

# Non-Destructive Testing (NDT) Technologies

Presented to: REDAC

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# Outline

- **Pavement Performance**
  - Structural and Functional
- **NDT Technologies**
  - Structural and Functional
- **NDT-Related Research Projects**
  - On-Going and Planned Projects



# Pavement Performance

- **Structural**
  - the ability of the pavement to support traffic without developing appreciable distress
- **Functional**
  - the ability of the pavement to provide a smooth, safe ride for the comfort and convenience of the traveling public/passengers.



# *NDT Technologies*



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# NDT Technologies

- Structural

- Pavement Response

- Heavy Weight Deflectometer (HWD)
    - Light Weight Deflectometer (LWD)
    - Portable Seismic Pavement Analyzer (PSPA)
    - D-PSPA
    - GeoGauge

- Pavement Layer Thicknesses

- Ground Penetrating Radar (GPR)



# NDT Technologies

- Functional
  - Surface Cracking
    - NDT Van 2D/3D Imaging
    - Manual Pavement Condition Survey
  - Surface Deformations
    - Leica 3D Scanner
    - Straightedge



# NDT Technologies

- Functional
  - Surface Profiles
    - NDT Van
      - Inertial Profiler
    - California Profilograph
    - Dipstick Road Profiler
    - SurPro
    - Leica 3D Scanner
    - Straightedge
  - Surface Texture
    - ELAtextur
    - British Pendulum Tester



# Heavy Weight Deflectometer (HWD)

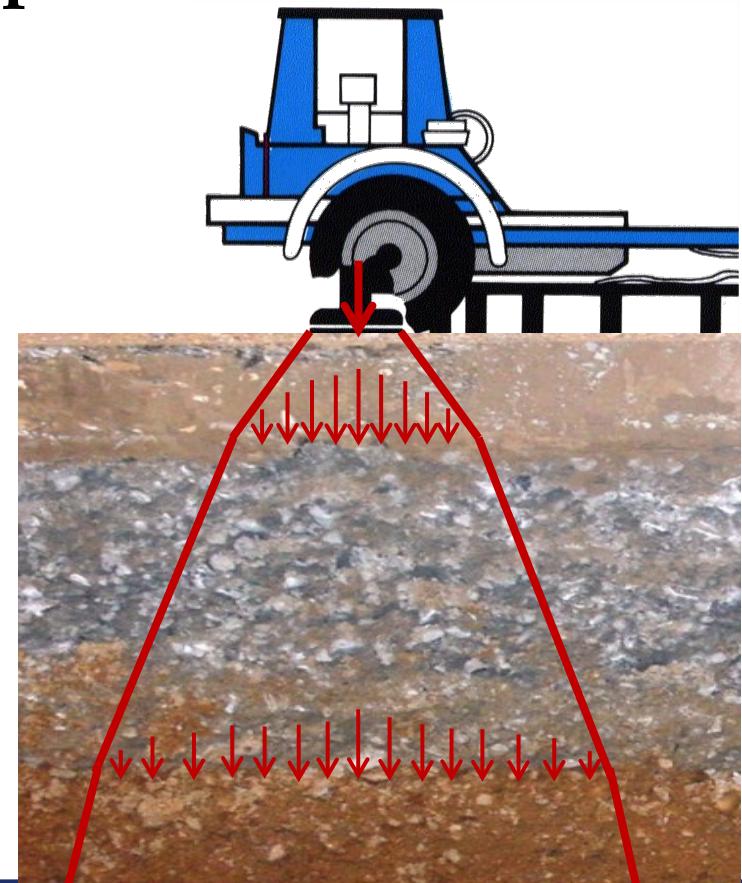
- **Falling Weight Deflectometer**
  - Applies a short impulse load
  - Measures surface deflections



Surface Layer

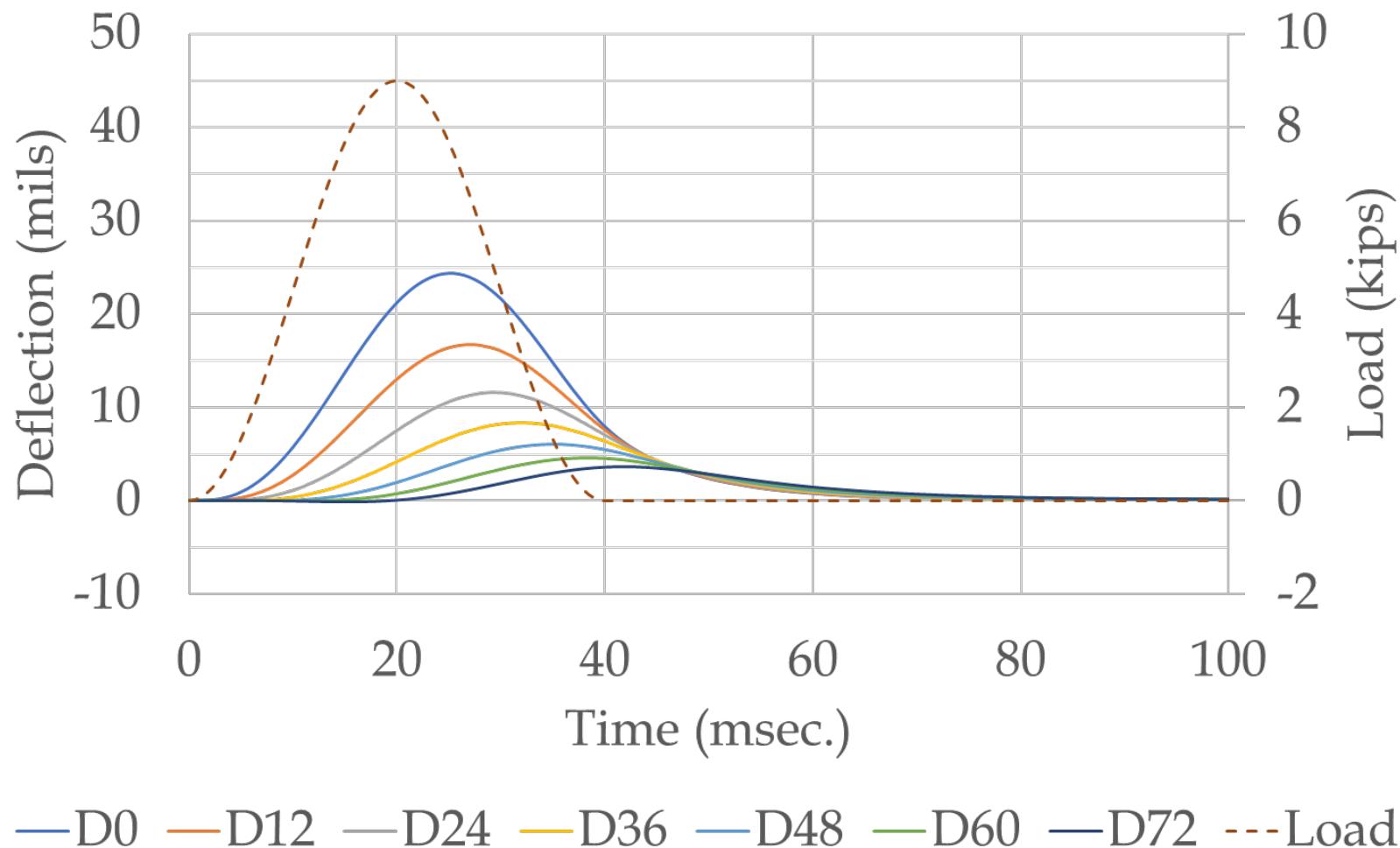
Base Layer

Subgrade Layer



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# FWD Time Histories



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# Light Weight Deflectometer (LWD)

