Non-Destructive Testing (NDT) Technologies

Presented to: REDAC

By: Gabriel Bazi, PhD, PE

Date: September 8, 2021

Outline

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

Pavement Performance

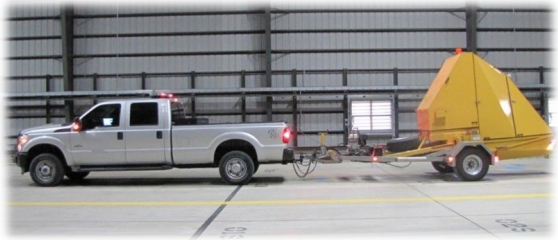
- **Structural**
  - the ability of the pavement to support traffic without developing appreciable distress

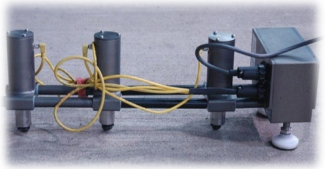
- **Functional**
  - the ability of the pavement to provide a smooth, safe ride for the comfort and convenience of the traveling public/passengers.

NDT Technologies

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)



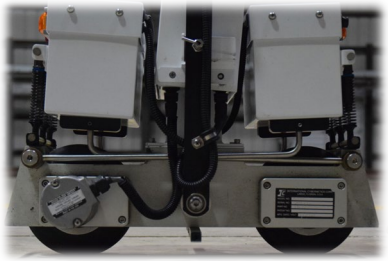


NDT Technologies

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

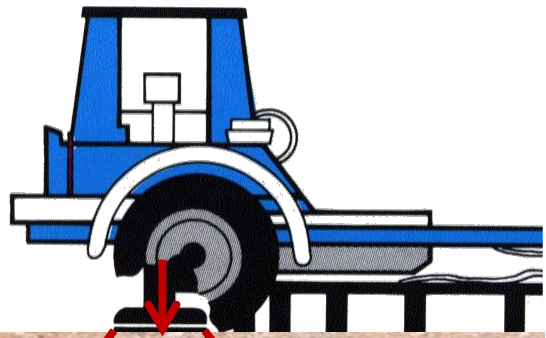
NDT Technologies

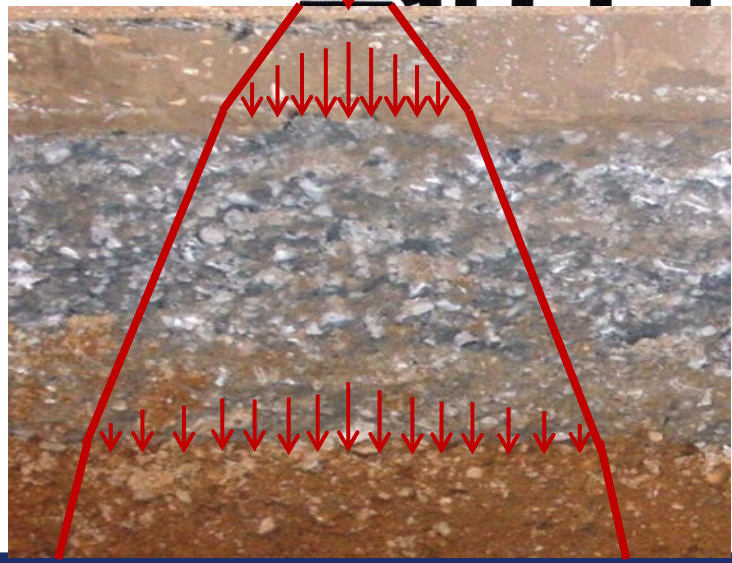
- **Functional**
  - Surface Profiles
    - NDT Van
      - Inertial Profiler
    - California Profilograph
    - Dipstick Road Profiler
    - SurPro
    - Leica 3D Scanner
    - Straightedge
  - Surface Texture
    - ELAtextur
    - British Pendulum Tester



