Friction Research Recommendations RPA S6

Presented to: SAS REDAC

By: Paul Giesman

Date: August 1, 2018

FAA Technical Working Group Meeting on Aircraft Braking Friction

- Tasking organization: REDAC Sub-committee on Airports
- Purpose: Tasked with assessing the results of on-going and completed FAA Research and to make recommendations regarding the direction of future efforts.
- Participants: The group includes representation from the FAA, academia, aircraft/braking system manufacturers, and others that are developing runway braking friction assessment technologies.
- Product: White paper produced by Technical Working Group has been forwarded to REDAC sub-committee.

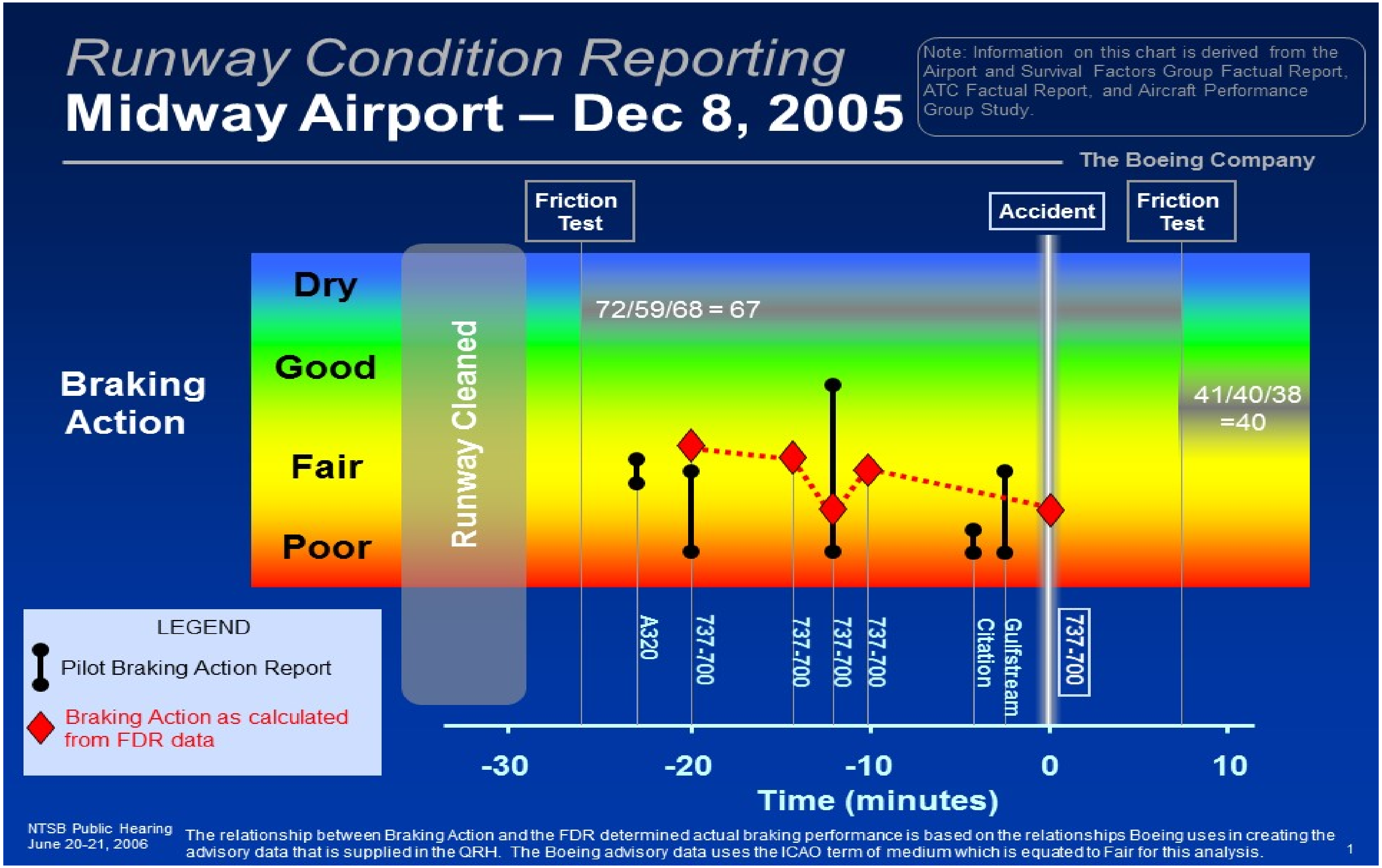
FAA Friction Research - Participants

- **Industry**
  - Dr. Zoltan Rado — *Aviation Safety Technologies –Friction*
  - Capt. John Gadzinski — *Zodiac Aerospace, SW pilot, ALOFT BASS*
  - Tom Yager* — *Retired - NASA researcher – friction issues*
  - Mr. Logan Jones — *Airbus, ROPS/ROWS/CORSAIR, NAVBLUE*
- **FAA Airport Technology R & D Branch**
  - Dr. Michel Hovan
  - Mr. Joe Breen
- **FAA**
  - Mr. Raymond Zee — *Airports, participant in Oper. Braking Research*
  - Dr. Angela Campbell — *Tech Center, participant in Oper. Braking Research*
  - Mr. Paul Giesman — *Retired Boeing, Airplane Perf. and Braking issues*

    FAA, Transport Standards, Sponsor of Oper. Braking Research
- **Other**
  - Mr. Eric Plyler — CSRA
  - Mr. Bryan Lesko — *ALPA*

- Background
  - Southwest Midway accident in 2005
  - Industry recommendations
  - TALPA ARC
  - FAA Research
- Gap Analysis
- Recommendations
- Future Aviation Considerations

From Boeing NTSB Sunshine Hearing Testimony



Safety Issue

- NTSB recommendations from March 5, 2015, accident in which Delta Air Lines flight 1086 re-iterates continuation of need:
  - NTSB A-16-023: Continue to work with industry to develop the technology to outfit transport-category airplanes with equipment and procedures to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll.
  - NTSB A-16-024: If the systems described in Safety Recommendation A-16-23 are shown to be technically and operationally feasible, work with operators and the system manufacturers to develop procedures that ensure that airplane-based braking ability results can be readily conveyed to, and easily interpreted by, arriving flight crews, airport operators, air traffic control personnel, and others with a safety need for this information.

Note: this recommendation updated, superseded and closed original recommendation A-07-64 from SW MDW accident

