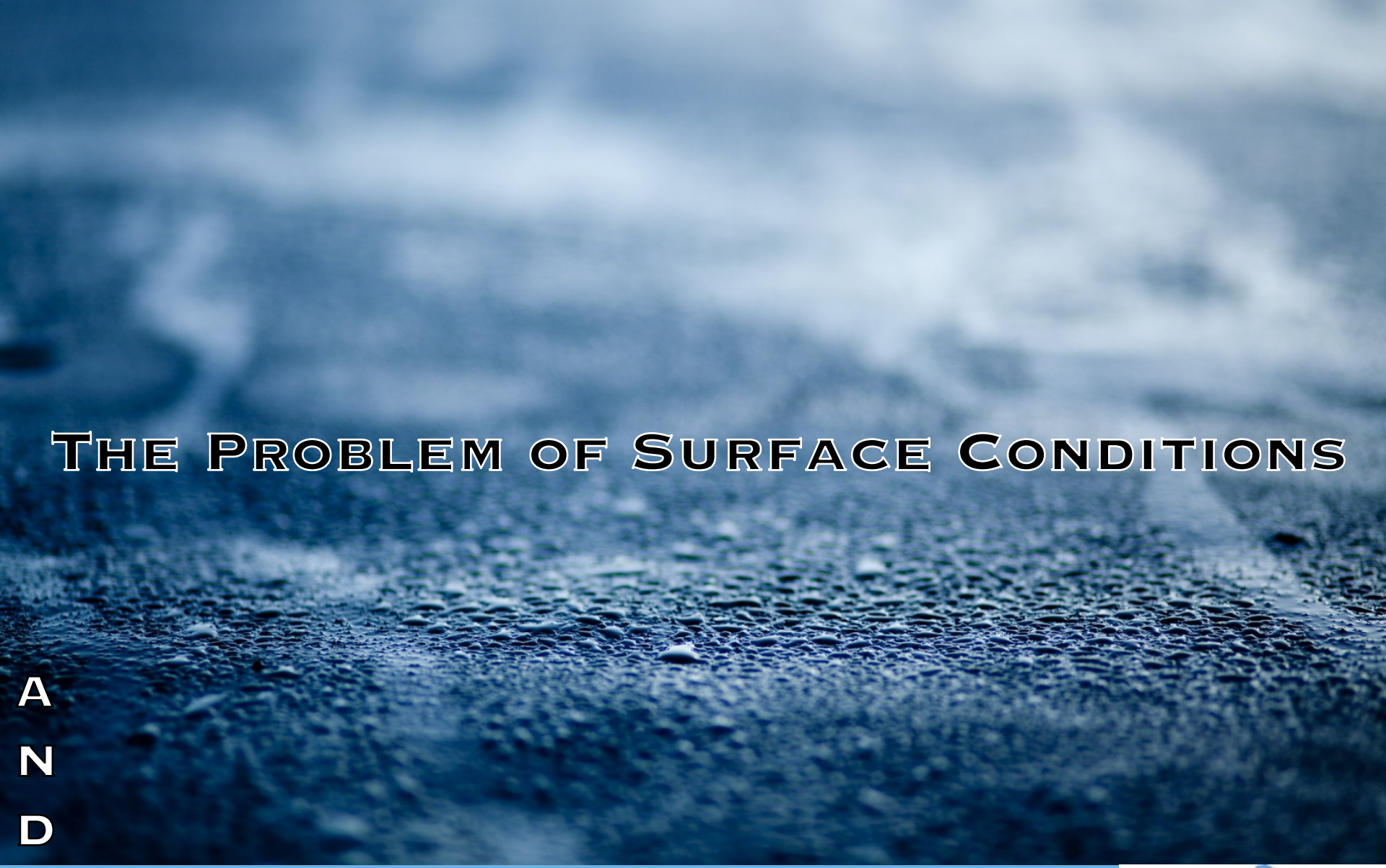
Aviation Safety Technologies, LLC

NASA – Airline Operations Workshop

August 3, 2016



The Problem of Surface Conditions

A

N

D

The AST Solutions

Industry Need

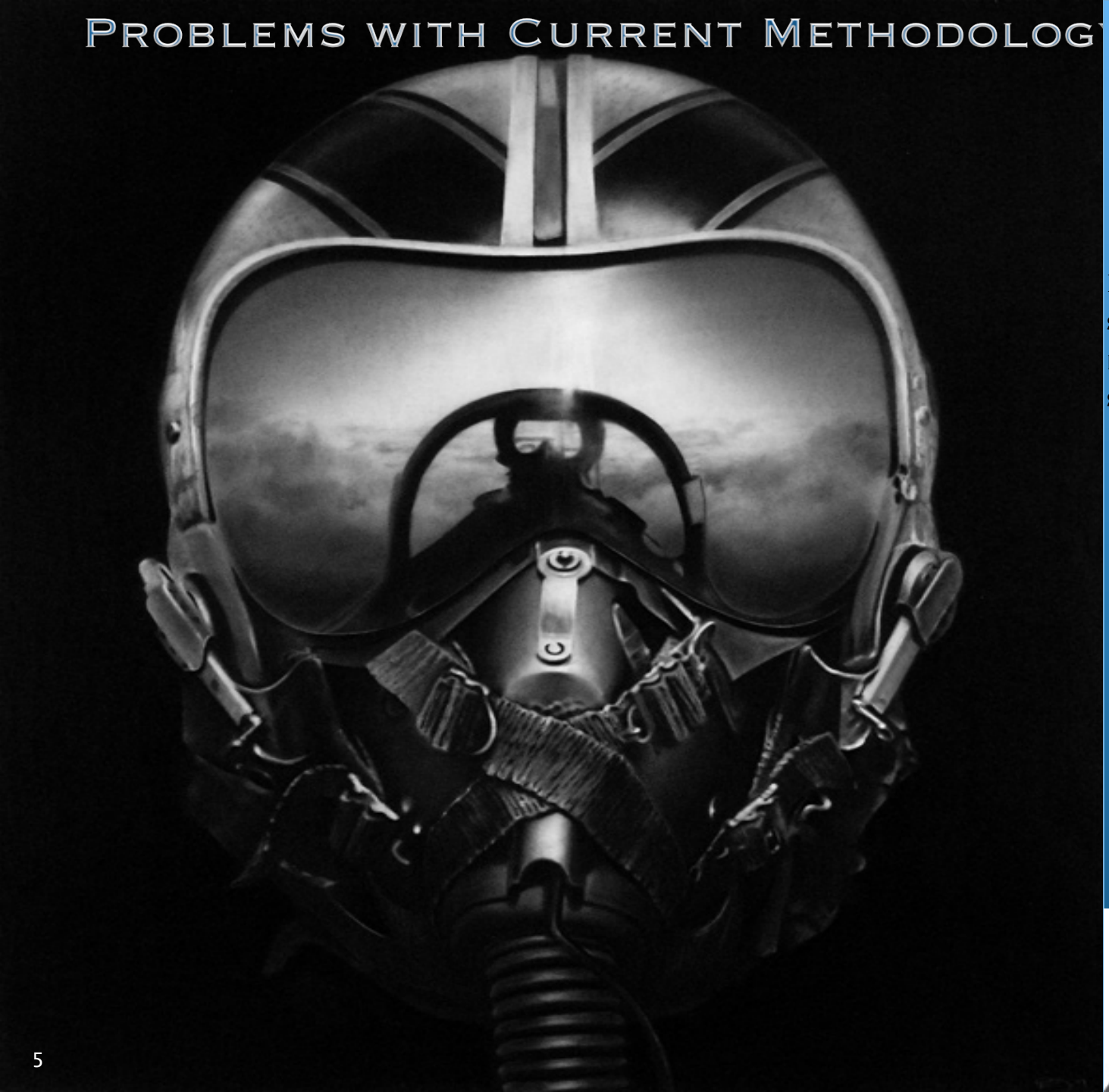
- Runway over-runs are among the most frequently reported accidents
- Runway over-runs do not often result in causalities to passengers or crew
  - Despite this fact, landing overruns are still considered a major threat to aviation safety
- Civil Air Navigation Services Organization: "Two runway excursion occur weekly on a worldwide basis".
  - "Landing overrun accidents in slippery conditions continue to occur..."

