BMT Fleet Technology

Runway Friction Characteristics Measurement and Aircraft Braking

Location: DGAC, Paris

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FUNCTIONAL CHARACTERISTICS MEASUREMENTS ROADMAP

- Scientific and operational consolidations of harmonization
  - Review present f FMD taking into account elements effecting friction readings
  - Assess the anticipated results of current R&D activities and indentify still existing knowledge gaps
  - Assess the feasibility for harmonization based on the investigation of above points
  - Develop proposals for amendment of harmonization table specified by ICAO Annex 14 Sup A – Table 1
- Investigation for alternative methods to evaluate surface friction characteristics and proposal of the most feasible methods standards
  - Conduct a survey of current technologies in use for friction characteristics measurement
  - Make a review on a global scale of other methods for texture measurements e.g. use of laser, stereo photography, digital image processing
- Define a stepwise procedure and guidelines for harmonization of measurement device
  - Establish conditions for friction characteristics measuring device qualification testing complying with ASTM, ISO, CEN and ICAO standards taking into account the following parameters: surfaces, speeds, depth of water film, temperature characteristics conditions and required practical test implementation conditions, e.g. number of measurement, accuracy, consistence of results,
  - Review technical criteria for measuring device compliance
  - Review acceptable methods, accuracy and consistency of implementing harmonization procedures in relation with ASTM, ISO, CEN and ICAO standards
  - Propose the establishment of a reference equipment database taking into account factors like type of equipment, type and location of surface, type of tire, inflation pressure, test speeds, and weather conditions during tests,
  - Assess the need to issue specific EASA specifications (i.e. ETSO) in this field
  - Develop proposals for amendment of harmonization table specified by ICAO Annex 14 Sup A – Table 1

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FUNCTIONAL CHARACTERISTICS MEASUREMENTS

The ultimate question:

IS there a way, and if there is, how can we get a reliable friction reading for functional characteristic measurements ??

<u>FUNCTIONAL</u> CHARACTERISTICS MEASUREMENTS

1) Investigate scientific and operational consolidations of harmonization
2) Investigate alternative methods to evaluate surface friction characteristics and propose the most feasible methods
3) Define a stepwise procedure and guidelines for harmonization of measurement device standards

Scientific and operational consolidations of harmonization

- Review present practices of FMD
- Review current R&D activities and indentify still existing knowledge gaps
- Assess the feasibility for harmonization based on the investigation of above points

Investigation for alternative methods to evaluate surface friction characteristics

1. Conduct a survey of current technologies in use for friction and texture characteristics measurement
2. Review of other methods for friction and texture measurements e.g. use of laser, stereo photography, digital image processing
3. Assessment of alternative method that can be used instead of the friction measuring devices

Define a stepwise procedure and guidelines for harmonization of FMD standards

1. Establish conditions for friction characteristics measuring device qualification testing complying with ASTM, ISO, CEN and ICAO standards taking into account the following parameters: surfaces, speeds, depth of water film, temperature characteristics conditions and required practical test implementation conditions, e.g. number of measurement, accuracy, consistence of results,
2. Review technical criteria for measuring device compliance,
3. Review acceptable methods, accuracy and consistency of implementing harmonization procedures in relation with ASTM, ISO, CEN and ICAO standards,
4. Propose the establishment of a reference equipment database taking into account factors like type of equipment, type and location of surface, type of tire, inflation pressure, test speeds, and weather conditions during tests,
5. Assess the need to issue specific EASA specifications (i.e. ETSO) in this field
6. Develop proposals for amendment of harmonization table specified by ICAO Annex 14 Sup A – Table 1

Detailed, point by point analysis can be found in the report.

Now:
Only the final result.

Why harmonization of FMDs are so difficult?