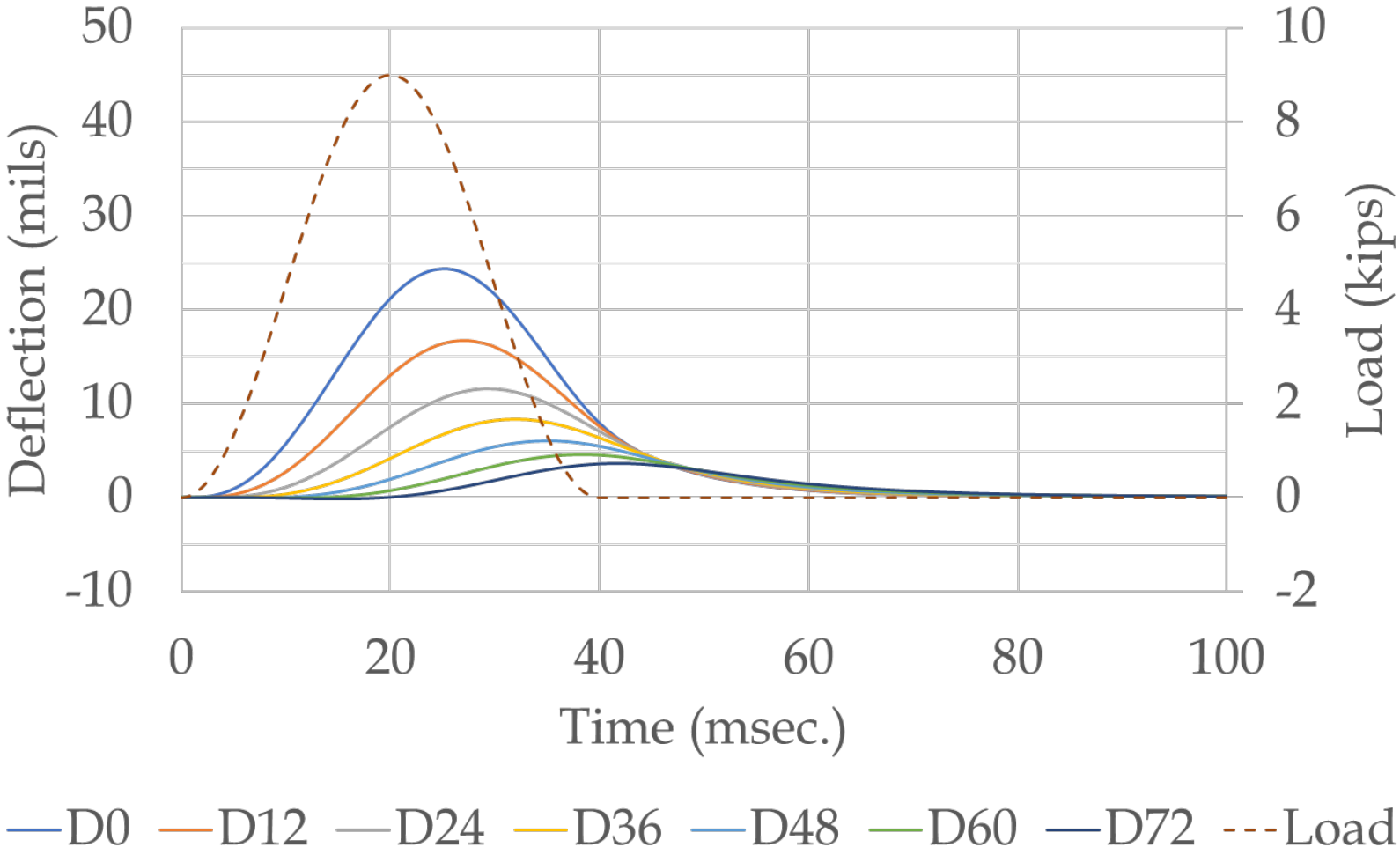
Heavy Weight Deflectometer (HWD)

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





FWD Time Histories



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

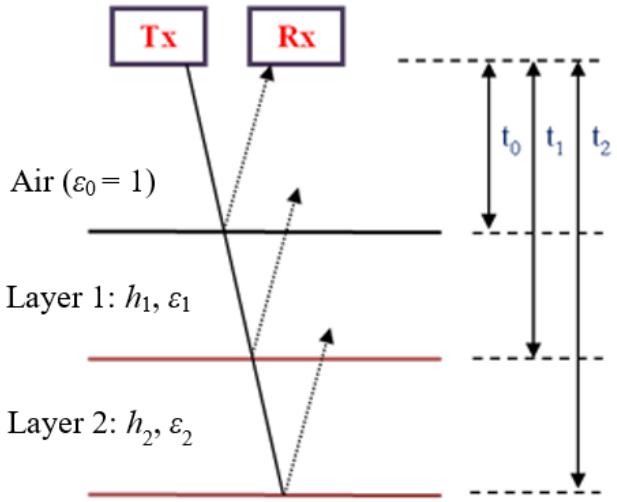
- **System**
  - One source (impact)
  - Two receivers (accelerometers)
  - Velocity determined
  - Young's modulus calculated

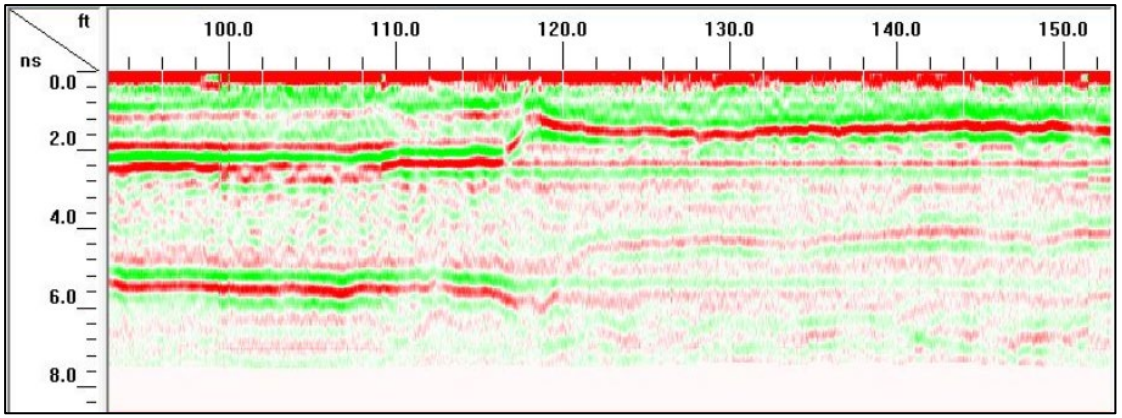
GeoGauge

- **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



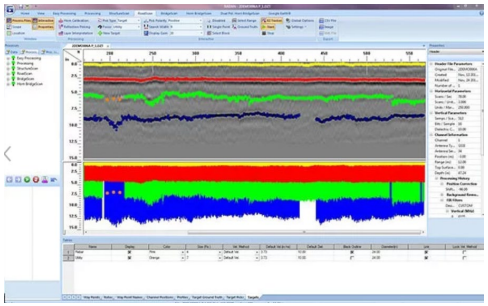


FAA GPR Systems

- **Cart-mounted GPR system**
  - 2.6 GHz ground-coupled antenna
  - 900 MHz ground-coupled antenna

