ICAO AERODROME PAVEMENT WORKSHOP

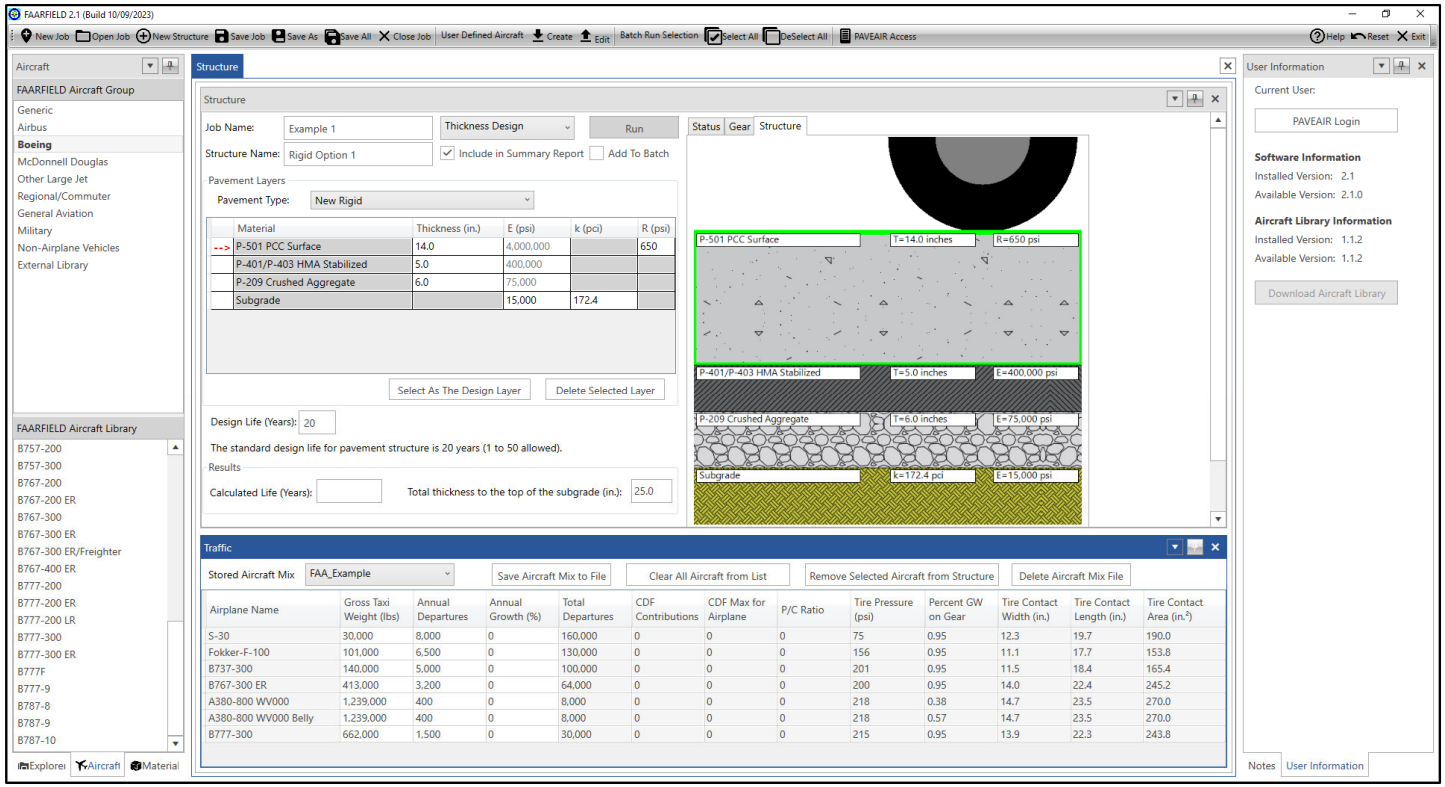
Introduction to FAARFIELD 2.1

Presented to: ICAO Aerodrome Pavement Workshop
Bangkok, Thailand

By: Harold Muniz
David R. Brill, P.E., Ph.D.

Date: 7 February 2024

Federal Aviation Administration

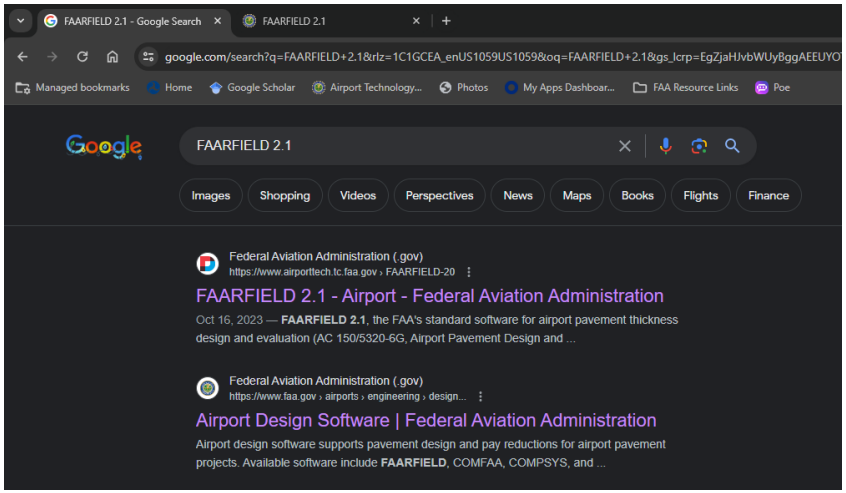


Download & Install FAARFIELD 2.1 Software

Download FAARFIELD 2.1

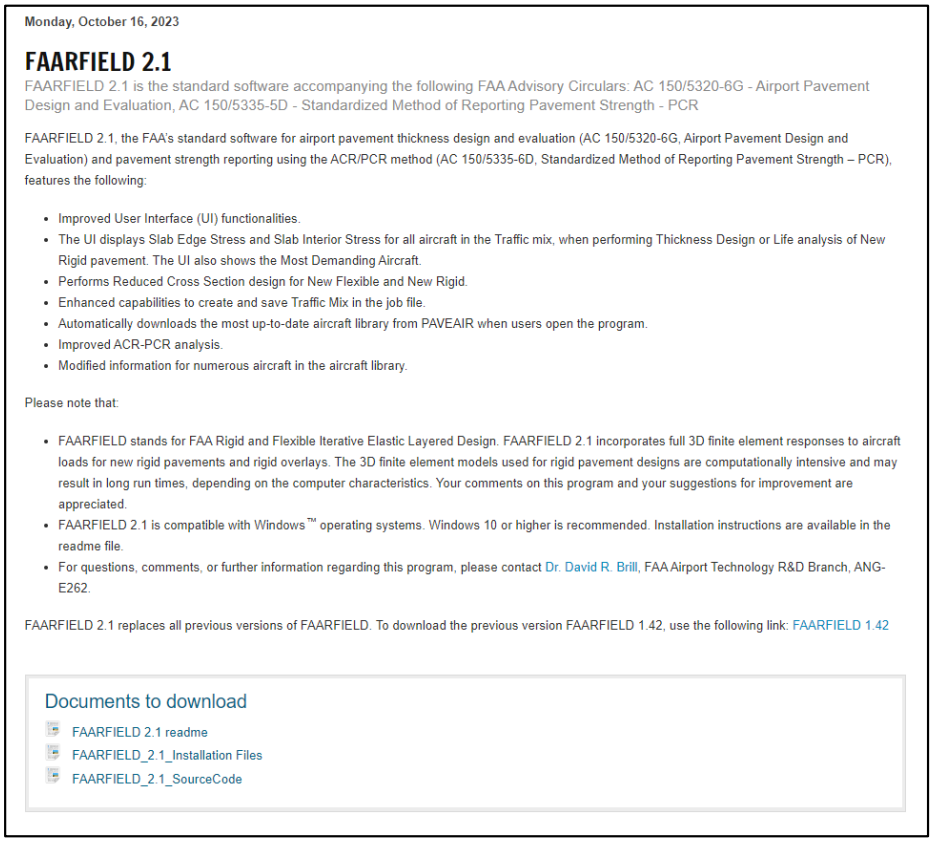
- **Link:** https://airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/faarfield-21
  - Alternate - Search “FAARFIELD 2.1”

FAARFIELD can only be installed on Windows OS



Download FAARFIELD 2.1

- **Click “Installation Files” to download**
  - Approximately 50 MB
  - Downloaded as compressed ZIP file
- **Source Code is also available at this webpage**



Monday, October 16, 2023

FAARFIELD 2.1

FAARFIELD 2.1 is the standard software accompanying the following FAA Advisory Circulars: AC 150/5320-6G - Airport Pavement Design and Evaluation, AC 150/5335-5D - Standardized Method of Reporting Pavement Strength - PCR

FAARFIELD 2.1, the FAA's standard software for airport pavement thickness design and evaluation (AC 150/5320-6G, Airport Pavement Design and Evaluation) and pavement strength reporting using the ACR/PCR method (AC 150/5335-6D, Standardized Method of Reporting Pavement Strength – PCR), features the following:

- Improved User Interface (UI) functionalities.
- The UI displays Slab Edge Stress and Slab Interior Stress for all aircraft in the Traffic mix, when performing Thickness Design or Life analysis of New Rigid pavement. The UI also shows the Most Demanding Aircraft.
- Performs Reduced Cross Section design for New Flexible and New Rigid.
- Enhanced capabilities to create and save Traffic Mix in the job file.
- Automatically downloads the most up-to-date aircraft library from PAVEAIR when users open the program.
- Improved ACR-PCR analysis.
- Modified information for numerous aircraft in the aircraft library.

Please note that:

- FAARFIELD stands for FAA Rigid and Flexible Iterative Elastic Layered Design. FAARFIELD 2.1 incorporates full 3D finite element responses to aircraft loads for new rigid pavements and rigid overlays. The 3D finite element models used for rigid pavement designs are computationally intensive and may result in long run times, depending on the computer characteristics. Your comments on this program and your suggestions for improvement are appreciated.
- FAARFIELD 2.1 is compatible with Windows™ operating systems. Windows 10 or higher is recommended. Installation instructions are available in the readme file.
- For questions, comments, or further information regarding this program, please contact Dr. David R. Brill, FAA Airport Technology R&D Branch, ANG-E262.

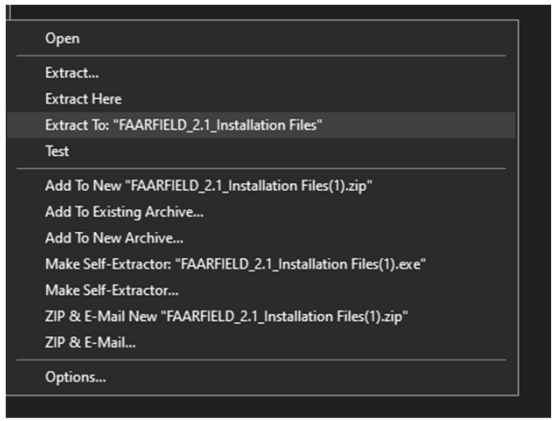
FAARFIELD 2.1 replaces all previous versions of FAARFIELD. To download the previous version FAARFIELD 1.42, use the following link: FAARFIELD 1.42

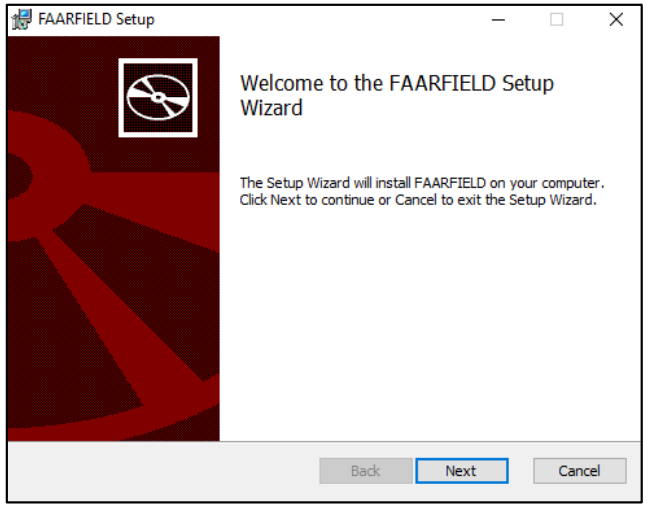
Documents to download

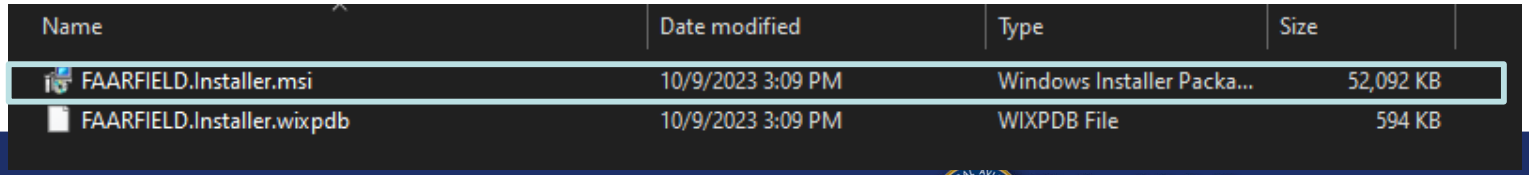
FAARFIELD 2.1 readme
FAARFIELD_2.1_Installation Files
FAARFIELD_2.1_SourceCode

Install FAARFIELD 2.1

- **Extract the downloaded ZIP file**
- **Run .MSI file to begin installation**



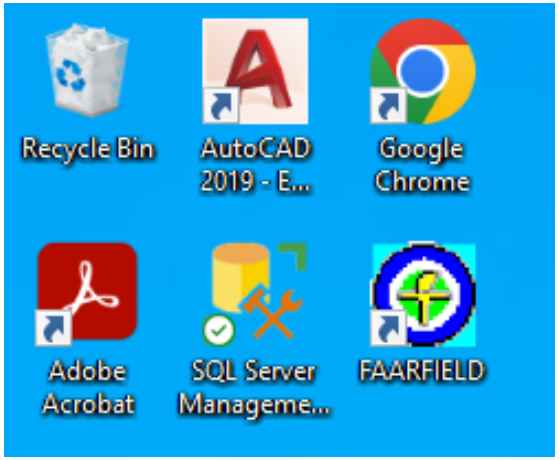


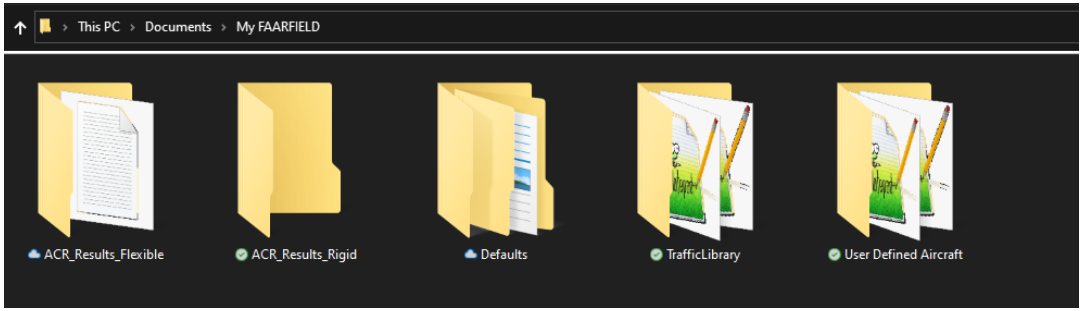


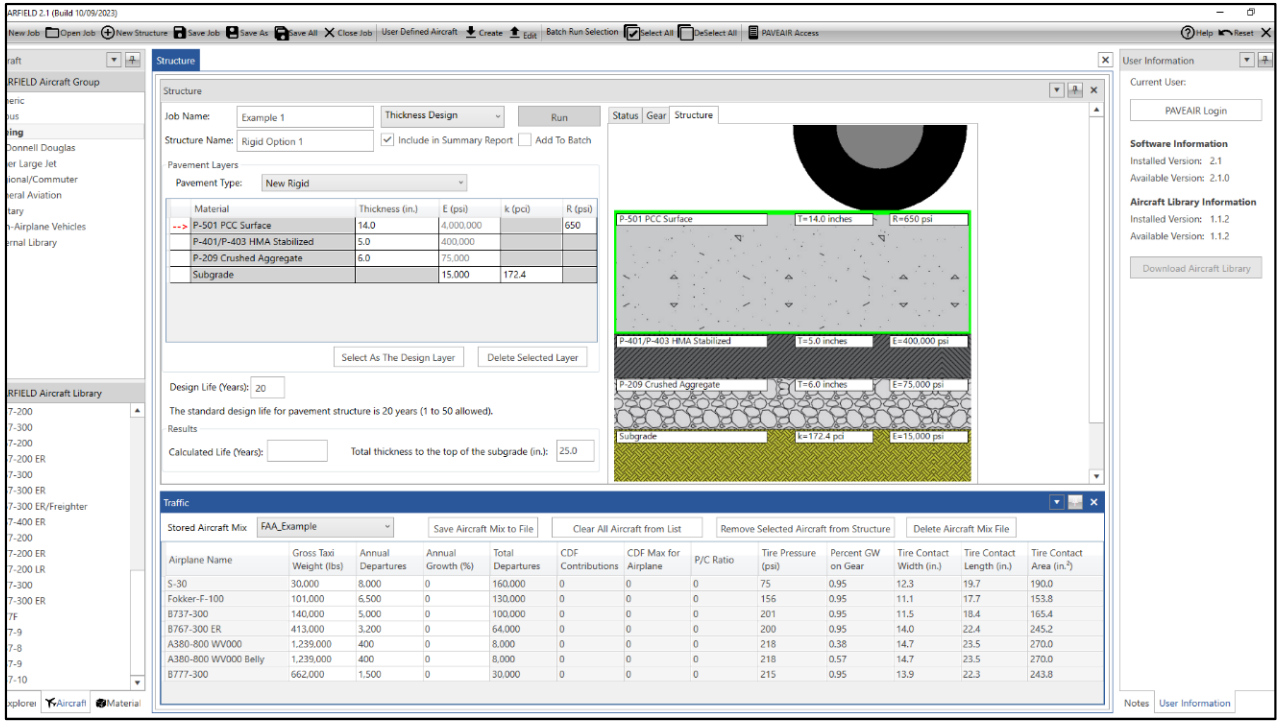
Install FAARFIELD 2.1

To confirm the installation, look for:

- FAARFIELD application on your desktop
- FAARFIELD in Windows menu
- *My FAARFIELD* folder in your Documents directory

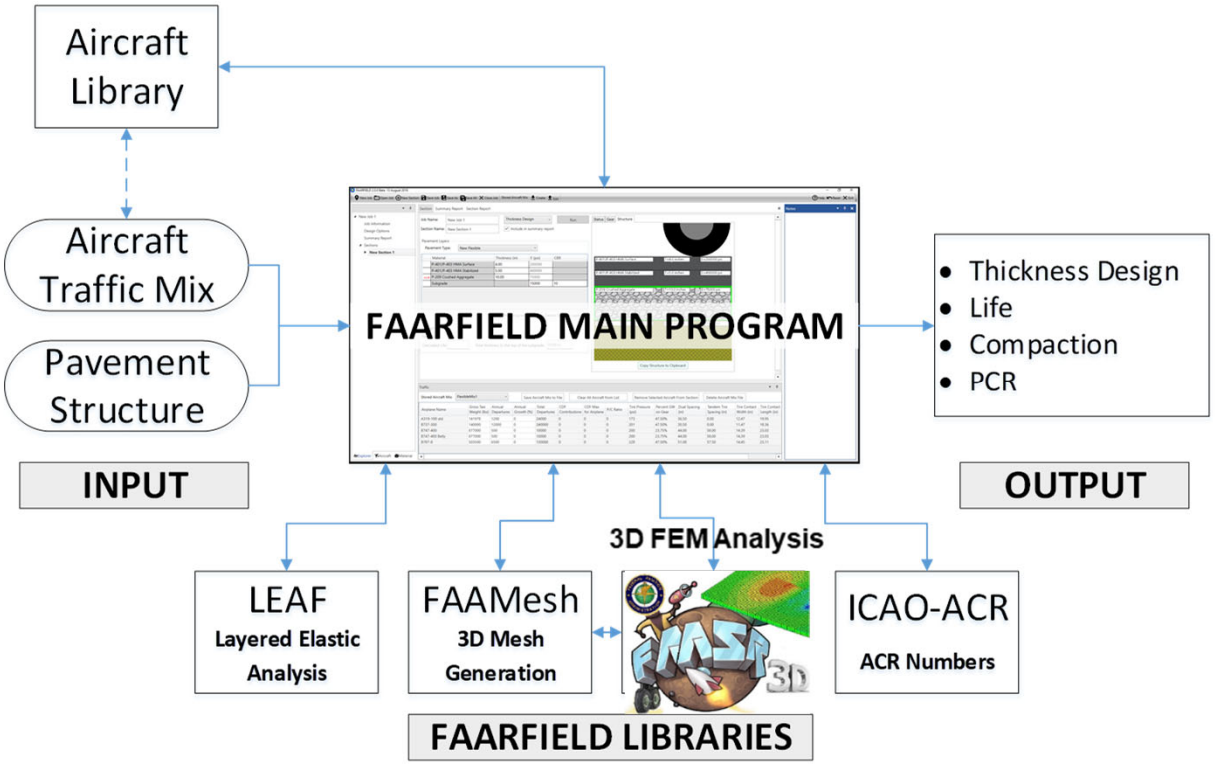






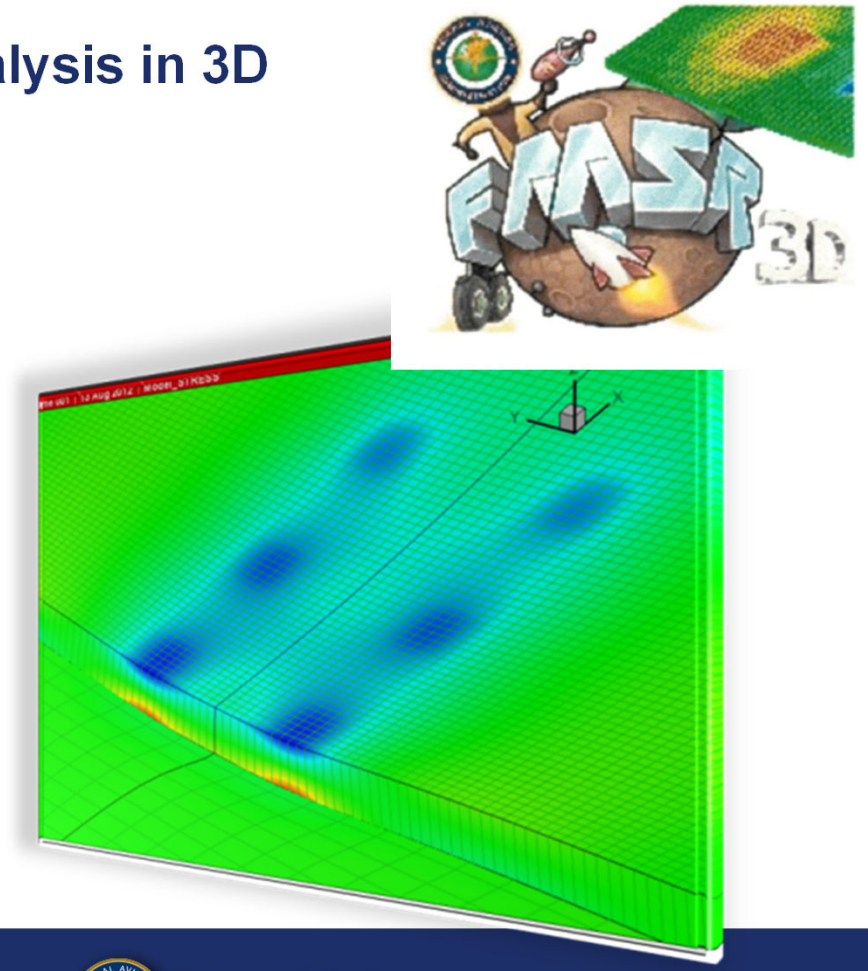
Navigating FAARFIELD 2.1 Software

FAARFIELD 2.1 Organization

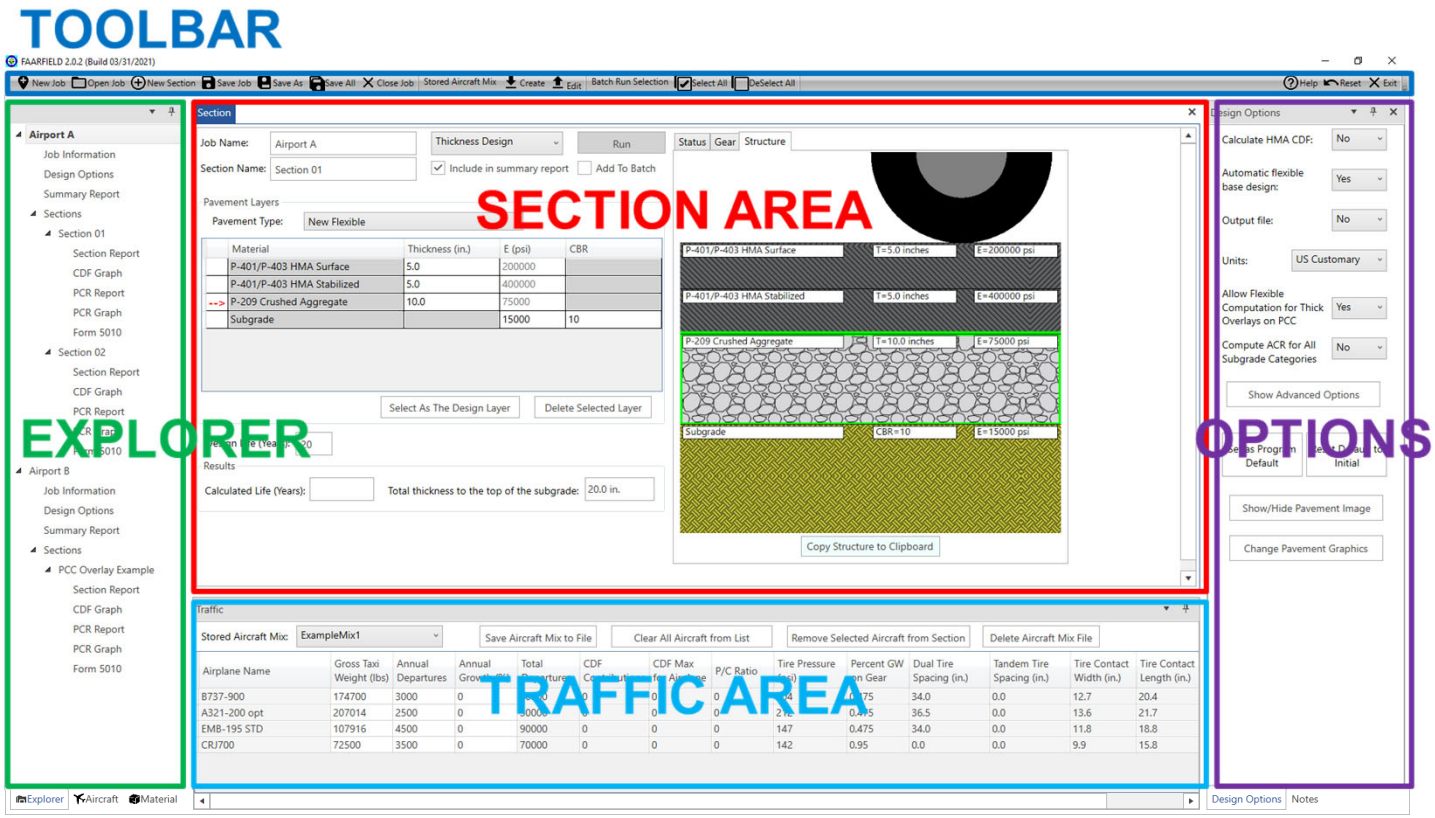


FAASR3D – FAA Structural Analysis in 3D

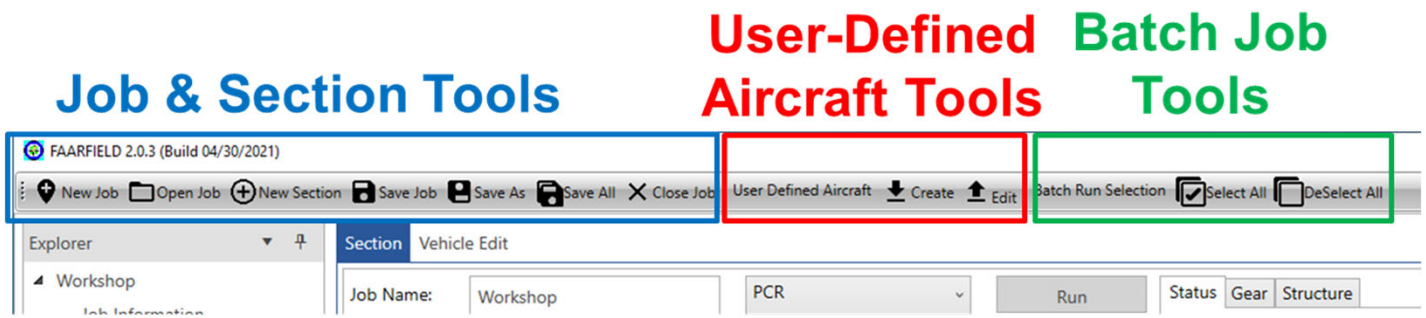
- **Visual Basic.NET library.**
- **Replaces obsolete NIKE3D Fortran program.**
- **Managed Code - compatible with Microsoft .NET memory management services.**
- **Improves performance. Old code was subject to memory conflicts and crashing.**
- **Freely distributable code.**
- **Continued updates to improve speed & efficiency.**

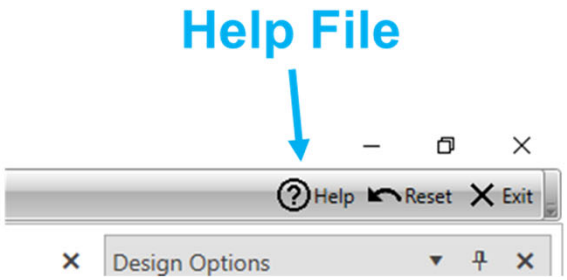


Navigating FAARFIELD 2.1



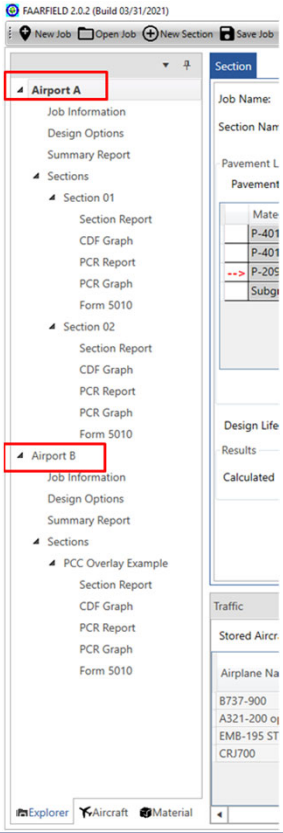
FAARFIELD 2.0 – Toolbar





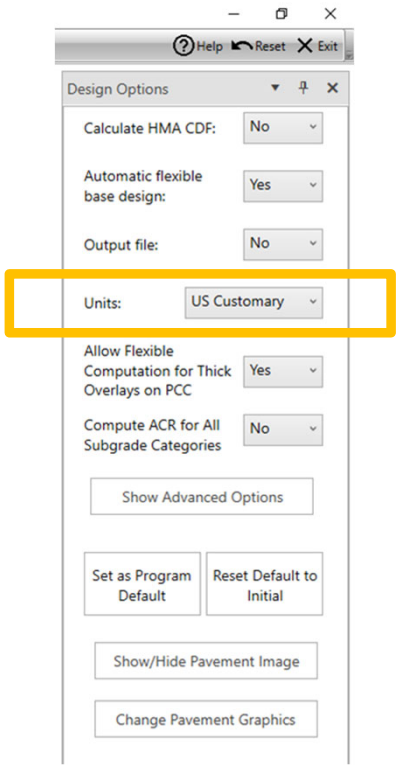
FAARFIELD 2.1 – Explorer Navigation

- FAARFIELD 2.1 supports multiple jobs open at the same time.
- Use the Explorer to navigate between jobs, and display:
  - Sections
  - Section Reports
  - PCR Reports/Graphs
  - 5010 Reports
  - Summary Reports (high-level run information on selected sections in a job)