PROBLEM DEFINITION

Devices are very different

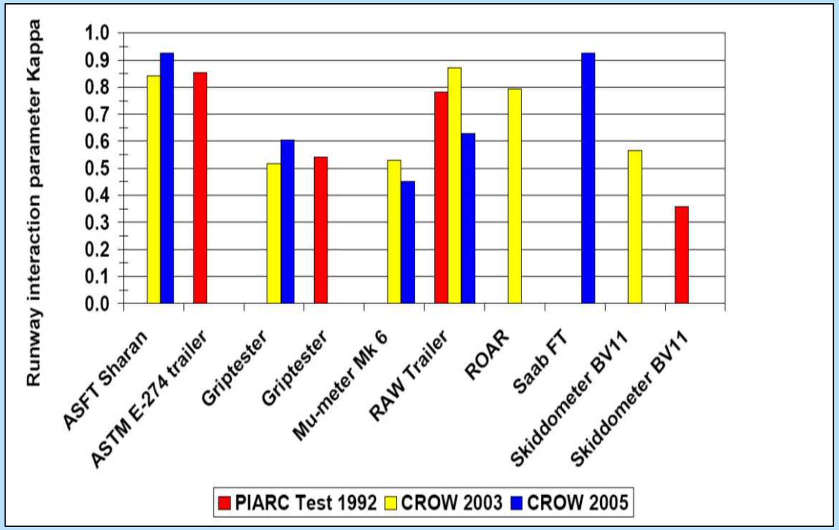
Harmonization trials tried to compensate for all the differences by a set of few constants and did not set any requirements for acceptance

PROBLEM DEFINITION

Poor device repeatability and device family reproducibility <u>prohibits</u> adequate harmonization

Harmonization trials tried to compensate for the variation between different devices and they used one (few) device(s) from a device family to represent the whole device family

