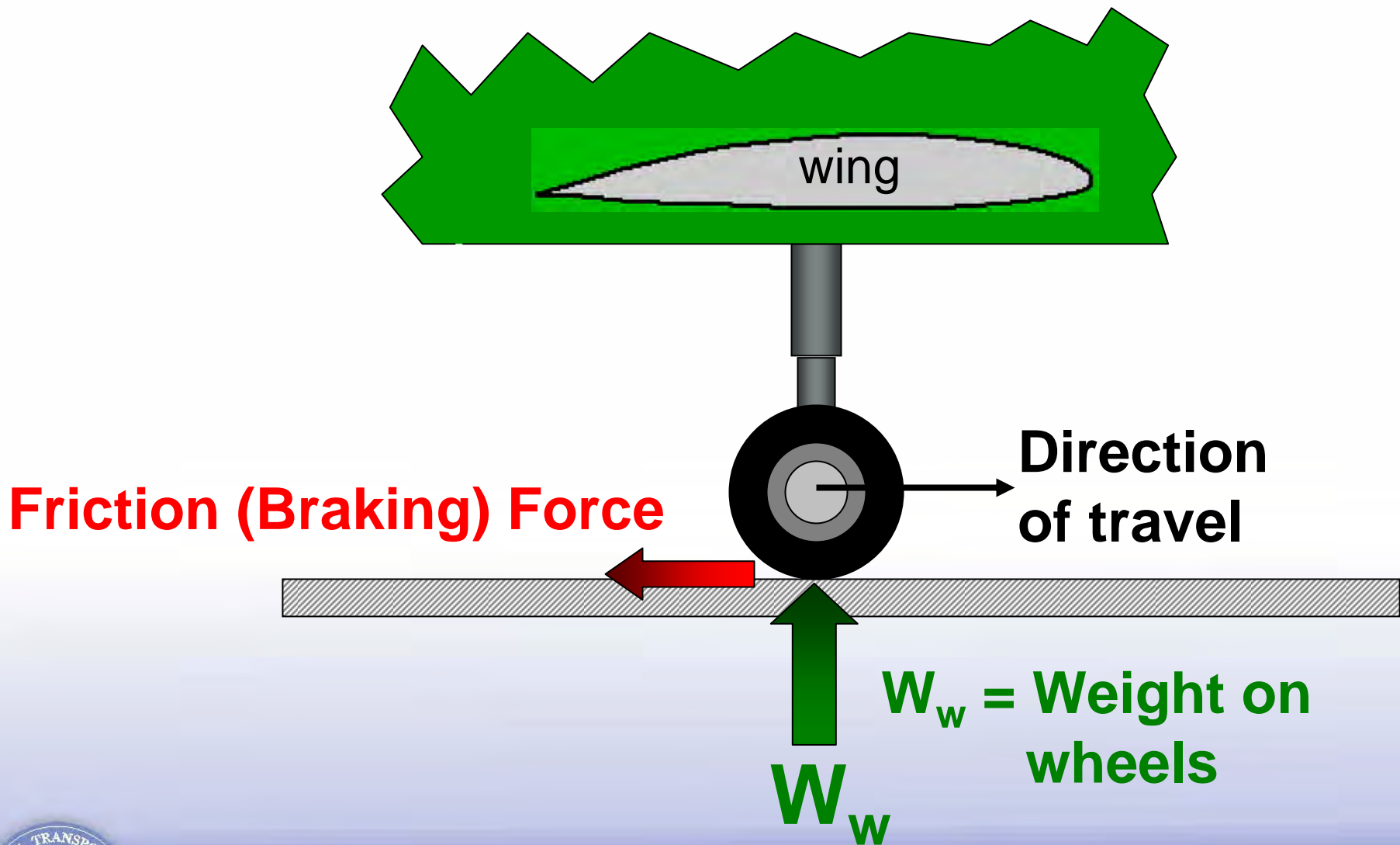


# **The Effect of Spoiler Deflection On Airplane Braking Performance**

**John J. O'Callaghan  
National Resource