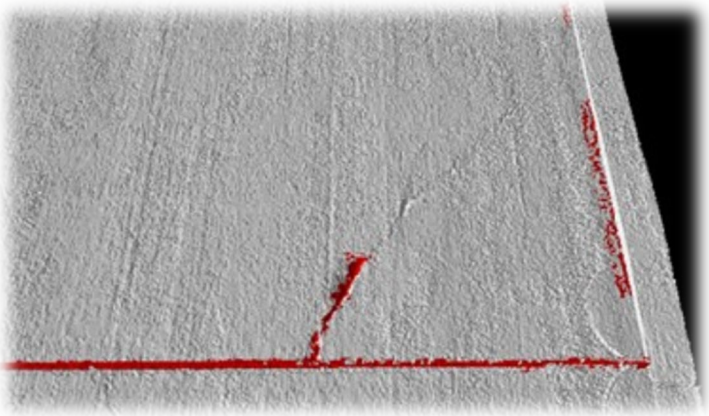
- **Van-mounted GPR system**
  - 2 GHz air-coupled antenna
  - 400 MHz ground-coupled antenna

- **Analysis**
  - GSSI RADAN



NDT Van 2D/3D Imaging

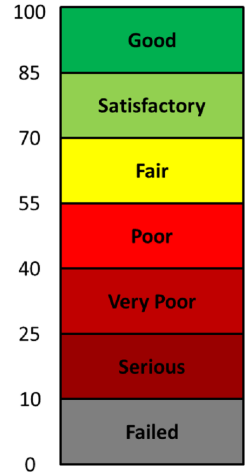
- **Waylink 2D and 3D Imaging system**
  - 1 mm resolution
  - Laser illuminated
  - 13-ft wide longitudinal strips
    - Overlap needed

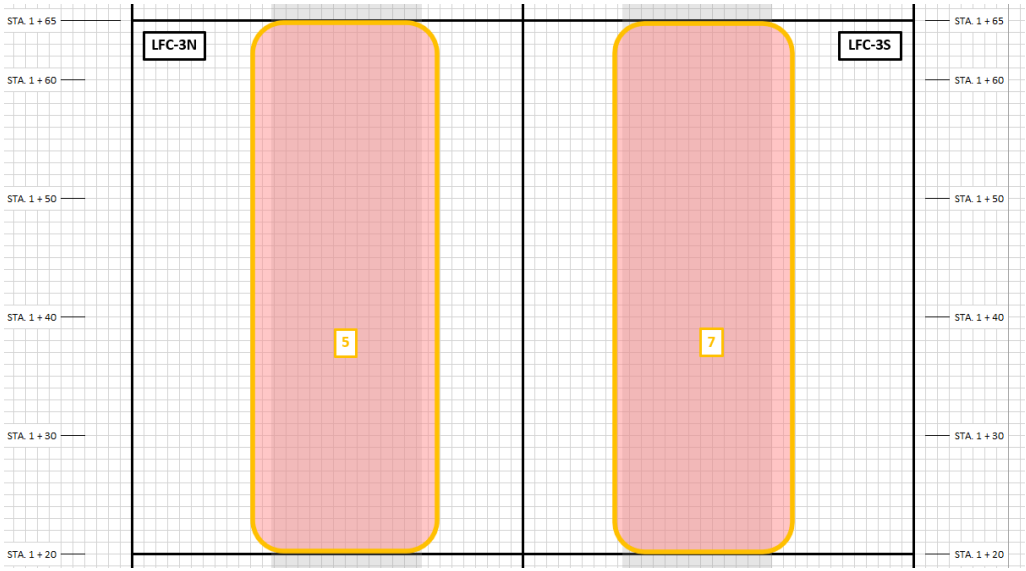


- **Multimedia based Highway Information System (MHIS)**
  - Stitch images to form complete image of test area
  - Limited automated distresses classification

Manual Pavement Condition Survey

- **ASTM D5340**
  - Standard Test Method for Airport Pavement Condition Index Surveys