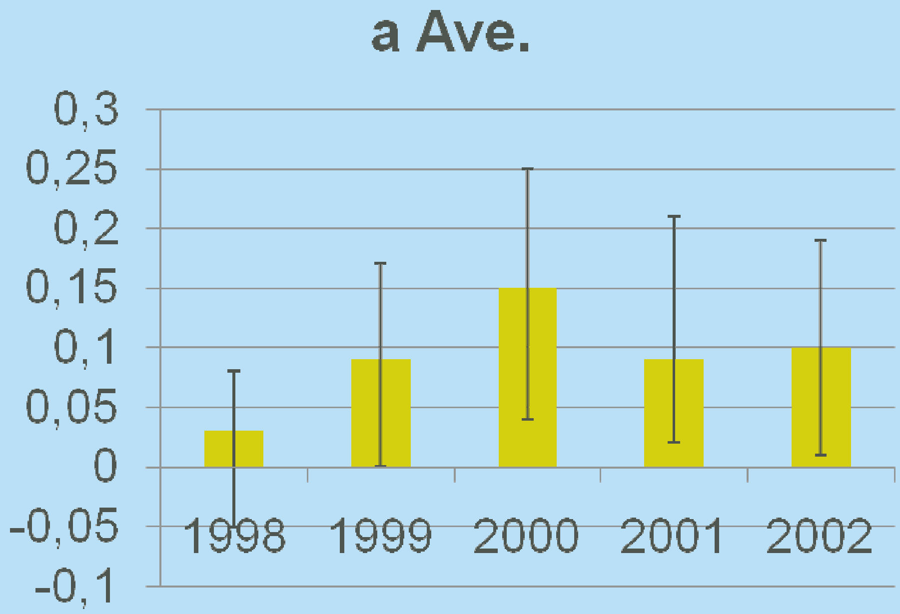
PROBLEM DEFINITION



Consistency of the Runway Interaction Parameter in ESDU Model, CROW, 2006

Harmonization trials came up with different constants each year

Devices are changing by time



Variation over Time for the “a” Constants in the IFI Model

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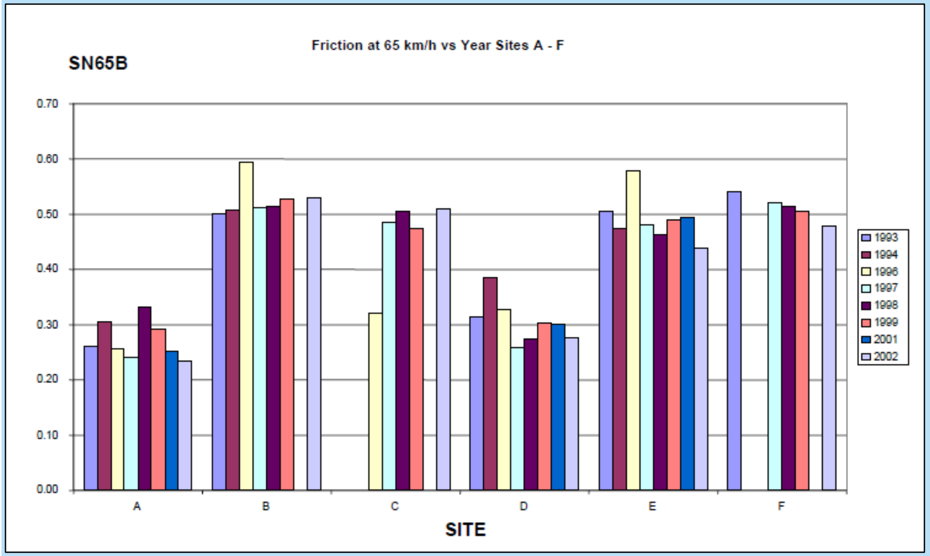
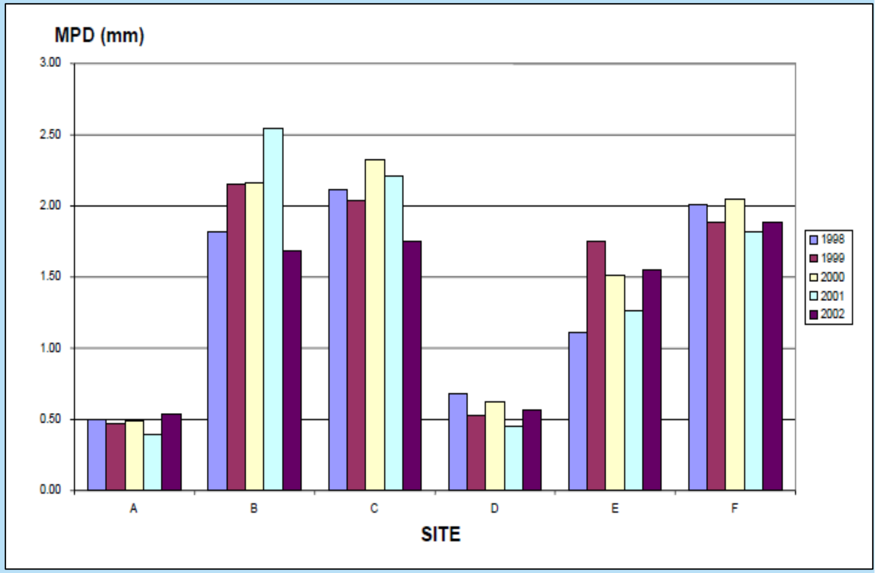
PROBLEM DEFINITION



Wallop NASA Site Surface Friction Changes over 8 Years as Measured by the VADOT E0274 Trailer

Surfaces are changing by time

Harmonization trials could not distinguish between the changes in the surface and the device



Wallop NASA Site Surface Texture Changes over 8 Years as Measured by the CT Meter

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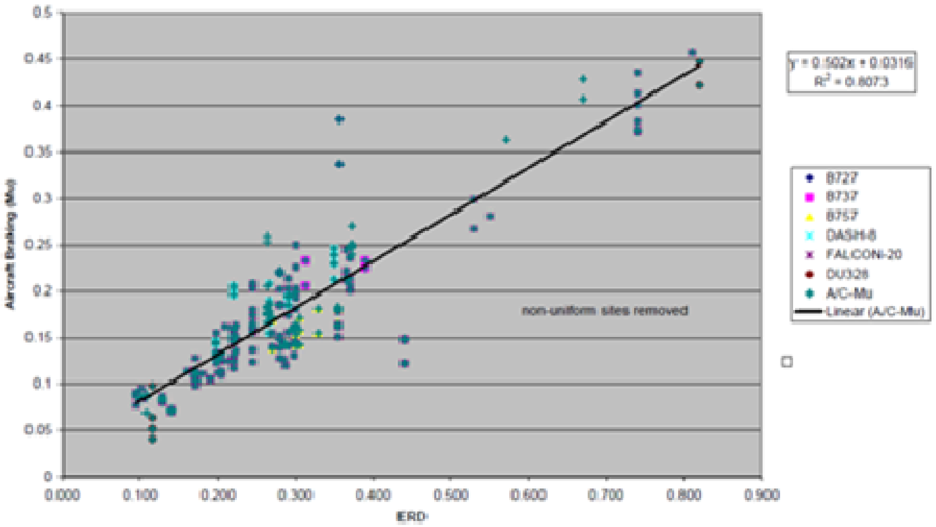
PROBLEM DEFINITION