Specialist – Aircraft Performance  
Office of Research and Engineering**

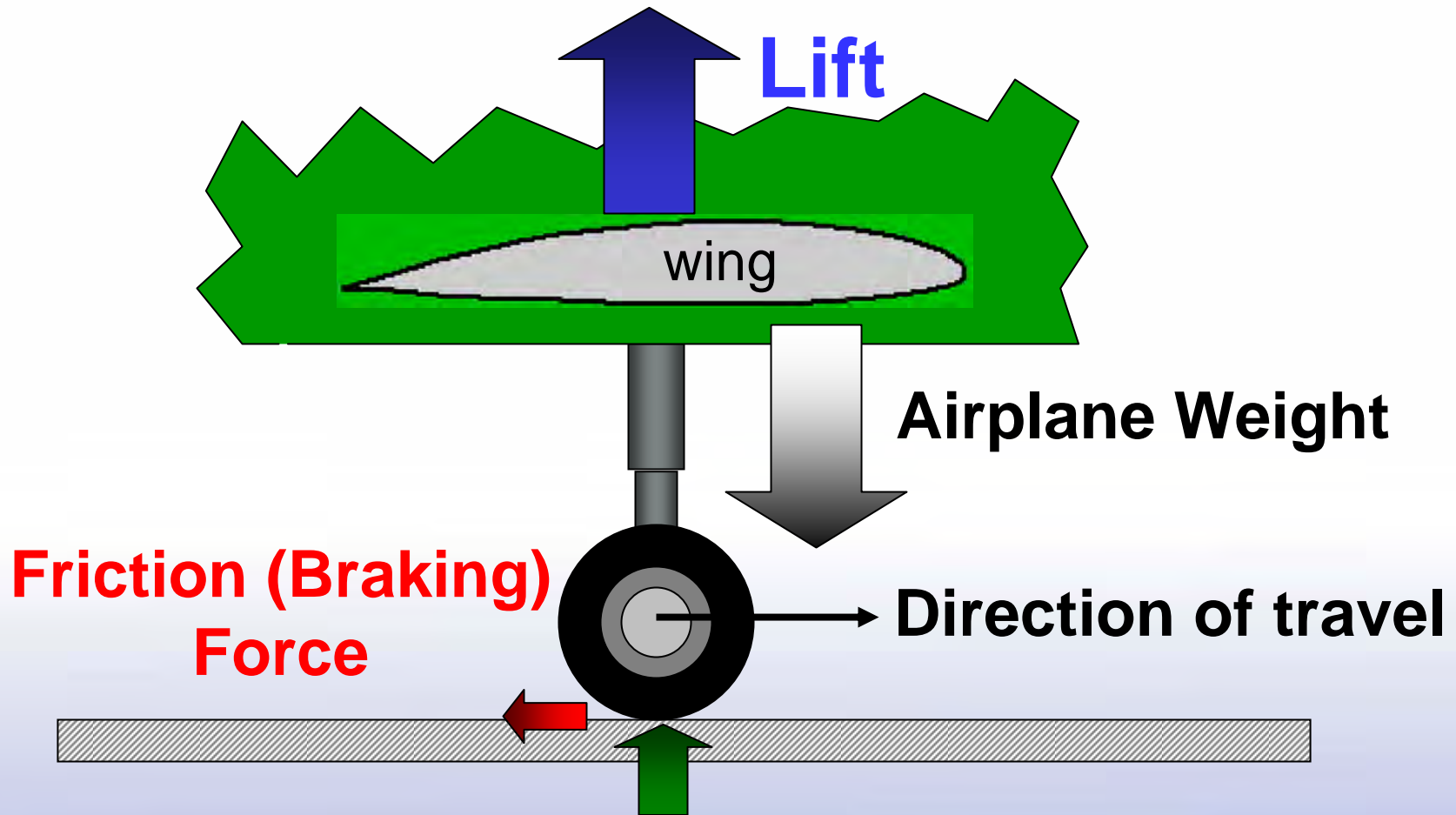


# Braking Forces on a Tire



# Braking Forces on