CAST Recommendation

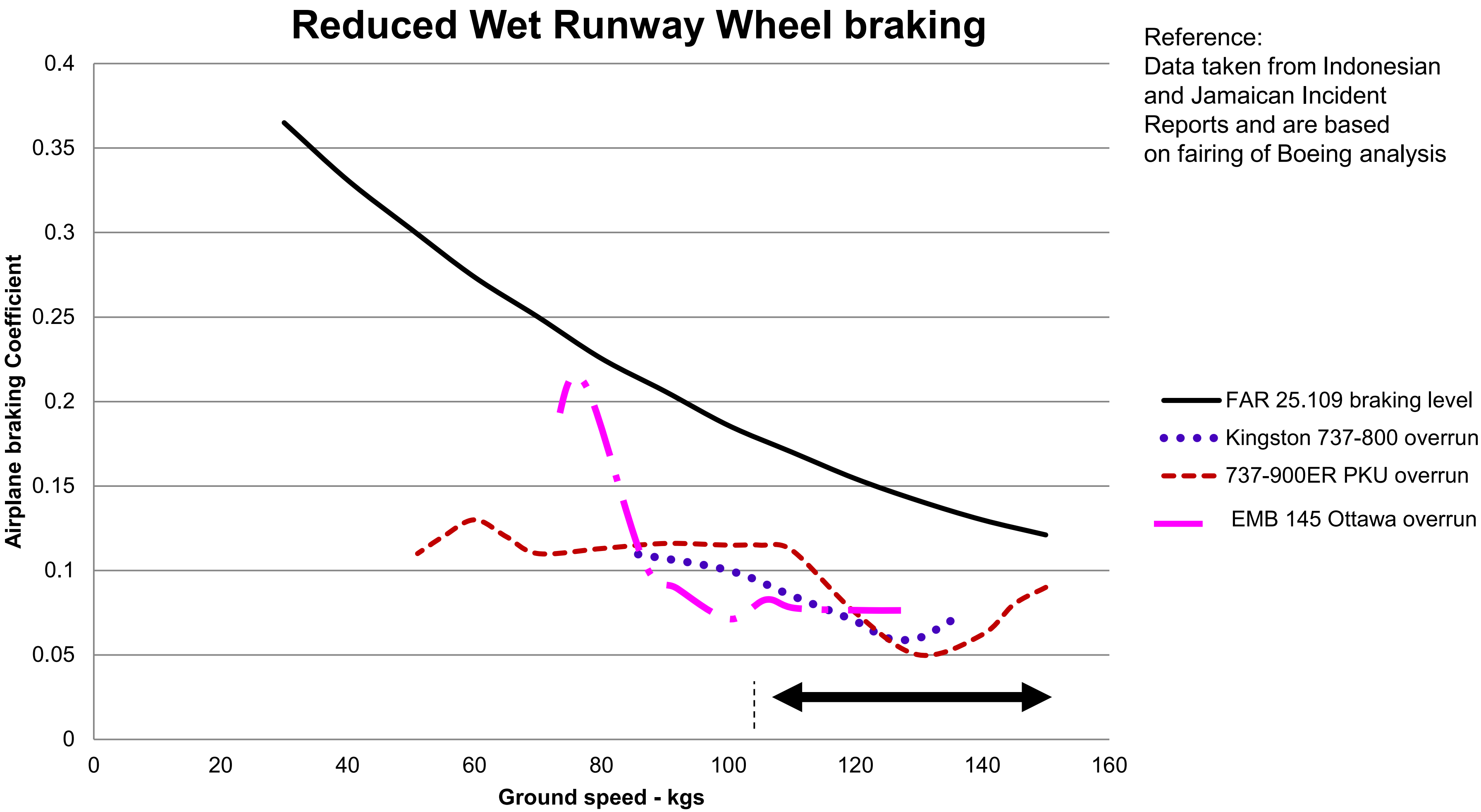
SE222: Runway Excursion - Airplane-based Runway Friction Measurement and Reporting (R-D)

The purpose of this Safety Enhancement is to outline research to be conducted by the aviation community (government, industry and academia) to enable development, implementation, and certification of on-board aircraft system technologies to assess airplane braking action and provide the data in real time to the pilot, other aircraft crews, air traffic controllers, and the airport operators.

Further NTSB recommendation

- A wet runway research project is slated to start in 2019 however it is not centered on these NTSB safety recommendations but rather on NTSB recommendation in a comment to TALPA CFR Part 25 AC's received in 2015
  - The NTSB encourages the FAA to perform flight tests on representative domestic and international runways that support turbine-powered airplane operations in order to validate the wet-ungrooved and wet-grooved wheel braking coefficient models in Section 25.109(c). The NTSB believes that issuing these draft ACs *relying on the untested and potentially insufficiently conservative models in Section 25.109(c) is premature.* The suggested ARAC flight test validation work should be used to update the wheel braking coefficients appropriate for wet runway operations.

Example of wet issue



Reference:
Data taken from Indonesian and Jamaican Incident Reports and are based on fairing of Boeing analysis

- **In 2017 an FAA Aviation Rulemaking Advisory Committee (ARAC):**
  - *"It is recommended airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways."*
  - *"The current standards are reliant on Continuous Friction Measuring Equipment (CFME) which are typically not available at the runways that have reduced wet wheel braking capability. Other techniques of recognizing poor wet runways need to be established that can be used at airports that do not have access to CFME equipment or that can be used in combination with CFME's. These techniques need to be specific and have meaning as to airplane stopping performance."*

Takeoff and Landing Performance Assessment (TALPA)

