Airfield Frangibility Criteria
Questions and Concerns with Current Standards

IES ALC

Orlando, Florida
October 21, 2014

Presenters

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- Daniel Duke, Ph.D., P.E., Principal Engineer, TriDynamic Solutions, Inc, Pell City, Alabama
- Clint Rooks, Program Manager/ME, Select Engineering Services, Layton, Utah

Thank You

JAFSG

JAFSG – Joint Airfield Frangibility Study Group

USAF – AFCESA,

Robert Dinan, Ph.D., P.E

USACE

John B. Gregory, P.E.

FAA

Joseph Breen, P.E.

Objectives

- Life safety
- Mitigate damage to aircraft
- Technically well founded
- Clearly understood
- Limits and suitability of application
- Consistency
  - Analytical methods and results
  - Test configurations, instrumentation
  - Report requirements
- Realistic and accepted

Questions and Concerns Overview

Dan Duke

Historical Summary

- Began in the 1970's (FAA, NASA, NAEC)
- Resulted in FAA's LIR ALS – Early 80's

- International
  - FASG – 6 meetings 1983 – 2003
    - Primarily: Canada, Netherlands, Sweden, USA
    - Last Meeting: Canada, Netherlands, USA
    - Limited Participation: Finland, Germany, New Zealand
  - ICAO – Aerodrome Design Manual, Part 6 Frangibility, 2006

- Detailed History - Jaap Wiggenraad, MsC, Ph. D.

Acknowledgement

- Non-trivial problem
- Significant commitment of resources
- Very capable people and organizations
- May have had access to information that we don’t have

Background Information

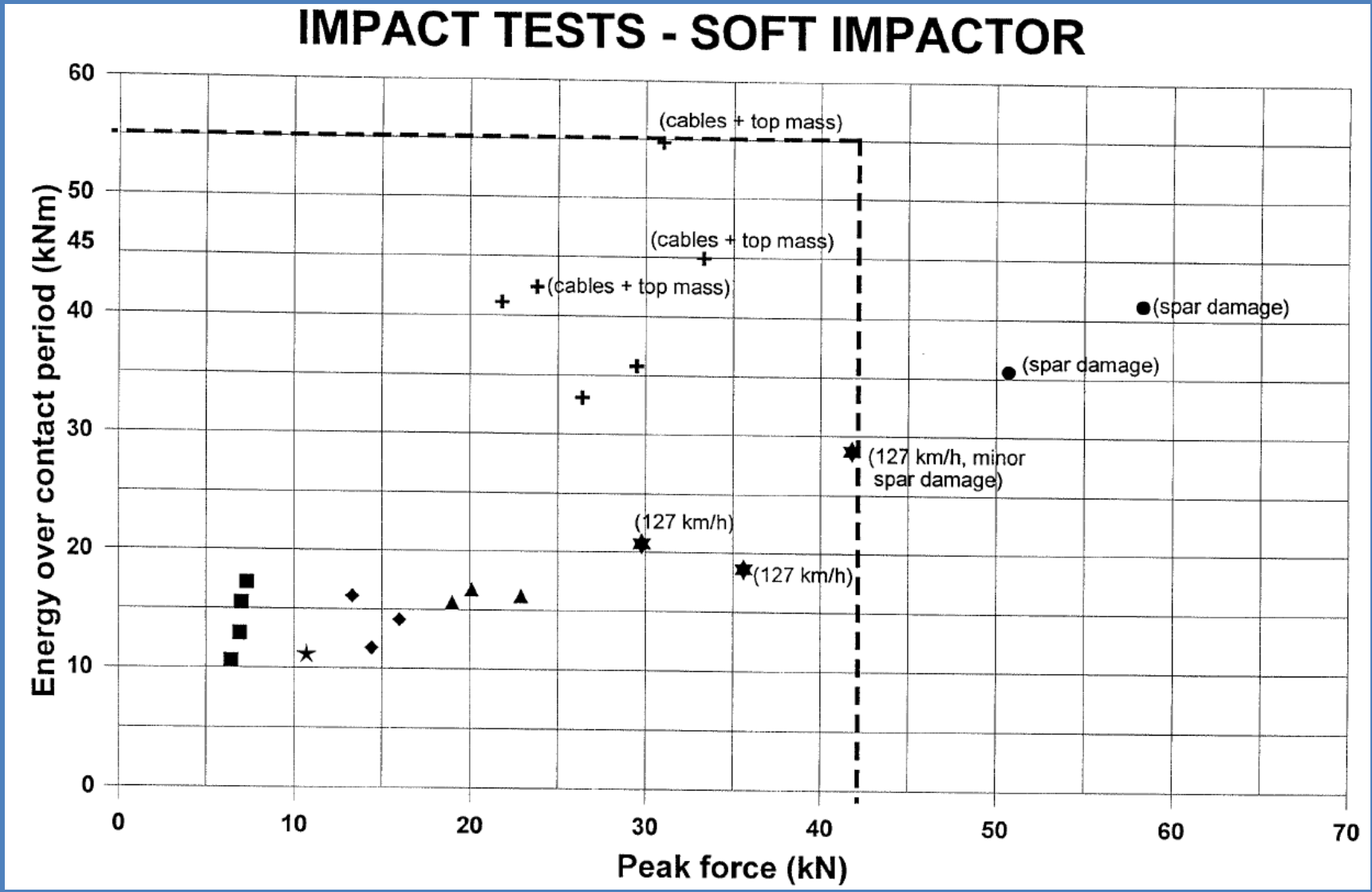
Frangible Object
(ICAO Definition)