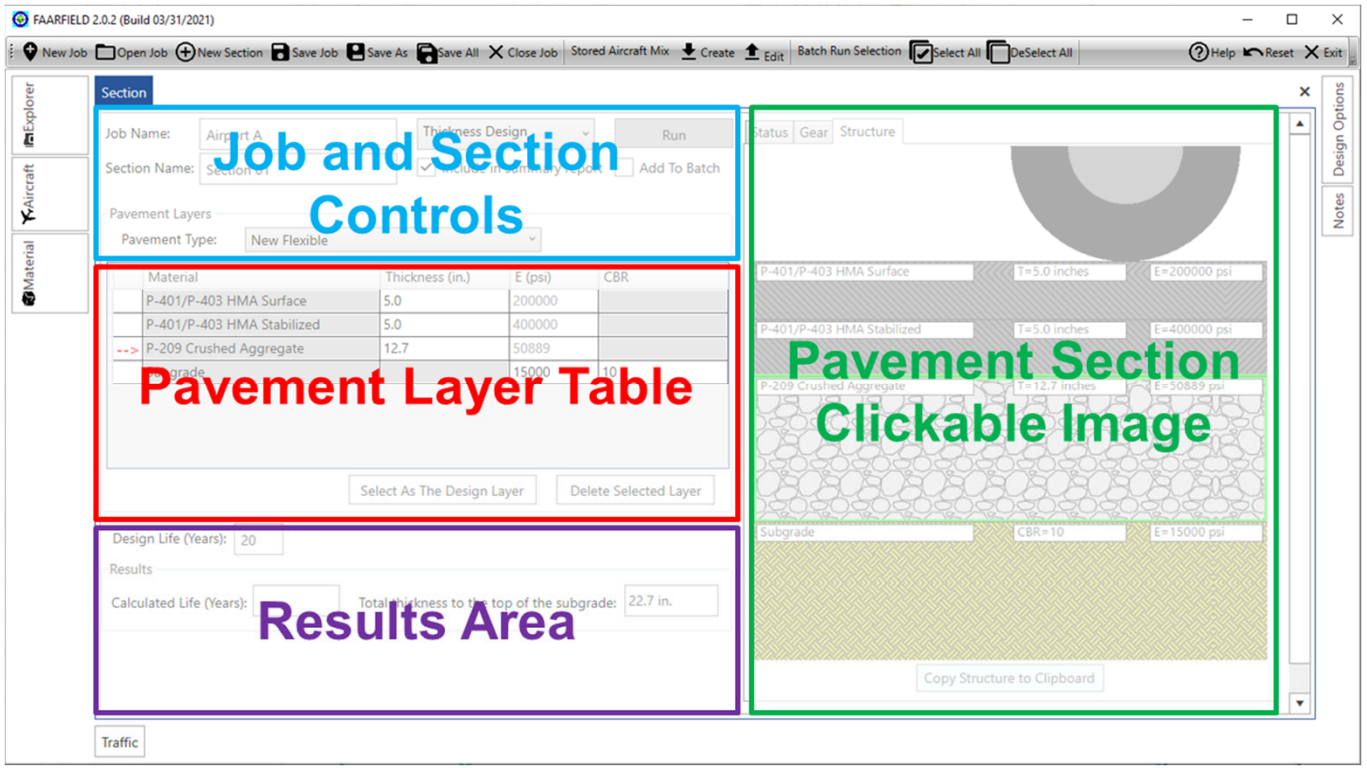


FAARFIELD 2.1 – Options

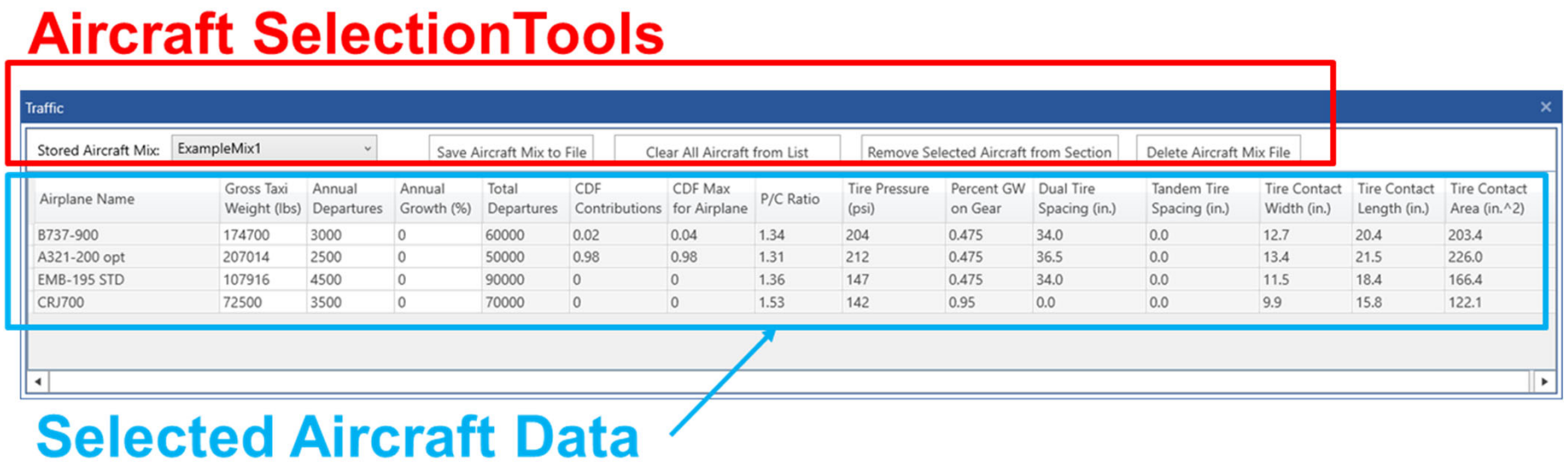
- Toggle between U.S. and metric units.
- Set user preferences for graphic display.
- One click restores default options.



FAARFIELD 2.1 – Pavement Section Area

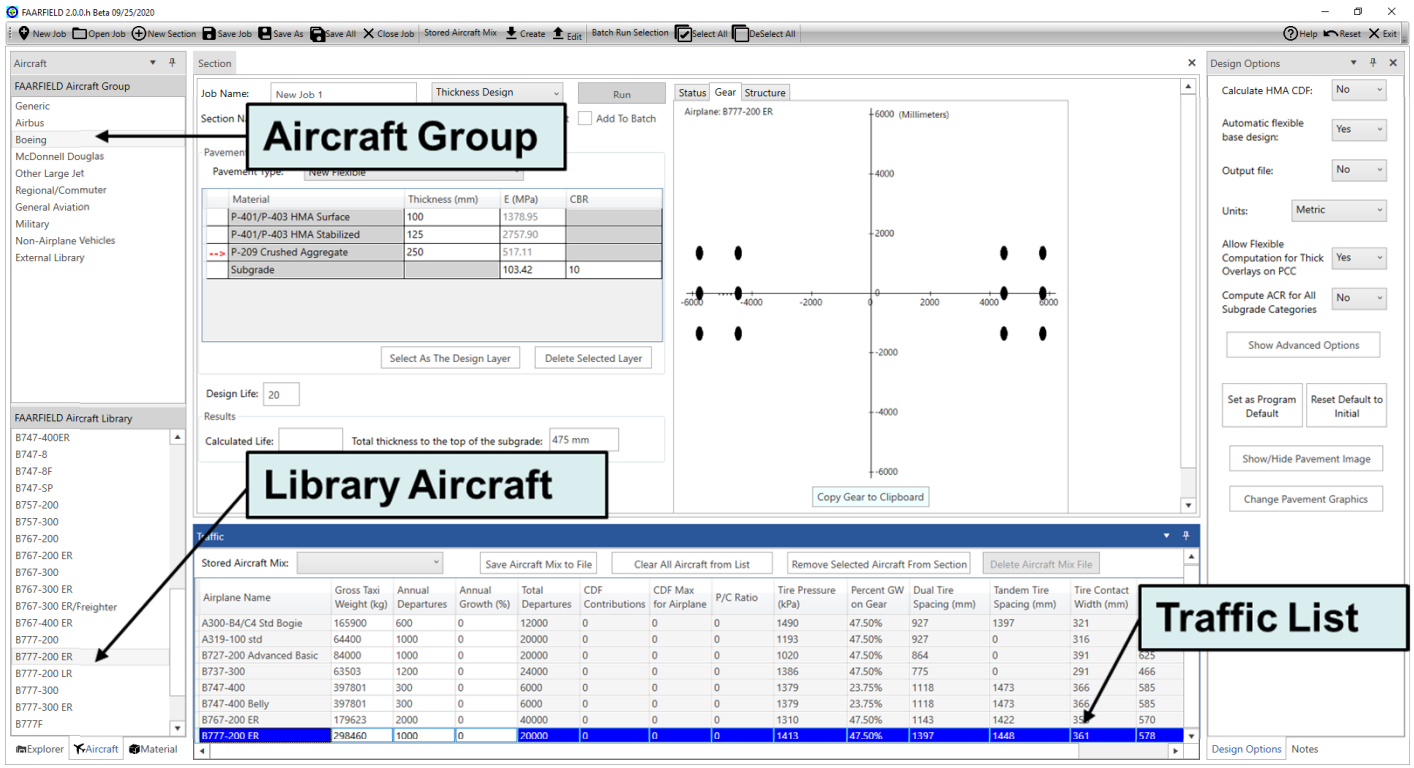


FAARFIELD 2.1 – Traffic Table (dockable)

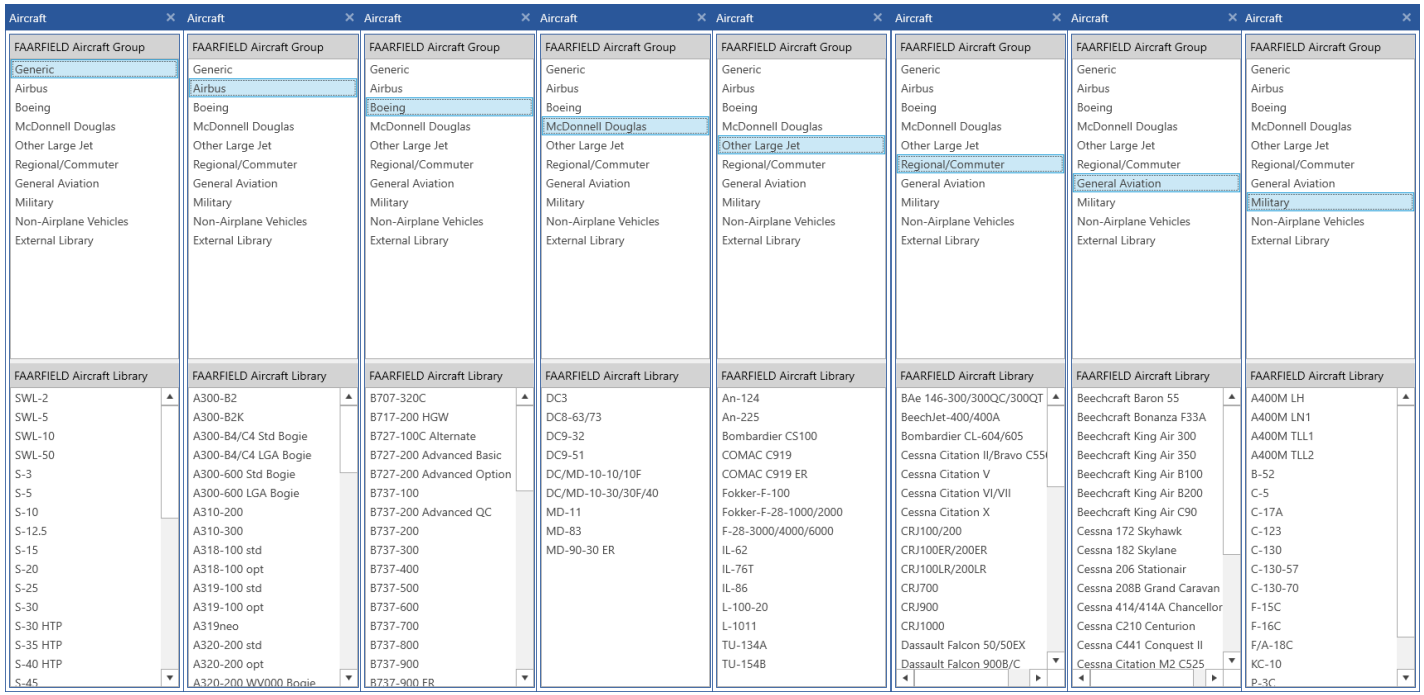


Aircraft Selection

Aircraft library has been completely reorganized and updated for FAARFIELD 2.1!

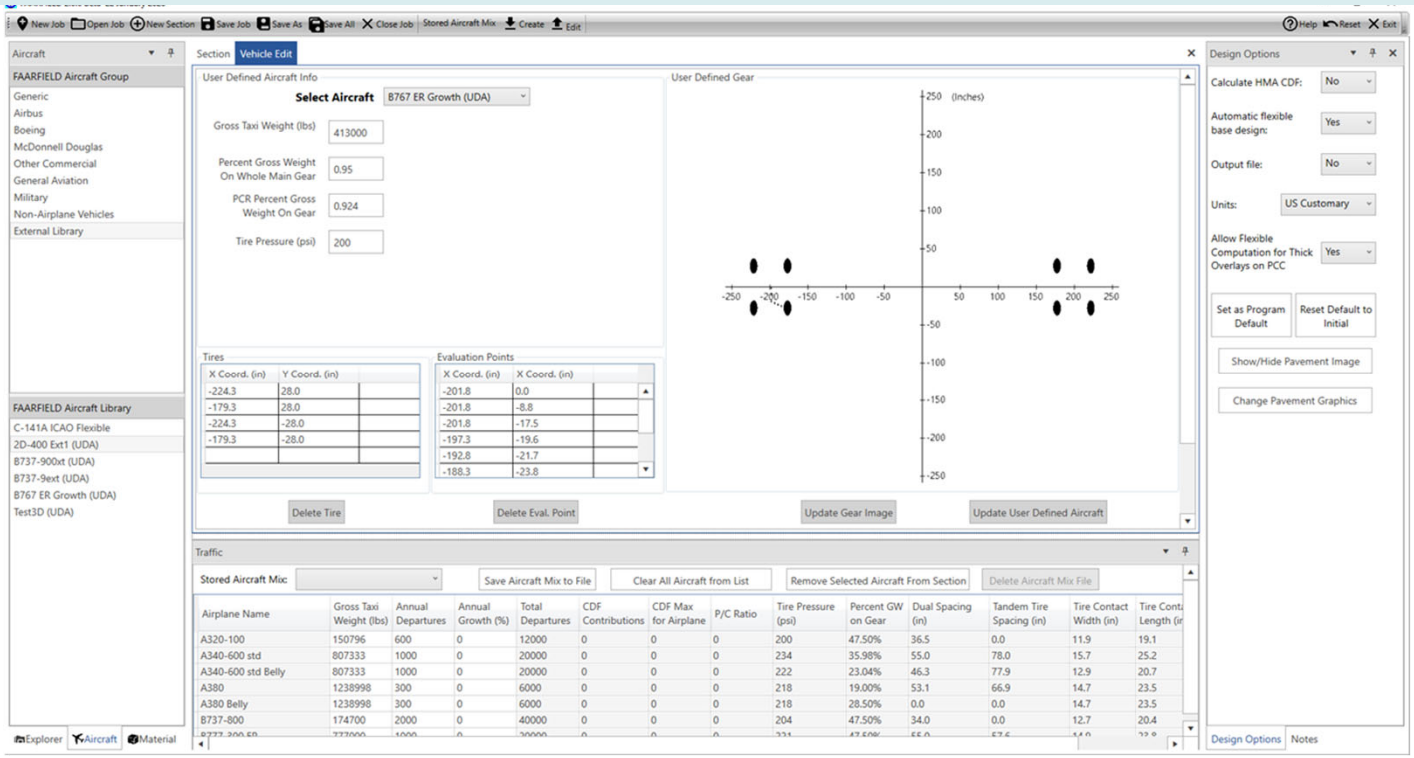


FAARFIELD 2.0 – Aircraft Library



User-Defined Aircraft Mode

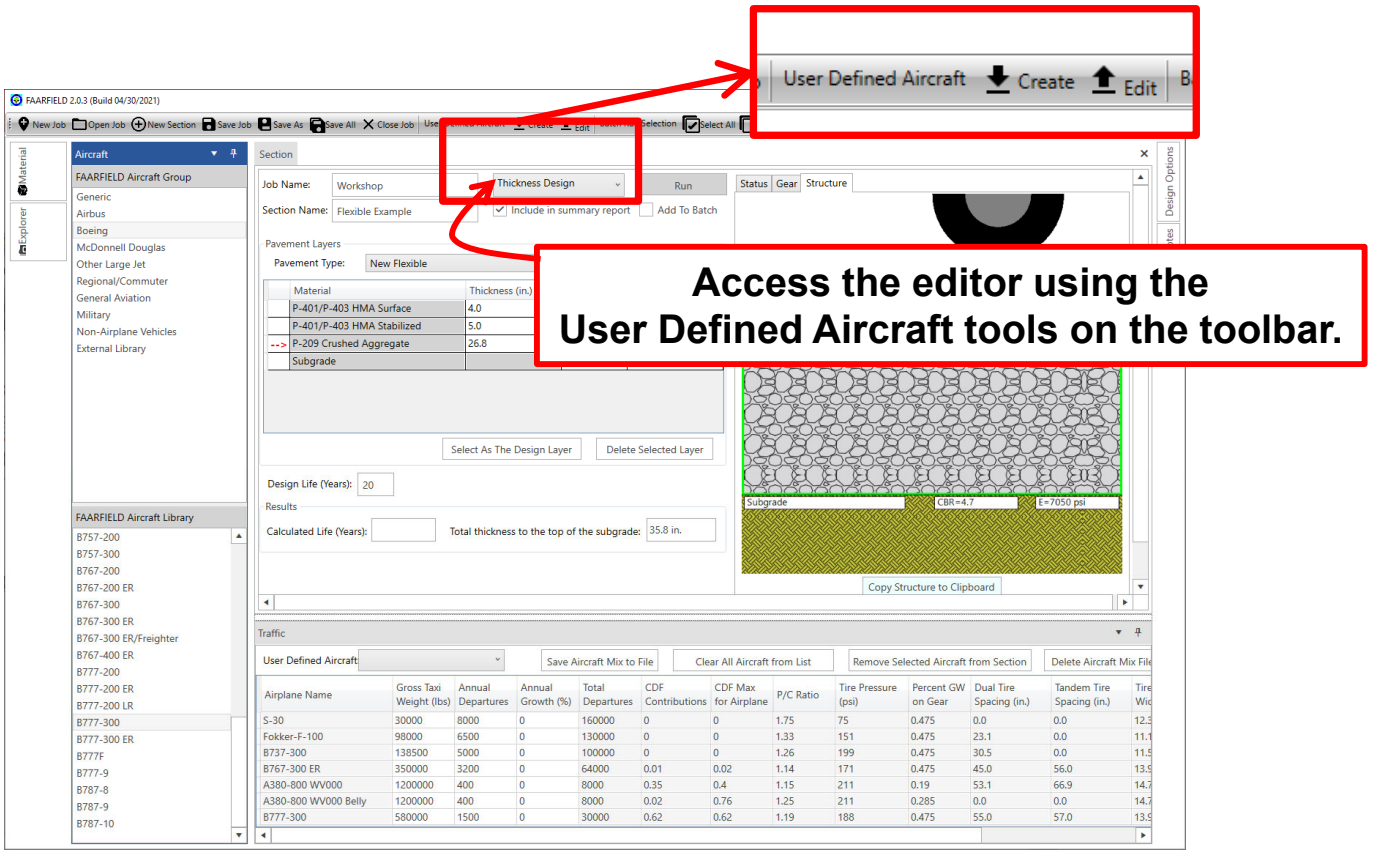
Create, edit and save user-defined aircraft within the program.