5/7: High severity rutting

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

Cyclone REGISTER

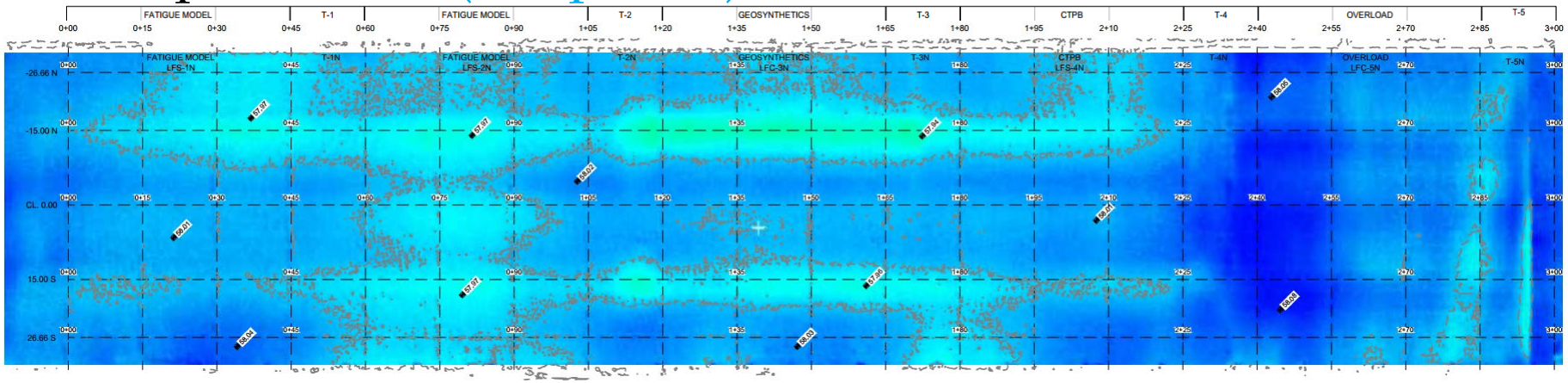
Cyclone MODEL

AUTOCAD

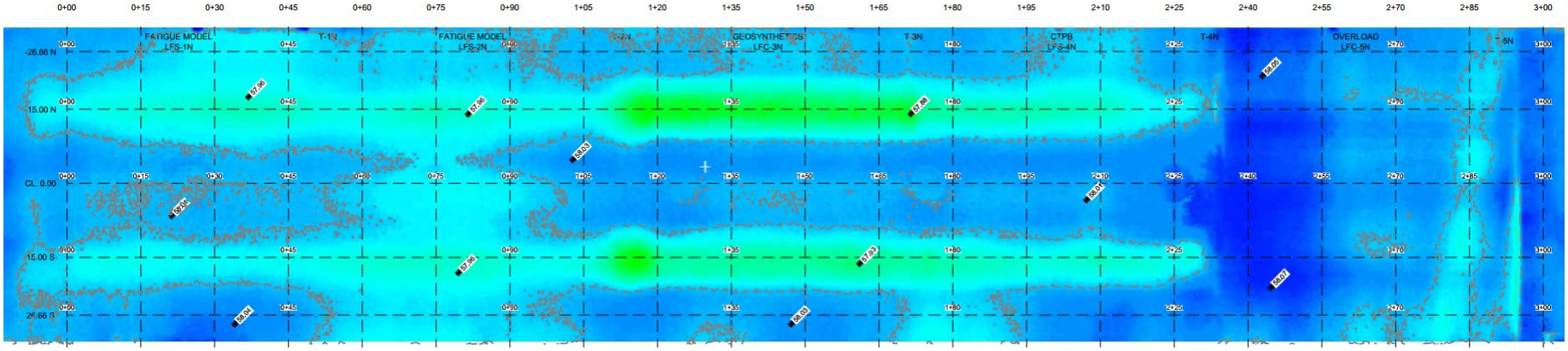
CC9 Heat Maps

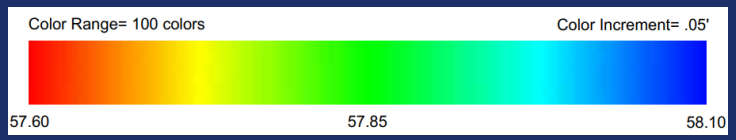
Trafficking Start:
April 5

- April 9, 2021 (330 passes)



- May 14, 2021 (3,234 passes)