An object of **low mass** designed to **break, distort or yield** on impact so as to present the **minimum hazard** to aircraft

Some Key Points from ICAO

- Impact tests using rigid impactor (thick-walled steel cylinder)
- Top 12 m required to be frangible
- Test impact height 1m from the top
- Pass / fail based on measured forces

From FASG Meeting 5



ICAO Pass / Fail Criteria

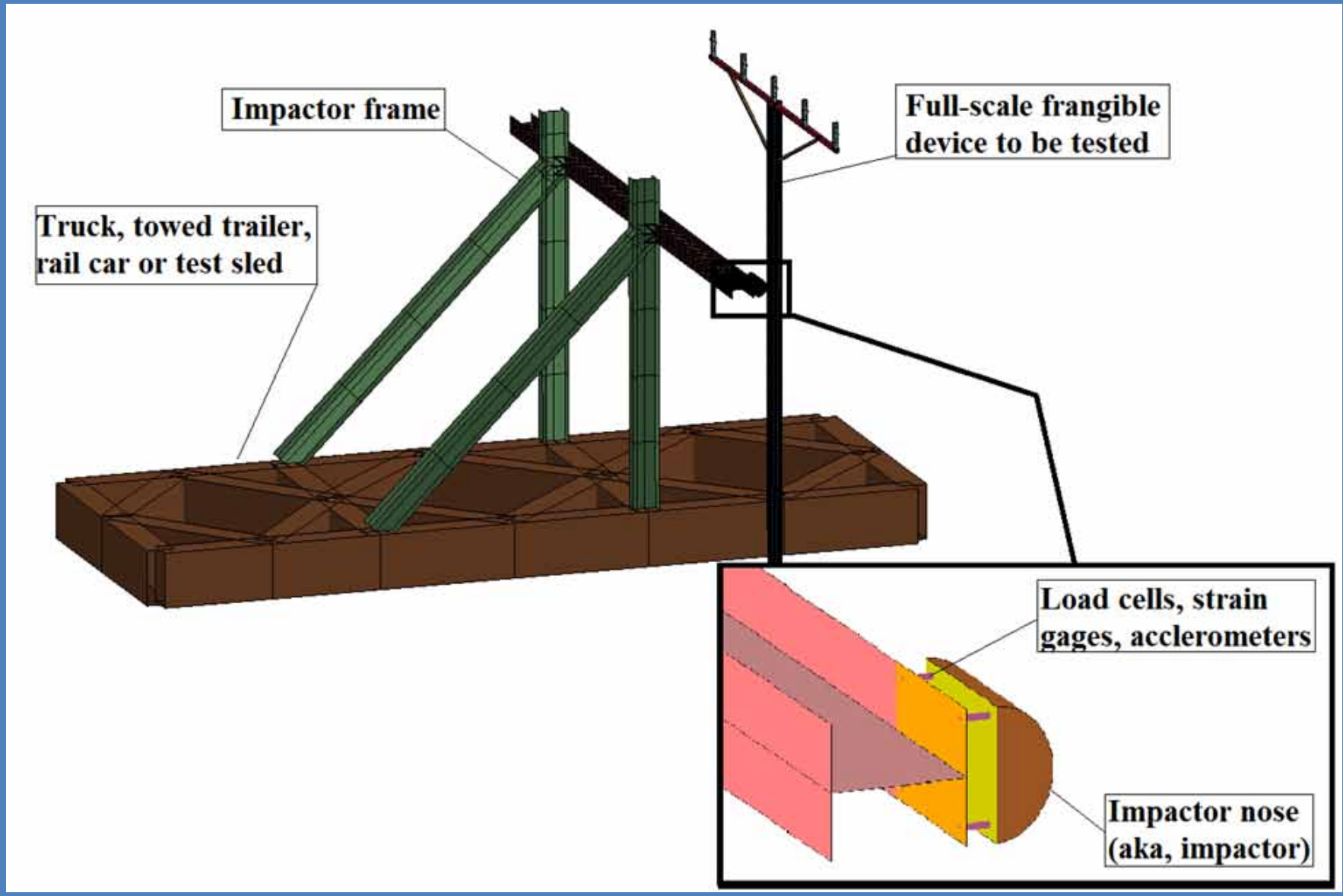
- Based on
  - Peak Force Limit = 45 kN ~10,100 lb
  - Energy
    - Calculated from Force Plot
    - Limit = 55 kJ ~ 40,600 ft-lb

Questions and Concerns

Seeking to Clarify and Improve

- Impactor assembly – structural dynamic response
- Vertical forces on impactor
- Soft vs rigid impactor (surrogate wing)
- Impact height on device
- Original failure criteria revisited (main spar)
- Flight stability
- Material property concerns
- Data measurement and reduction
- Analytical models
- Documentation