- Kicked off in 2008, FAA voluntarily implemented in 2016
  - Participants
    - FAA, airplane operators, airport operators and manufacturers
  - Created a new system of
    - Reporting, computing data, and operational use of common terminology, description of runway conditions assumptions for computing performance data.
  - Pre-first landing
    - Airport reports FICON based on an assessment of runway conditions using all available tools in the tool box
  - Once airplane operations start,
    - Crew are responsible for providing PIREPs of runway braking action.
    - *Future – PIREP's may be augmented by real-time aircraft braking measurements*

TALPA and Aircraft Performance Data

- All aircraft performance data based on best knowledge of effect of runway conditions on aircraft acceleration and wheel braking and agreed upon braking action scale.
  - Best knowledge based on limited historical testing and analysis
    - Further discussed in gap analysis section
    - Should be noted historically much more work/research has been done on friction measuring devices that aircraft
    - Similar to EASA certification methods

TALPA in Action

Manufacturer Performance Engineers create takeoff and landing distance data based on best information available.
Takeoff, AC 25-31, type and depth
Landing, AC 25-31/32 type/depth and runway condition code (RWYCC)

Airplane operators uses airport and manufacturer information to assess whether the takeoff or landing should be performed.
AC 91-79A, FAA Order 8900

Landing performed and pilot provides feedback in terms of PIREP's

Feedback Loop

Airport Operations assess runway condition based on standard observations and reports observed contamination type and depth and assessed runway condition code
AC 150-5200-30D

What is missing?

Measured friction information off the airplane which provided the Pilot Report (PIREP)!

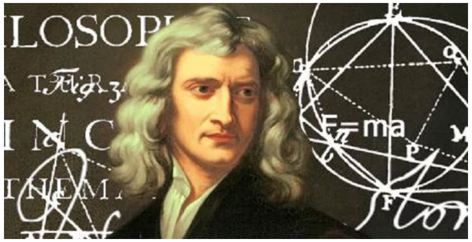
Original NTSB Safety Rec A-07-064 led to two FAA research programs

Transport Standards/Tech Center research on obtaining braking capability directly from operational landings of jet transport aircraft

Inferred wheel braking from performance data

PIREP

Quantifiable Engineering based



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Inferred wheel braking from performance data

Airports/Tech Center work using 727 “aircraft”

Measured wheel braking

Operational landing research project

- **Determine runway braking conditions in real time using data obtained from airplanes during landing rollout**
  - Using knowledge of airplane performance parameters to determine wheel braking contribution

$$\mu_B = \frac{\frac{W a}{g} - (T - D - \phi W)}{(W - L)}$$

  - Infer the wheel braking contribution
  - Answer as good as knowledge of parameters
- Manufacturers - Metron Airbus vs. third party (Aviation Safety Technologies, AST)
- Usage
  - Real time transmittal of data to following airplanes
  - Tracking deteriorating wheel braking – winter ops, wet runway
- How do you know you have the right answer?
- How do you know multiple systems give the same answer on the same runway?

Tech Center work on 727 for Airports

- Objectives of 727 Testing
  - Friction levels that can be achieved on the winter weather contaminants.
  - Methods to quantify the friction levels
  - The behavior of Anti-Skid Systems in responding to these low friction surfaces
  - Items that civil transport aircraft measure, or can be equipped to measure, that could determine the friction level available.
  - Direct calculation of wheel braking
  - Limited to 100-110 kts

FAA AC 25-32

Basis for TALPA airplane performance data

Runway Condition Code	Runway Surface Condition Description	Pilot-Reported Braking Action	Wheel Braking Coefficient	Implied mu max i.e.friction
6	• Dry	—	90% of certified value used to comply with § 25.125[1].	Based on manf. testing
5	• Frost • Wet (includes damp and ⅛″ (3 mm) depth or less or water) ⅛″ (3 mm) depth or less of: • Slush • Dry snow • Wet snow	Good	Per method defined in § 25.109(c).	Defined in CFR 25.109
4	-15 °C and colder outside air temperature: • Compacted snow	Good to Medium[2]	0.20[3]	0.25
3	• Wet ("Slippery When Wet" runway) • Dry snow or wet snow (any depth) over compacted snow Greater than ⅛″ (3 mm) depth of: • Dry snow • Wet snow Warmer than -15 °C outside air temperature: • Compacted snow	Medium[2]	0.16[3]	0.2
2	Greater than ⅛″ (3 mm) depth of: • Water • Slush	Medium[2] to Poor	(1) For speeds below 85% of the hydroplaning speed[4]: 50% of the wheel braking coefficient determined in accordance with § 25.109(c), but no greater than 0.16[3]; and (2) For speeds at 85% of the hydroplaning speed[4] and above: 0.05[3].	CFR 25.109 divided by ½, above hydroplaning speed – 0.0625
1	• Ice	Poor	0.08[3]	
0	• Wet ice • Water on top of compacted snow • Dry snow or wet snow over ice	Nil	Not applicable. (No operations in Nil conditions.)	