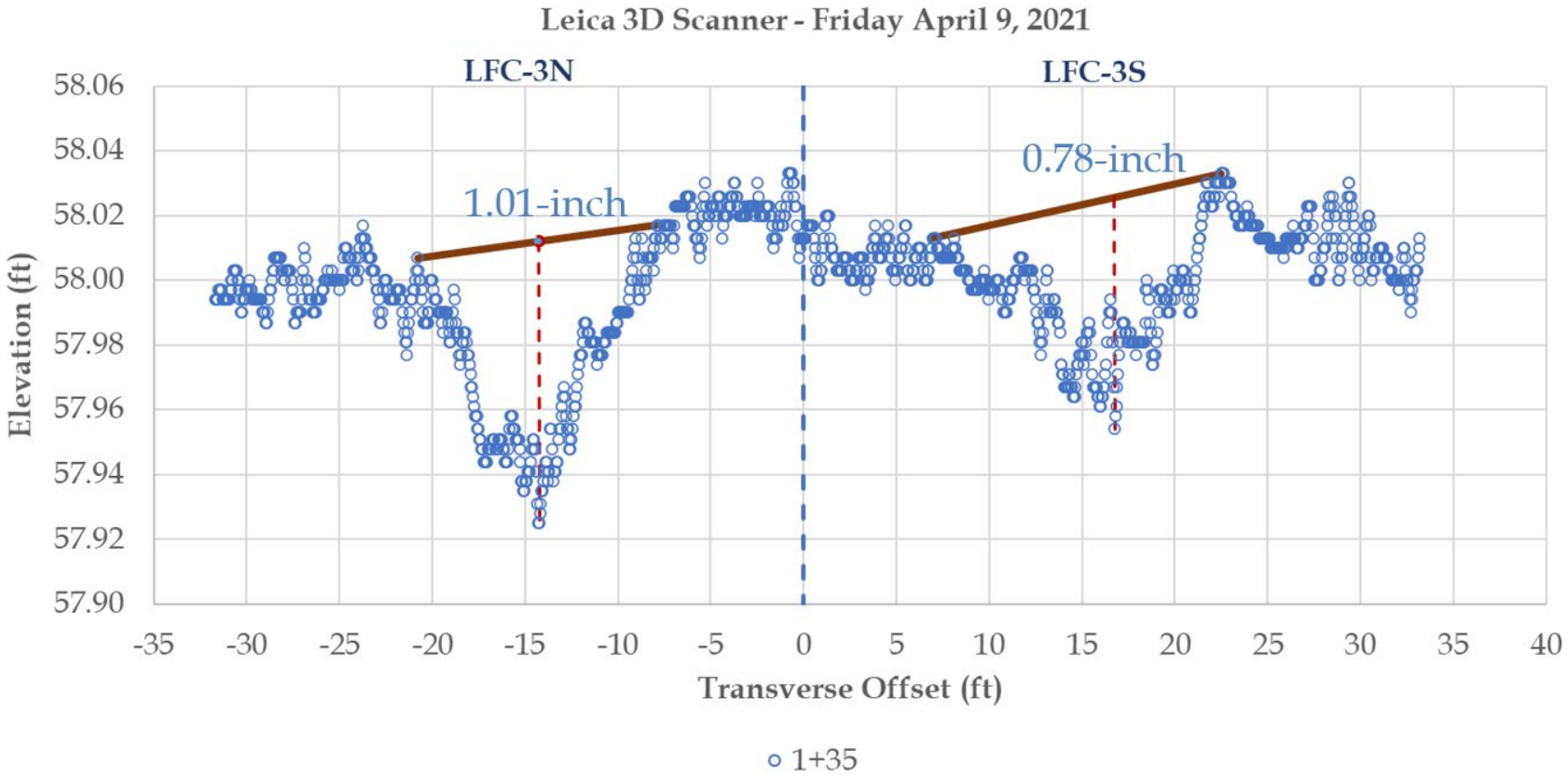




Federal Aviation Administration

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/

California Profilograph

- **Measure surface roughness**
  - Profilograph Index (PI)

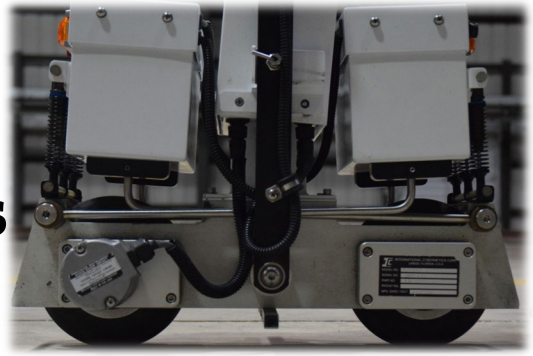
- **Single wheel mounted in center**
  - measures change in height relative to support wheels