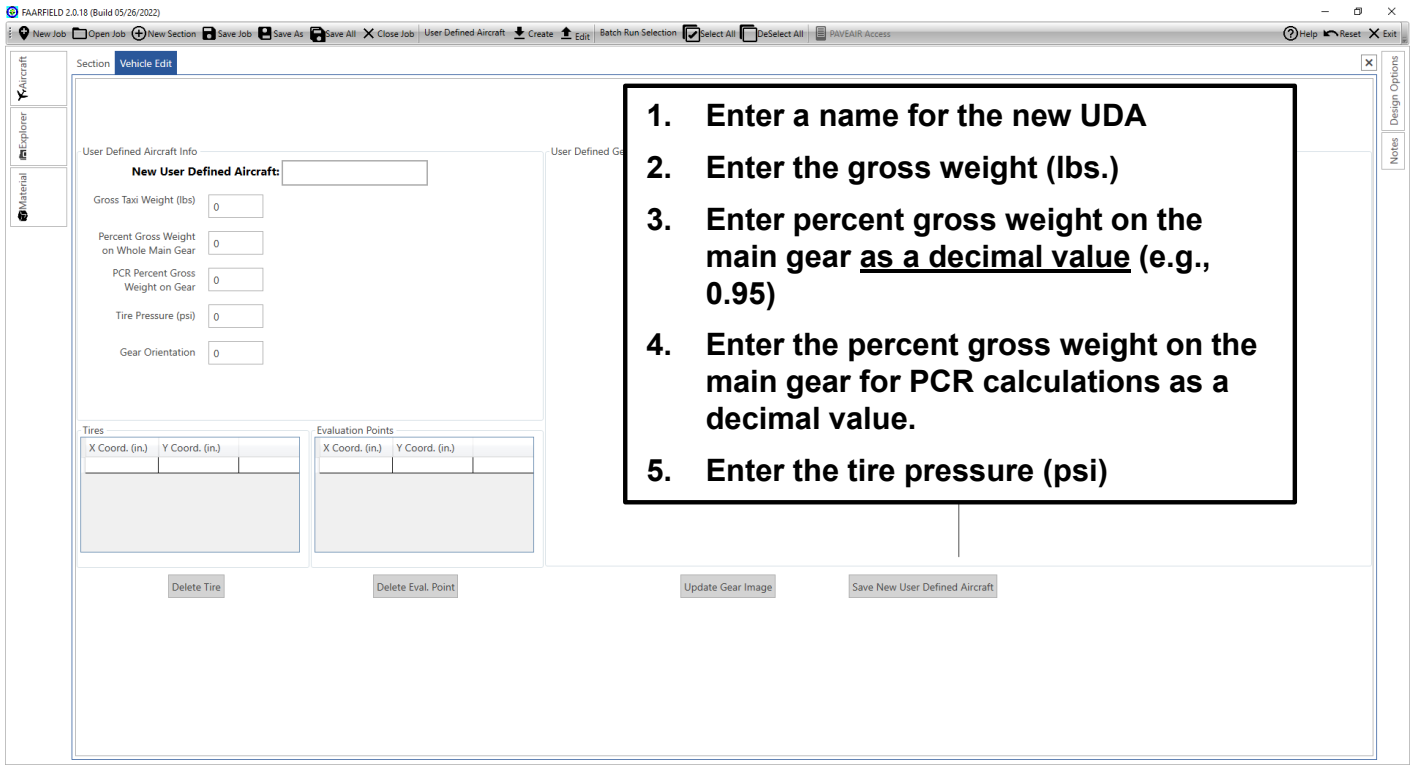
User-Defined Aircraft Mode

- **FAARFIELD treats UDA just like other library aircraft, except they have (UDA) appended to the aircraft name.**
- **UDA data are stored in files in: C:\Users\[user]\Documents\My FAARFIELD\User Defined Aircraft**
- **UDA data are also saved to the job file – useful if a job is sent to another user.**

FAARFIELD 2.1 – User Defined Aircraft

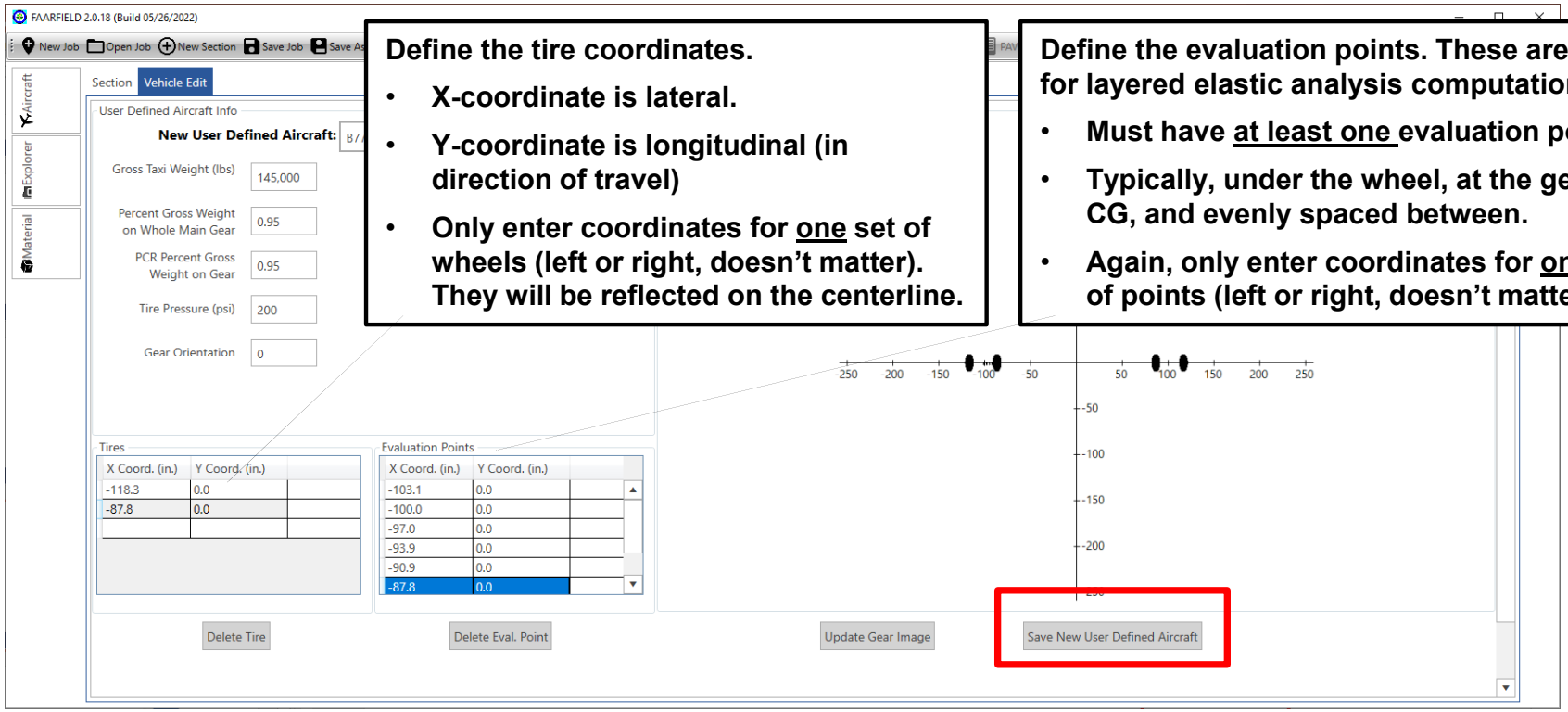


FAARFIELD 2.1 – User Defined Aircraft Mode



1. **Enter a name for the new UDA**
2. **Enter the gross weight (lbs.)**
3. **Enter percent gross weight on the main gear <u>as a decimal value</u> (e.g., 0.95)**
4. **Enter the percent gross weight on the main gear for PCR calculations as a decimal value.**
5. **Enter the tire pressure (psi)**

User-Defined Aircraft Mode



Define the tire coordinates.

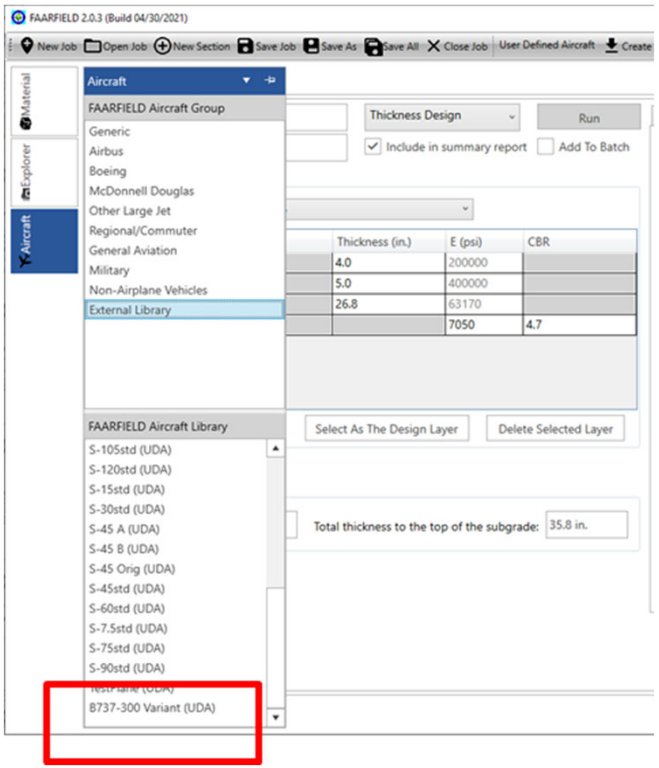
- **X-coordinate is lateral.**
- **Y-coordinate is longitudinal (in direction of travel)**
- **Only enter coordinates for <u>one</u> set of wheels (left or right, doesn't matter). They will be reflected on the centerline.**

Define the evaluation points. These are used for layered elastic analysis computations.

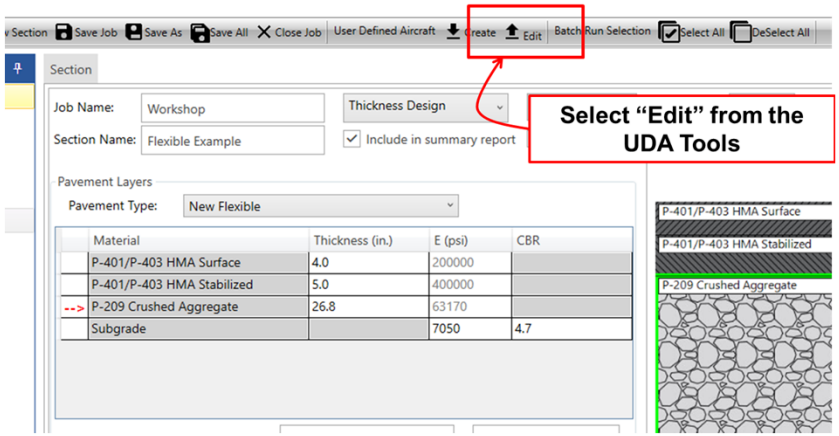
- **Must have <u>at least one</u> evaluation point.**
- **Typically, under the wheel, at the gear CG, and evenly spaced between.**
- **Again, only enter coordinates for <u>one</u> set of points (left or right, doesn't matter).**

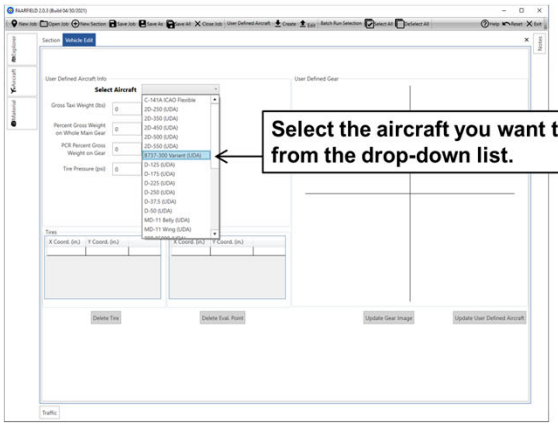
User-Defined Aircraft Mode

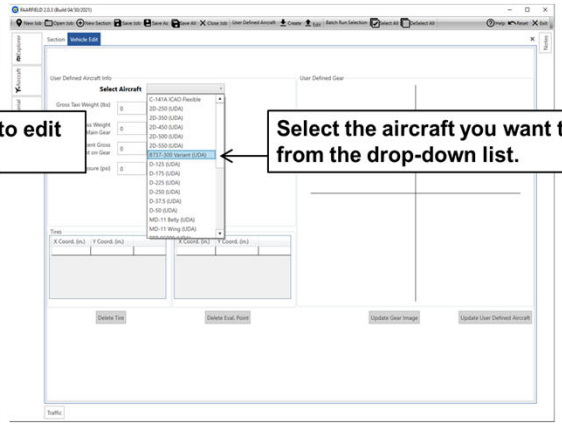
- **New UDA will appear in your External Library group.**
- **Identified by the suffix (UDA)**
- **Can be used in designs the same as internal library aircraft.**
- **Use the editor to define non-airplane vehicles (ARFF vehicles, tugs, etc.) not in the internal library.**



Editing an Existing UDA







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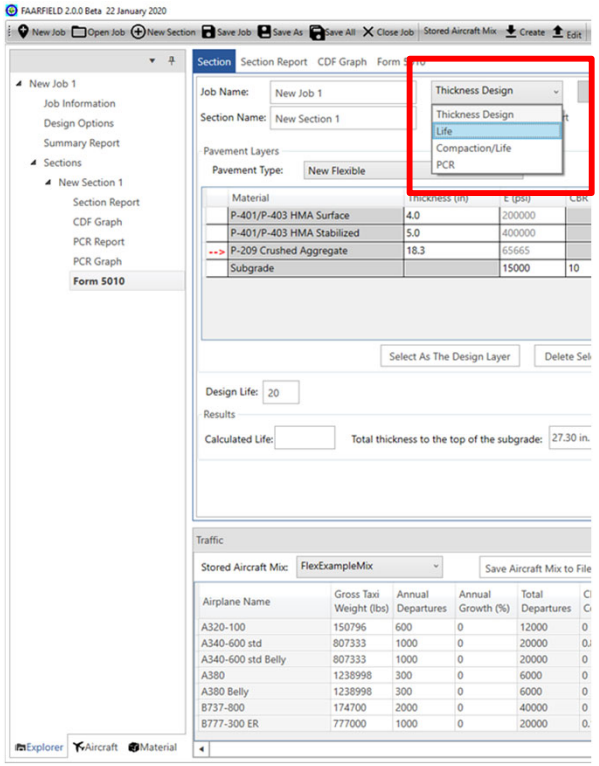
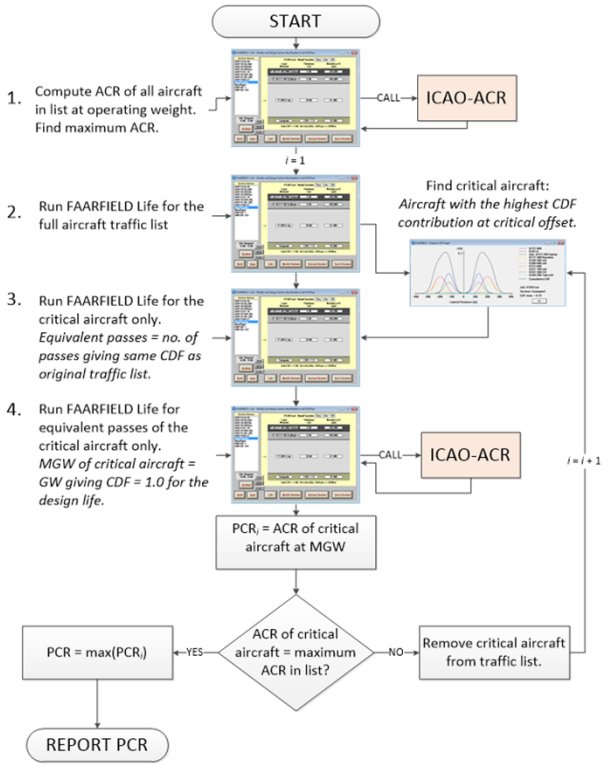
Four Functions in FAARFIELD 2.1



- **THICKNESS DESIGN – Compute required thickness per AC 150/5320-6.**
- **LIFE – Compute structural life for a given structure and traffic mix.**
- **COMPACTION – Compute subgrade compaction requirements per AC 150/5320-6 for a given structure and traffic mix. (Applies to completed designs.)**
- **PCR – Compute Pavement Classification Rating (PCR) for the structure and traffic mix following AC 150/5335-5D.**