Anatomy of Impactor Assembly

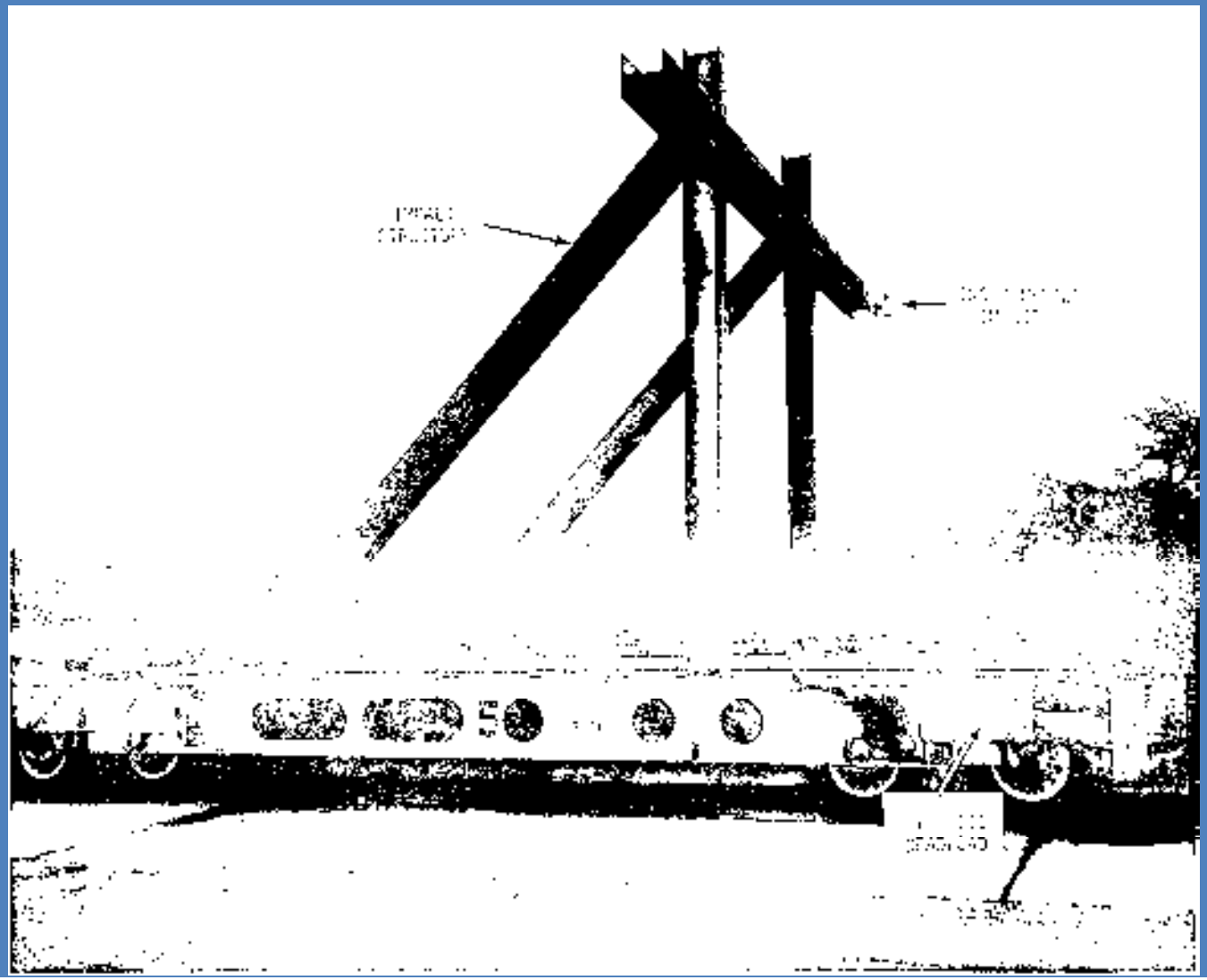


Example

- FAA Development
  - NASA Langley
  - NAEC, Naval Air Engineering Center, Lakehurst, NJ
- Included Full Scale Impact Testing
- Resulted in Design LIR-ALS FAA D-6155
- Test Report TR-181 Very Similar to Current
- Rigid Impactor (TR181-8)
- Piper Navajo Wing

TR-181-8 Rigid Impactor

37,300 lb Rail Car W10x49 Steel Beams



TR-181-8 (Rigid Impactor)