Gap Analysis

Gap Analysis – Item A

A. Validity of Assumptions for Performance Calculations
- Wet runway issues of note
  - Heavy rain – when does it go from acceptable to unacceptable
  - Microtexture, polishing – affect needs to be quantified
  - Drainage – current modeling inconsistent and questionable
    - Tracking depressions
  - Speed effect – little historical testing above 100-110 kts
  - All possible combinations of the above issues
- Quantify effects of special preparations of winter runways
  - Economic as well as safety
- Contaminant depth issues
  - Current threshold – 3 mm

Gap Analysis – Item B

B. Lack of effective aircraft design in measuring and reporting wheel braking
   - Currently operational aircraft are not designed to facilitate the measuring of wheel braking
     - Anti-skid boxes have more parameters than are available on the airplane and/or available for download
     - Typically have either brake pressure upstream (Boeing) of the anti-skid or downstream (Airbus) of the anti-skid but not both
       - Some exceptions, FAA Global 5000 has both upstream/downstream
       - Current BASS project installs additional pressure taps
   - Tech Center Research has set up the 727 to directly measure wheel braking
     - This would be a big plus in obtaining real time wheel braking data

Gap Analysis – Item C

C. Integration of Braking Data into Flight Standards related Operational risk management practices

- Traditionally wind and visibility have been environmental issues that mitigate risk (or add threats if adverse)
- With implementation of TALPA the affect of runway condition has been highlighted. To properly mitigate risk based on runway conditions good knowledge of the runway capability in paramount
  - Mitigations
    - Effectively correlate observations and assessments (assist airport assessment and performance data determination)
    - Accurately measure braking after it has occurred (replace PIREPS with measured TALPA codes)
    - Trend analysis to help effectively recognize when deteriorating conditions become critical

Gap Analysis – Item D

D. Lack of industry standards for mapping braking performance to TALPA ARC
   - TALPA ARC braking action categories were created based on using the parameters to create performance data
   - New systems of obtaining braking coefficient off of airplanes needs to do the inverse
     - ASTM/SAPOE starting to work on standard
     - Final proof would be different systems obtaining same TALPA level in demonstration on the same known runway in same conditions

Gap Analysis – Item E

E. Absence of adequate testing facilities for certification and research

- To demonstrate intended function of obtaining braking coefficient and/or TALPA classification a flight test should be accomplished.
- It is highly desired that groundspeeds of 140 knots or greater be achieved for at least three seconds.
  - Earlier noted limitations on earlier testing
  - Especially true for wet runway verification (*or not*) of models
- Additionally, the test surface must be engineered to provide specifically controlled conditions that simulate or replicate braking levels as described in AC 25-32 to the greatest degree possible

Industry Friction Issues

- **Need to keep airplane performance and airports and flight operations working together on whatever future research brings**
  - Verify existing performance assumptions based on wheel braking are accurate and if not why not
    - Wet runway
      - What combination of cross slope, macro texture and micro texture becomes and rain rate becomes critical
      - How much variation with tire pressure
        - » Verify critical depth of contaminant for when we go from wet to contaminated
    - Magic depth defined as 3 mm
    - Hydroplaning – radial tires vs. traditional