a Tire: Spoilers Stowed

Wing lift reduces weight on wheels and braking force

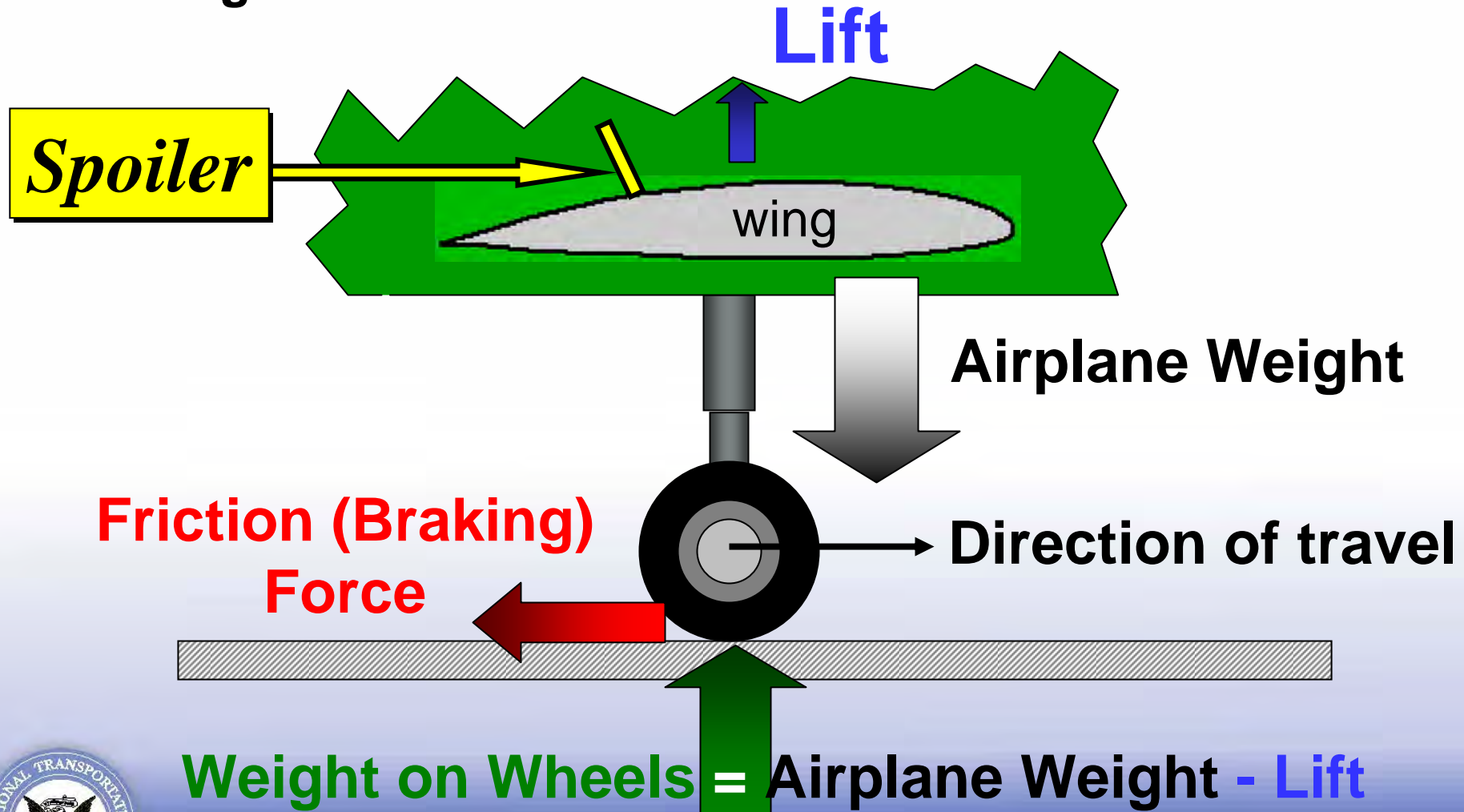


$$\text{Weight on Wheels} = \text{Airplane