- **Measure surface deflection**
  - up to 3,300 lbf (15 kN) impact force
  - Unbound materials
- **System**
  - Load cell and center seismic transducer (geophone)
  - Two external geophones with extension bar



# Portable Seismic Pavement Analyzer (PSPA)

- **Seismic Device**
  - Spectral Analysis of Surface Waves (SASW)
  - Response of the surface due to induced seismic waves
    - AC, PCC or unbound materials
- **System**
  - One source (impact)
  - Two receivers (accelerometers)
  - Velocity determined
  - Young's modulus calculated



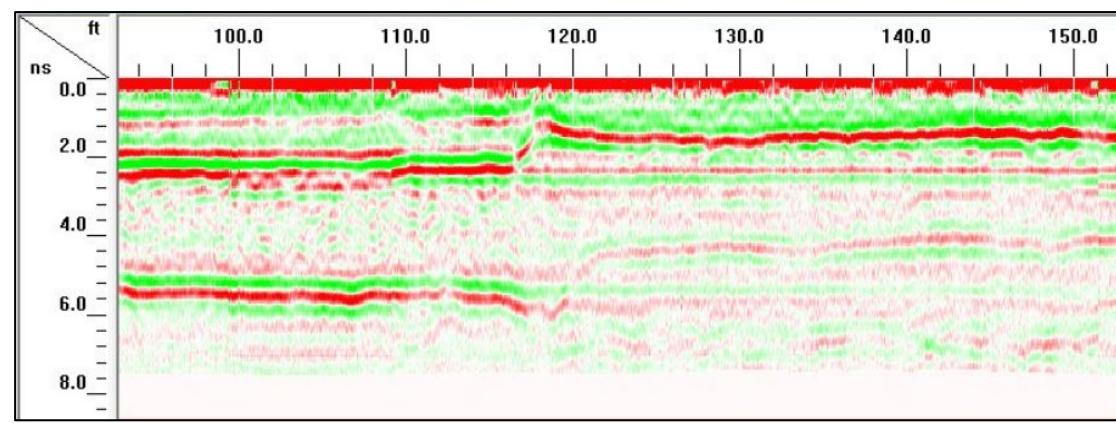
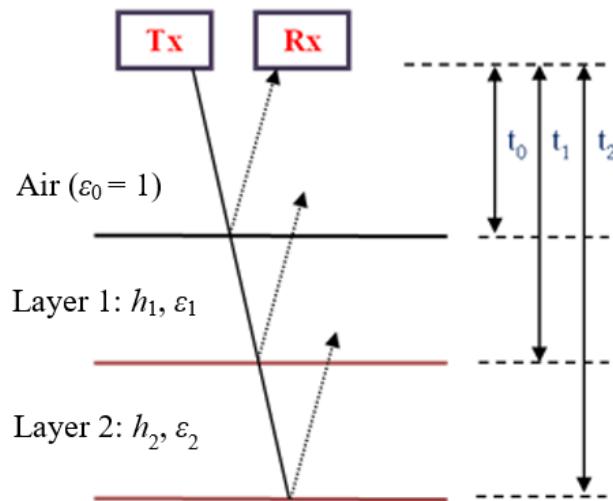
# GeoGauge

- **Measure modulus**
  - Unbound materials
- **System**
  - Applies a small dynamic load
  - Ring-shaped foot
  - Vibrated using motor
  - Sensors measure applied force and induced surface deflections
    - Varying frequencies



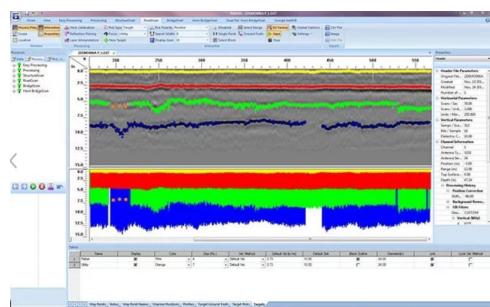
# Ground Penetrating Radar (GPR)

- Electromagnetic (EM) signal-based NDT equipment for subsurface evaluation
  - Transmitter
  - Receiver



# FAA GPR Systems

- **Cart-mounted GPR system**
  - 2.6 GHz ground-coupled antenna
  - 900 MHz ground-coupled antenna
- **Van-mounted GPR system**
  - 2 GHz air-coupled antenna
  - 400 MHz ground-coupled antenna
- **Analysis**
  - GSSI RADAN



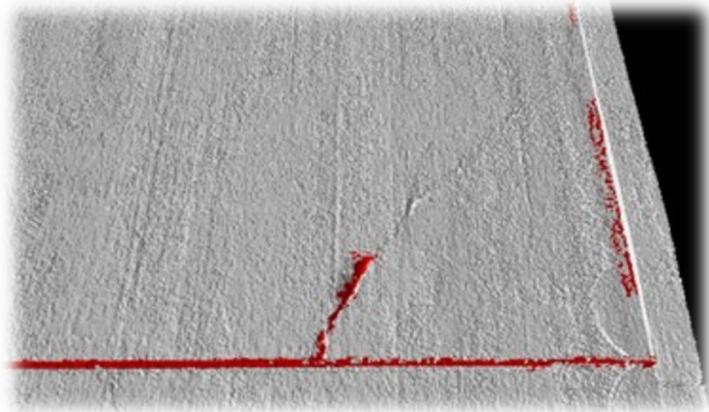
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# NDT Van 2D/3D Imaging



- **Waylink 2D and 3D Imaging system**

- 1 mm resolution
  - Laser illuminated
  - 13-ft wide longitudinal strips
    - Overlap needed



- **Multimedia based Highway Information System (MHIS)**

- Stitch images to form complete image of test area
  - Limited automated distresses classification