NTSB Recognition

FAA Grant Solicitation

...The NTSB recommended that the FAA should "Demonstrate the technical and operational feasibility of outfitting transport-category airplanes with equipment and procedures required to routinely calculate, record, and convey the airplane braking ability required and/or available to slow or stop the airplane during the landing roll. If feasible, require operators of transport-category airplanes to incorporate use of such equipment and related procedures into their operations."

Problems with Current Methodolog



Pilot Reports

Pilot reports are subjective, not normalized, and subject to error

Current methods at times create disruption to airport and flight operations – causing unpredictable runway closures for measurement and treatment (sometimes unnecessarily)

Impact of this reduced predictability: Increased disruption, costs, fuel usage, uncertain risk environment

Problems of current methodology:

Direct Runway Measurement

Problem Summary

- Current means of definition can be inaccurate and misleading
- PIREPS are subjective, can lead to runway closures and operational chaos
- Ground device measurements don't correlate to airplane braking capability or other ground devices; requires closure of runway to measure
- Sub-optimal overrun risk and operational efficiency environment
- Obsolete FICONs and METAR information is often the norm
- Incomplete information for flight planning and dispatch; costly equipment, load and balance decisions made under conservative assumptions

Unique Perspectives

- **Pilot:**
  - Directional control operating several hundreds of thousand pounds of machinery in slippery conditions
  - Special Procedures, i.e. increased spacing, slower ground speeds
  - Vital to know surface conditions and weather accurately and timely
  - RTO Considerations

- **Airport:**
  - Maintain safe operating environment
  - New procedures: RCAM / RCC, enhanced FICON-NOTAM reporting
  - PIREPS drive runway cleaning process, coordination to build gaps in traffic…etc

- **FAA / ATO:**
  - Pre-Season procedural meetings with Airport and tenents
  - Safety through coordination, passing PIREPS and common SA

Accidents – Incidents Persist

- 5 snow related events winter 2015/16
- MD88: RWY excursion @ LGA 3/5/15: wx potential factor
- 737-800 RWY-TWY @ DTW 11/22/14 closes airport for 2 hours
- CRJ-200 RWY-TWY @ JFK 1/5/14-closing airport for 2 hours (8 diversions to BDL alone)
- MD-80 RWY-TWY @ DTW 1/30/12
- B737 @ GEG 01/2008
- CLE closes for 2 hours on 2/2008 due 3 a/c departing surface
- MD-80: @ IDA 12/10/2007
- CRJ 900: @ TVC 4/12/2007

Who is AST?

Confidential Information

AST is Part of Dillon Kane Group

DKG Facts:

- Founded: November 2001
- HQ: Chicago, IL
- Financial
  - $80M Annual Revenue
  - 40% Compound Growth Rate
- Intellectual Capital
  - 11 Partners
  - 246 Associates
    - 91 Business Consultants
    - 146 Technical Architects
    - 9 Administrative

Core Competencies:

- Complex Software Development and Services
  - IOT
  - Cloud
  - Security
  - Mobile Internet
  - Big Data
  - SOA
  - Digital Strategy
  - Business Architecture
  - Knowledge Worker Automation
- Business Incubation

Who is AST? Cont'd...

- AST is one of several companies incubated by the Dillon Kane Group (DKG) of Chicago, IL
- Only aviation platform business at DKG; related entity Friction Sciences developing technology for the ground transportation market
- Answered FAA BAA Solicitation and received FAA Grant
- Formed in 2007 after Midway Airport overrun incident
  - Purpose: to create network and software service on computational systems of Dr Zoltan Rado, head of Larson Transportation Institute and DOT Crash Safety Center at Penn State

About Dr. Zoltan Rado

- PhD Mechanical Engineering, Penn State University
- AST calculation engines built on Dr. Rado's 25+ years of research in the field of surface friction measurem and analysis
- Dr. Rado is a leading expert on runway braking action serves as an expert witness and analyst in aircraft cr investigations
- Dr. Rado is the Managing Director of the Larson Transportation Institute and the DOT Crash Safety Center at Penn State University. His research interests include vehicle dynamics, vehicle surface interaction, dynamic frictional characteristics and braking, road surface characteristics, automotive-aviation safety, dynamic vehicle modeling and simulation, finite element analysis and vehicle crash safety research.

The AST Solution

- Utilize landing aircraft as runway condition measurement devices: Toolkit for 'NextGen on the ground' services

- AST runs landing simulations from down-loaded airplane data and measures "Experienced Friction" as function of braking applied and ranges from zero to the Fiction Limit (an aircraft calling for more deceleration without deceleration being delivered