Weight} - \text{Lift}$$

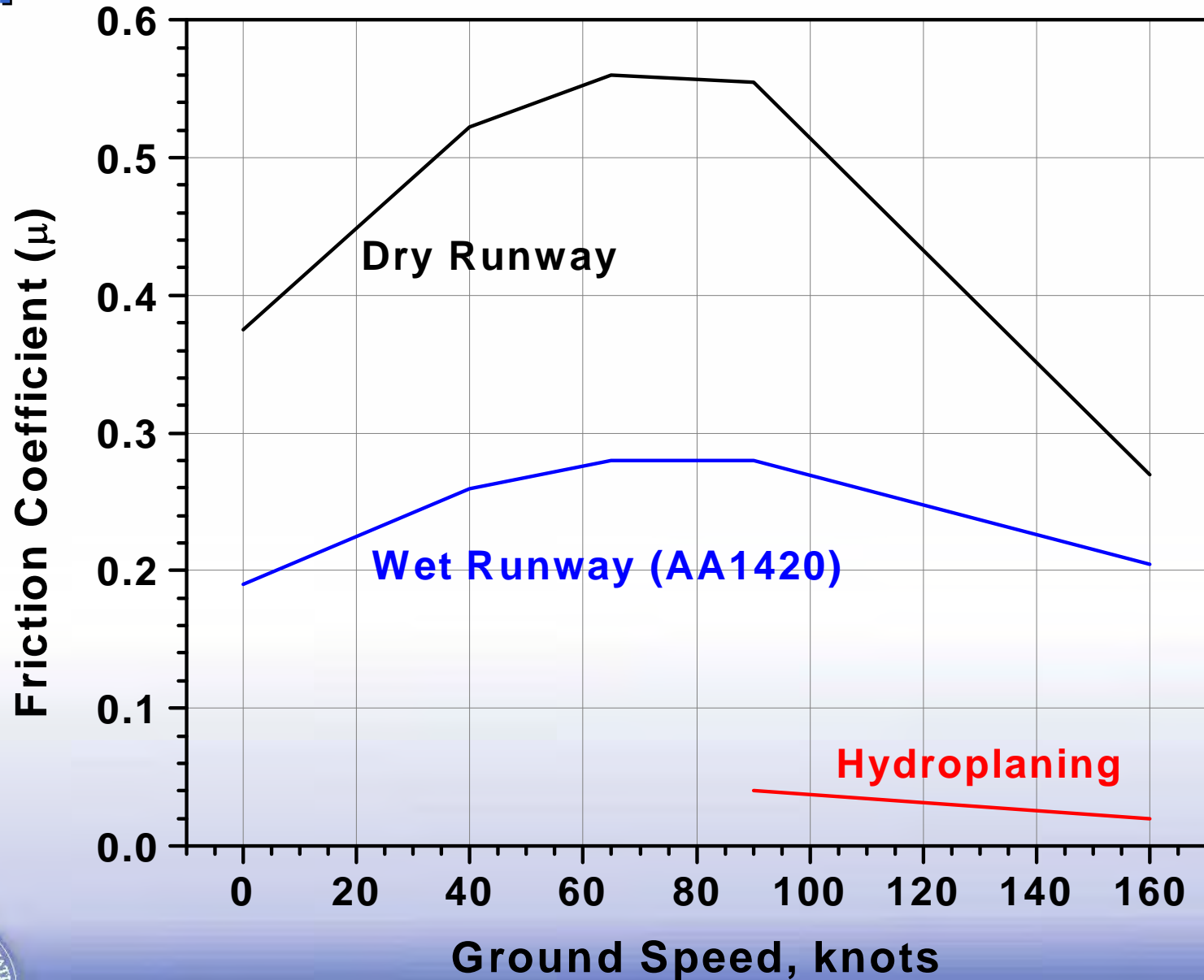


# Braking Forces on a Tire: Spoilers Deployed

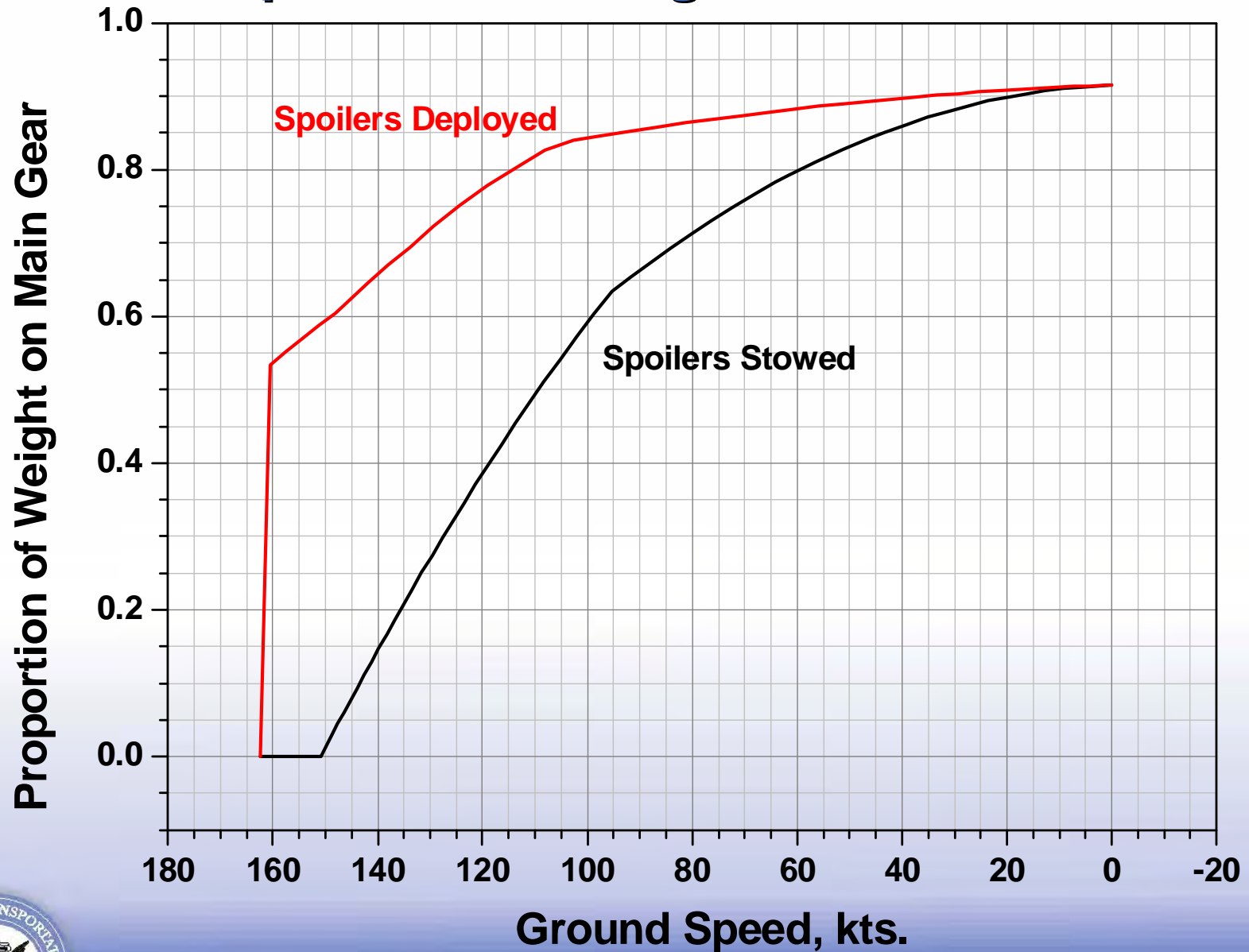