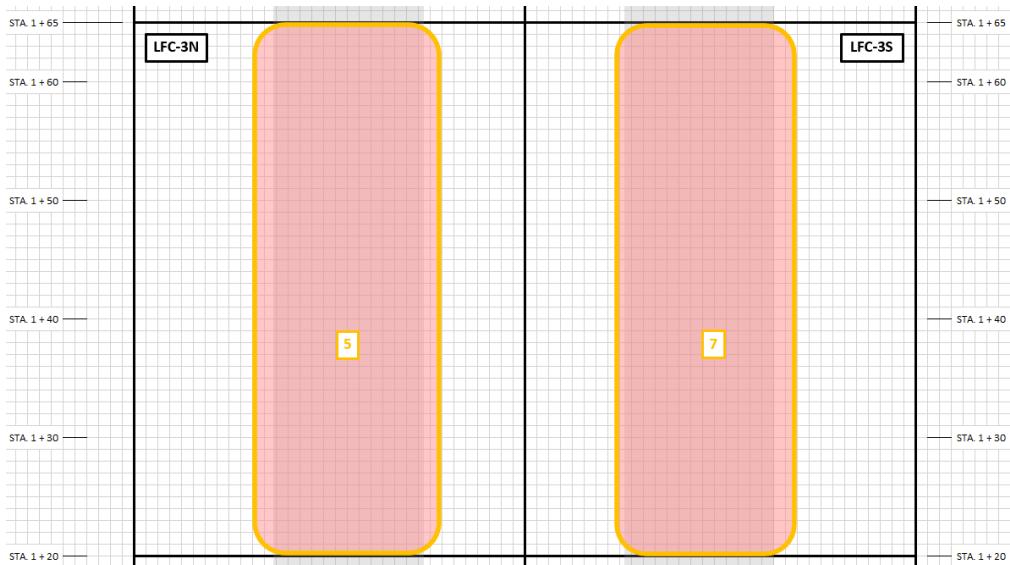
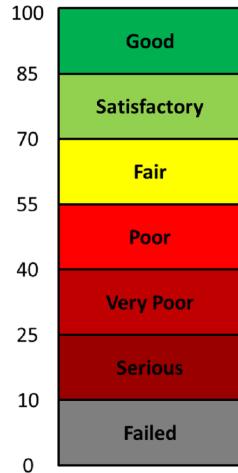


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# Manual Pavement Condition Survey

- **ASTM D5340**

- Standard Test Method for Airport **Pavement Condition Index** Surveys



5/7: High severity rutting



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# Leica 3D Scanner

- Generates 3D model of surface
  - Speed of scanning
    - Million points per second
- 2D profiles
  - Longitudinal and transverse
- Leica Cyclone 3D Point Cloud Processing Software
  - Two modules



A AUTOCAD



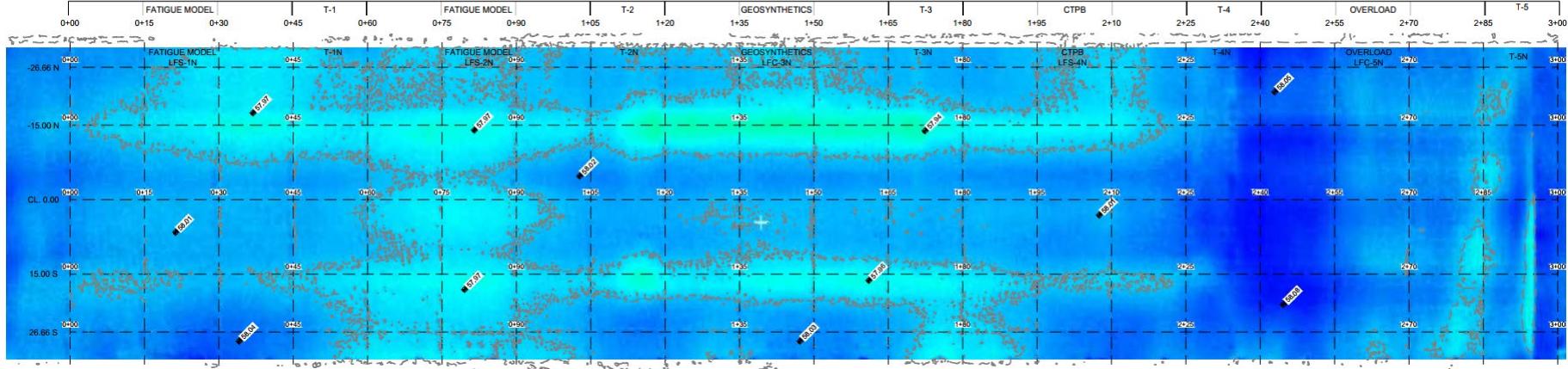
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# CC9 Heat Maps

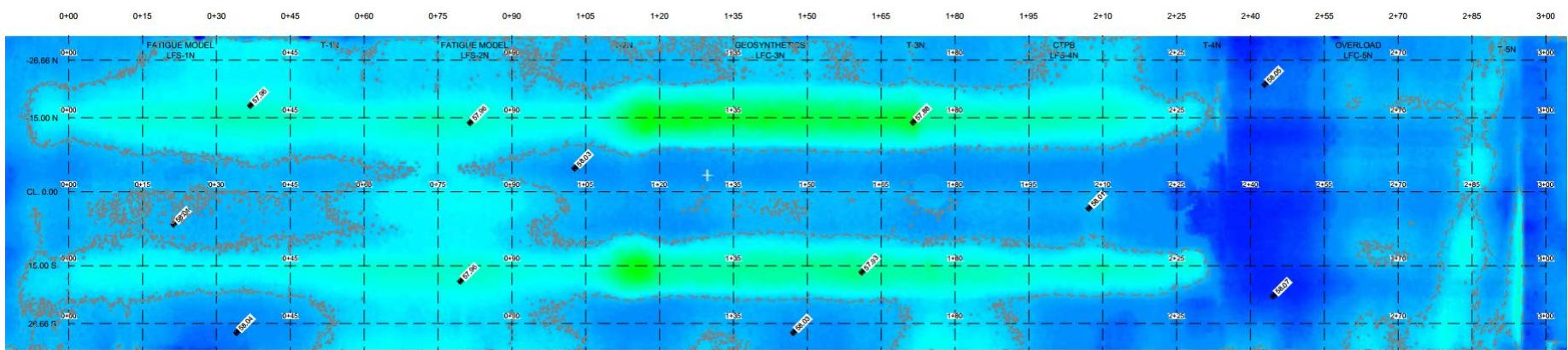


Trafficking Start:  
April 5

- April 9, 2021 (330 passes)

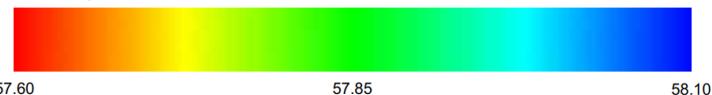


- May 14, 2021 (3,234 passes)