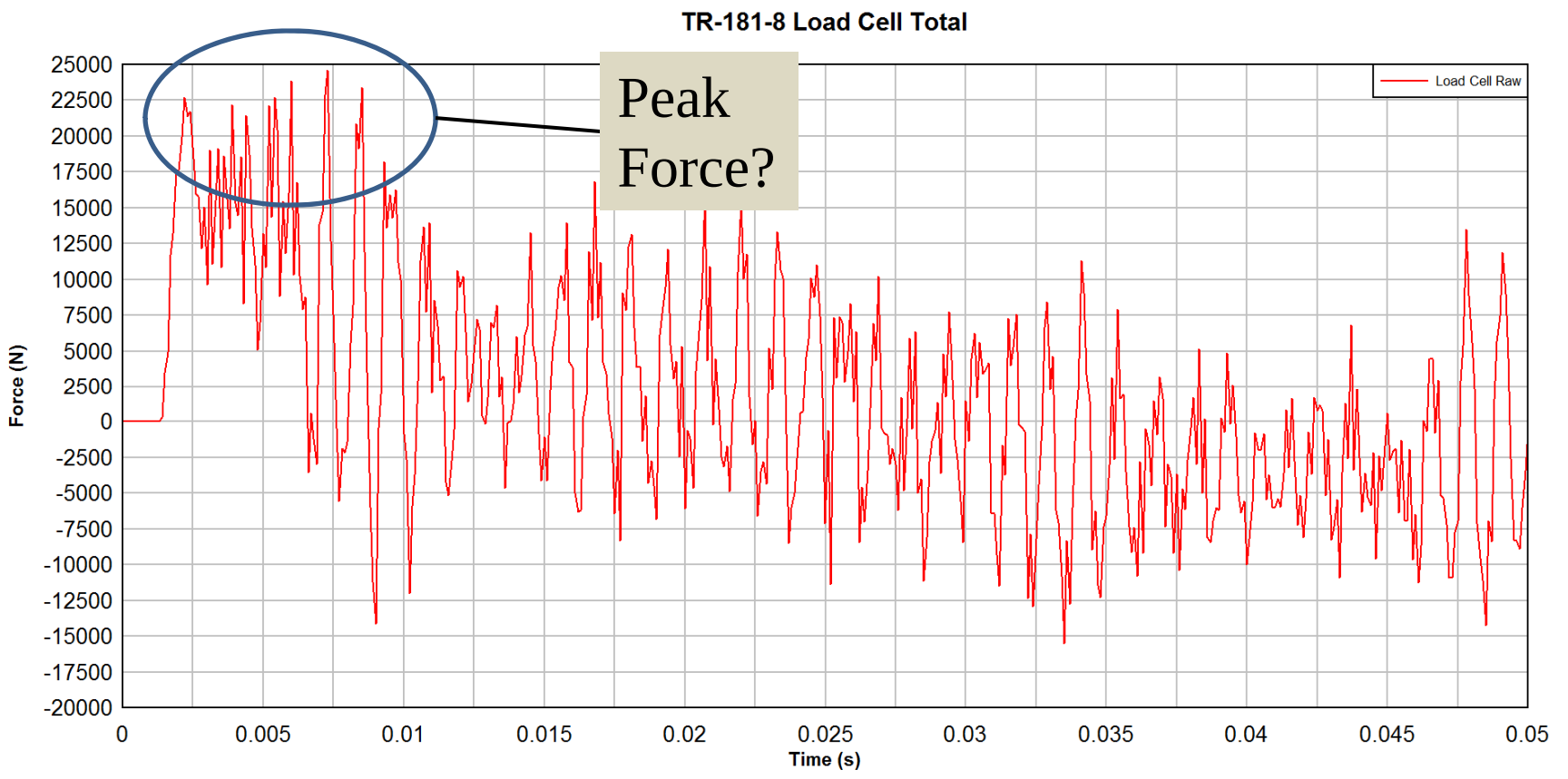
TR-181-8 FEA Simulation

- Based on
  - FAA / NAEC reports
  - Preproduction qualification tests
  - Photographs
  - Video
- Missing Information
  - Dimensions of impactor assembly
  - Measured force versus time
  - How data was processed

