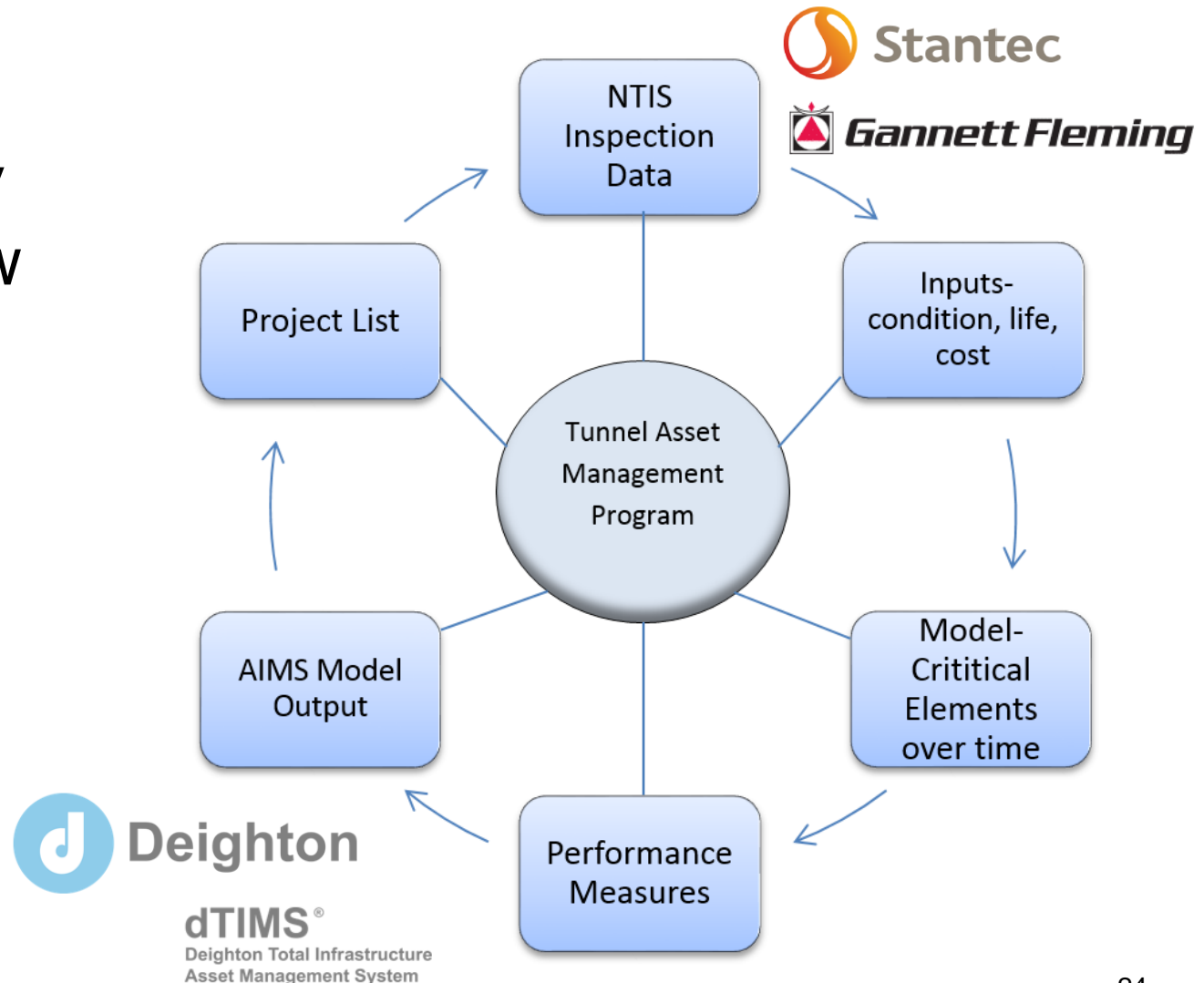
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	Tunnel_Name	Year	Treatment	FinCost
1	Beavertail WB	2016	tunnel_elem_Major_Repair	\$ 500,000.00
2	Eisenhower (EJMT WB)	2016	tunnel_elem_Major_Repair	\$ 1,500,000.00
3	Clear Creek #1	2016	tunnel_elem_Minor_Repair	\$ 2,209,250.00
4	Reverse Curve	2016	tunnel_elem_Major_Repair	\$ 677,000.00
5	Johnson (EJMT EB)	2016	tunnel_elem_Major_Repair	\$ 276,000.00
6	Johnson (EJMT EB)	2016	tunnel_elem_Major_Repair	\$ 179,220.00
7	Eisenhower (EJMT WB)	2016	tunnel_elem_Major_Repair	\$ 178,860.00

Model output gives a list of recommended treatments for tunnel elements.