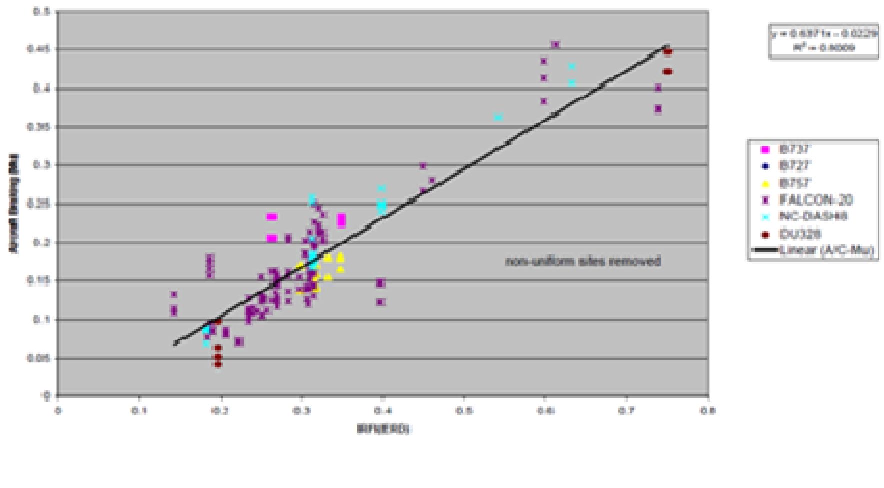


Figure 4b. Aircraft Braking versus IRFI(ERD) with Non-uniform Sites Removed

Before harmonization
$R^2 = 0.8073$

After harmonization
$R^2 = 0.8009$

Harmonization does not ensure better correlation to aircraft

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Did we try everything ???

	Scenario =>	#0	#1	#2	#3a	#3b	#4	#5	#6	#7	#8a	#8b	#9	#10	#11	#12	#13
F-model	$F = F_0 \cdot e^{-S/S_0}$	×	×	×	×	×	×	×	×	×	×	×				×	×
	$F = F_0 \cdot e^{-(S/S_0)^{\alpha}}$												×	×	×		
S₀-model	$S_0 = 57 + 56 \cdot MPD$	×	×														
	$S_0 = a \cdot MPD^b$ (1)			×	×	×	×	×	×	×	×	×	×	×	×		×
	Actual S_0-value from *F(S)*															×	
EFI-model	$EFI = A + B \cdot F_{30}$	×	×	×	×	×	×										
	$EFI = B \cdot F_{30}$							×	×	×	×	×	×	×	×	×	×
Calibration method	$<< EFI >>= \alpha + \beta \cdot EFI$	×	×	×	×	×											
	$EFI = \alpha' + \beta' \cdot << EFI >>$						×										
	$<< EFI >>= \beta \cdot EFI$							×	×	×	×	×	×	×	×	×	
	$<< EFI >>= \beta \cdot < EFI >$																×
Statistical tests	$F > 0.01$	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	$S_0 > 0$	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	$\sigma_r(F) < 0.04$	×	×														
	$\sigma_{EFI} > 0.07$	×															
	$R_F^2 > 0.5$			×			×	×	×	×	×	×	×	×	×	×	×
	$R_{EFI}^2 > 0.5$			×	×	×	×										
	$CV_{EFI} >$				10%	5%	10%										
	"k-test" (0,5%)			×													
	"h-test" (0,5%)			×													
Discarded devices									F05	F05 F15	F05 F15 SFC	BFC (2)	F05	F05 F15	F05 F15	F05 F15	F05 F15

(1) With weighting . (2) F05 and F15 were also discarded here since they are of *BFC*-type

FEHRL, 2006

IS THERE ANY OTHER WAY ?