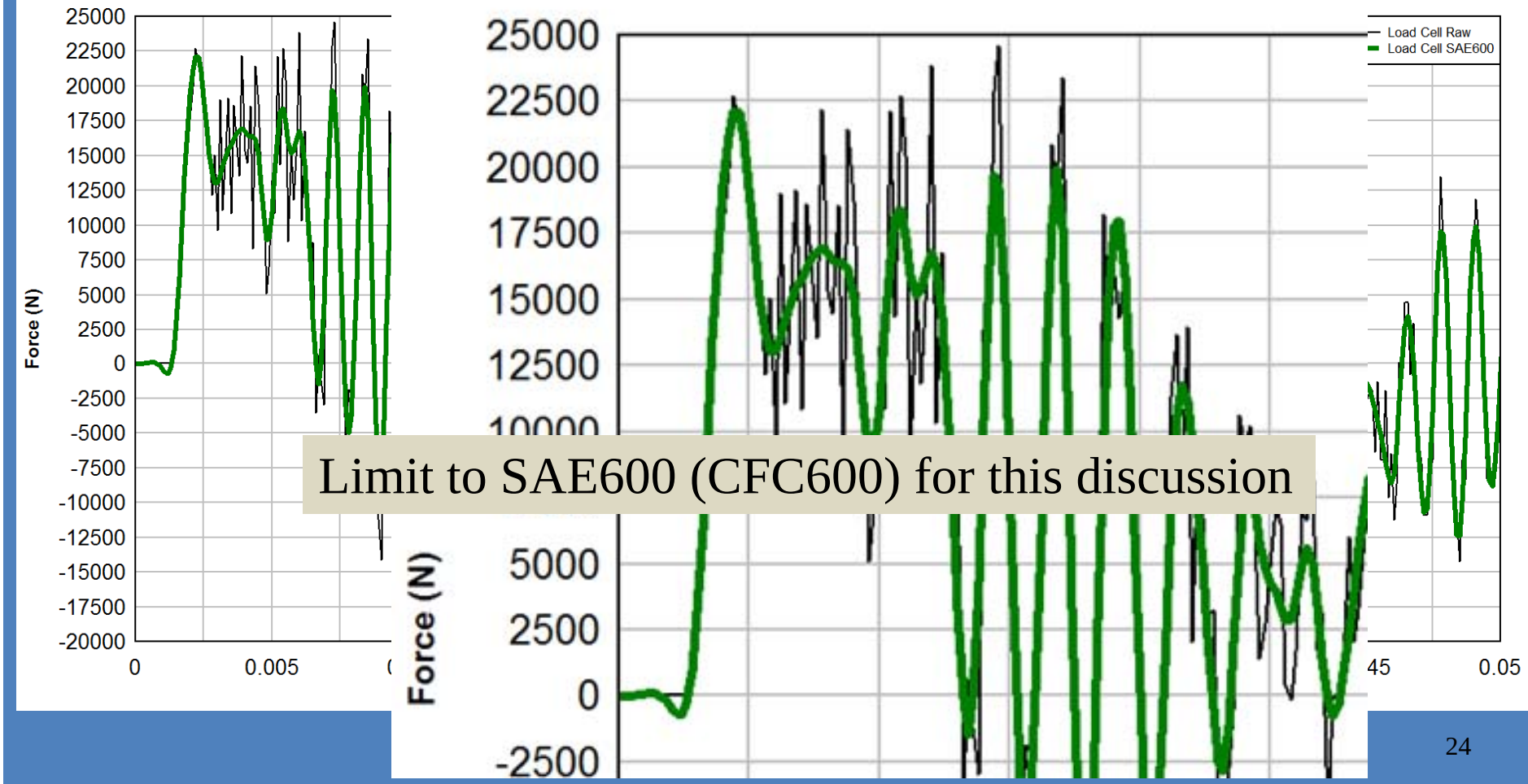
Simulation Results

Force Measurements and Resulting Plots

Measured (Calculated) Force



Load Cell Force
RAW and SAE600



Limit to SAE600 (CFC600) for this discussion

Historical Force Data – Questions

- Filtering?
- Smoothing?
- Sample Rate?
- Noise suppression?
- . . . . .