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**

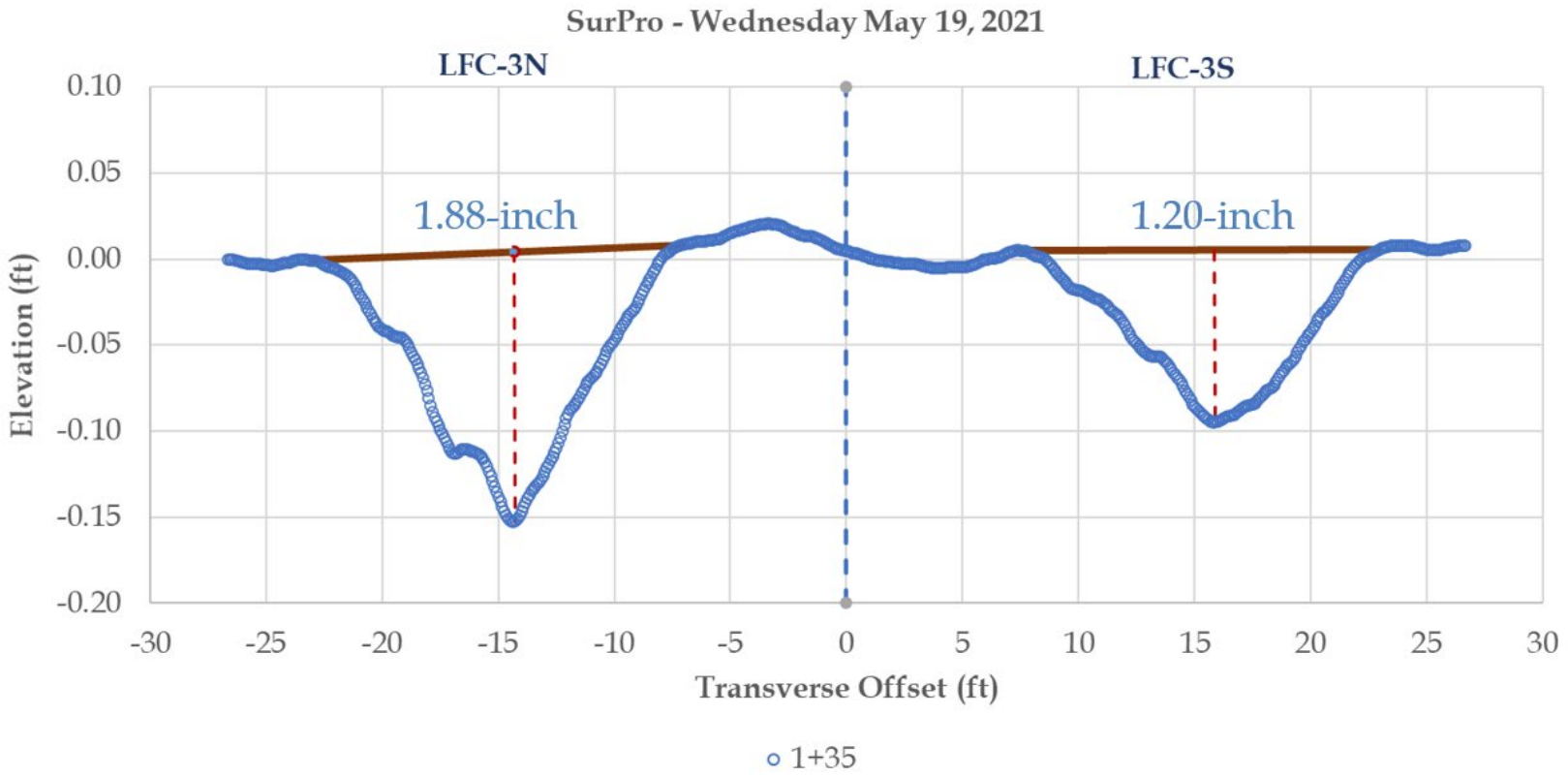
SurPro

- **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**

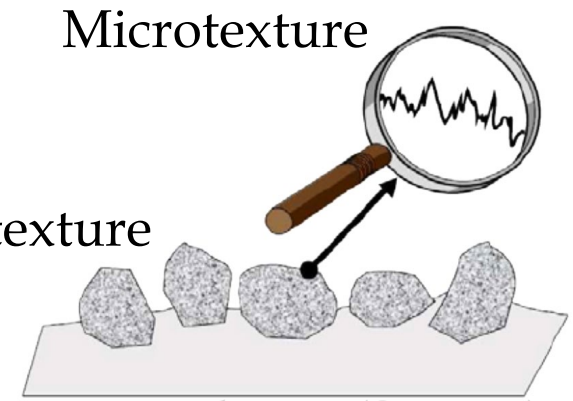


Rutting using Virtual Straightedge

- **SurPro Transverse Profile**



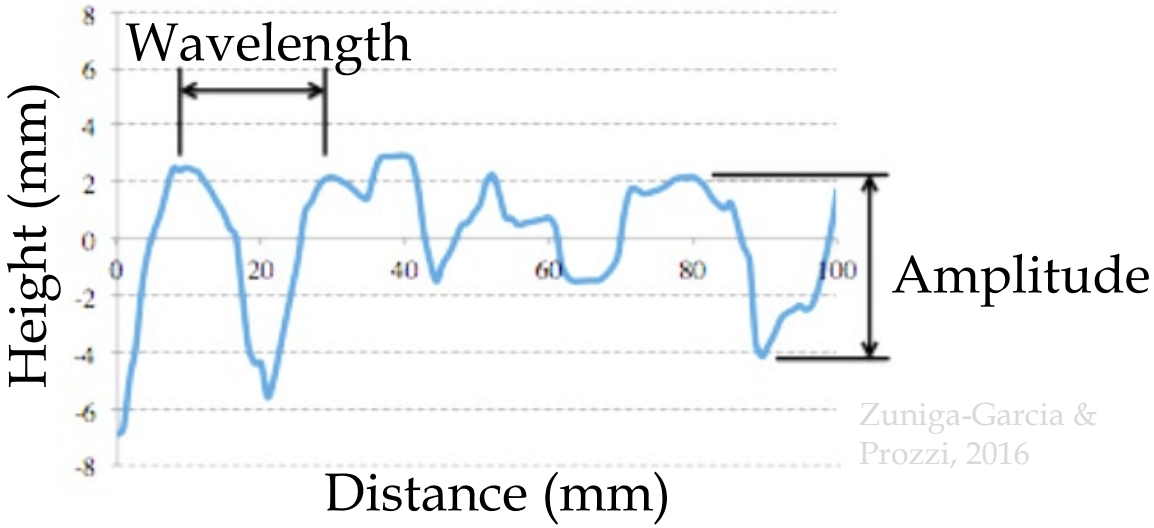
Pavement Texture



www.researchgate.net (Crow, 2003)

- **Texture Components**

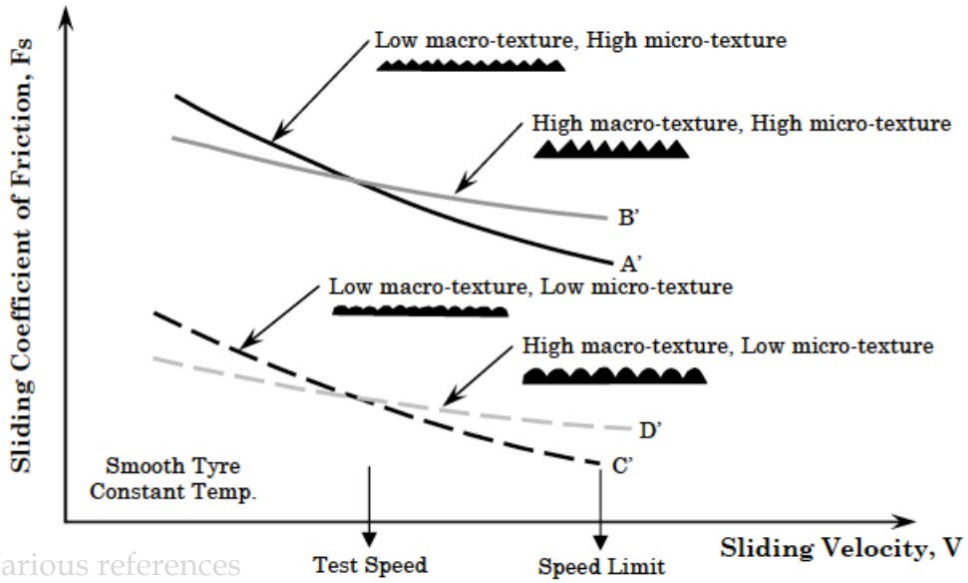
Component	*Wavelength*	*Amplitude (PIARC, 1987)*
Mega-texture	50 to 500 mm	1 to 50 mm
Macro-texture	0.5 to 50 mm	0.2 to 10 mm
Micro-texture	0 to 0.5 mm	0 to 0.2 mm