Color Range= 100 colors

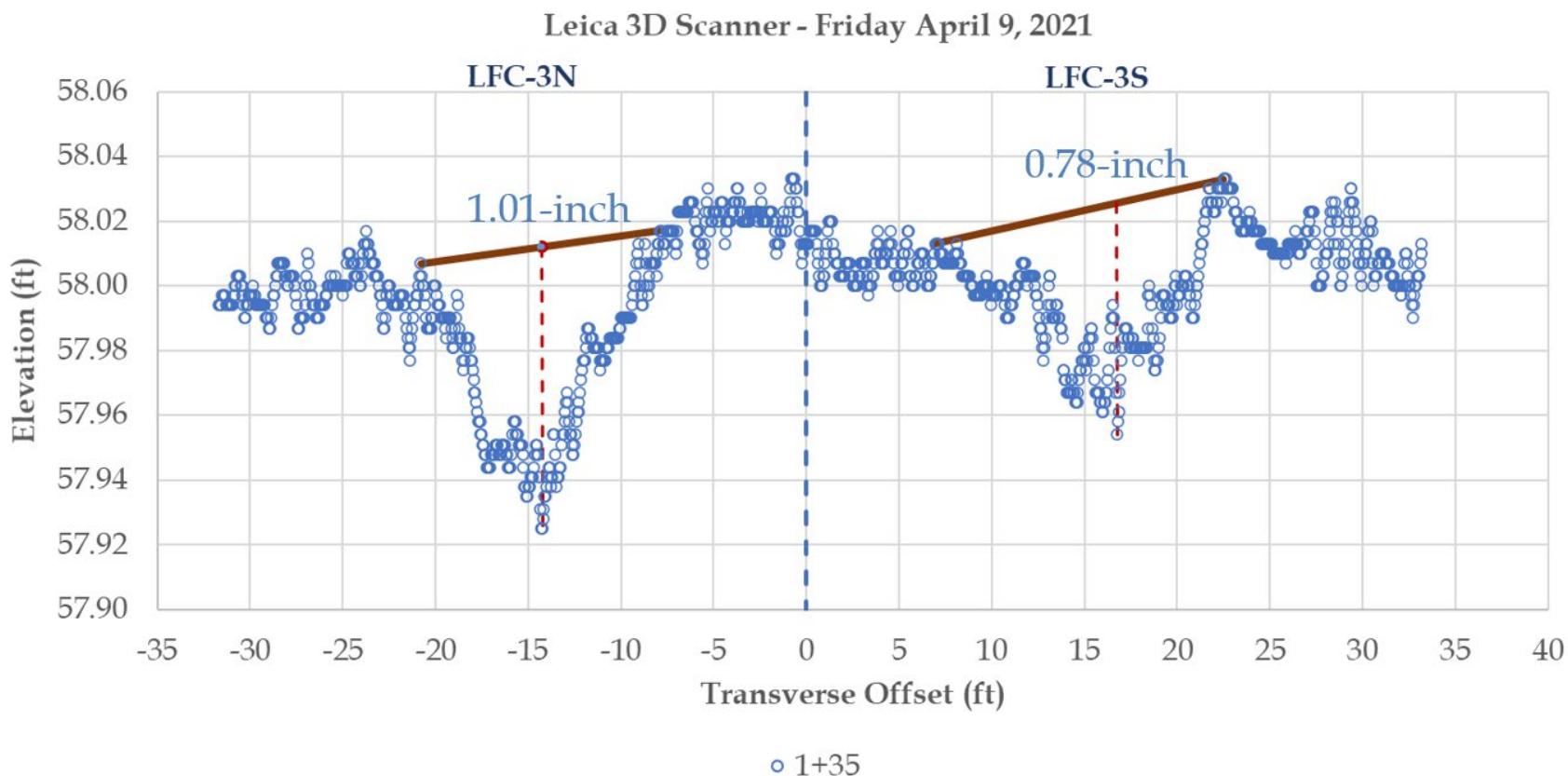
Color Increment=.05'



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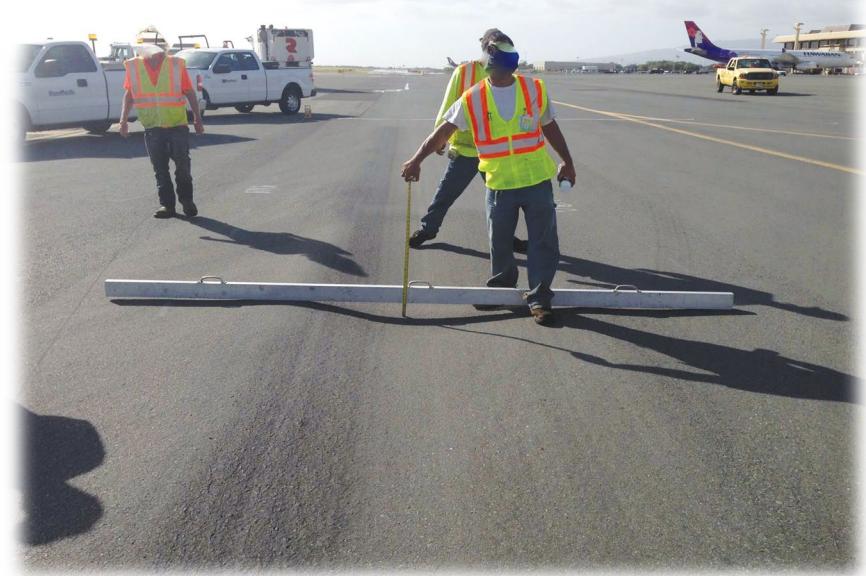
# Rutting using Virtual Straightedge

- Transverse Profile
  - Leica 3D Scanner



# Straightedge

- **ASTM E1703**
  - Measuring Rut-Depth of Pavement Surfaces Using a Straightedge
  - 16-ft straightedge



Honolulu International Airport  
Source: <http://www.forta-fi.com/>



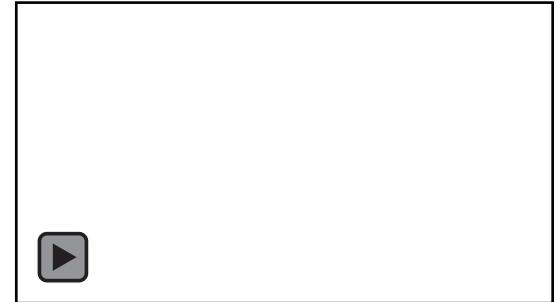
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# California Profilograph

- **Measure surface roughness**
  - Profilograph Index (PI)
- **Single wheel mounted in center**
  - measures change in height relative to support wheels



# Dipstick



- **Measure surface profile**
  - Profile measured using inclinometer
    - Determines height difference between feet
  - Precise, accurate and repeatable
    - 0.001-inch differences in height
- **ASTM E950 Class 1 profiler**
- **Longitudinal & transverse profiles**
- **Calculates roughness indices**