Some reported – most not

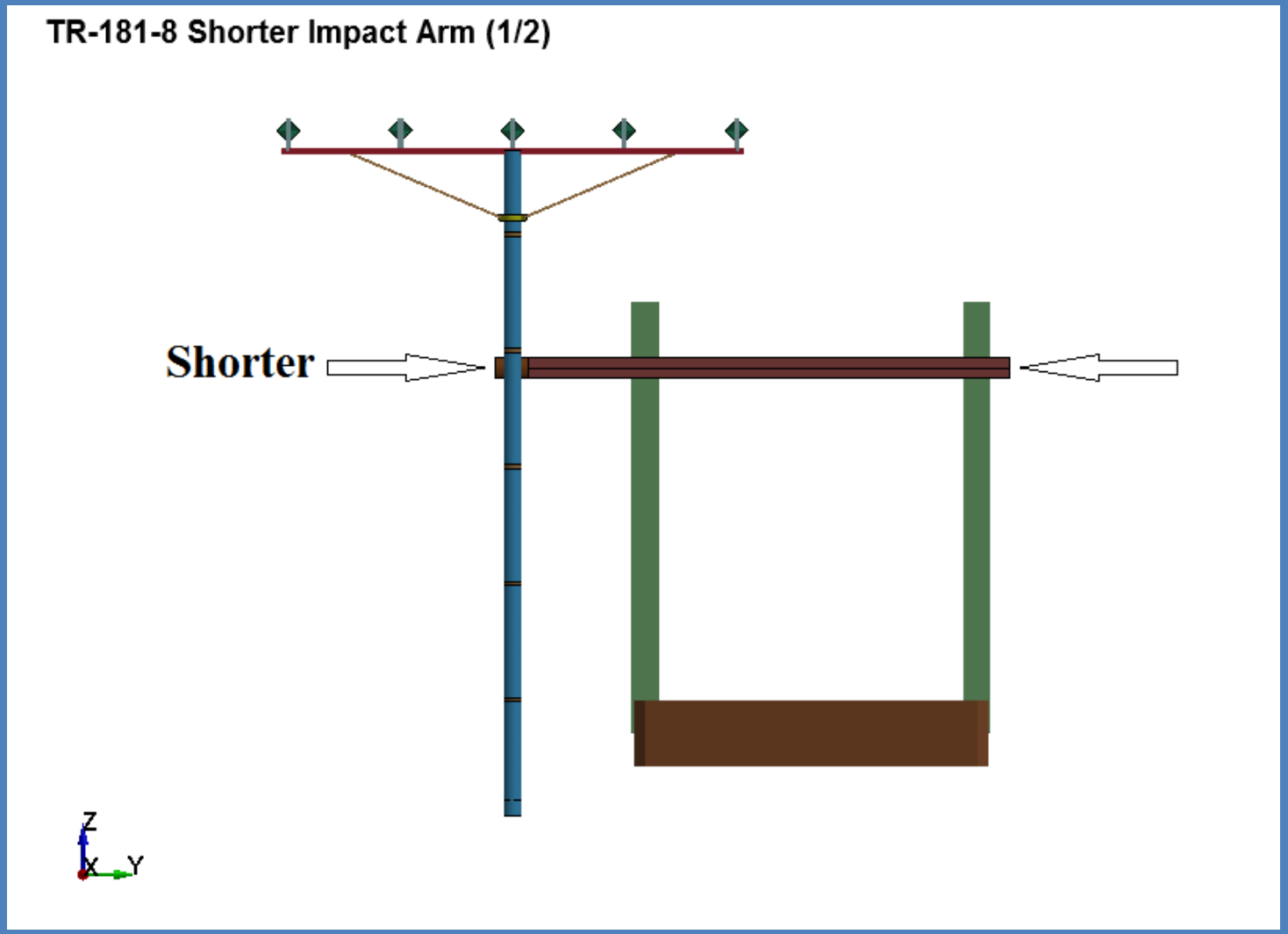
Impactor Assemblies – Various Tests (Data Used to Develop Standards)