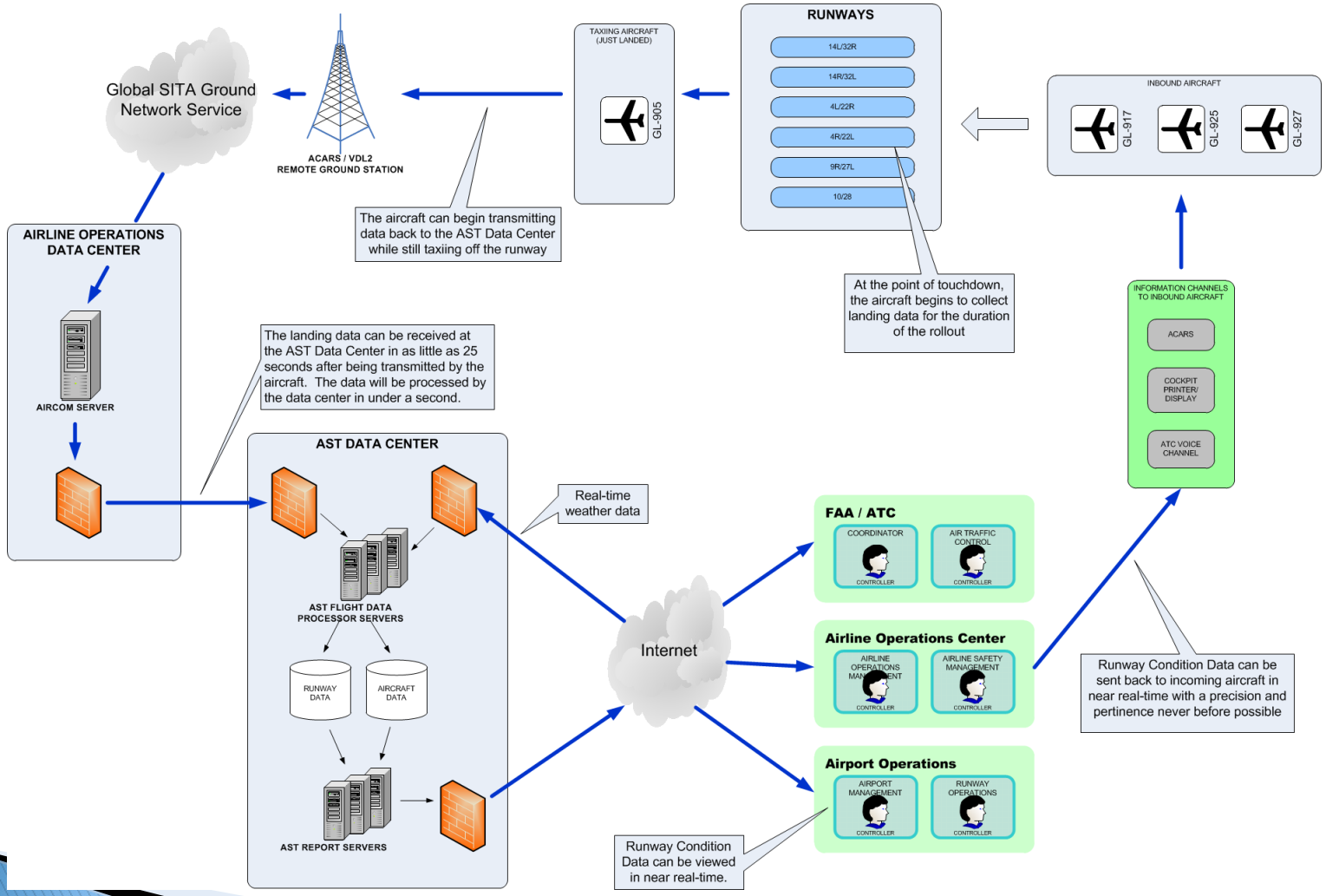
- Landing reports generated for any runway utilized, with minimal latency (60 seconds from end of roll out), presented in new TALPA nomenclature (Good, Good to Medium, Medium, Medium to Poor, etc)

- Connected fleets, AST upgraded weather capability, other technology enhancements provide a robust situational awareness advisory network

Underlying Technology Features

- 16 US patents, >25,000 hours of development time
- Reporting served via AST web portal, SMS/Web alerting, third party API via web services and direct API to airline/airport systems
- AST Data Center performs calculations < 1 second. Braking advisories available 40-80 seconds after landing rollout and data transmission off a/c
- AST developed higher fidelity, on-the-minute weather aggregation capability to increase landing report precision (vs METAR on the hour)
- Network architecture scalable for enhanced inputs (weather, contamination) and deliverables (friction forecast, FICONs, departure / load and balance advisories

Underlying Technology



Validation of Concept

- SafeLand is in its 5th year of operation on commercial passenger transport aircraft; series of prototyping exercises are in progress

  Carrier partners: Delta, American, Southwest, Alaska, JetBlue & United

- 1000+ aircraft connected, delivering >2,500 landings per day; over 2M landings to date, no operational interference (AA expanding to include former USAir Airbus fleet)

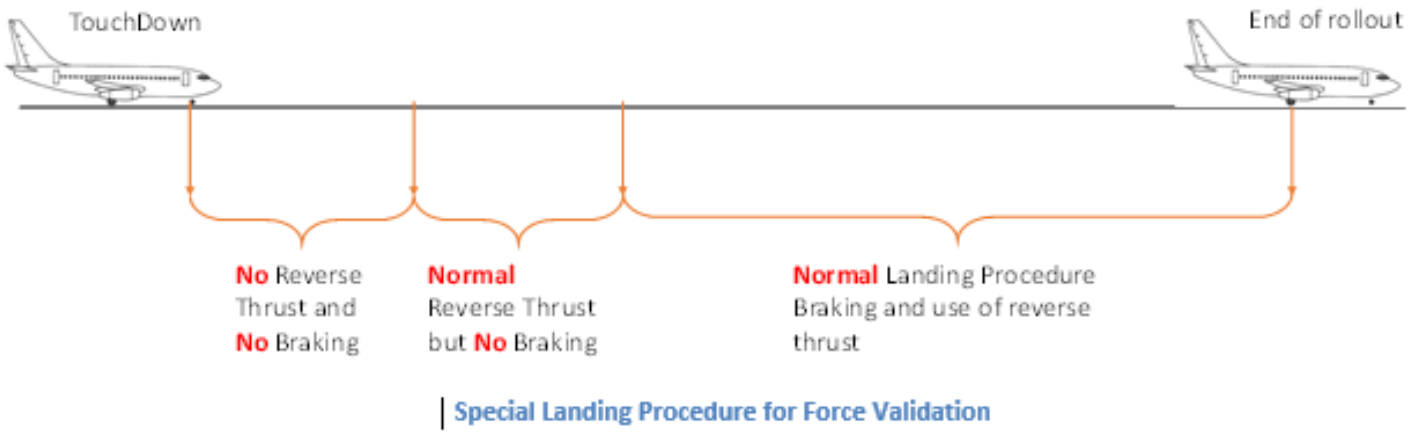
- FAA Grant: Determining Runway Friction Conditions in Real Time Using Data Obtained from Airplanes during Landing Rollout
  - Industry peer review validating technology and computational models, data analysis, system architecture, user assessments, NAS deployment recommendations
  - Sensitivity Analysis across all input variables

- Multi-year statistical analyses performed by Tom Yager, NASA runway condition specialist
  - Consistency in standardized Mu values across multiple aircraft types; very high correlation in Mu values from paired landings of different aircraft types on same runway, short intervals