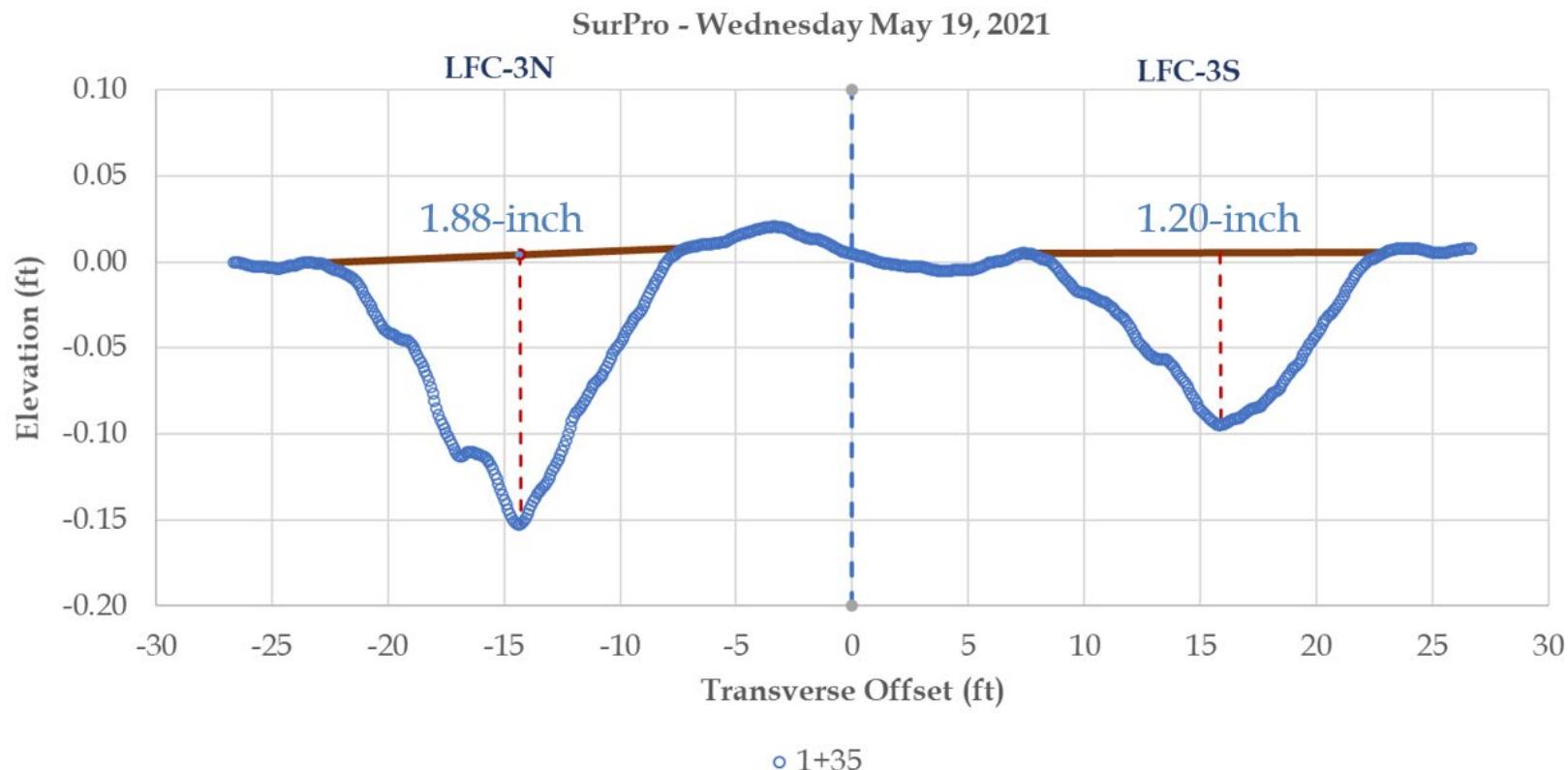
# SurPro

- Measure surface profile
  - Transducers:
    - Multi-axis Inclinometer
    - 1 optical encoder
    - 1 temperature sensor
- Sample distance interval
  - 0.25 to 12-inch
- ASTM E950 Class 1 profiler
- Longitudinal & transverse profiles
- Calculates roughness indices



# Rutting using Virtual Straightedge

- SurPro Transverse Profile

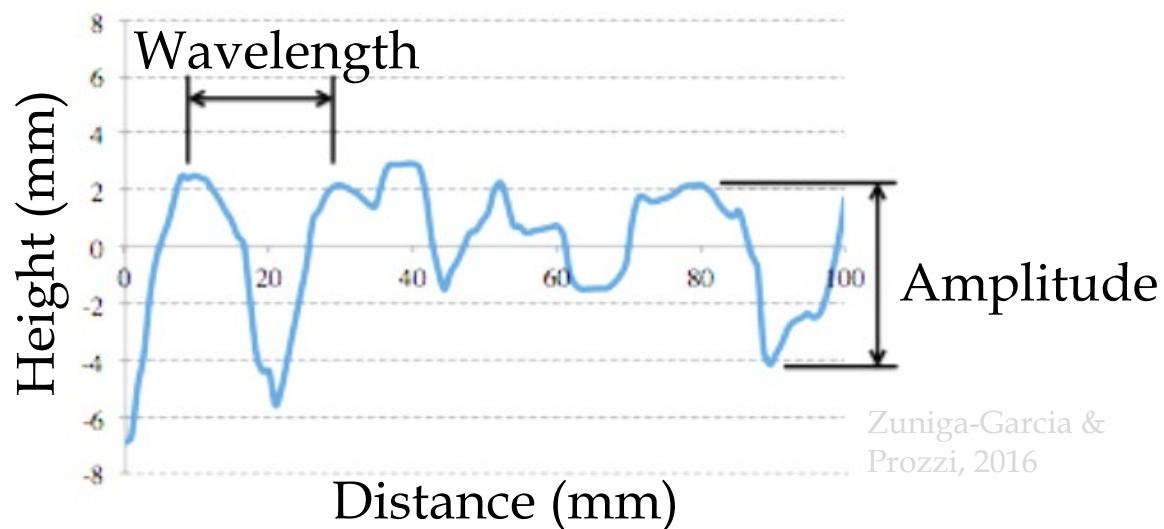
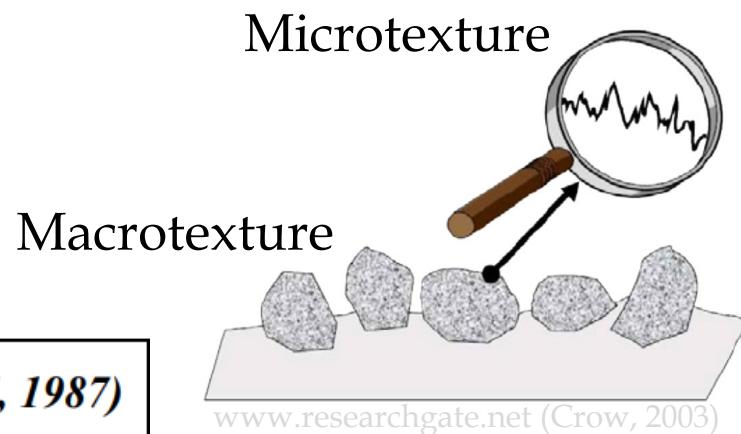