Alternative solutions

1. Theoretical approach – using surface macro- and micro-texture properties and the tire's visco-elastic properties – No efficient way of measuring micro-texture
2. Aircraft based assessment approach – calculation of the true aircraft braking friction and the assessment of runway conditions directly from the flight data management systems of a landing aircraft – early stage
3. Criteria based on the pavement texture and its geometrical properties – this involves using criteria based on texture measurements and runway construction, geometry and pavement condition properties – early stage
4. Other – ice or other contaminant detection on the surface – directly and at the present not applicable
5. Cross Pollination from other industries – presently not probably

SHORT TERM: TWO PROMOSING APPROCHES (#2 -3, need further observation and validation)
LONG TERM: HIGH RISK, 15-20 YEARS

WHAT ARE OUR OPTIONS??

FORGET ABOUT FRICTION MEASURMENT

(NORWAY IS ON ITS WAY, FAA AND ICAO CONSIDERING OPTIONS)

OR

MAKE IT WORK

OUR OBJECTIVES

Determine :

- if it is possible with the given state of art to harmonize FMDS
- how it can be done

PROBLEM DEFINITION & POSSIBLE SOLUTION

1. **Devices are very different : different measuring principles and device designs deliver significant sources of differences**

   - Some of these difference can be modeled and encountered for the differences. However some models are adequate, some are OK, and there are differences that can not be modeled

1. For those models that are adequately describes the difference, use them in the harmonization models
2. For those models that are not adequate, improve to acceptable adequacy or move it to the non –existing category (point #3)
3. If model does not exist, develop and **enforce** strict **standardized technical specification** to remove the source of differences

PROBLEM DEFINITION & POSSIBLE SOLUTION

- **Poor device repeatability and device family reproducibility <u>prohibits</u> adequate harmonization**

- Develop dynamic calibration procedure to measure repeatability and reproducibility
- Develop and **<u>enforce</u>** strict requirement for device repeatability and device family reproducibility

- **Devices are changing by time (reference devices too)**

- Find a reference device that is time stable, economic, repeatable and reproducible
- Check all devices regularly to check time stability
- Develop and **<u>enforce</u>** strict requirement for time stability (more strict requirements for ref. device)

PROBLEM DEFINITION & POSSIBLE SOLUTION

- **Surface are changing by time (reference surface too)**

- Design reference surface that are time stable, economical and repeatable and reproducible

- **Issues with harmonization process**,

- Develop or choose a harmonization procedure that encounters for the device differences using adequate models
- Develop and **enforce** strict quality requirements for the harmonization testing
- Develop and **enforce** strict plan for the frequency of the execution of this harmonization testing

RECOMMENDATIONS

OUR RECOMMENDATION INCLUDE

1. **<u>NEW</u> standardized technical specification, where all the device parameters that can not be adequately modeled are standardized (In our example, most of the parameters)**
2. **<u>NEW</u> dynamic calibration procedure that includes the level 1 and level 2 repeatability and device family reproducibility measurements**
3. **<u>NEW</u> device repeatability and device family reproducibility requirement (cut off values)**
4. **<u>NEW</u> reference device for friction and texture measurements: DF tester and CT meter**
5. **<u>NEW</u> requirement for time stability (more strict requirements for ref. device) and its measurement frequency**