Experienced Friction Model

Z-axis (Vertical)	Y-axis (Lateral)	X-axis (Longitudinal)
Net Load on braking tires (or Normal Force) =	Net Lateral Force (mass x lateral acceleration) =	Net Longitudinal Force (mass x longitudinal deceleration) =
Gravitational weight on tires	Effect of Crosswind	Effect of Reverse Thrust
+/- Effect of Bounce	+/- Effect of Rudder	+ Effect of Air Drag
- Effect of Wing Lift	+/- Effect of Steering	+ Effect of Rolling Resistance
- Effect of Brake Load Lift (transfer of weight from braking rear tires to non-braking front tires	+/- Effect of Lateral Runway Tilt	+ Effect of Contaminant Drag
	- Effect of Lateral Friction	+ Effect of Longitudinal Tilt
		+ Effect of Longitudinal Friction

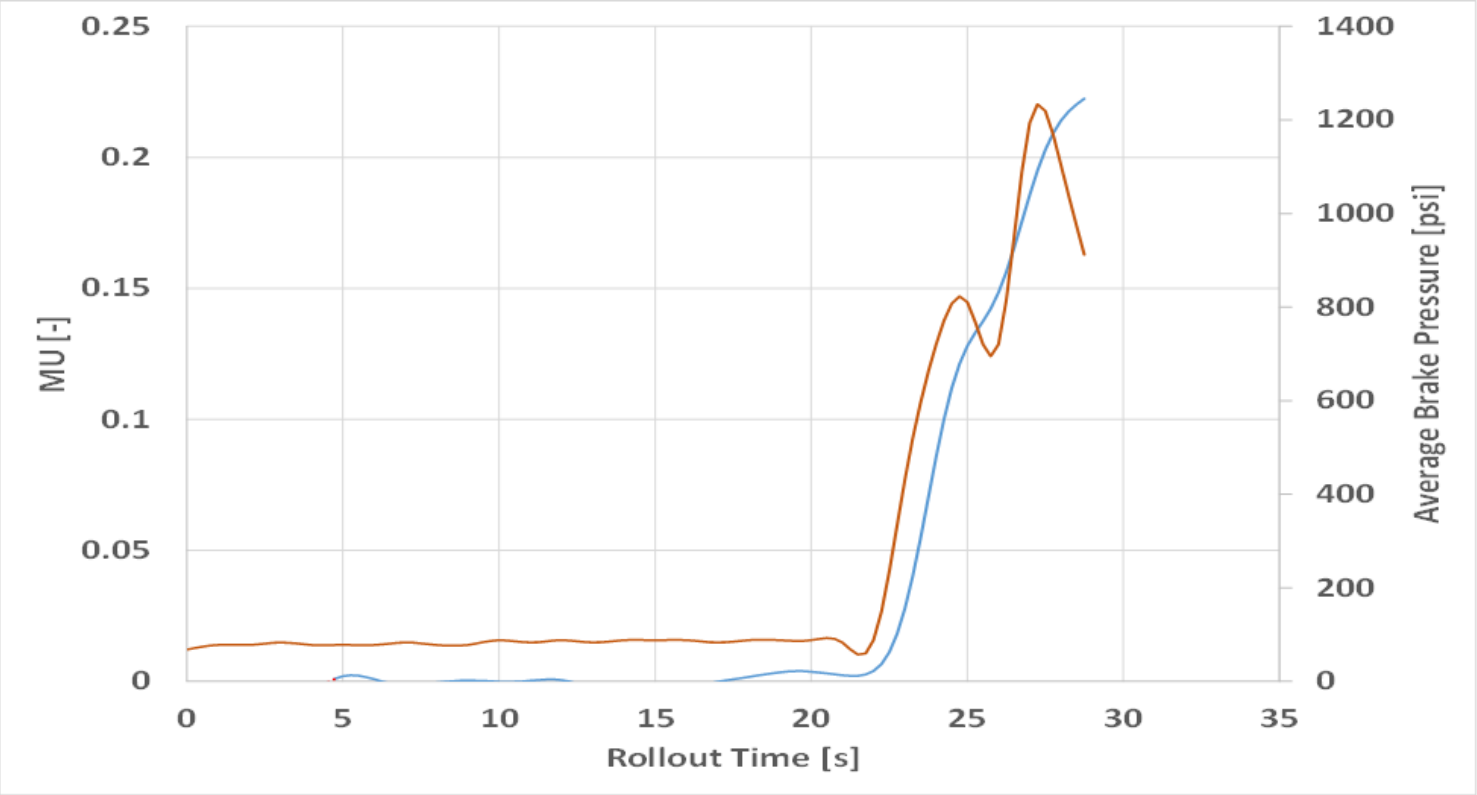
Experienced Friction Validation



Specific pilot action required to isolate a landing into segments

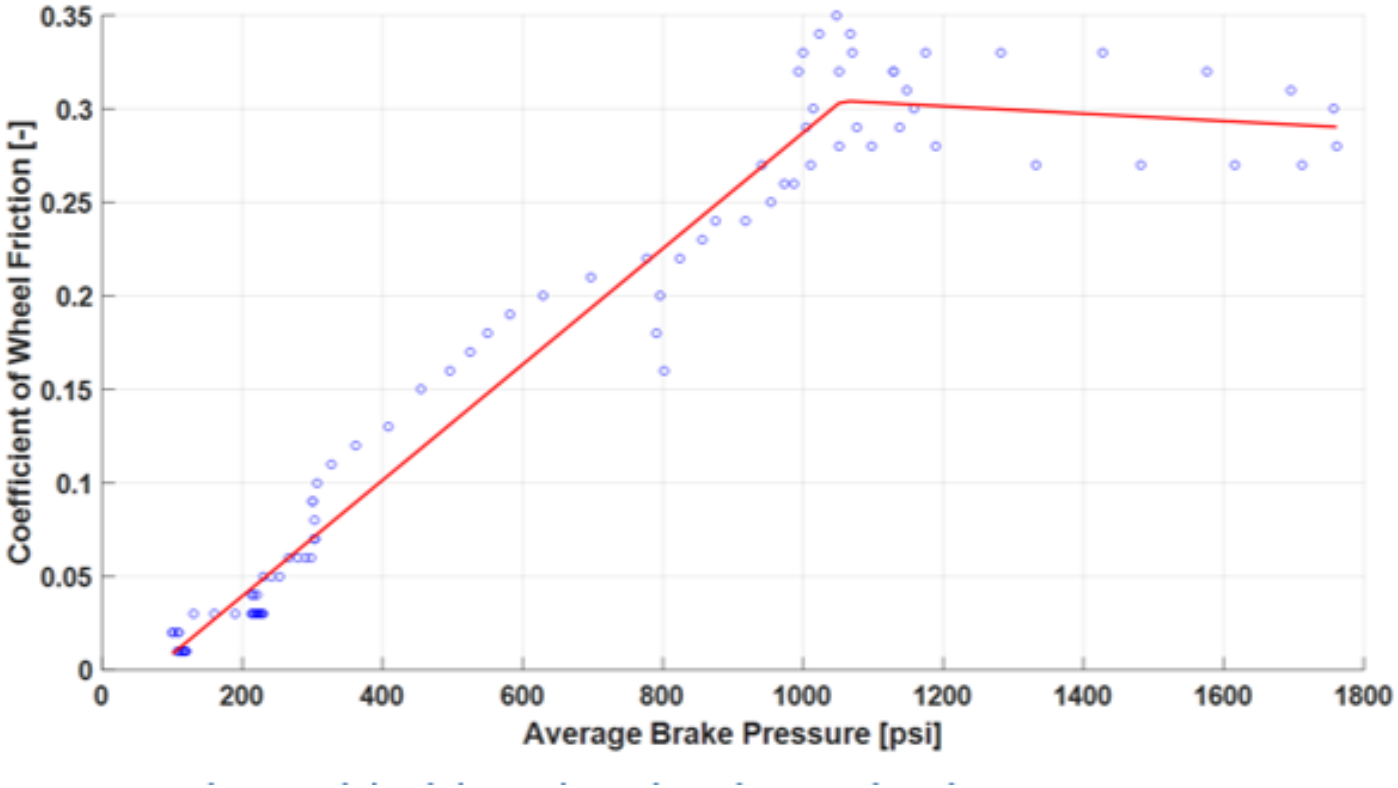
- After touchdown: no-hydraulic wheel braking and no thrust reverser
- Thrust reverser only
- TR + wheel braking