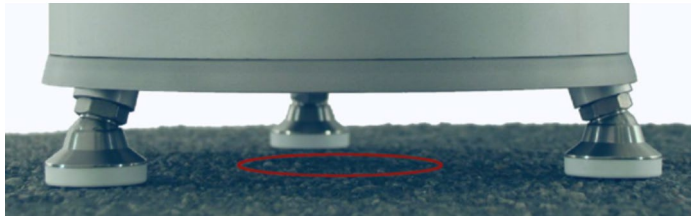
Zuniga-Garcia & Prozzi, 2016

ELAtextur

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



Various references



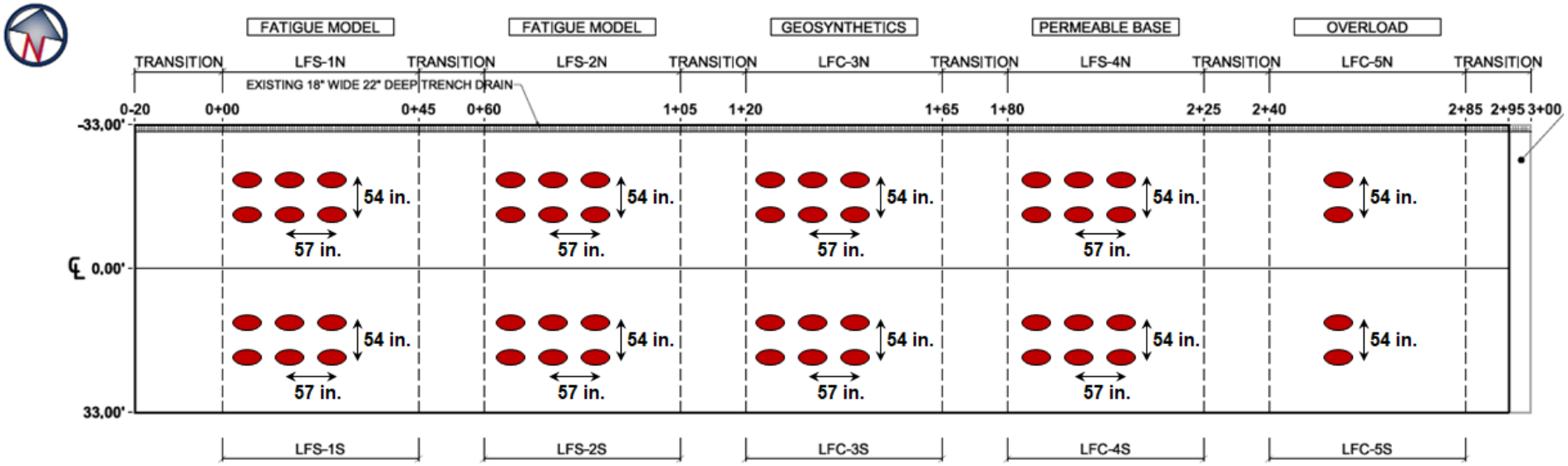
British Pendulum Tester

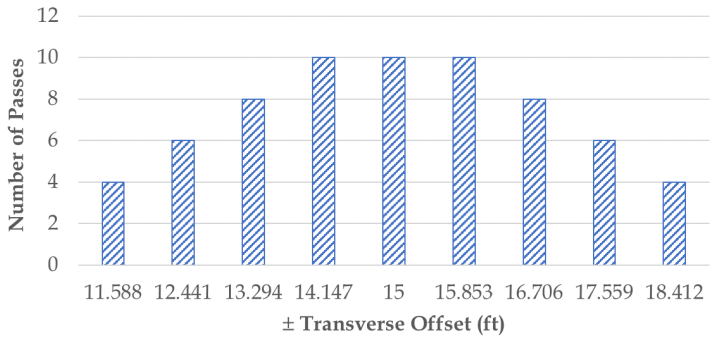
- **Measure skid resistance**
- **Swinging pendulum measures energy lost to friction**
  - when rubber slider contacts surface
- **Pendulum test value (PTV)**

NDT-Related Research Projects

NAPTF Construction Cycle 9 (CC9)

NDT Testing (RF every other week)

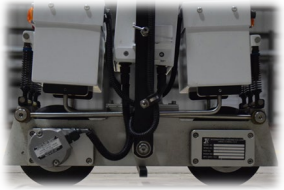




NAPTF Construction Cycle 9 (CC9)

- **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

globalgilson.com

- **FAARFIELD**
  - FAA AC 150/5320-6G
  - Mechanistic-empirical design methodologies

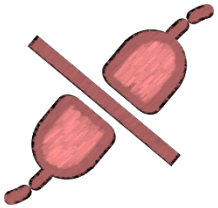
- **Current practice for field QA/QC**
  - FAA AC 150/5370-10H: Construction of Airports
  - Density and moisture content
  - Sand cone test and/or nuclear density gauge (NDG)
- **Modulus-based devices to <u>replace</u> or <u>complement</u> density measurements**

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



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  - FAA AC 150/5370-10H: Construction of Airports
  - Density and moisture content
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BAKFAA

- **Forward Model**
  - Linear Elastic Theory (LET)
  - Odemark-Boussineq (OB)
  - Finite Element (FE)
- **Optimization**

Surface Layer $h_1, E_1, \ldots$

Base $h_2, E_2, \ldots$

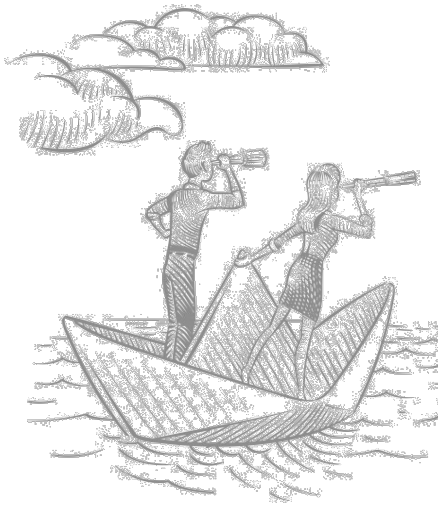
Subgrade $h_3=\infty, E_3, \ldots$

Future of BAKFAA

- **Forward Model**
  - Finite element analysis
    - Dynamic
      - Newmark-β method
      - Hilber-Hughes-Taylor α-method (HHT-α)