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# Pavement Texture

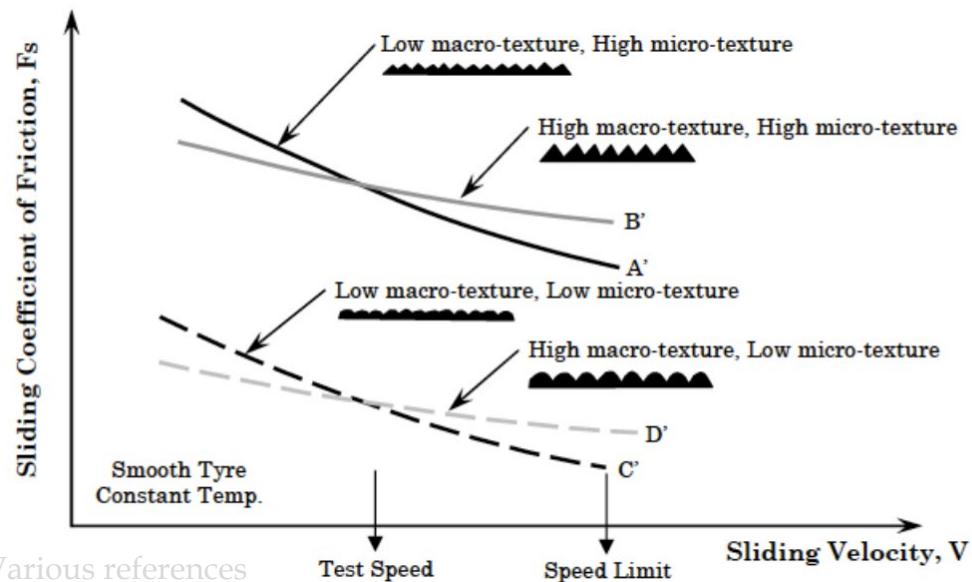
- **Texture Components**

<i>Component</i>	<i>Wavelength</i>	<i>Amplitude (PIARC, 1987)</i>
Mega-texture	50 to 500 mm	1 to 50 mm
Macrotexture	0.5 to 50 mm	0.2 to 10 mm
Microtexture	0 to 0.5 mm	0 to 0.2 mm

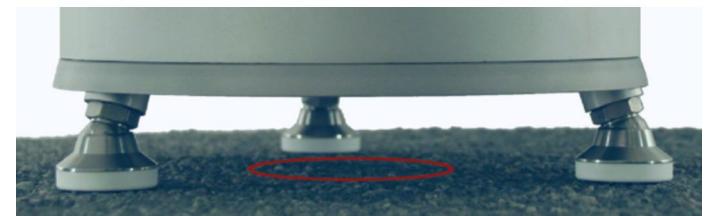


# ELAtextur

- **Macrotexture laser scanner**
  - Mean profile depth (MPD)
  - Estimated texture depth (ETD)



Various references



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# British Pendulum Tester

- Measure skid resistance
- Swinging pendulum measures energy lost to friction
  - when rubber slider contacts surface
- Pendulum test value (PTV)



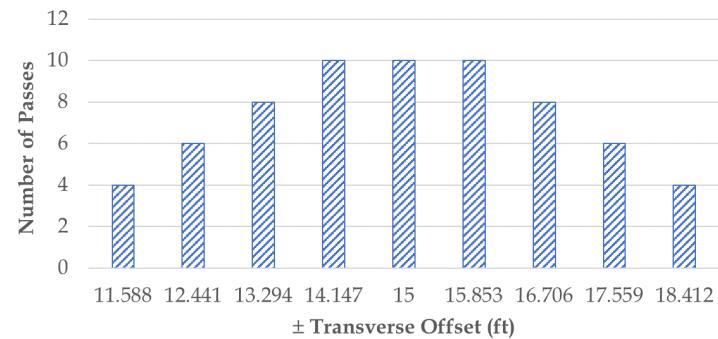
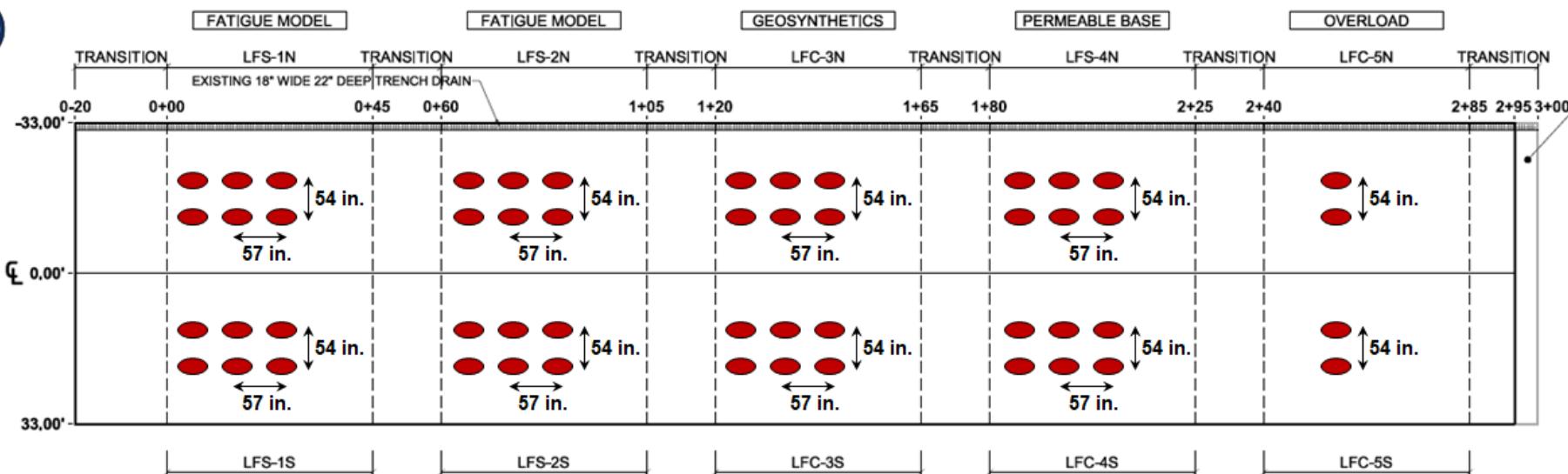
# *NDT-Related Research Projects*