Friction Limit Detection



Example of friction (Left Axis) increasing as Brake Pressure increases

Friction Limit Validation



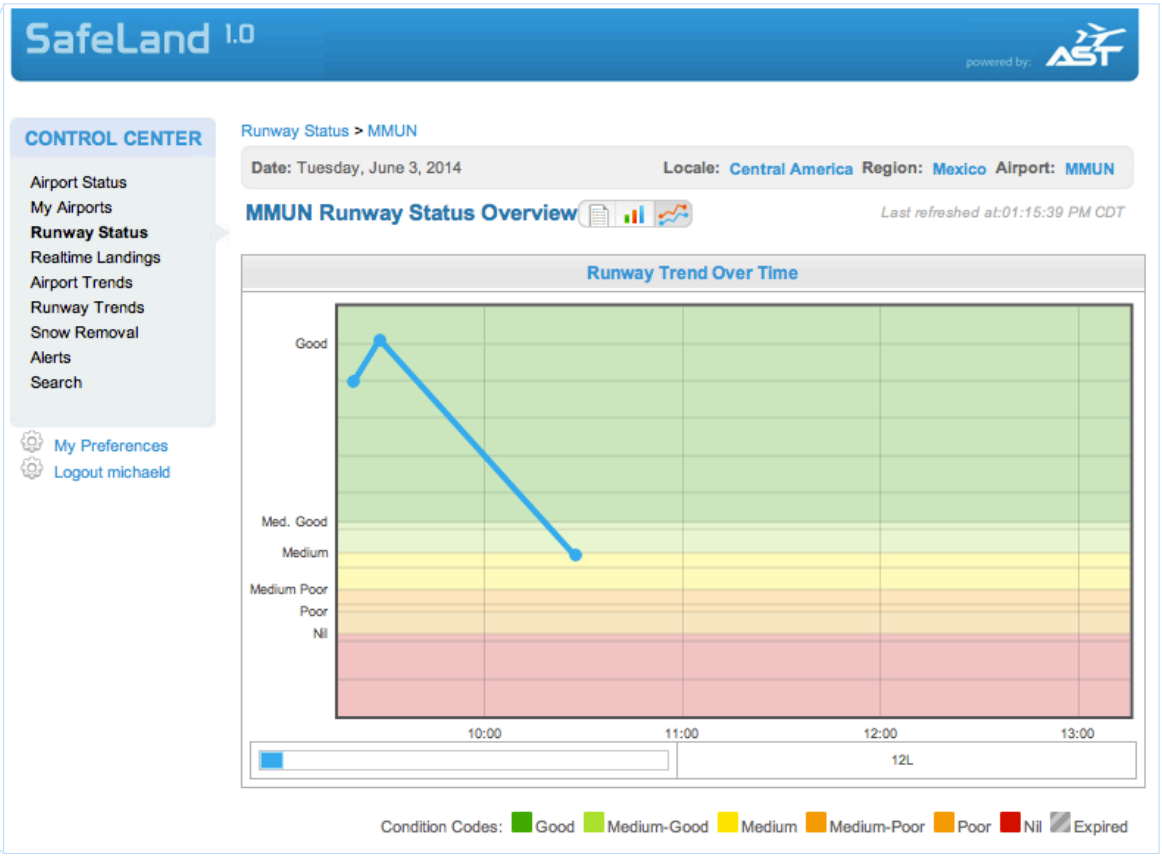
Example of a Friction Limited Landing where friction does not continue to increase despite brake pressure increasing