Our RECOMMENDATION includes

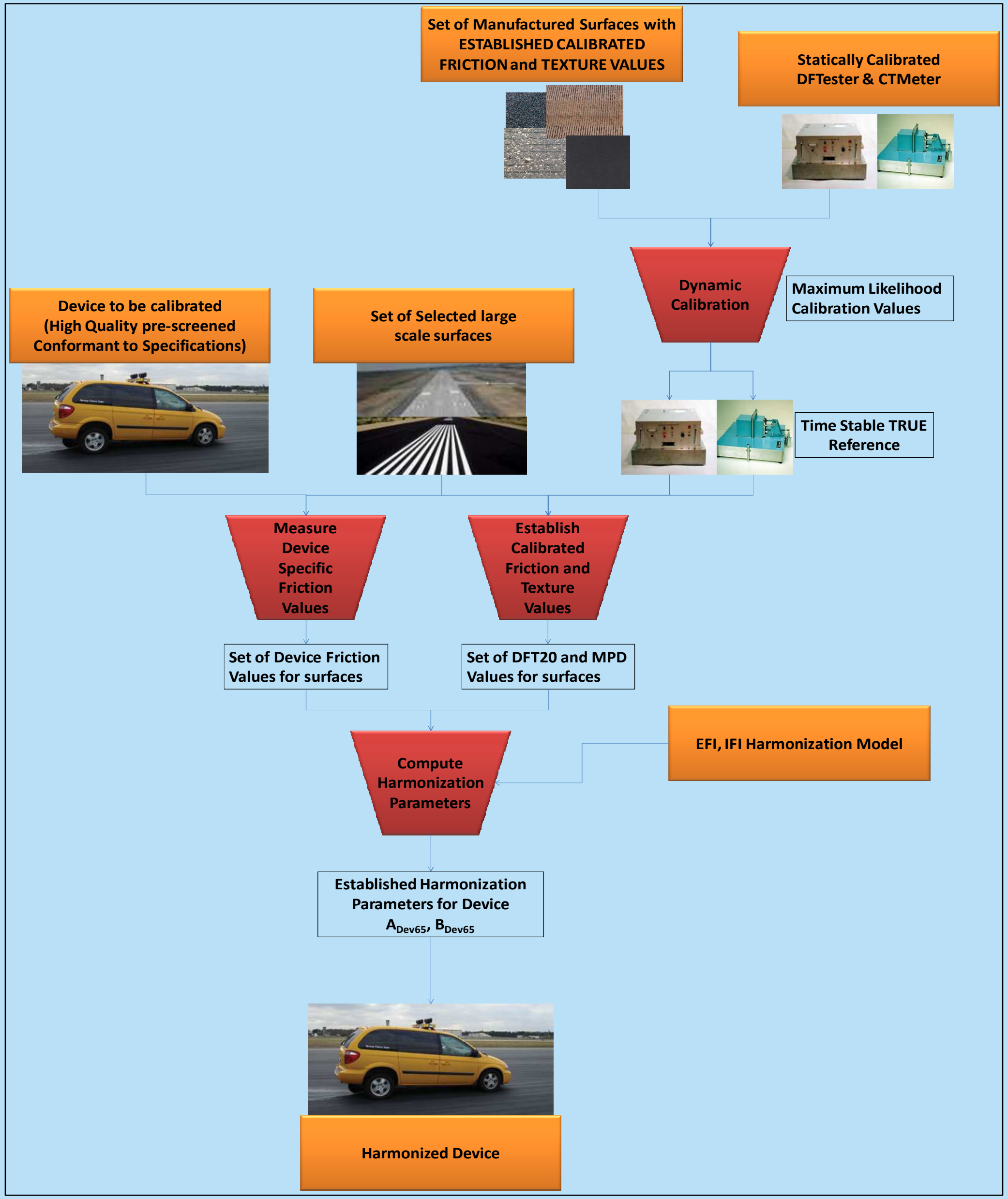
6. NEW reference surface strategy: use a 60cmx60cm reference surfaces to statically and dynamically calibrate the DF testers and CT meter