Industry Friction Issues - continued

- **Need to keep airplane performance and airports and flight operations working together on whatever future research brings**
  - Runway Overrun Awareness and Alerting Systems
    - Go-around systems reliant on accuracy of runway braking capability knowledge
  - Friction measured off of airplanes
    - Important we know if different systems give the same answer
    - Can we prove the systems categorize information into appropriate TALPA categories
  - Can we provide airport observers with better methods to assess runway conditions
    - Downgrades – TALPA, slippery when wet
    - Upgrades - specially prepared winter fields
    - Wet grooved runway performance eligibility

Recommendation 1 – Gaps A, B, C

- **Test aircraft** similar in type to a B737NG/A320 should be obtained
  - Airworthy
  - Fully modulating anti-skid system
  - Test speeds of at least 140 knots ground speed
  - Accommodate sensors for appropriate sensors and data systems to support braking tests
  - Ability to directly measure and record braking forces/coefficients

Recommendation 2 – Gaps A, B, C

- **Testing facility with an available runway**
  - Criteria
    - Minimum 8000’ / 150’ wide
    - Test speeds of at least 140 knots ground speed
    - Built in wetting capability
    - “Slippery when wet” section
      - Good runway outside of test section
    - Possible to vary surface to some degree
      - Simulate micro/macro texture for wet issues
    - Winter conditions
    - Capable of testing with aircraft having similar size/weight as 737-700 or A-320 – runway loading

Recommendation 3 – Gaps C, E

- **Workgroup**
  - FAA should establish a working group to support the design and construction of the above-mentioned test facility
  - Test surface design: Construction of the test area should include recommendations regarding;
    - Type of material such as concrete or asphalt.
    - Design of surface such as smooth, grooved, PFC, or other.
    - Validation method such as comparison to known poor runway conditions as documented by recent studies and measurement by ground friction devices.
  - Testing protocols
    - Test safety issues
    - Standard test plans
    - Equipment – cameras, friction devices, water measurements and controls

Recommendation 4 – Gap D

- For applied research to be relevant, a means must be available to apply the findings of the research to the operational community. This has been a barrier to research that has been reviewed. To ensure the listed recommendations are harmonized with the standards being developed for obtaining friction information from operational airplanes, the following recommendation is made:
  - SAPOE/ASTM Standards Coordination: The FAA should commit to continued participation in the SAPOE/ASTM standards effort on obtaining friction information from operational aircraft. Recommended participants are:
    - Flight Standards (final implementation group for operating standards)
    - Transport Standards (sponsor of original research and organization responsible for on-airplane certification requirements)
    - Tech Center (future research discussed in this paper which supports implementation of this effort)

Recommendation 5 - Gaps A, B, C, and E

- **Supported Research -** FAA should commit to supporting the following research with the above resources
  - Proof of concept testing for new technology
    - Airplane as friction measuring device
    - Airport surfaces
  - Development of new certification methods for aircraft braking recording – inferred vs. measured
  - Investigate aircraft wet runway braking performance that falls below FAR 25.109(c) levels.
    - NTSB issue
    - Validate when existing models are accurate

Recommendation 5 - Gaps A, B, C, and E

- **Supported Research -** FAA should commit to supporting the following research with the above resources
  - Validation of TALPA ARC correlations between airport observations and aircraft performance
    - Goal of improving reliability and reducing the risk of unexpectedly non-conservative initial assessments
    - Identifying too conservative initial assessments
  - Development of predictive methodologies to estimate/compute aircraft landing distances on contaminated runways.

Safety Recommendation Status

NTSB A-16-023: 'develop the technology to outfit transport-category airplanes with equipment and procedures to routinely calculate, record, and convey the airplane braking ability'

SE222: Runway Excursion - Airplane-based Runway Friction Measurement and Reporting (R-D)

- Assigned to Transport Standards, research accomplished and NTSB debriefed on Feb. 16, 2018. Expect to be closed
- Result of research is industry and FAA moving forward with systems to obtain friction information from airplanes
    - Standards – ASTM/SAPOE group working
    - Verification/Certification/Acceptance
  - Recommendations would be helpful in accomplishing these tasks
    - How do you demonstrate different systems provide same TALPA categorization on same runway
    - How do you prove the different systems provide the correct TALPA categorization

NTSB Safety Recommendation Status

- NTSB A-16-024: ‘work with operators and the system manufacturers to develop procedures that ensure that airplane-based braking ability results can be readily conveyed to, and easily interpreted’
  - Assigned to Flight Standards
  - Follow on to A-16-023

Wet Runway

- NTSB recommendation in a comment to TALPA CFR Part 25 AC's received in 2015
  - '**NTSB encourages the FAA to perform flight tests on representative domestic and international runways** that support turbine-powered airplane operations **in order to validate the wet-ungrooved and wet-grooved wheel braking coefficient models** in Section 25.109(c).'