Functional Alerting

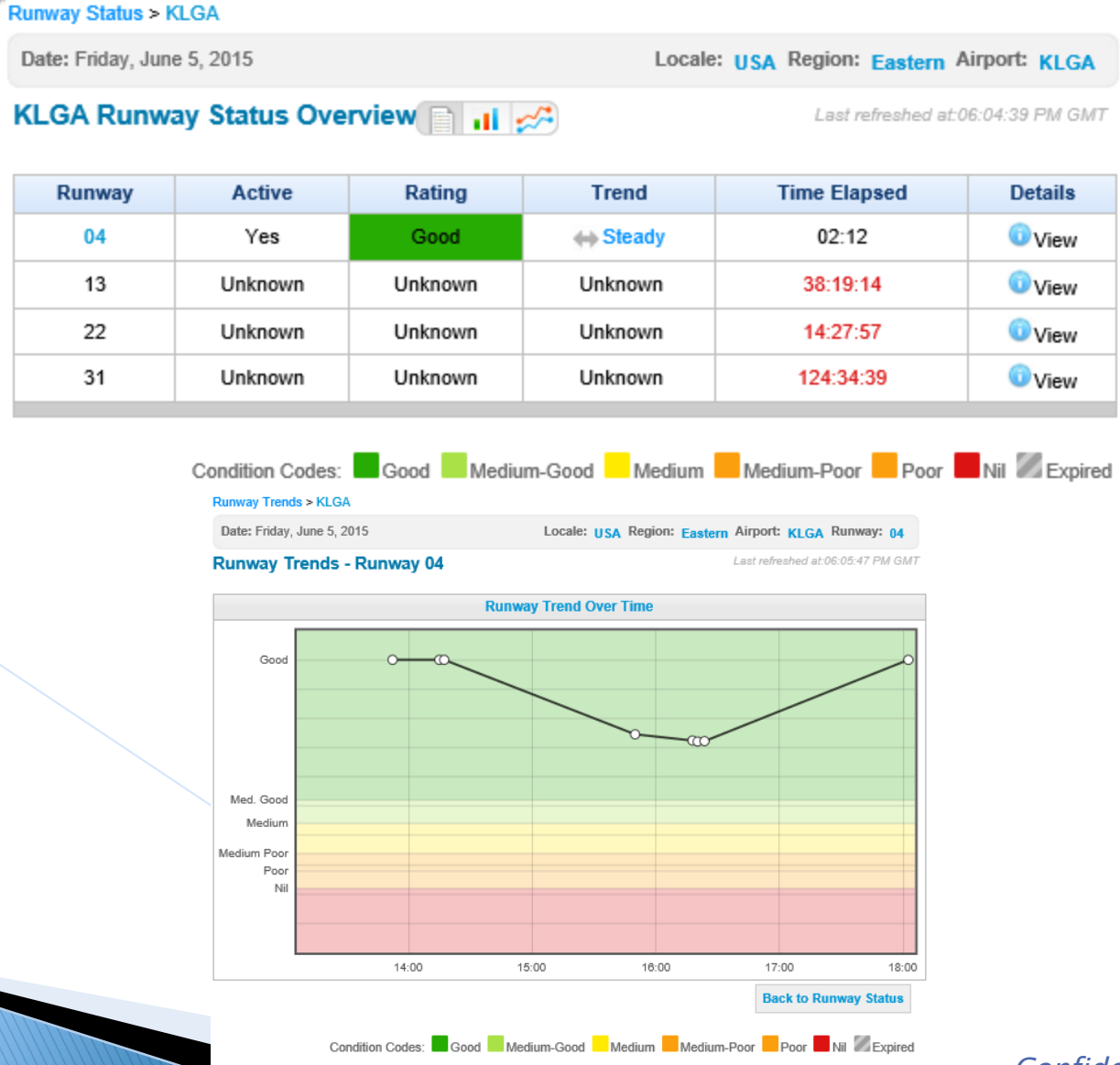
From: Alerts@avsafetech.com
Subject: **Low Mu Reported at MMUN on Runway 12L**
Date: June 1, 2014 12:34:59 PM CDT
To: Undisclosed recipients:;

Low Mu Reported at MMUN on 12L
Landing Time: 2014-06-01 12:32:56 CDT
Mu1: Medium (0.20)
Mu2: Medium (0.20)
Mu3: Medium (0.22)
Heavy RA
Temp: 26.0 C.
Air Press: 1012.0 mB
Hum: 94%
Press Alt: -5.0 ft.
Surf Temp: 35.83 C.
Wind: 6.95 Knots from 150 degrees

View Landing Details



Tabular or Graphic Display



Application Program Interface

AST's API

Third Party or Proprietary Airline Interface

AST Displays Experienced Friction when a Friction Limit has been detected

Airport	Date - Time	Runway	RCC
KCVG	6/27/2016 10:01:32 UTC	9	4 G-M

Operational Realities... AST solutions

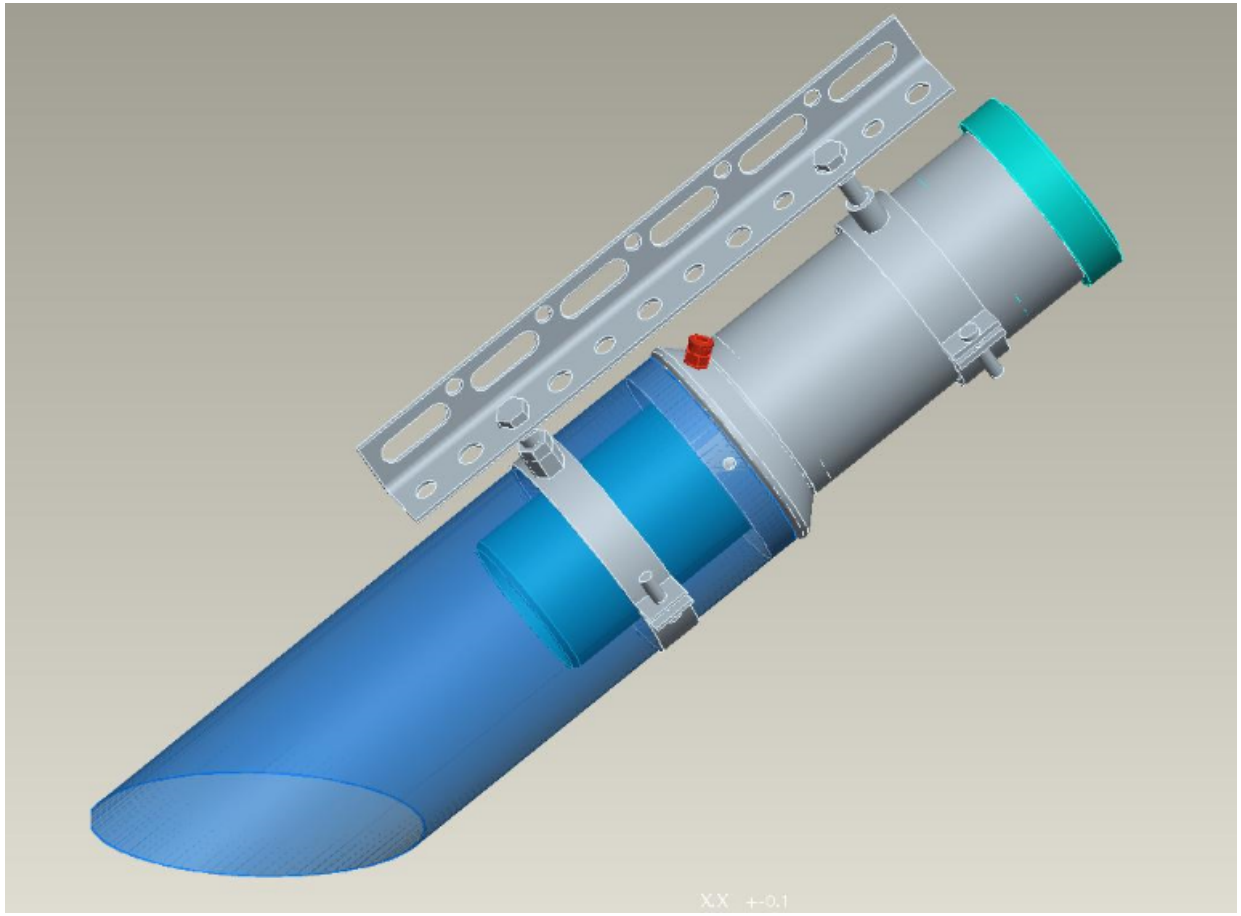
- PIREPS only cover "used" portion of the runway
- Roll-out section of take-off runway is not reported leading to sub-optimal overrun risk during rejected take-offs
- Low frequency airports do not have a sufficient number of landings to make high quality, verifiable assessments
- Ground device friction measurement takes time and closes runway from use-and results are suspect due to lack of correlation and FAA does not recommend CFME's for operational decision making
- Introduction of new processes: TALPA, SAFO Issued (landing distance assessment, reinforced FICON / NOTAM process), NTSB recommendations to FAA