7. It is recommended to use the European Friction Index or EFI or the equivalent IFI type of harmonization

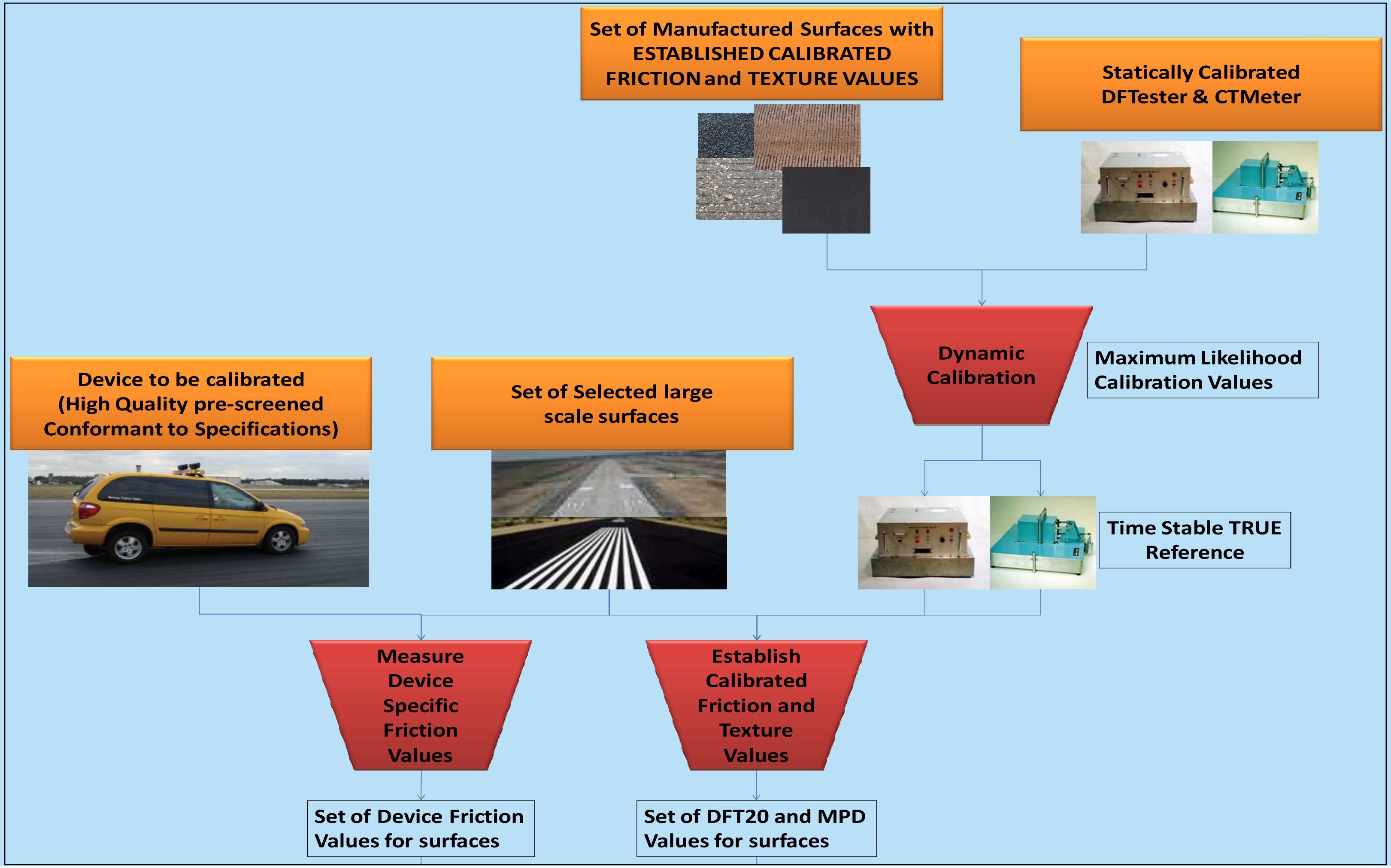
8. NEW quality requirements (cut off values) for the harmonization testing