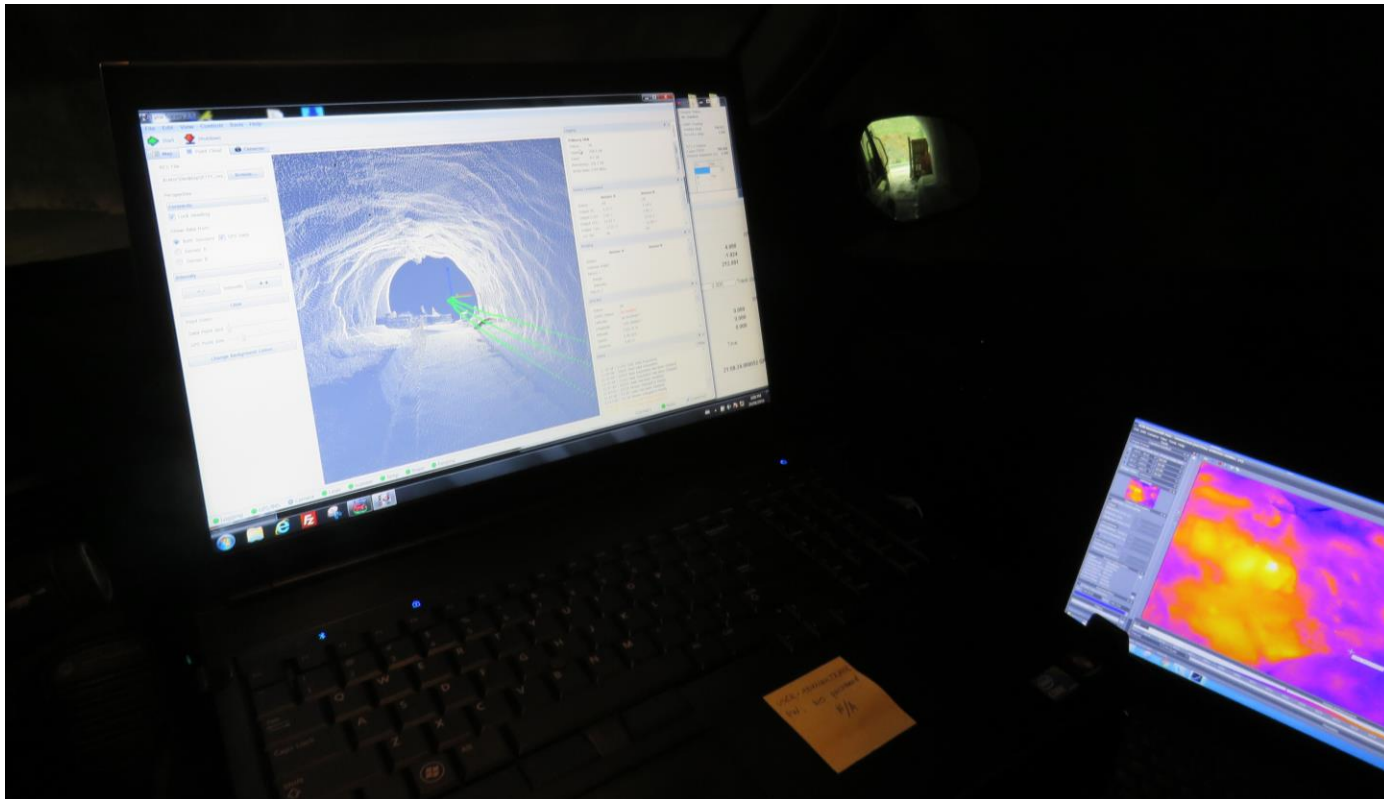
Tunnel Asset Management

- Complete Cycle every year as new data is collected.



Next Step for R06G

- Complete additional tunnels
- Showcase Event Spring 2017



CDOT Spring 2017 Preliminary Showcase Event

- Presentations in Lakewood/Golden
- Field trip to tunnel No. 4
- Continue on to Eisenhower/ Johnson Tunnel
- Passing through new Veteran's Memorial Tunnel (2-lane to 3-lane expansion project)



Thank you

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