New AST Tools

- Upgraded Weather Reporting System – can refresh on the minute versus hourly METAR and SPECIs -- Weather Data Fidelity enables very high precision landing simulation + friction forecasting capability
  - Supplements ASOS – 1 minute & 5 minute reporting
- AST is testing new runway contaminant sensor technology that can uplink runway condition data into SafeLand computational models
- Sensor Data can define surface characterization for end of landing runway, full-length of departures runways, turnoffs, taxiways and ramps
- Data can be packaged in FICON format, produced real time
- Contaminant characterization dramatically impacts take off overrun risk and provides precise inputs for load / balance computations of carrier

SafeScan Contaminate Detector

AST is testing new runway contaminant sensor technology that can uplink runway condition data into SafeLand computational models. I



Contaminant Detector

- SafeScan Data can define surface characterization for end of landing runway, full length departures runway, turnoffs, taxiways and ramps

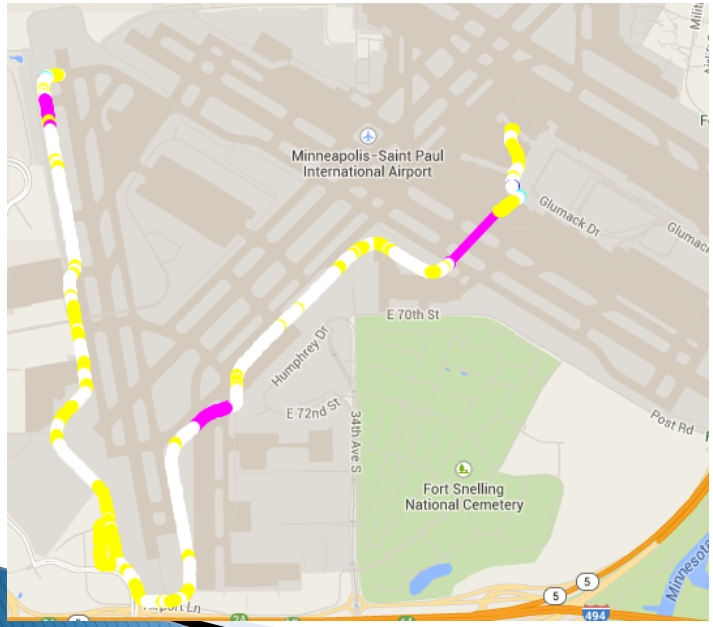
SafeScan Contaminant Sensor

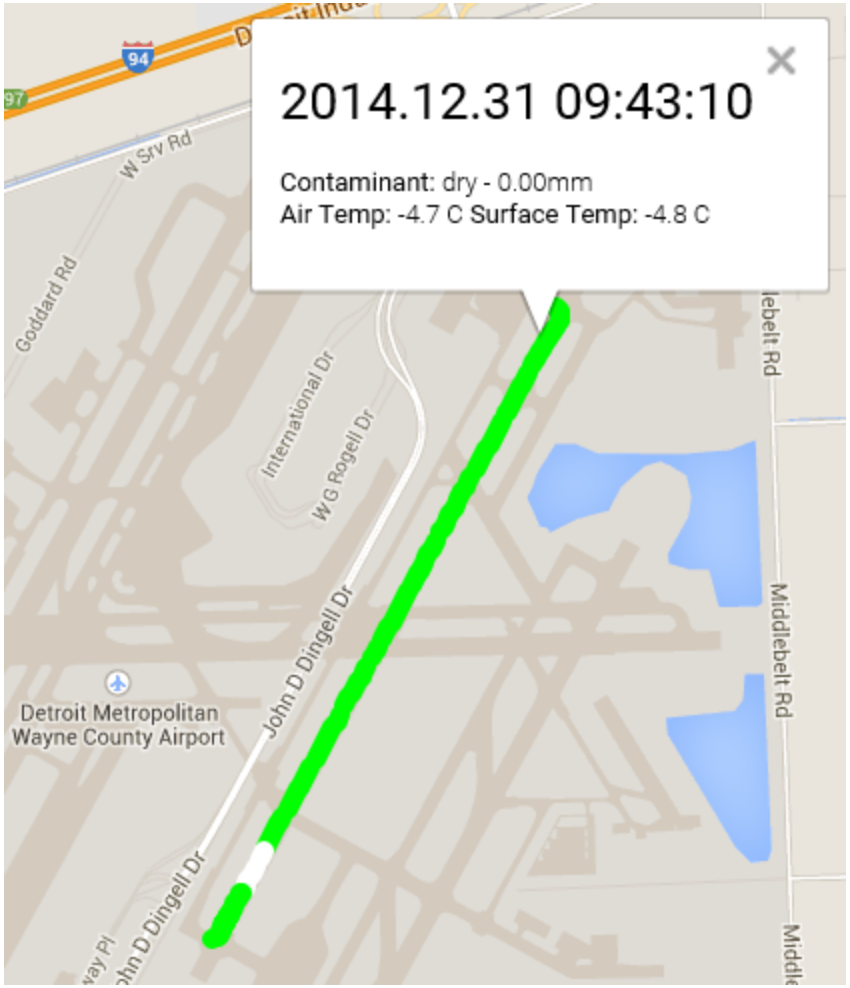
SafeScan Contaminant Sensor

SafeScan Output Display

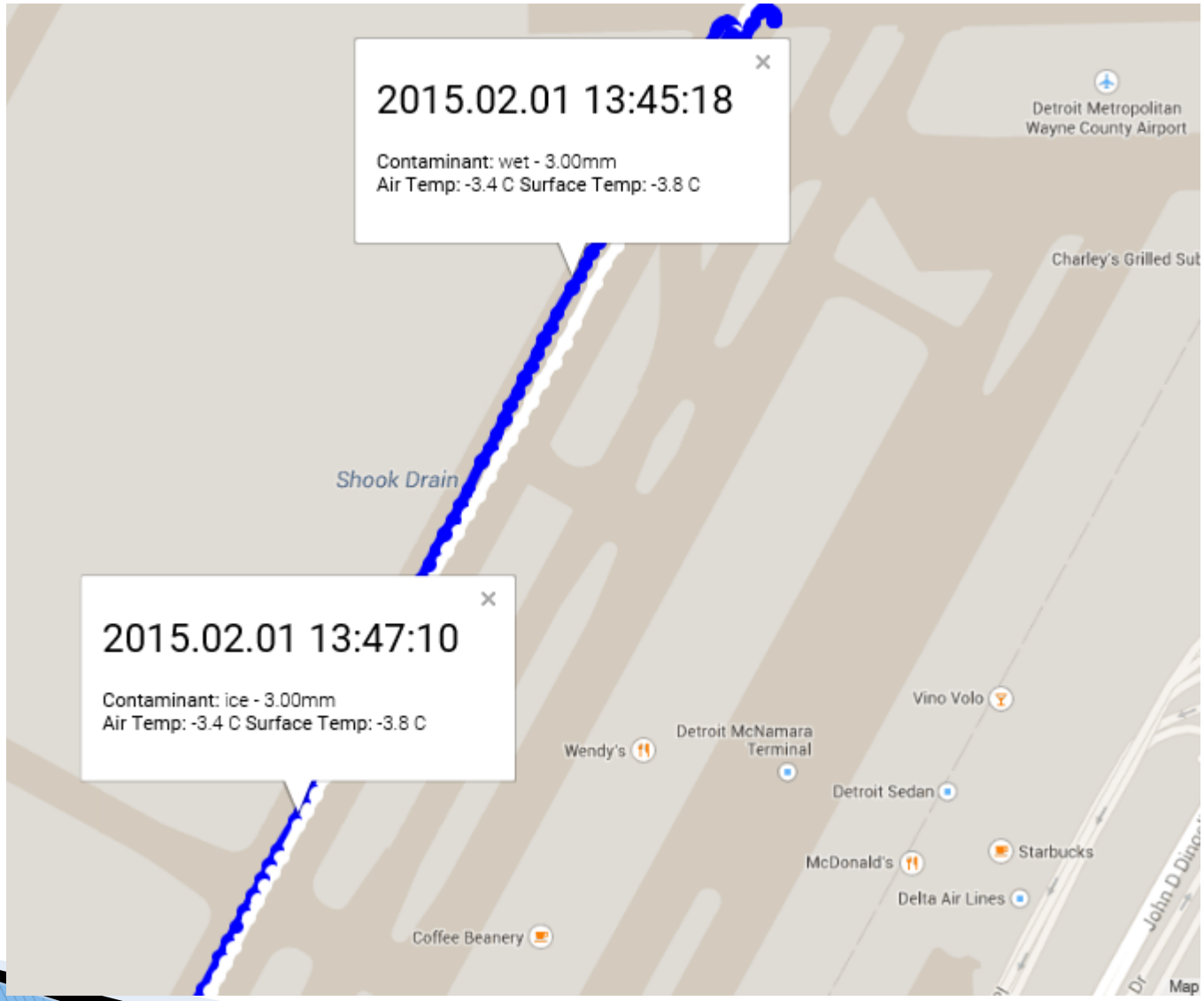
WEB-Based Display

- Color coded for contaminate type
- Ramps / Taxi-ways
- Runways
- Click on display for detail





Multiple passes on a runway



Tabular Format
TALPA RCAM Notation

User Display

Time	Runway	RCAM 1/3		RCAM 2/3		RCAM 3/3		Recommended
		Code	Coverage	Code	Coverage	Code	Coverage	Treatment
8:12:00 AM	12R	3	35%	4	45%	3	65%	Potasium Acetate
		Snow: 1.2mm Surf. Temp.: -3C Air Temp.: -9C		Snow+Slush: 0.8mm Surf. Temp.: -4C Air Temp.: -9C		Slush: 1.6mm Surf. Temp.: -3C Air Temp.: -9C		

MAP TO RCAM VALUES

Airport Operator Assessment Criteria		Control/Braking Assessment Criteria	
Runway Condition Description	**Code**	**Deceleration or Directional Control Observation**	**Pilot Reported Braking Action**
• Dry	6	---	---
• Frost • Wet (includes damp and less than 1/8 inch depth of water) ***Less than 1/8 inch (3mm) depth of:*** • Slush • Dry Snow • Wet Snow	5	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	Good
-15°C and Colder outside air temperature: • Compacted Snow	4	Braking deceleration OR directional control is between Good and Medium.	Good to Medium