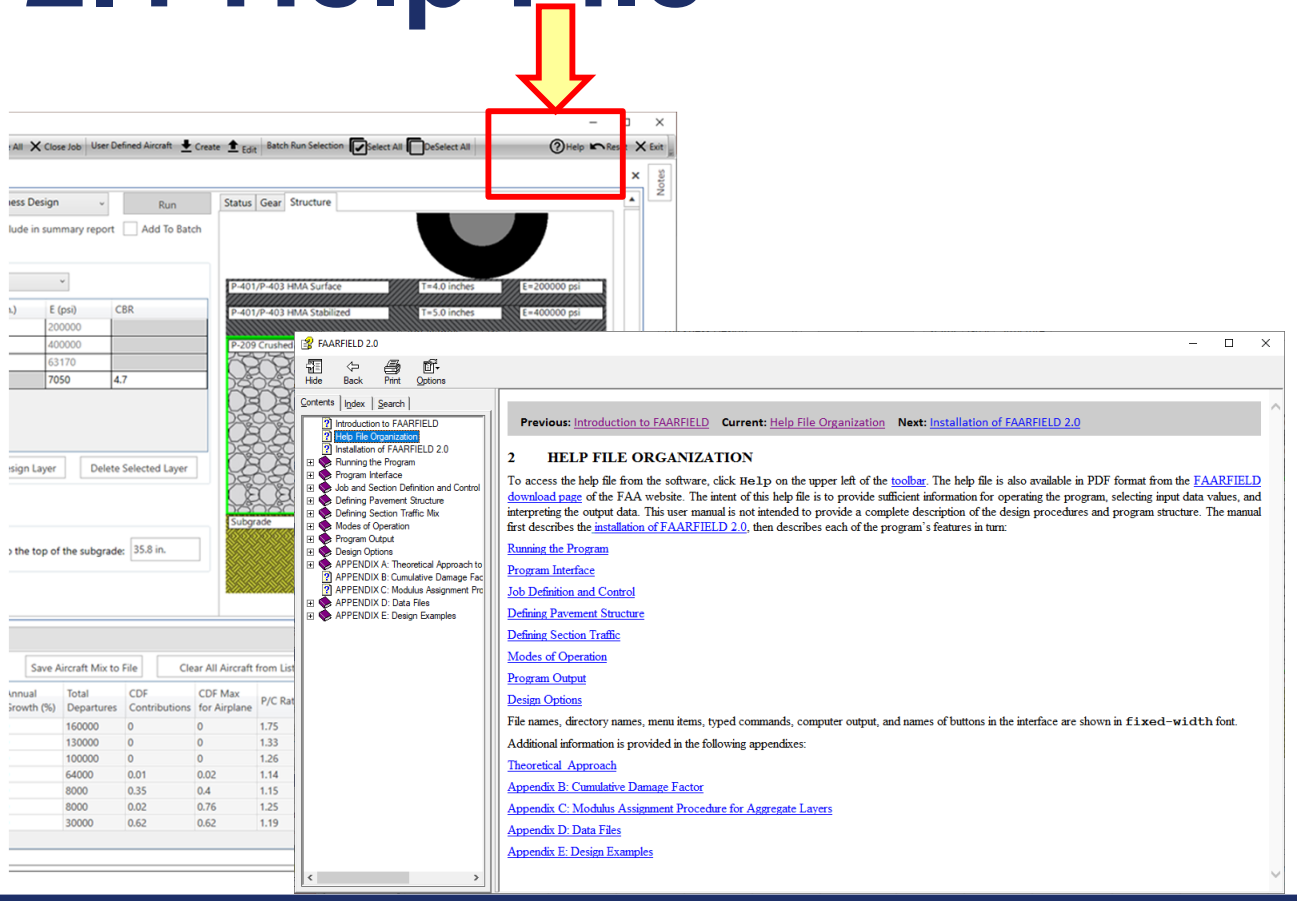
FAARFIELD 2.1 Provides PCR

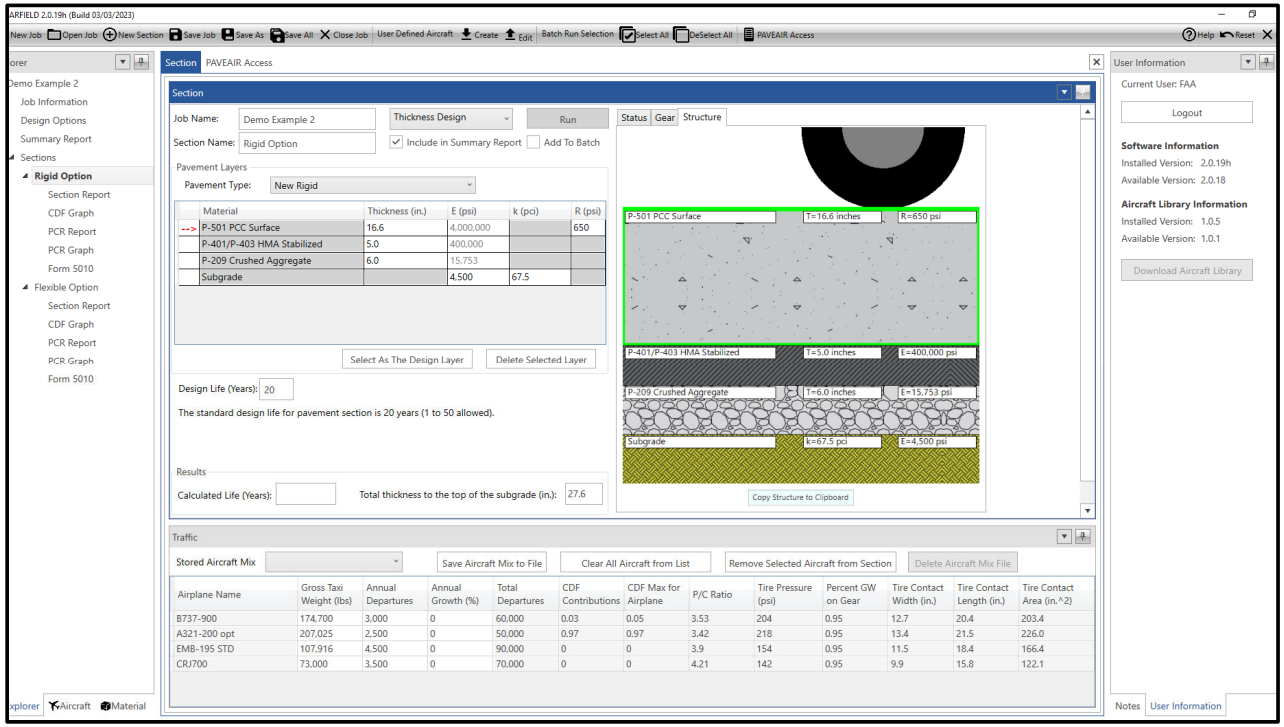
- **Directly uses FAARFIELD structure and traffic list.**
- **Replacement for COMFAA 3.0 & support spreadsheets.**
- **Method yields uniquely defined PCR – no more looping through all aircraft in the list.**
- **Implemented in FAARFIELD 2.1**
  - Solves problem of computing PCR for mixed traffic (i.e., many narrow bodies and few long range aircraft) without unnecessary operating weight restrictions on the LRs.
  - Seamlessly handles HMA overlays on rigid pavements (topic of afternoon presentation).



FAARFIELD 2.1 Help File

- **Completely rewritten for FAARFIELD 2.0.**
- **This is the <u>first</u> resource you should go to with your questions on FAARFIELD.**
- **Contains examples.**

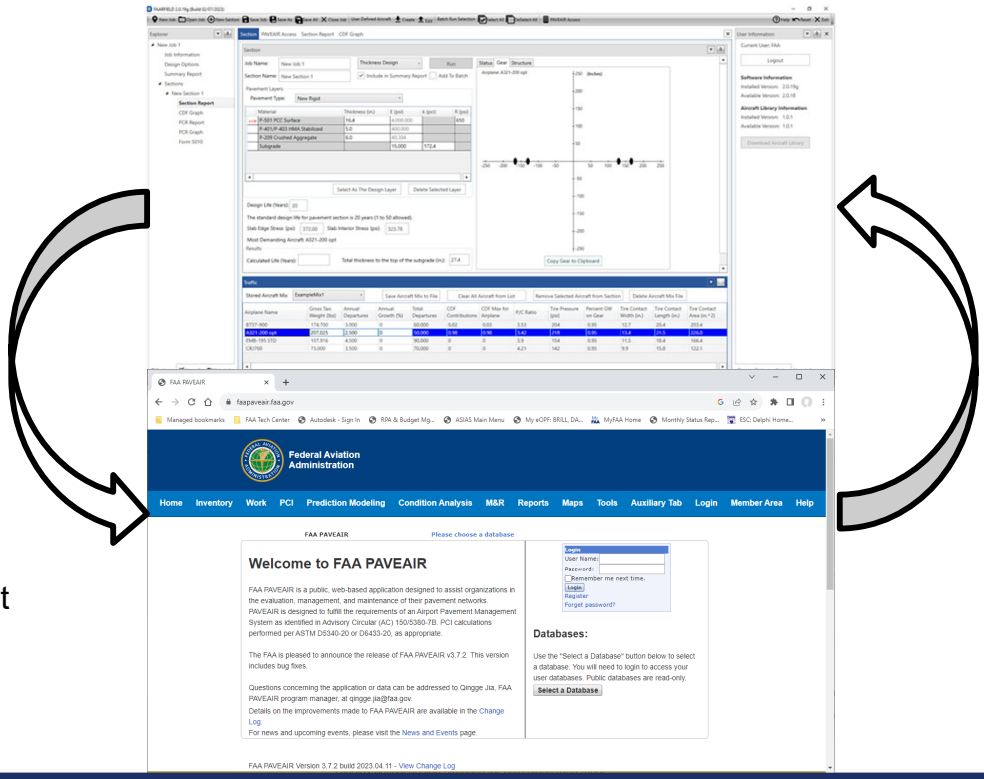




New Features in FAARFIELD 2.1

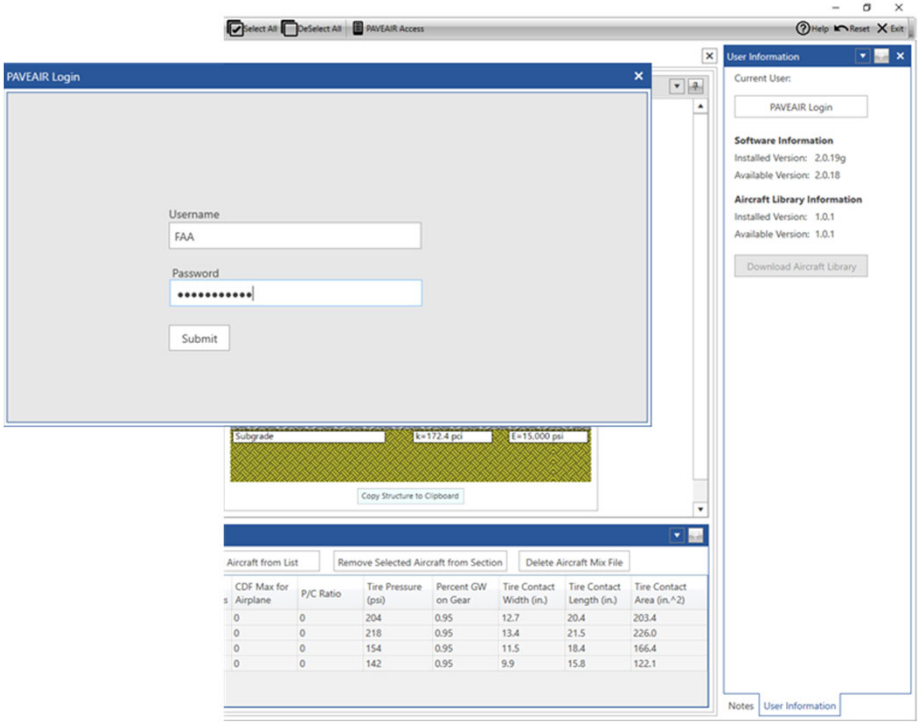
FAARFIELD 2.1 –
New Features and Links to FAA PAVEAIR

- **FAA PAVEAIR**
  - FAA's web-based airport pavement management system (APMS)
  - https://faapaveair.faa.gov/
- **Data Integration with FAA PAVEAIR**
  - Log in to PAVEAIR using PAVEAIR user credentials
  - Update to current library version (and eventually to current software version) online
  - Access user-owned PAVEAIR databases
  - Populate Job Information from PAVEAIR data
  - Upload/download/store FAARFIELD job files
- **More New Features**
  - Display critical design stresses for rigid slabs (and most demanding aircraft for A-1 joint design).
  - Option to automatically perform reduced cross section design (1% of traffic).



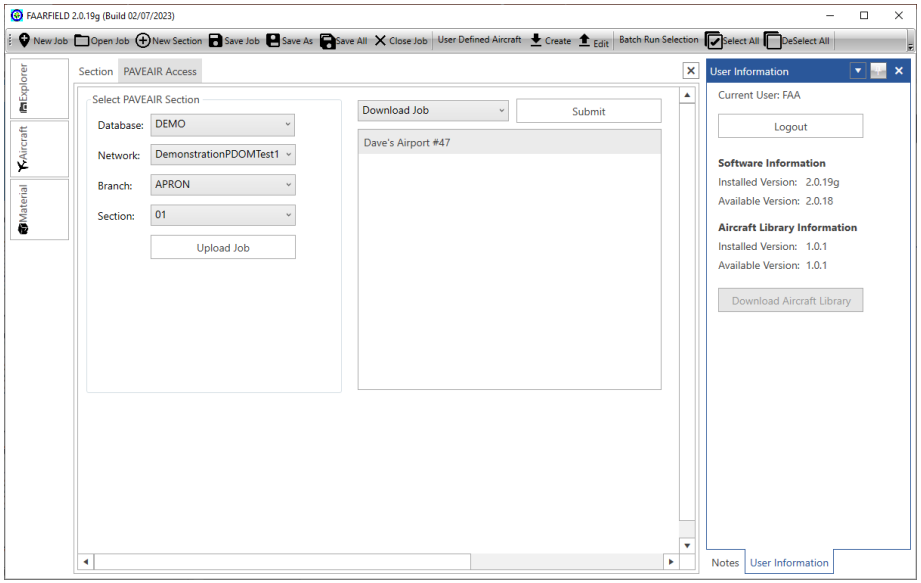
FAARFIELD User Sign-In

- **Select “User Information” tab at right**
- **Sign in using existing PAVEAIR account login and password.**
- **Panel displays installed and currently available versions of software and aircraft library.**
- **If your aircraft library is out of date, you have the opportunity to download the latest version.**
- **In the future, you will be able to update to a newer version of FAARFIELD, run software patches and bug fixes, etc.**



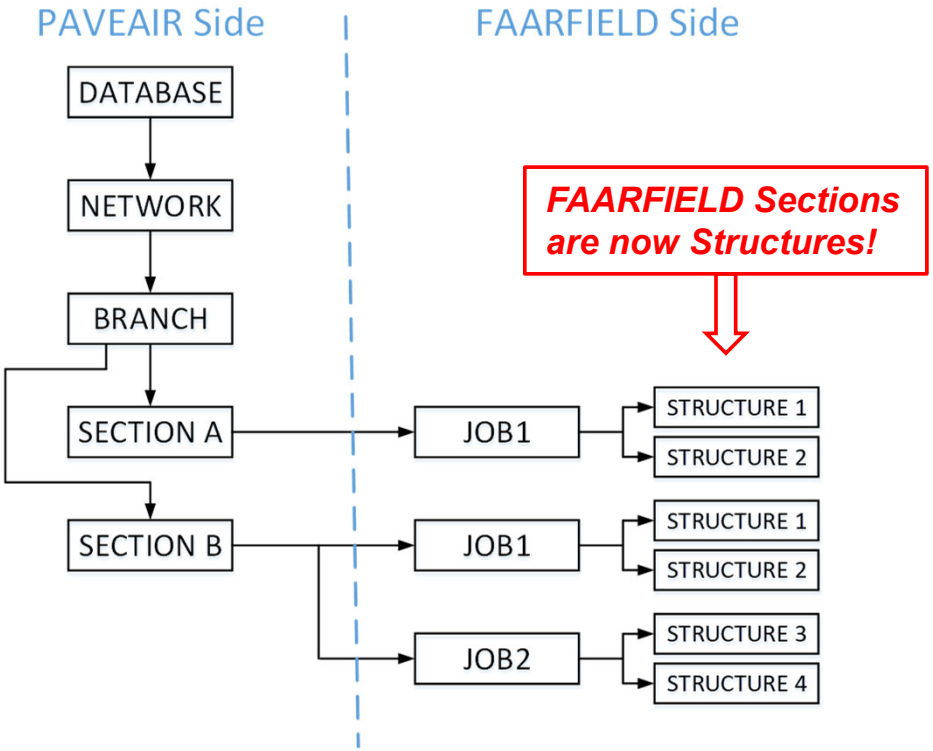
FAARFIELD – PAVEAIR Access Screen

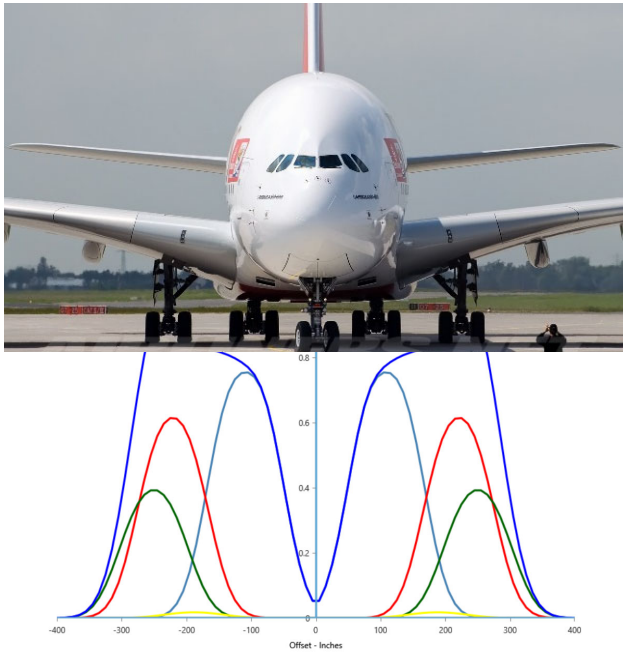
- **Once signed in, you have access to all user-owned databases in PAVEAIR.**
- **Navigate to Network/Branch/Section**
- **Four possible actions:**
  - **Upload Job** – Uploads the current FAARFIELD job to the selected PAVEAIR Network/Branch/Section
  - **Download Job** – Downloads and opens the selected job from the PAVEAIR list in FAARFIELD
  - **Update Job** – Overwrites the selected job
  - **Delete Job** – Deletes the selected job from the PAVEAIR database. (Does not delete from FAARFIELD or the FAARFIELD job file).