Spoilers reduce lift, increasing weight on wheels and braking force



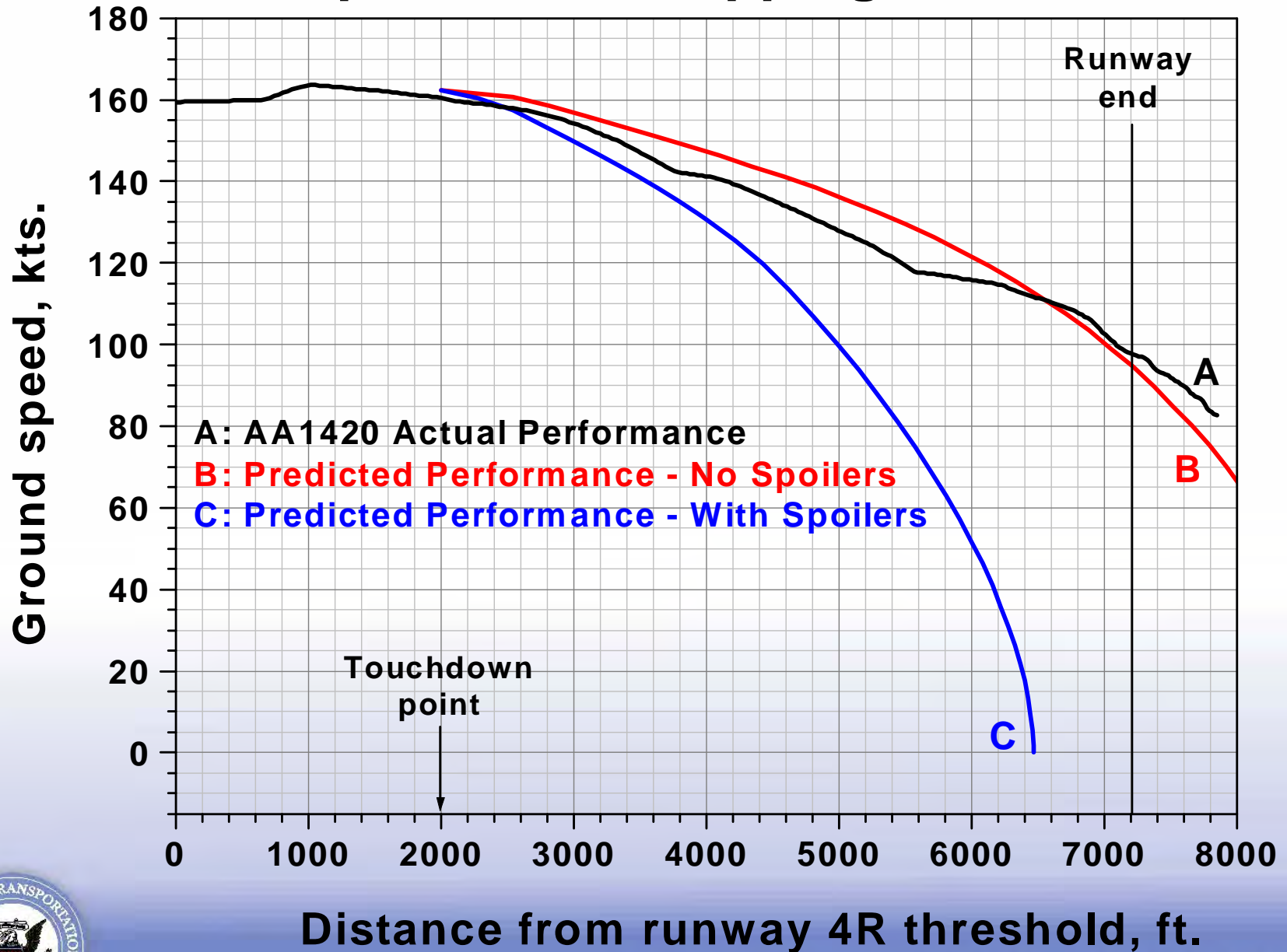
# Typical Values of the Friction Coefficient $\mu$