• Slippery When Wet (wet runway) • Dry Snow or Wet Snow (any depth) over Compacted Snow ***1/8 inch depth or greater of:*** • Dry Snow • Wet Snow ***Warmer than -15°C outside air temperature:*** • Compacted Snow	3	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	Medium
1/8 inch depth or greater of: • Water • Slush	2	Braking deceleration OR directional control is between Medium and Poor.	Medium to Poor
• Ice	1	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	Poor
• Wet Ice • Water on top of Compacted Snow • Dry Snow or Wet Snow over Ice	0	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	Nil

Operational Impact....pg 1

- Common situational awareness of actual values in near real time creates significant safety and operational value to airports, carriers, ATO. Enables proactive planning in all operating phases of runway management, contributes significant economic impact
- Optimized landing set-up: lower fuel burn, safe taxi speeds
- Shorter runway / airport closure periods
- Avoidance of closure during high traffic through collaboration with ATO, A/P.
- Airborne speed control vs. holding
- Higher payload when applying clutter due to increased accuracy of contaminate measurement.

Operational Impact....pg 2

- Diversion avoidance – reduced loss of slots
- Gate management and ground holds
- Reliability: Additional throughput vs. current
  - Fewer passenger delays, re-book / re-route and related costs, baggage fees
  - Of 77 ASPM (Pacing) airports, 21 have acute surface delays 60 days per year or more
- Airport Cost Savings: Optimization of chemical treatment
- Community Impact: i.e MSP is a $10.1 Billion annual economic engine for the region – translating to $28M/daily, $1.2M/hourly

Summary

- Real-time surface friction reporting provides revolutionary safety awareness benefits, reduces risk of runway excursions, contributes to operational efficiencies

- Access to SafeLand UI provided at minimal cost to carrier partners. Airport subscriptions primarily pay to operate network and reporting system, offset by airport savings. Can contribute payback to major carriers in US of tens of million $$ each through improved schedule reliability and waterfall of benefits

- Focus on pacing airports with chronic surface delays first, scale to all 77 ASPM airports, providing landing frequency in 30 minute intervals of less; 'System View' offered to 3,000 landing facilities

- Carriers will need to get behind wide adoption to create meaningful landing frequency, optimized outcomes

- Technology advances include friction forecasting, departure / load advisories, improved FICON systems

Questions