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# NAPTF Construction Cycle 9 (CC9)

NDT Testing (RF every other week)



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# NAPTF Construction Cycle 9 (CC9)

- Structural NDT

- Heavy Weight Deflectometer (HWD)
- Portable Seismic Pavement Analyzer (PSPA)
- Ground Penetrating Radar (GPR)



- Functional NDT

- NDT Van 2D/3D Imaging
- Manual Pavement Condition Survey
  - Straightedge
- Leica 3D Scanner
- SurPro
- ELATextur



# Specification for Use of Nonnuclear Technology in Measuring Properties of Unbound Pavement Materials

- FAARFIELD
  - FAA AC 150/5320-6G
  - Mechanistic-empirical design methodologies
- Current practice for field QA/QC
  - FAA AC 150/5370-10H: Construction of Airports
  - Density and moisture content
  - Sand cone test and/or nuclear density gauge (NDG)
- Modulus-based devices to replace or complement density measurements



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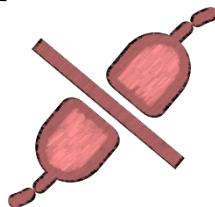
# Specification for Use of Nonnuclear Technology in Measuring Properties of Unbound Pavement Materials

- University of Texas at El Paso
- PI
  - Soheil Nazarian
- Co-PI
  - Cesar Tirado
- Award Start Date:
  - 09/26/2019
- Final Report Due
  - December 2021



# Background

- **FAARFIELD**
  - FAA AC 150/5320-6G
  - Mechanistic-empirical design methodologies
- **Current practice for field QA/QC**
  - FAA AC 150/5370-10H: Construction of Airports
  - Density and moisture content
  - Sand cone test and/or nuclear density gauge (NDG)
- **Modulus-based devices to replace or complement density measurements**



# BAKFAA

- **Forward Model**

- Linear Elastic Theory (LET)
- Odemark-Boussineq (OB)
- Finite Element (FE)

- **Optimization**

Surface Layer



$h_1, E_1, \dots$

Base

$h_2, E_2, \dots$

Subgrade

$h_3 = \infty, E_3, \dots$



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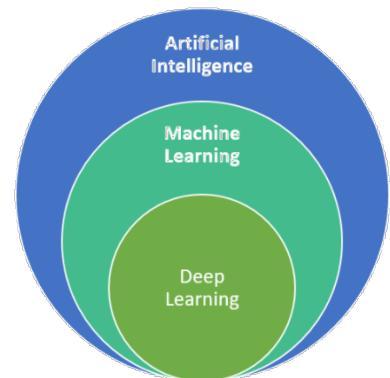
# Future of BAKFAA

- Forward Model
  - Finite element analysis
    - Dynamic
      - Newmark- $\beta$  method
      - Hilber-Hughes-Taylor  $\alpha$ -method (HHT- $\alpha$ )
  - Materials
    - Linear elastic (LE)
    - Linear viscoelastic (LVE)
      - » Prony series
  - Effective and Efficient



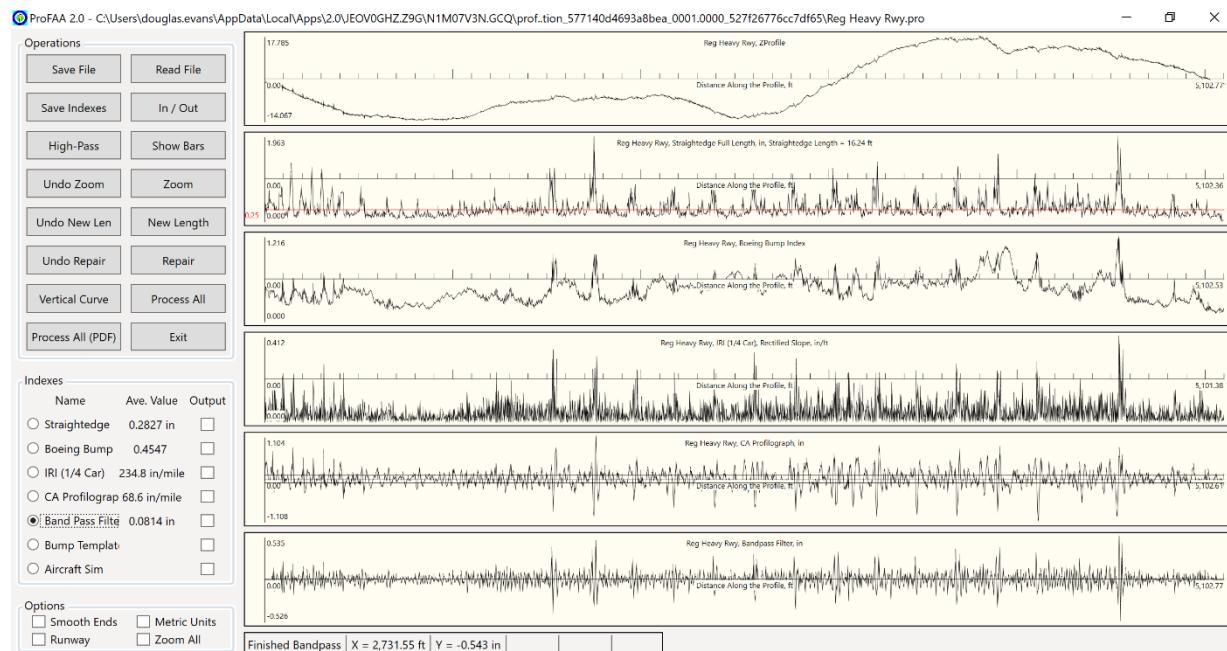
# BAKFAA

- **Optimization**
  - Classical optimization techniques
    - Newton-Raphson Method
    - Quasi-Newton Methods
    - Kalman Filter
    - Genetic Algorithm
    - Bayesian Optimization
  - Modern Optimization techniques
    - Deep Reinforcement Learning (RL)



# ProFAA

- Evaluate airport pavement roughness and smoothness from airport pavement profiles
- Indices
  - BBI
  - IRI
  - SE
  - BP
  - PI