# Effect of Spoilers on Weight on Wheels: AA1420



# Effect of Spoilers on Stopping Performance



# **The Effect of Spoiler Deflection On Airplane Braking Performance**

**John J. O'Callaghan  
National Resource Specialist – Aircraft Performance  
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# Flight Crew Performance: Operational Factors

Captain Dave Tew  
Operational Factors Investigator



# OPERATIONAL ISSUES

- Spoilers
- Crosswind Limits for Landing
- Stabilized Approach Guidance
- Rudder Blanking
- Braking



# SPOILERS ARMED FOR LANDING

- Training and normal operating inconsistencies
- Neither pilot armed the spoilers
- Checklist did not require confirmation by the captain and first officer



# CROSSWIND LANDING LIMITS

- Determined by runway conditions or runway visual range (RVR)
- Several wind reports given to the crew during the approach that exceeded AA landing limitations
- **Result**: Crosswind limitation for landing was exceeded



# STABILIZED APPROACH PROCEDURES

- **Required**: Airplane configured to final flap setting prior to descending below 1,000 feet above field level (AFL) in instrument meteorological conditions (IMC)
- **Actual**: Final flap setting not completed until about 900 feet AFL - first officer prompted captain



# STABILIZED APPROACH PROCEDURES

- **Required**: Airplane remain on proper flight path below 1,000 feet above field level (AFL)
- Acceptable deviations from flight path not defined
- First officer believed flight was unstabilized at about 400 feet AFL



# SPOILERS

- If armed - extend automatically after landing
- Not armed prior to landing
- No automatic or manual extension occurred after landing
- No verbal confirmation of extension or non-extension required
- No verbal spoiler announcement recorded on CVR



# REVERSE THRUST

- Reverse thrust normally limited to 1.6 engine pressure ratio (EPR) power setting
- Excessive reverse thrust causes directional control problems –one is that it blanks out the rudder affecting rudder efficiency
- AA - reverse thrust limited to 1.3 EPR on slippery runway





# REVERSE THRUST

- CVR - no discussion of reverse thrust limits prior to landing
- FDR - left engine reached 1.98 EPR & right engine reached 1.74 EPR
- CVR - no recognition by crew that reverse thrust limitations exceeded



# BRAKING

- AA - Max autobrakes or aggressive manual braking on short, slippery runway
- Captain elected to use manual braking
- 5 & 10 seconds after touchdown before brake pedals began to move
- 11 seconds after touchdown before full braking was applied
- Max Autobrakes activate 1-2 seconds after touchdown and braking continuously applied



# Flight Crew Performance: Operational Factors

Captain Dave Tew  
Operational Factors Investigator



National Transportation Safety Board

# **Flight Crew Performance: Human Factors**

Evan Byrne, Ph.D.