Data Organization

- **The same FAARFIELD job can be uploaded to multiple locations in a PAVEAIR database.**
- **Note to users of FAARFIELD 2.0: "Sections" have been renamed to "Structures." This is to avoid confusion with sections as defined in APMS.**
- **For the PAVEAIR user, structures can represent:**
  - Asphalt vs. concrete options, for use in PAVEAIR LCCA tool
  - Before/after overlay or replacement of section
  - Different possible traffic mixes
  - Etc.





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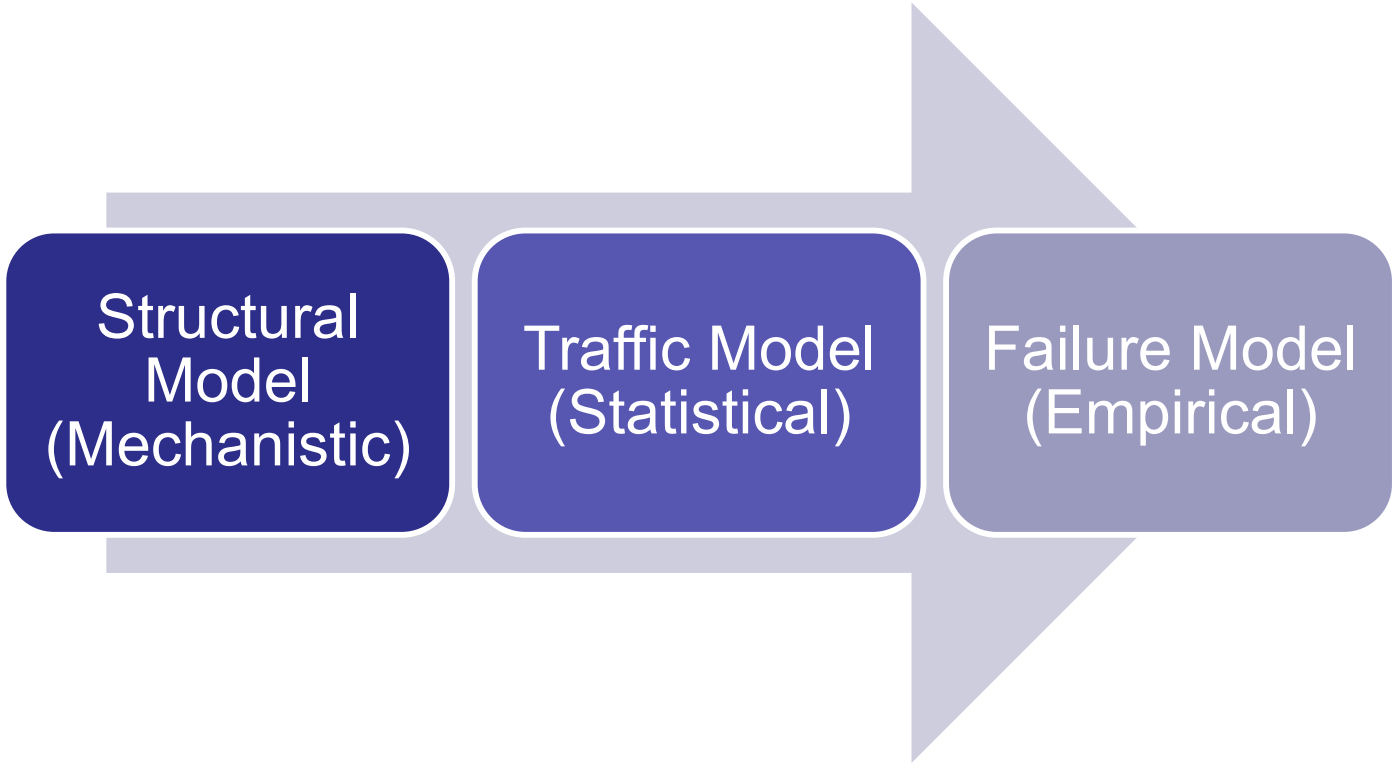
Review of Key Concepts in FAARFIELD

Mechanistic/Empirical Design; Pass-to-coverage; Cumulative Damage Factor (CDF)

Mechanistic-Empirical Design

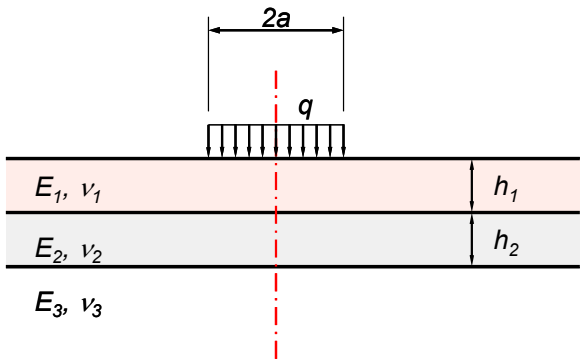


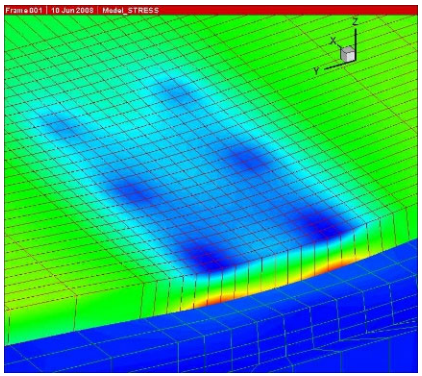
Key Concepts in FAARFIELD

- **Layered Elastic Analysis**
- **Wander**
- **Pass/Coverage Ratio (P/C)**
- **Miner's Rule (linear summation of damage)**
- **Cumulative Damage Factor (CDF)**

Structural Models in FAARFIELD

- **Both layered elastic (LEAF) and 3D-FEM (FAASR3D) are used in FAARFIELD.**
- **Flexible pavement design**
  - LEAF is used for all structural computations.
  - For flexible, no advantage to using 3D-FEM.
- **Rigid pavement design**
  - LEAF to generate a preliminary thickness design.
  - Final iterations are done using FAASR3D.



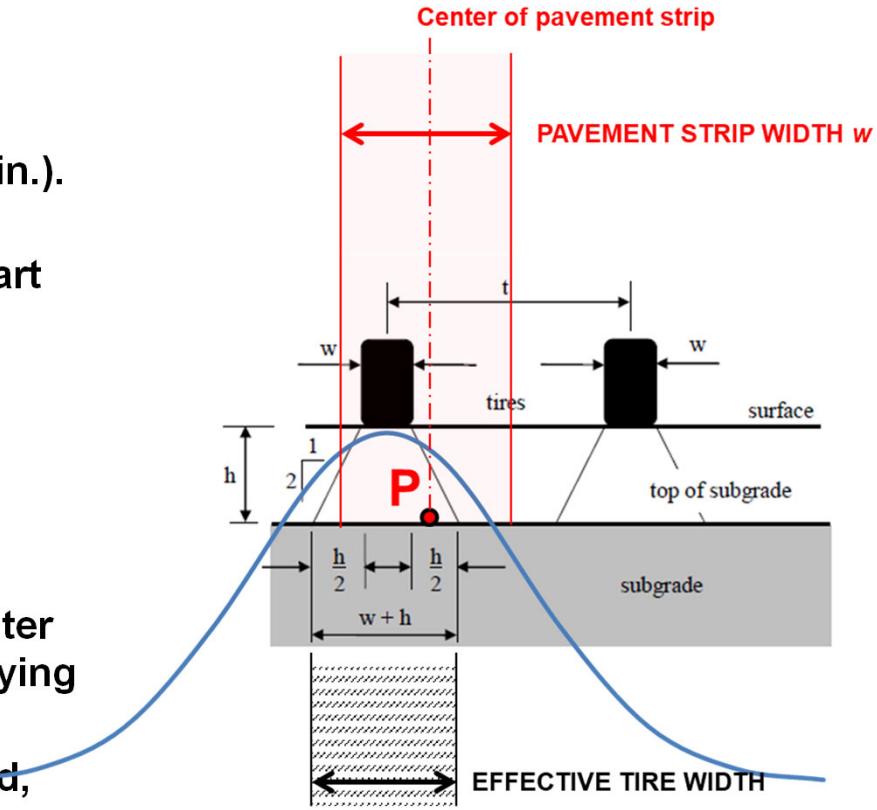


Definitions

- **Coverage = application of the maximum stress or strain at a point on the pavement.**
- **Pass/Coverage Ratio = the number of aircraft passes resulting in one coverage on a given strip.**
- **Wander = the width over which the centerline of the aircraft is distributed 75% of the time.**
- **Effective Tire Width = the width of a horizontal surface assumed to be affected by a tire load at a given depth.**

P/C Ratio in FAARFIELD

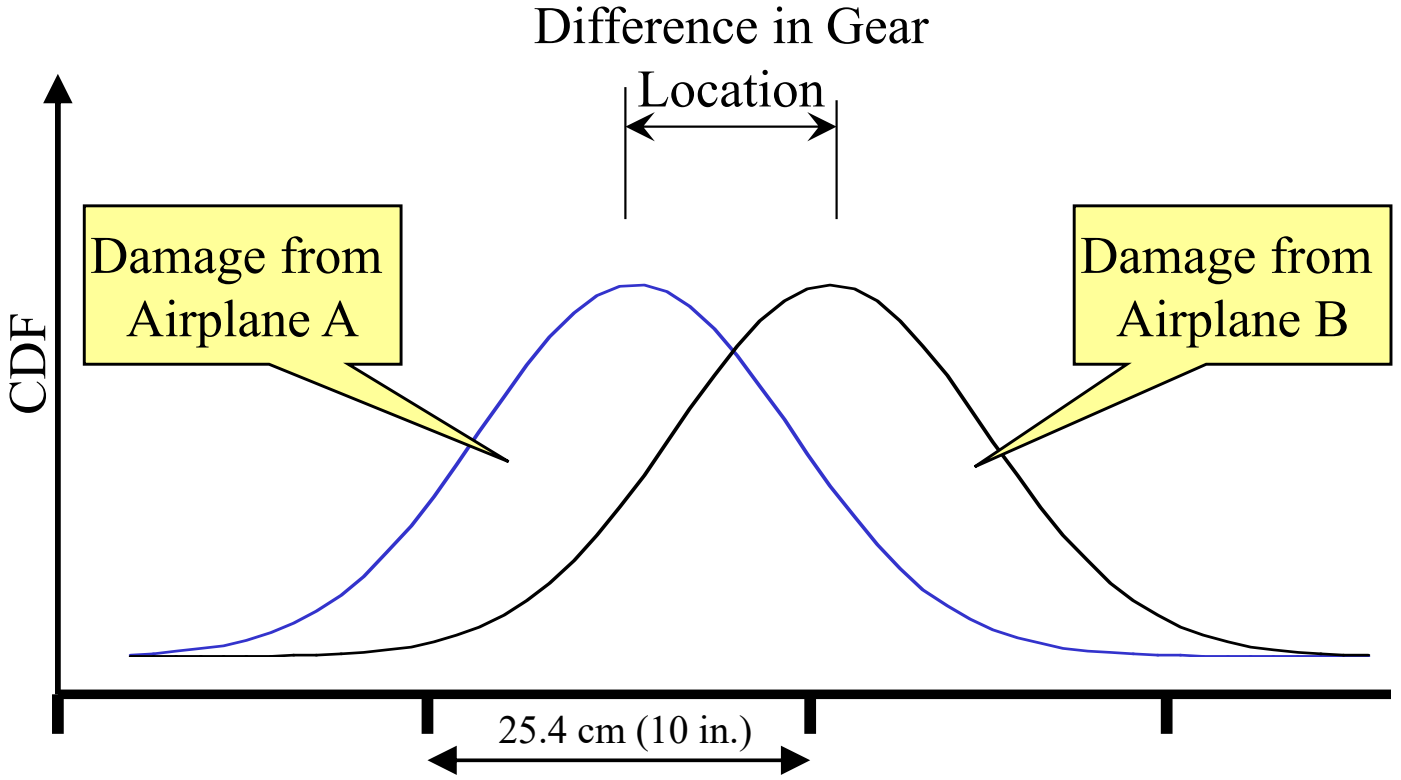
- **Assume the tire has a normal lateral distribution with wander width = 1.78 m (70 in.).**
  - Equivalent to standard distribution σ = 30.54 in.
- **The probability that, for a given pass, any part of the effective tire width covers point P, is defined as the <u>coverage/pass ratio</u> (C/P) for point P.**
- **P/C is the reciprocal of C/P.**
  - P/C is always greater than or equal to 1.0.
  - When does P/C = 1.0?
- **On a pavement strip of width *w*, P is the center point of the strip, and we define P/C as applying to the whole strip.**
- **Depending on which layer is being evaluated, the P/C ratio may vary with thickness!**



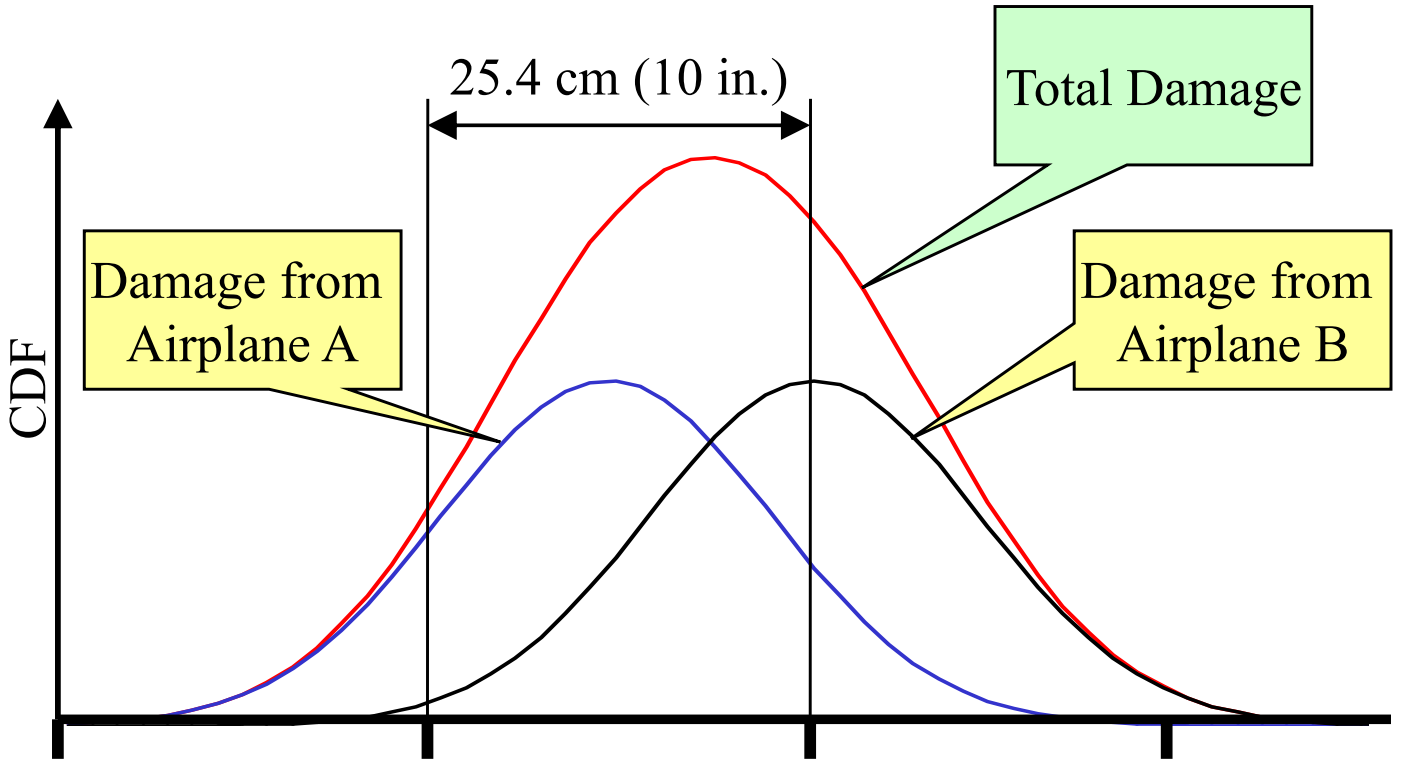
Cumulative Damage Factor (CDF)

- **Sums the damage contributed from each aircraft - not from equivalent aircraft.**
- **CDF = Σ (n_i /N_i), where:**
  - n_i = actual passes of individual aircraft *i*
  - N_i = allowable passes of individual aircraft *i*
- **When CDF = 1, design life is exhausted.**
- **In FAARFIELD:**
  - The gear location and wander are considered separately for each aircraft in the total mix.
  - CDF is calculated for each 25.4 cm (10 inch) wide strip over a total 20.83 m (820 inch) width.
  - Use Miner's rule to sum damage for each strip.
- **Important: Input the fleet mix, NOT equivalent departures of design aircraft.**