9. NEW plan for the frequency of the execution of the harmonization testing

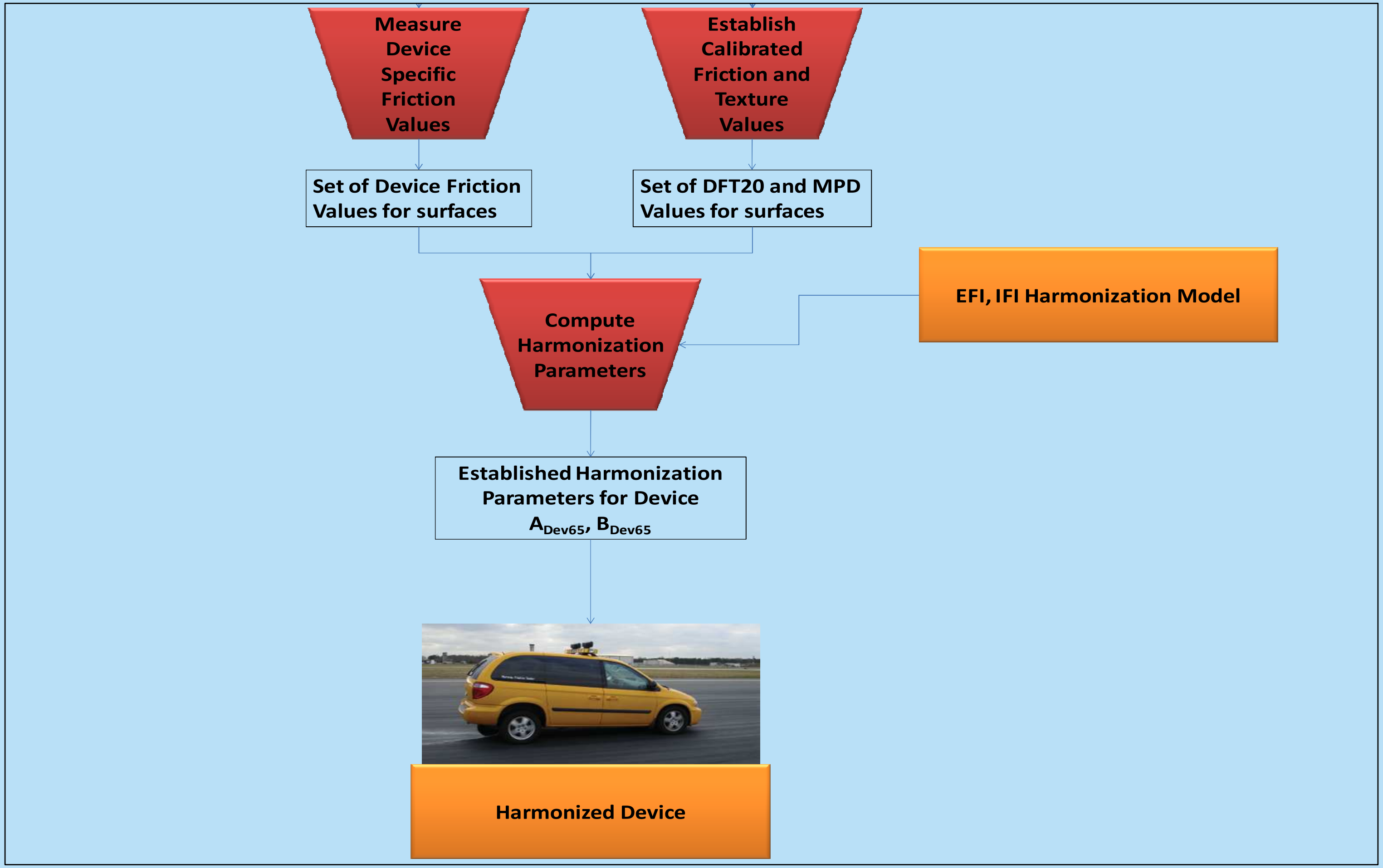
THE HARMONIZATION PROCEDURE



THE HARMONIZATION PROCEDURE



THE HARMONIZATION PROCEDURE



Technical advantages

- The proposed process eliminates the problems stemming from the time instability and changes in the used reference surfaces and reference devices..
- The established repeatability and reproducibility minimum criteria will ensure that the harmonized friction measurement equipment deliver low variability and precise measurements. At the same time help CFMD manufacturers to maintain high quality repeatable equipment.
- The established technical specifications will ensure higher standardization among the different friction measurement principles and devices. This helps deliver a higher quality and fidelity harmonization process that produces much higher confidence results.

Practical advantages

- The used small and portable measurement devices can be transported easily. The devices can be kept in ideal laboratory environment where perfect conditions of the equipment are easy to ensure.
- The devices can be calibrated in laboratory environment to a set of high quality small scale surfaces under ideal conditions.
- The measurement equipment can be operated after calibration at the selected large scale filed test sites easily and efficiently
- The small devices are easy to ship and perform calibration and harmonization at different areas or countries effectively and rapidly.
- The developed set of laboratory calibration surfaces are small easy to produce, store and handle.
- The small reference surfaces can be repeatably and reproducibly manufactured to very high quality requirements.

Economic advantages

- The two small devices are relatively inexpensive compared to full size CFMDs.
- The small calibration devices are inexpensive to ship from location to location and can be effectively and efficiently used for harmonization and calibration in many different areas.
- The proposed calibration surfaces are very inexpensive to produce compared to large scale surfaces that can be traveled by CFMDs.

FINAL CONCLUSION

The ultimate question was:

If there is a way, how can we get a reliable friction reading for functional characteristic measurements ??

YES, a set of procedures, standards, specification and methodology were identified that could deliver a harmonization with high probability

FINAL CONCLUSION

1. **Regulate yearly mandatory calibration**
2. **Regulate reference surface change frequency**
3. **Regulate reference device calibration frequency**