Human Performance Investigator



# Reasons for Degraded Performance

- Fatigue
- Approaching thunderstorms



# Evidence for Fatigue - Conditions

- Cumulative sleep loss
- Continuous hours of wakefulness
- Circadian disruption



# Evidence for Fatigue - Conditions

- Cumulative sleep loss: ***no factor***
- Continuous hours of wakefulness: ***at least 16 hours***
- Circadian disruption: ***accident occurred 2 hours past normal bedtime***



# Evidence for Fatigue – Outcome

- Performance errors
  - Checklists (*spoiler not armed*)
  - Recall (*final flap setting confusion*)
  - Information processing (*wind readback error*)
- Decision-making





# Role of Approaching Thunderstorms

- Threat to be addressed
- Created additional workload
- Required directed attention



# Improper Decision-Making

- Workload and stress can degrade decision-making via:
  - narrowing of attention
  - incomplete situation assessment
  - increased tendency to continue with original plan



# Reasons for Degraded Performance

- Fatigue and the effects of the crew's response to the weather threat were factors
- Relative contribution of these factors cannot be determined



# Industry Standards & Practices



# Industry Standards & Practices

- Avoidance of thunderstorms is advocated
- Thunderstorm penetration has occurred
  - Accidents and incidents
  - Research using operational data



# Industry Standards & Practices MIT Study

- NASA-sponsored research conducted by Massachusetts Institute of Technology's Lincoln Laboratory
- Examined air carrier operations approaching Dallas-Fort Worth International Airport when thunderstorms were in the terminal area

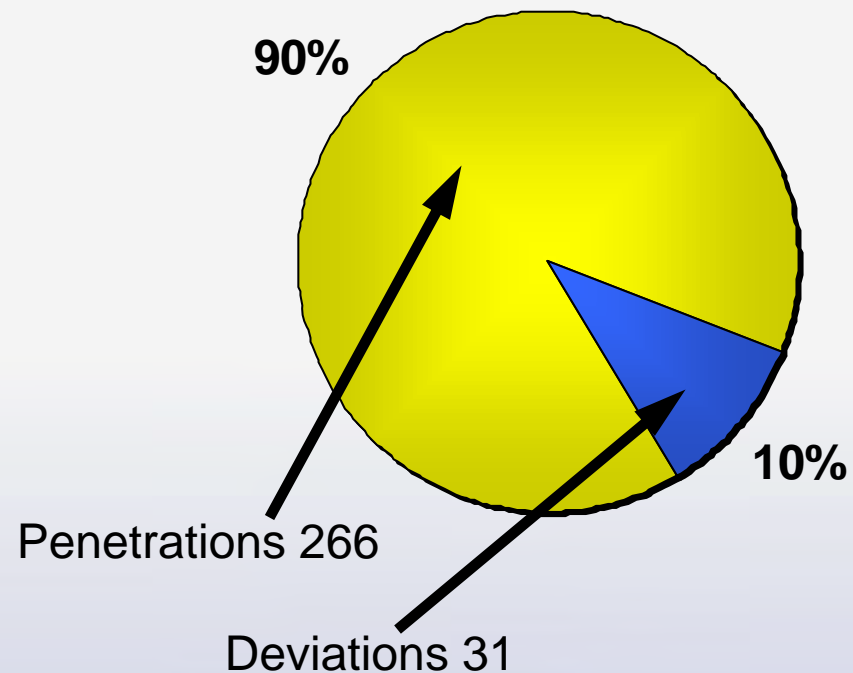


# Industry Standards & Practices

## MIT Study

- Most of the encounters near the destination airport resulted in penetrations rather than deviations
- Penetrations were more likely when airplane was:
  - following another airplane
  - behind schedule
  - flying after dark

**Encounters With Level 3, 4, & 5 Returns Within 13.5nm of Airport**



(Rhoda & Pawlak, 1999)



# Industry Standards & Practices

## Operational Guidance

- Guidance is provided on thunderstorm avoidance
  - General advisory information
  - Specific operational guidance
- Specific operational guidance and criteria can facilitate flight crew decision-making under adverse situations