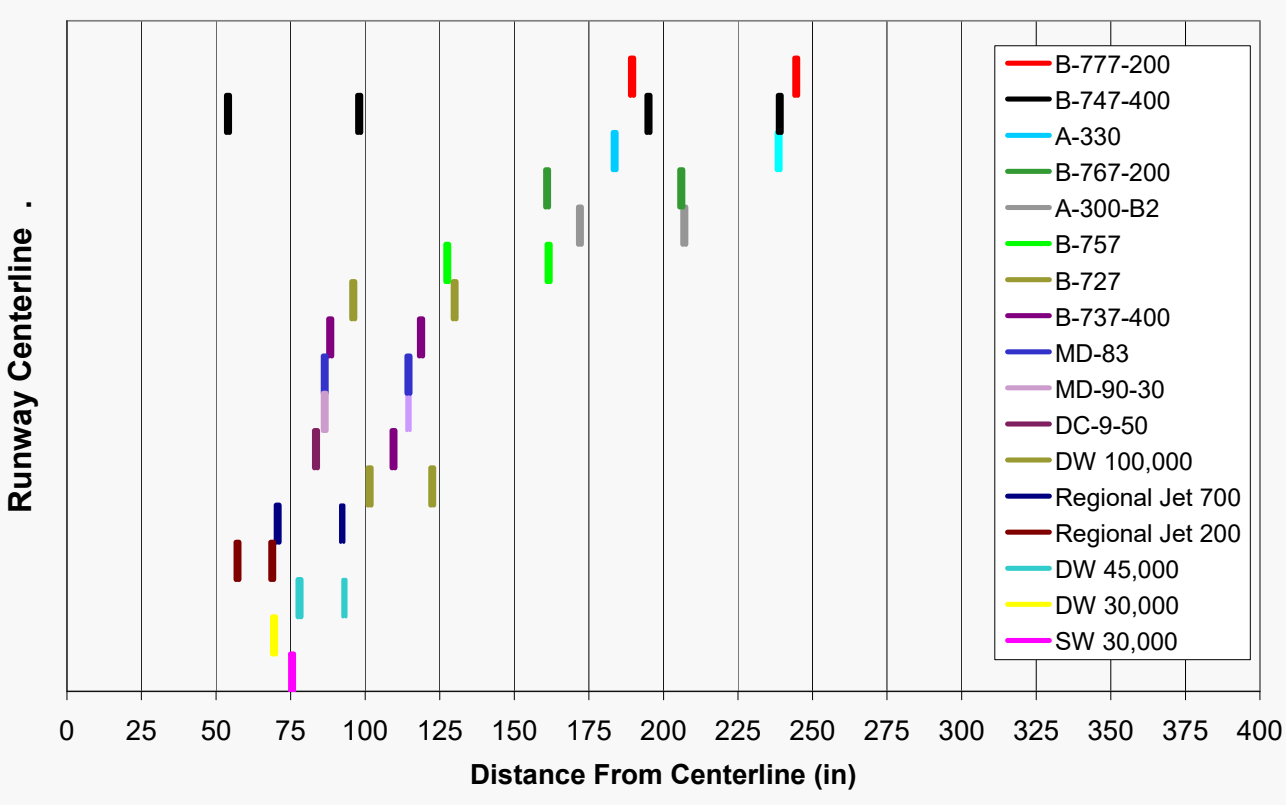
Cumulative Damage Factor (CDF)



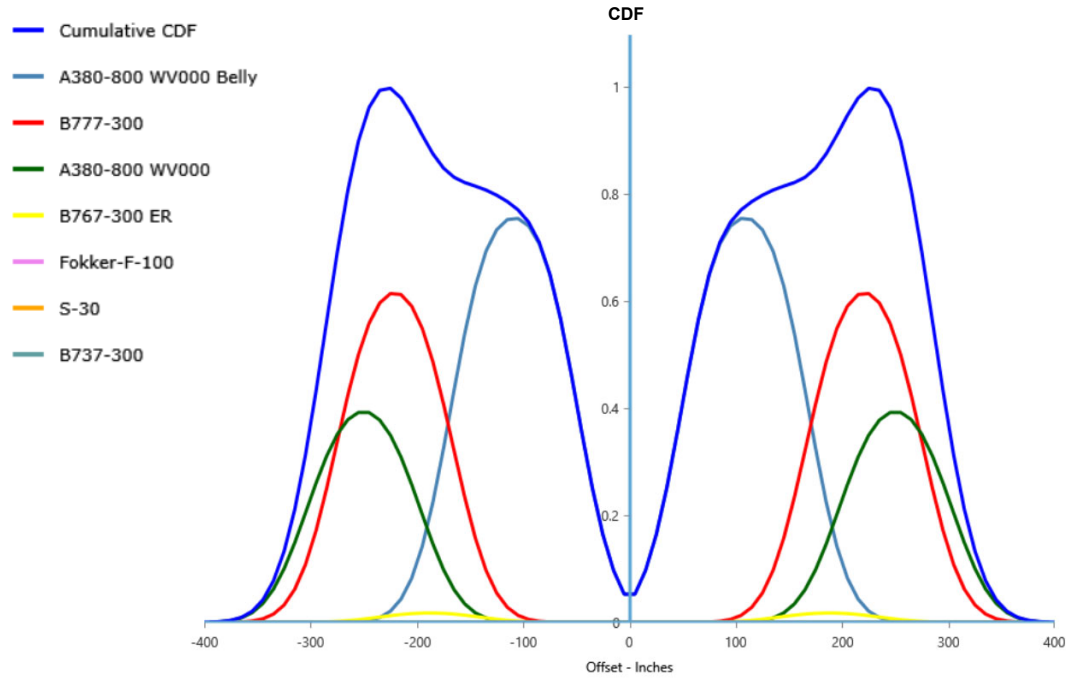
Cumulative Damage Factor (CDF)



Large Airplane Traffic Mix Gear Locations



FAARFIELD – CDF Graphical Display

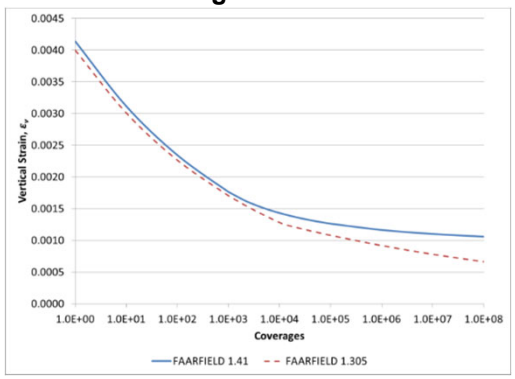


- **Design based on critical offset from centerline.**
- **Does not necessarily agree with track of "most demanding" aircraft.**

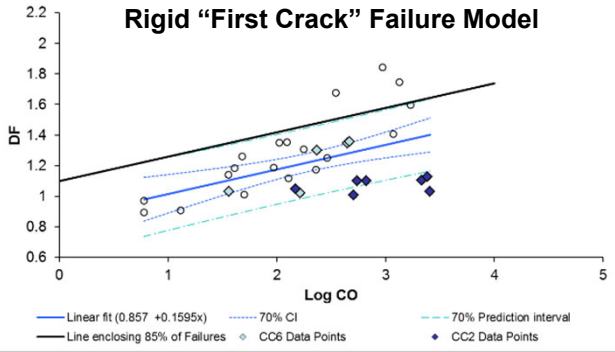
Failure Models in FAARFIELD

- **This is the "empirical" part of mechanistic-empirical.**
  - **Derived from full-scale traffic tests at the FAA National Airport Pavement Test Facility (NAPTF)**.
  - Relates strain or stress to allowable coverages (fatigue).
  - Tied to CDF through P/C ratio.
- **Flexible: Function of maximum vertical strain at the top of the subgrade.**
- **Rigid: Function of maximum horizontal stress in concrete slab.**

Flexible Subgrade Failure Model

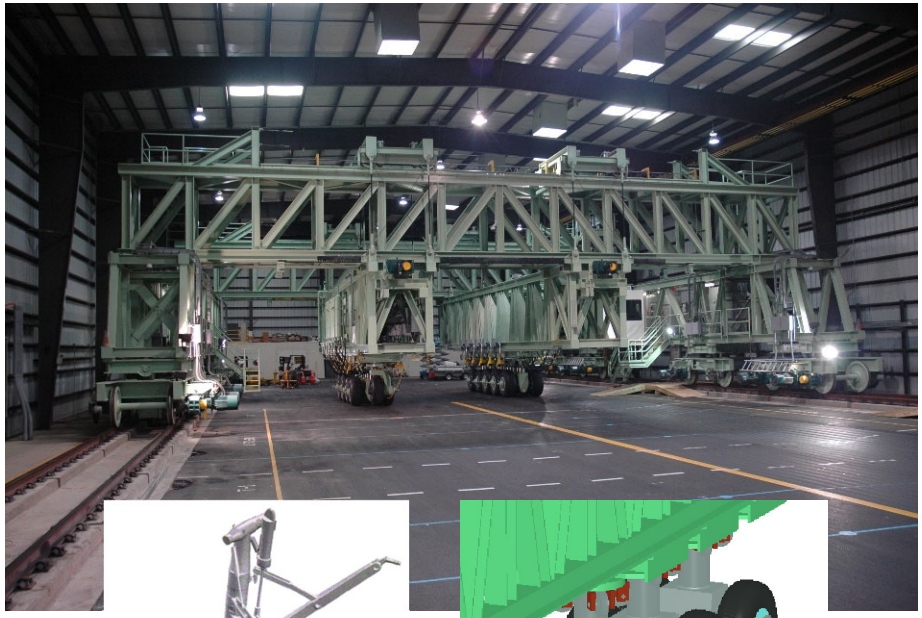


Rigid "First Crack" Failure Model



Full-Scale Testing at the NAPTF

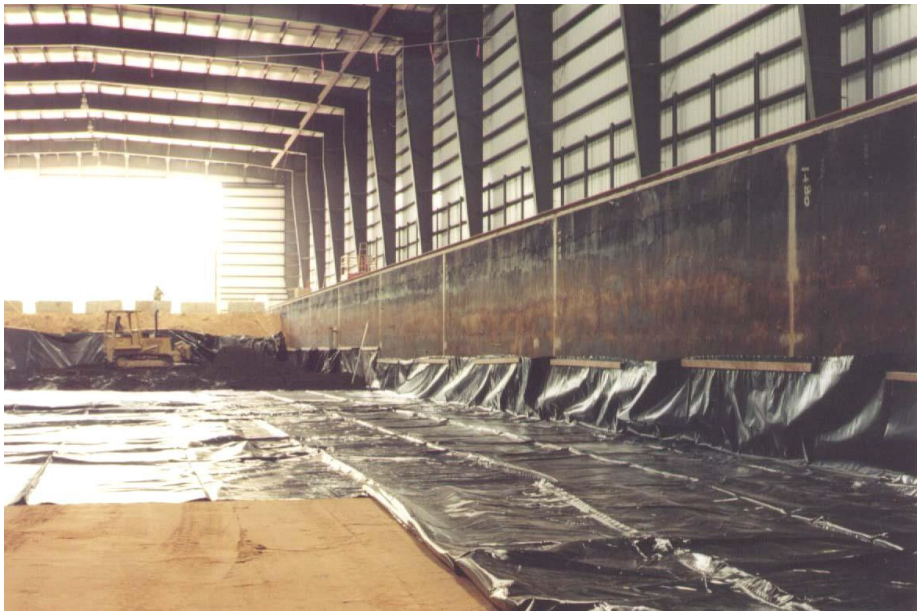
- **FAA / Boeing (CRDA) Partnership at $21M – Opened 1999.**
- **Fully enclosed instrumented test track 900 feet long by 60 feet wide.**
- **Fully automated computerized data acquisition system.**
- **Rail-based test vehicle capable of simulating aircraft weighing up to 1.3 million pounds.**
- **Wheel loads independently adjustable up to 75,000 pounds per wheel.**
- **Controlled aircraft wander simulation.**
- **Radial aircraft tires (52X21.0R22).**
- **Vehicle is capable of speeds up to 15 mph. In practice, tests are conducted at 2.5 – 3.0 mph.**
- **Ability to simulate all common landing gear configurations up to 5 axles (i.e., An-124).**



B777 Landing Gear **NAPTF Simulated Gear**

NAPTF Construction (1995-1999)

Aerial view of NAPTF facility under construction

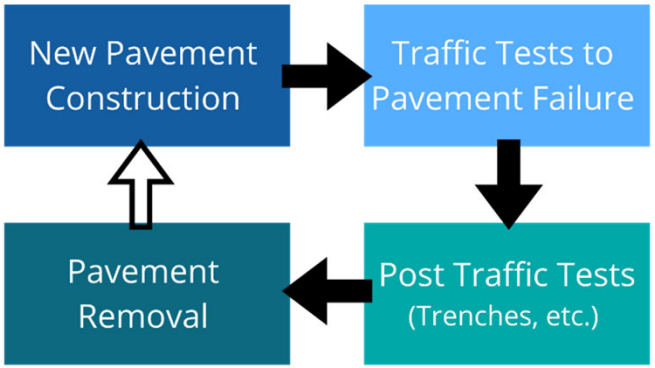


20 mil membrane on the floor of the low-strength subgrade

Full-Scale Testing at the NAPTF

- **Completed 9 Construction Cycles (CC) to date. CC10 in planning.**
- **Flexible and rigid pavements.**
- **Full-scale test data improve the standard FAA pavement design software, FAARFIELD.**
  - Required software for Federally funded airport pavement projects.
  - Current version is FAARFIELD 2.1
- **Test data available online:**
  https://www.airporttech.tc.faa.gov/Airport-Pavement/National-Airport-Pavement-Test-Facility-NAPTF/NAPTF-Program/Construction-Cycles

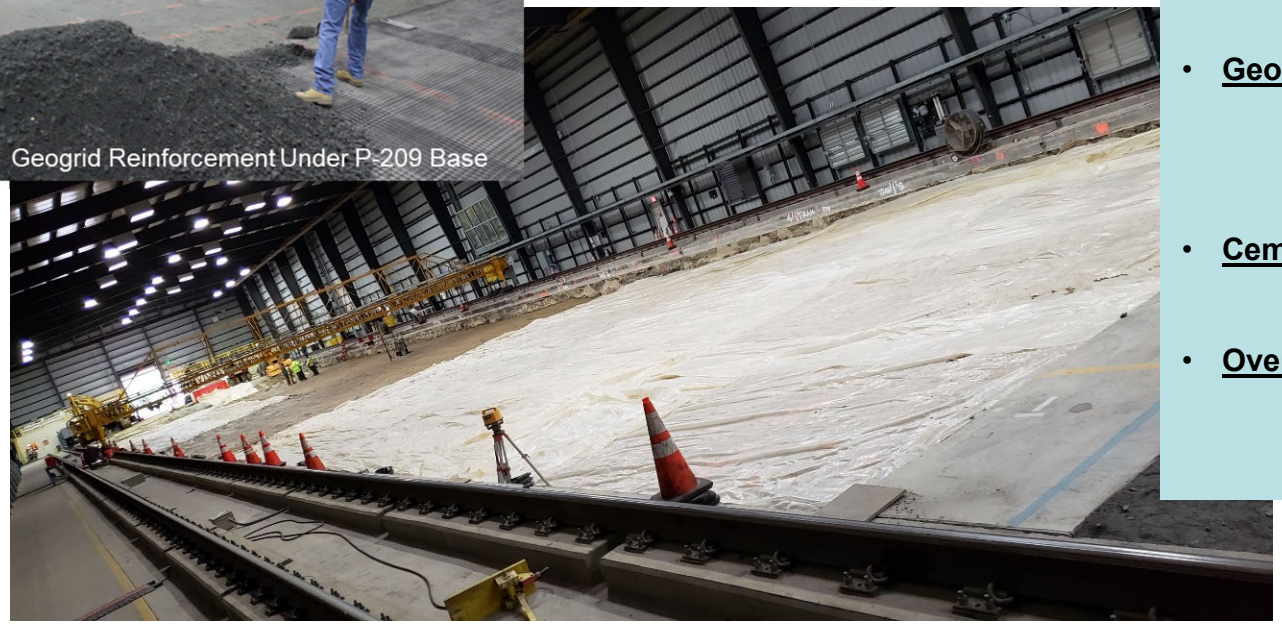
Construction Cycles (CC)



The timeline for a construction cycle is 2-3 years and includes the construction of the test pavement, installation of embedded pavement sensors, traffic testing to failure, post-traffic testing (trenching activities and other tests), and pavement removal.