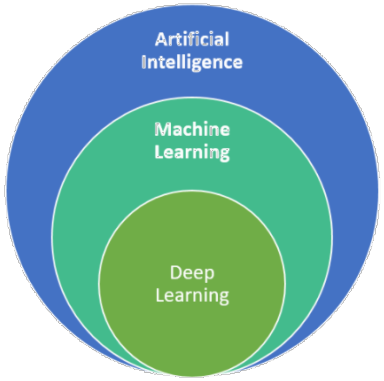
$$M\ddot{U} + C\dot{U} + KU = R$$

    - Materials
      - Linear elastic (LE)
      - Linear viscoelastic (LVE)
        - » Prony series
    - Effective and Efficient



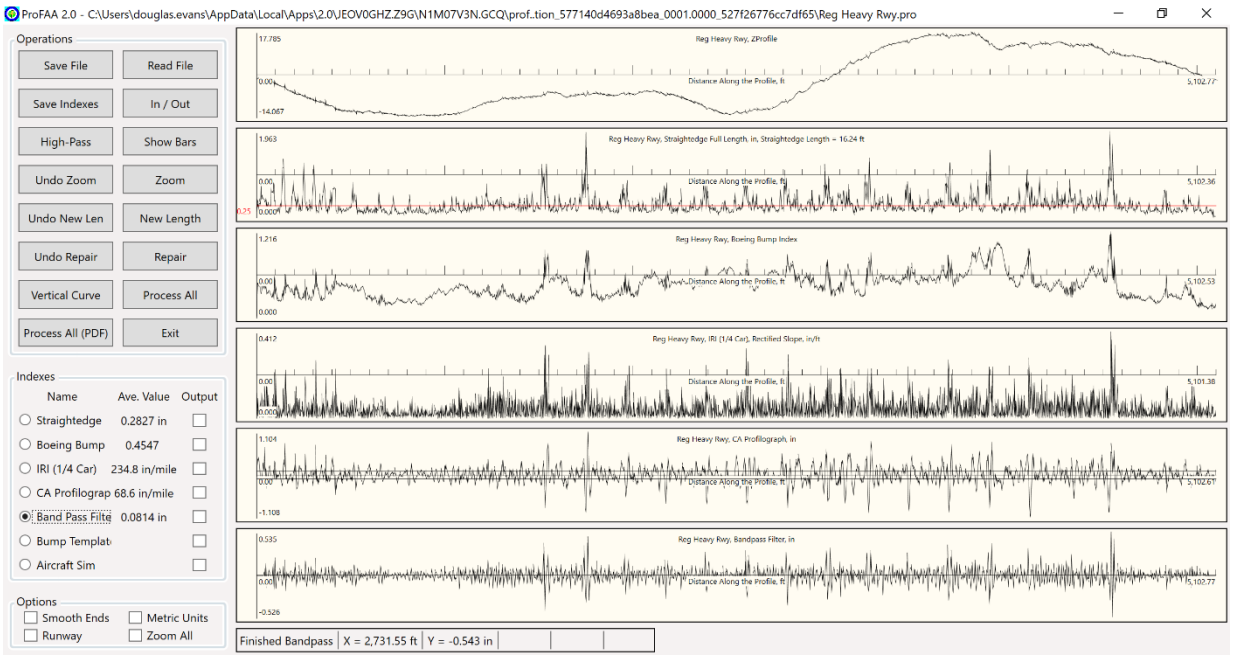
BAKFAA

- **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

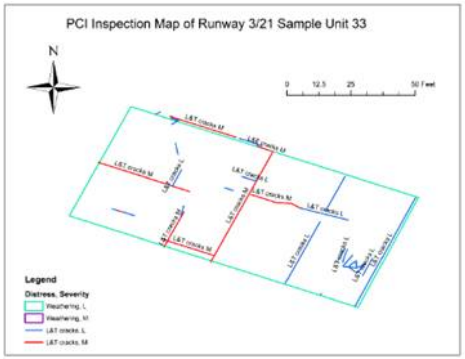


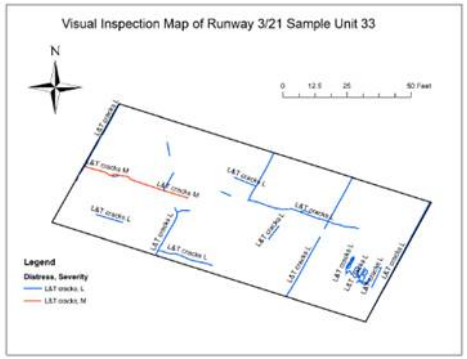
Multiple Event Roughness Project

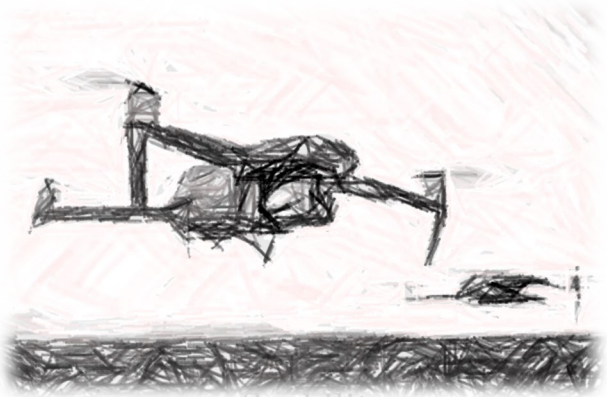
- **Multiple Event Roughness research outcomes**
  - Incorporate Boeing 737-800 simulation model into ProFAA
  - Develop procedure that locates and quantifies multiple event airport pavement roughness using measured profile data only.
  - Correlate Boeing "g" criteria and FAA's pilot simulation tests 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

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 comparted 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

NEW

Thank you