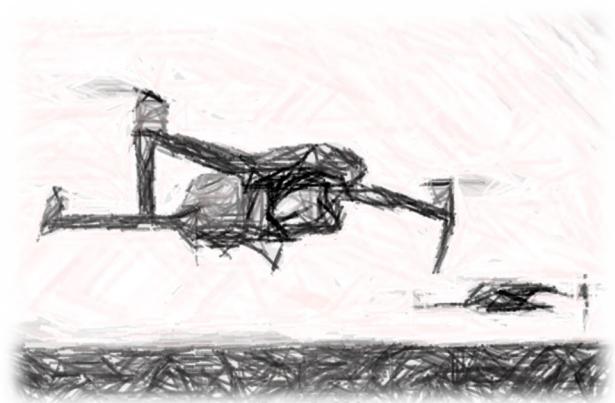
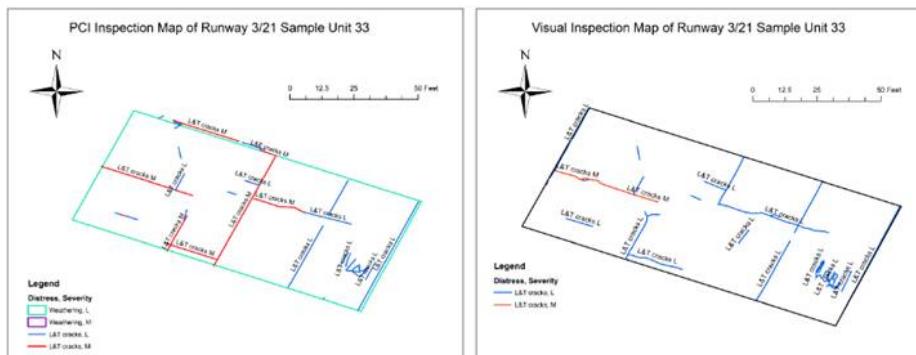
# Multiple Event Roughness Project

- **Multiple Event Roughness research outcomes**
  - Incorporate Boeing 737-800 simulation model into ProFAA
  - Develop procedure that locates and quantifies multiple event airport pavement roughness using measured profile data only.
  - Correlate Boeing “g” criteria and FAA’s pilot simulation tests rating to developed roughness factor
  - Update FAA AC 150/5380-9 and ProFAA



# sUAS for Pavement Inspections

- Practical and economical for airport geometry
- Image-based distress detection limitations exist
  - ASTM D5340: Airport PCI Surveys
- Best:
  - 0.75 mm/pix at 18.3 m with a 45.7 MP mirrorless RGB sensor



[www.flyability.com](http://www.flyability.com)



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# Surface Treatment Project

- **Surface treatment field performance research outcomes**
  - Performance restrictions, if any
  - Effectiveness of surface treatments in protection of pavement from deterioration due to environment as compared to a control section
  - Impact of surface treatment on surface friction after installation and after being in service



# NDT Website

<https://www.airporttech.tc.faa.gov/Airport-Pavement/Nondestructive-Testing-Technology-NEW>

**Nondestructive Testing Introduction**

To support its mission of providing the safest, most efficient aerospace system in the world, the Federal Aviation Administration (FAA) stands at the forefront of technology innovation. The Pavement Branch (X57) provides vital services to ensure the safety, efficiency, and efficiency of the United States airports by disseminating and developing new technologies and research findings by advancing the policies and standards of the industry. Any guidance required for the safe and efficient working methods of the aerospace industry.

The selected group of the industry in the coming decades, especially those involved in aircraft maintenance and repair, must be prepared to remain in service longer and have higher capacities to accommodate the increasing number of flights and passengers. This requires the ability to more accurately and effectively maintain and repair aircraft structures. Nondestructive testing (NDT) technologies provide a way to do this.

Through the X57, the FAA commits resources to invent and implement NDT technologies for the evaluation and management of aircraft structures. This includes the development of a suite of NDT systems and several extensive research programs that directly support the X57's mission to meet the needs of the aerospace industry.

Technology is the key to meeting the natural and growing demands. These efforts are spotlighted here to show the importance of the aerospace industry.

**Section:**

- Nondestructive Testing - Systems developed by the FAA
- Research Initiatives - Research conducted by the FAA for the development of NDT technologies and their employment
- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

**Links to:**

- NDT Initiatives
- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

**NDT Technology Introduction**

Traditionally, an airport pavement is evaluated through visual inspection of the surface, but this can be subjective and supplies little information about the structural condition. To overcome this limitation while keeping the cost low, non-destructive testing (NDT) was developed by utilizing the natural modulus of elasticity of materials under stress. Under actual field conditions, the damage is represented by reduced modulus of elasticity.

The measurement of an array of parameters using NDT technologies, however, does not involve the removal or destruction of pavements. Instead, these technologies are able to measure the thickness and integrity of the pavements without causing any damage. NDT technologies measure the physical properties of the pavements, which are then used to evaluate the safety and efficiency of the pavements. The measurement of an array of parameters using NDT technologies, however, does not involve the removal or destruction of pavements. Instead, these technologies are able to measure the thickness and integrity of the pavements without causing any damage. NDT technologies measure the physical properties of the pavements, which are then used to evaluate the safety and efficiency of the pavements.

The functional condition is measured by the surface characteristics of the system and deal with the mechanical behavior of the system and, thus, the levels of aircraft operations. These characteristics include surface irregularities, which affect an aircraft's response to the pavements. During aircraft landing, such operations or induced stresses and strains can damage the supports of aircraft pavements. During aircraft landing, such operations or induced stresses and strains can damage the supports of aircraft pavements, leading to premature fatigue failure.

NDT technologies maintain a wide variety of methods, including acoustic, electrical, and optical methods, that assess a spectrum of pavement properties. This research maintains a series of programs to analyze the NDT data for use by engineers and researchers.

**Links to:**

- Research Initiatives
- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

**Future Research and Objectives**

The FAA's Airport Technology Research (ATR) Pavement Research and Development Division's Aims is to ensure the safety, capacity, and efficiency of U.S. airports. The team's evaluation, analysis, and advancement by the ATR is done to promote, implement, more cost-effective, and environment-friendly pavements. The advancement is aimed, as the needs on aircraft and airports are always increasing, both passenger and freight traffic. The ATR always strives for future progress with its research.

The ATR has four areas of focus:

- Pavement Design: The main aim is for advanced technologies being explored for each.
- Pavement Long-term Pavement Testing and Subsequent Pavement Design: Increasing the design life from 20 years to 40 years.
- Pavement Maintenance: Improvement in pavement materials calls for the testing and characterization of new advanced materials, such as nanomaterials.
- Pavement Evaluation: Progression in pavement evaluation, as many areas of interest, including development of methods for pavement identification, improvement in testing speed and accuracy, and updating to standards.
- Special Projects: Each special project is unique and explores new technologies or innovative ideas. Some examples are heated pavements for winter use, pavement with geopolymer, and a life cycle assessment program.

**Links to:**

- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

**Showcase Research Projects**

Research projects are the ATR's way of sharing new knowledge, experiences, and technologies, as well as keeping up-to-date with the latest developments in the field of air transportation. These projects are a way to communicate efforts that have been made to research and develop new technologies. Many of these projects are very new, showcasing efforts that have been made to research and develop new technologies.

**Links to:**

- NDT Initiatives
- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

**Links to Individual Research Projects**

- NDT Initiatives
- Nondestructive Testing - Research conducted by the FAA for the development of NDT technologies and their employment
- Future Research and Objectives

# NEW



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# Thank you



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