Construction Cycle 9 Construction (2019)


Geogrid Reinforcement Under P-209 Base

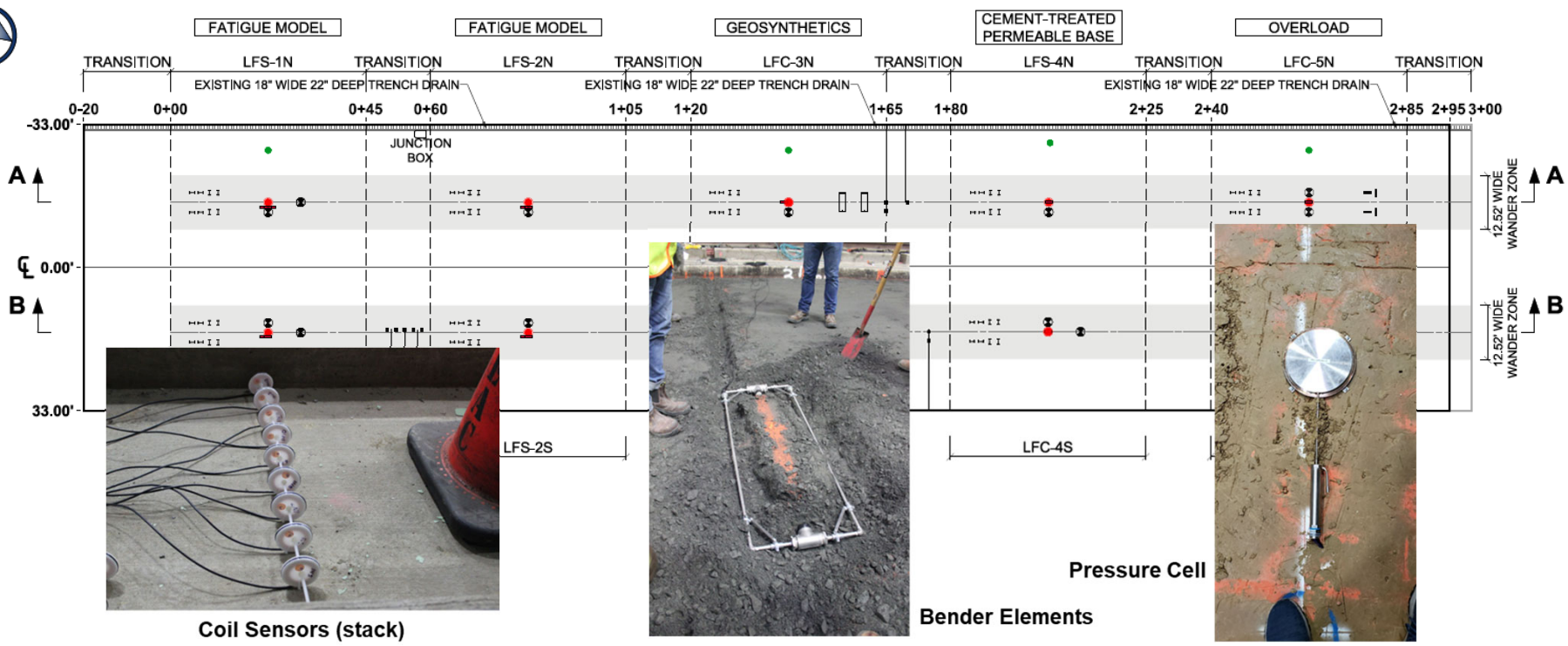


Flexible Pavement

Construction Cycle 9 (CC9) Test Objectives:

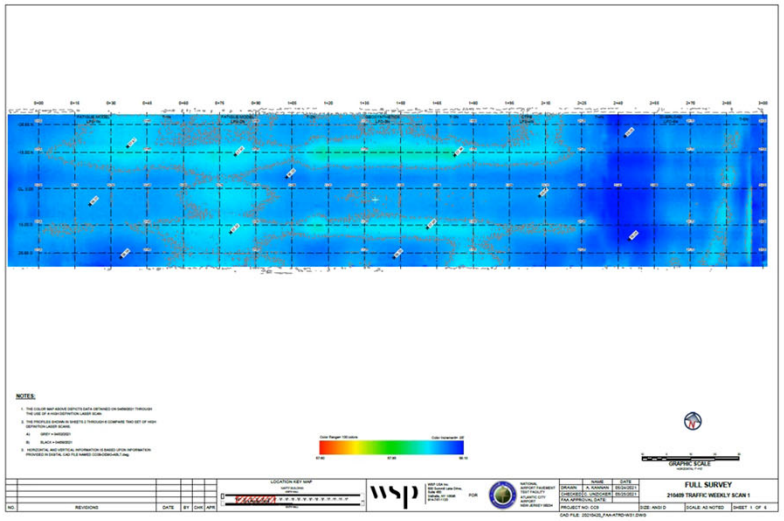
- **Fatigue Model and Base Thickness Test**
  - Improve the asphalt concrete fatigue cracking model.
  - Test sensitivity of thickness design model to base course thickness.
- **Geosynthetics Test**
  - Investigate the effects of geogrids on airport pavement performance.
  - Responds to Sec. 558, FAA Reauthorization Act 2018.
- **Cement-Treated Permeable Base (CTPB) Test**
  - Evaluate performance of P-307 CTPB course.
  - Follow-on to ATPB Test in CC7.
- **Overload Test**
  - Develop criterion for allowable overload in flexible airport pavement.
  - Supports ICAO ACR-PCR system.

CC9 Instrumentation Overview



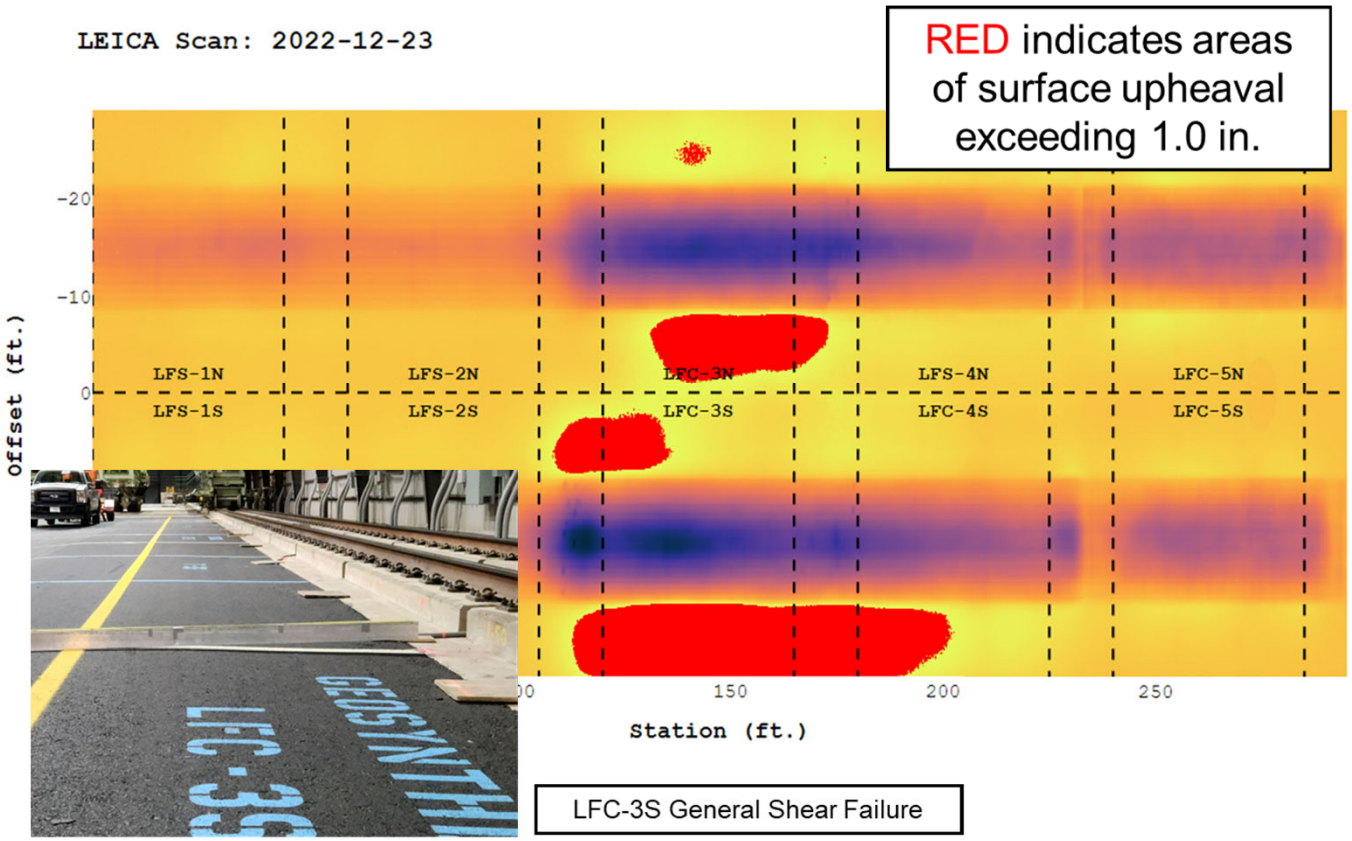
CC9 – Evolution of Surface Distortion

2021-04-09

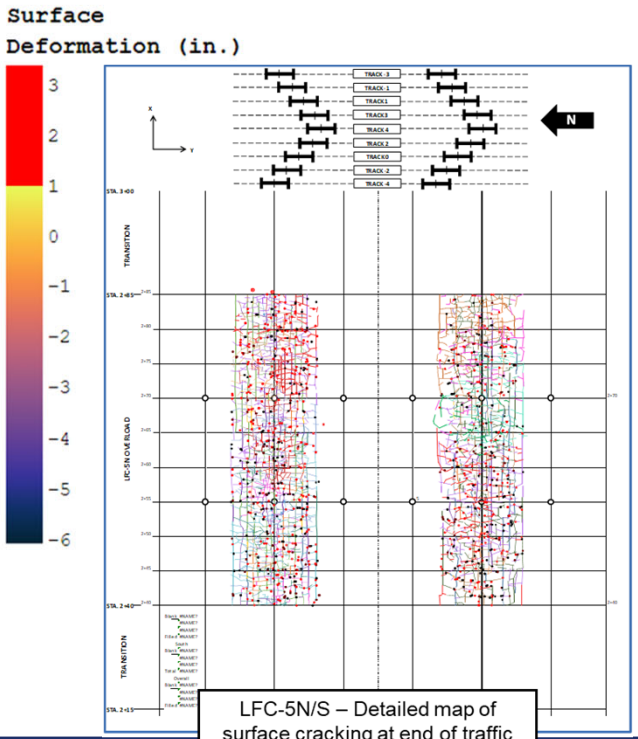


Dates	Passes on Test Items:			Description of Loading
	LFS 1-2	LFC 3-4	LFC 5	
4/5/2021 – 6/3/2021	5544	5544	0	Traffic test items 1-4
7/1/2021	0	0	66	Overload LFC 5N
7/1/2021 – 7/28/2021	0	0	5478	Traffic LFC 5 only
8/2/2021 – 10/14/2021	7066	7066	7066	Traffic all test items
1/15/2021 – 2/21/2022	0	0	0	Vehicle down for maintenance
2/22/2022 – 3/28/2022	3956	3956	3956	Resume traffic all test items
3/29/2022	0	0	66	2nd overload LFC 5N
3/29/2022 – 10/5/2022	24354	24354	24288	Traffic all test items
10/12/2022	0	0	396	3rd overload LFC 5N
10/13/2022 – 12/21/2022	0	0	15312	Traffic LFC 5 only
1/3/2023 – 2/1/2023	2244	0	0	Traffic test items LFS 1-2
Total (as of 2/1/2023)	**43164**	**40920**	**56628**	

CC9 – Post-Traffic Failure Condition



LFC-3S General Shear Failure



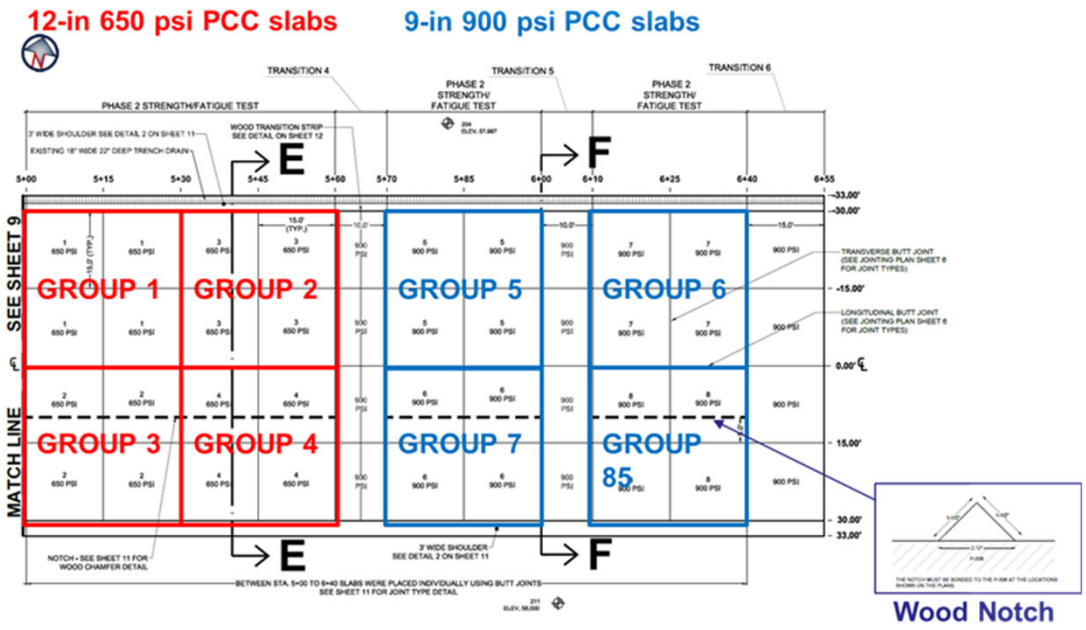
LFC-5N/S – Detailed map of surface cracking at end of traffic

Construction Cycle 8 Construction (2015)

Construction Cycle 8 (CC8) Test Objectives:

- **Phase 1 – Overload Test**
  - Develop rational criteria for allowing **occasional overloads** of rigid airport pavements.
  - Supports ICAO Annex 14 international standards.
- **Phase 2 – PCC-on-Rigid Overlay Test**
  - Develop design criteria for concrete overlays of old rigid pavement.
  - Utilized failed test pavement from Phase 1.
- **Phase 3 – Joint Comparison Test**
  - Compare performance of standard (Type E) doweled longitudinal construction joints to new sinusoidal keyway joints (see inset).
- **Phase 4 – Strength and Fatigue Full-Scale Test**
  - Obtain slab strength (rupture strength) for in-situ slabs, and fatigue life under non-wandered traffic.
  - Find the trade-off between slab thickness and flexural strength in design.

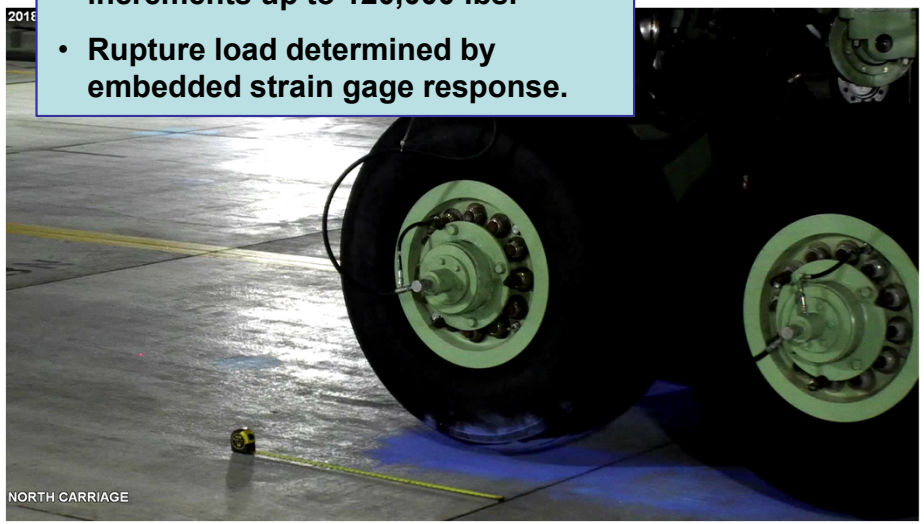
CC8 Phase 4 – Experimental Layout

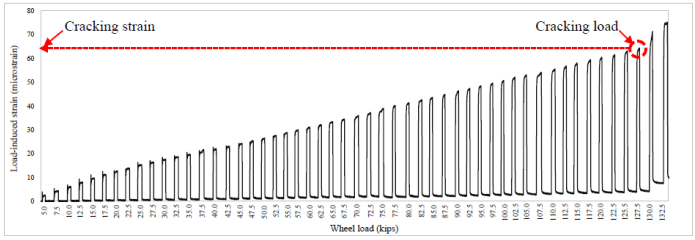


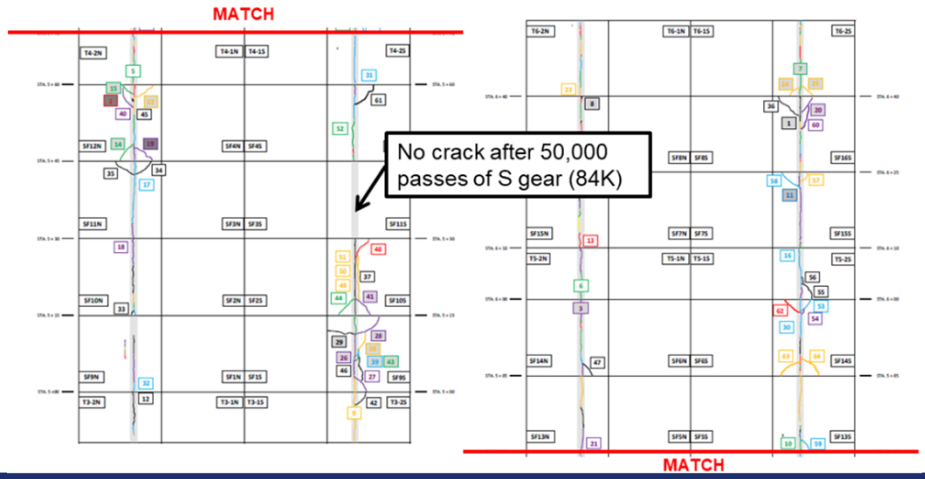
- **Single wheel load.**
  - Zero wander.
  - Wheel load at estimated 80% slab cracking load.
  - **84.0 kips** on 12-in. - 650 psi concrete.
  - **63.5 kips** on 9-in. - 900 psi concrete.
- **Outside lanes.**
  - North lane: All slabs pre-cracked.
  - South lane: No pre-crack.
- **Inside lanes.**
  - North lane: No notch
  - South lane: Notched at bottom
- **Observe passes to propagate initial bottom-up crack to surface.**
- **FAARFIELD life predicts the *median* number of passes for a given slab to complete the crack.**

CC8 Phase 4 – Testing & Post-Traffic Analysis

- **Stepped load in 5,000 lb. increments up to 120,000 lbs.**
- **Rupture load determined by embedded strain gage response.**







Thank You!

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