- In 2017 an FAA Aviation Rulemaking Advisory Committee (ARAC):
  - *'team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.'*

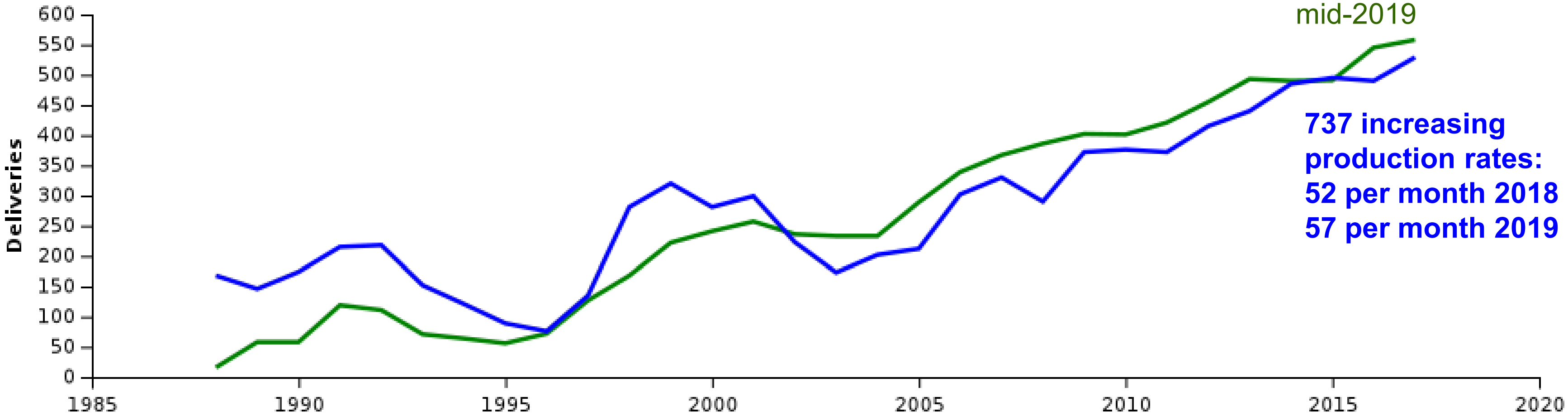
Future identified research

- **A wet runway research project has been "selected for funding" for 2019 to 2021**
  - Methods to identify poor performing wet runways
    - Runway issues
      - Texture – microtexture
      - Drainage
    - Heavy rain – FAA SAFO 15009 (General)

Future Aviation Considerations

Fleet continues to grow

Airbus has indicated single-aisle output may increase to 60 aircraft per month by mid-2019



737 increasing production rates:
52 per month 2018
57 per month 2019

Airbus A320 family deliveries, List of Airbus A320neo family orders and deliveries[3][113]

Boeing 737 series deliveries[114]

More airplanes being added to the fleet everyday expanding to new airports

Many in tourist destinations with shorter runways or second tier airports

Airlines will continue to expand

- **Derivative airplanes often need more runway than original models**
  - Body lengthening, weight increase
  - Same wing
- **Airlines want more seats on same airplane**
  - Economics
- **Airports want shorter runways**
  - Cost
- **Airlines continue to expand to challenging airports**
  - Market
  - Charters

Finally

- Airfield – Wallops Island may be useful
  - 8700’
  - Public use airfield
  - Looking for partners to work with
  - Existing water ingestion testing facility – may be modifiable
  - 41” rain (82 days average) and 7” snow (3 days)

Discussion