Variation in Impactor Assemblies

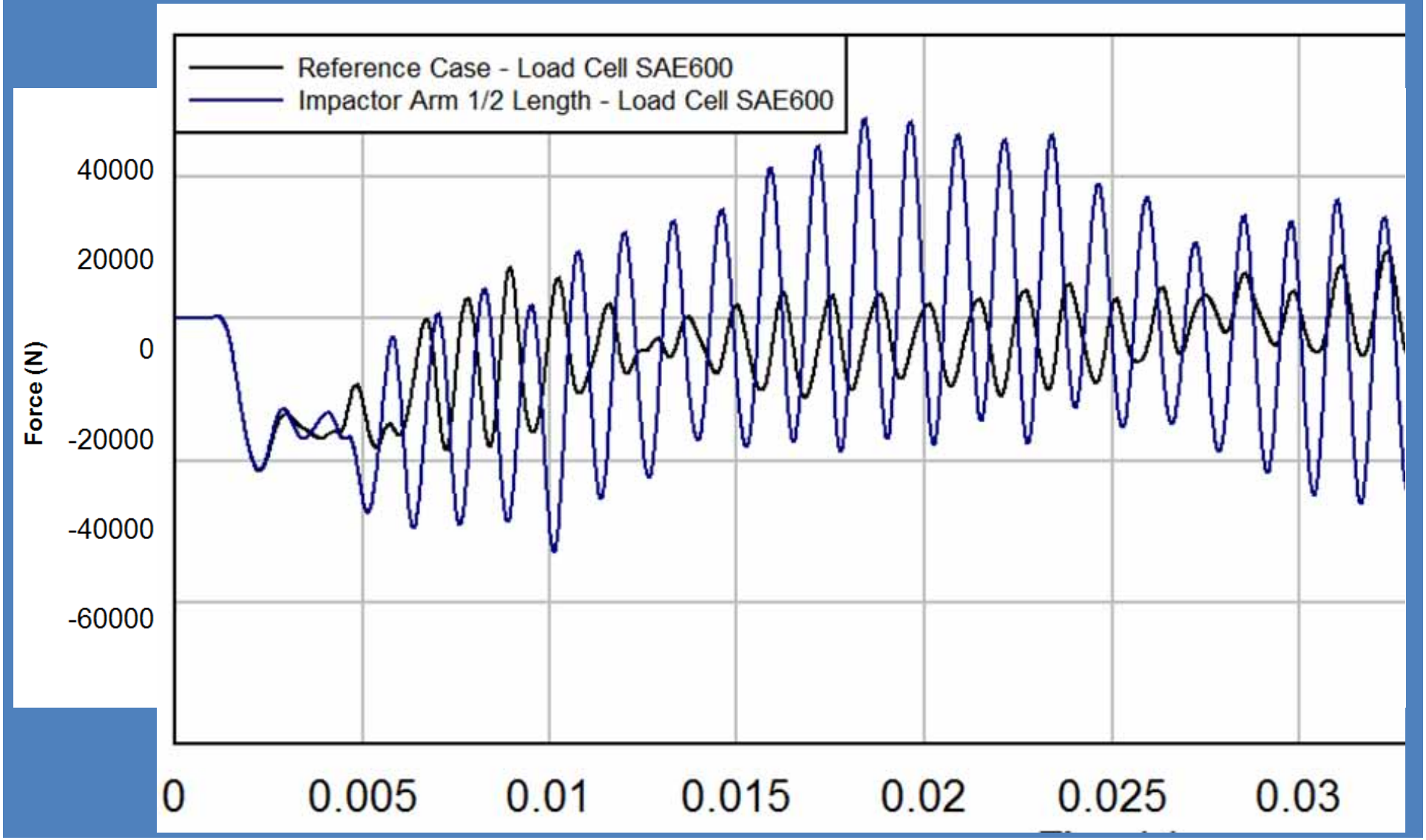
Weight (lb)	Transporter	Impactor Support
120000	Carriage	Modified Space Frame Spring Interface
3730		Elevated Frame Beams
1100		me square
6000	Truck	Truck Bed Height
10000	Towed Trailer	Elevated Frame Slender Members

Does It Make Any Difference?

Reference Case Except Shorter Impactor Arm



Reference Case and Shorter Arm



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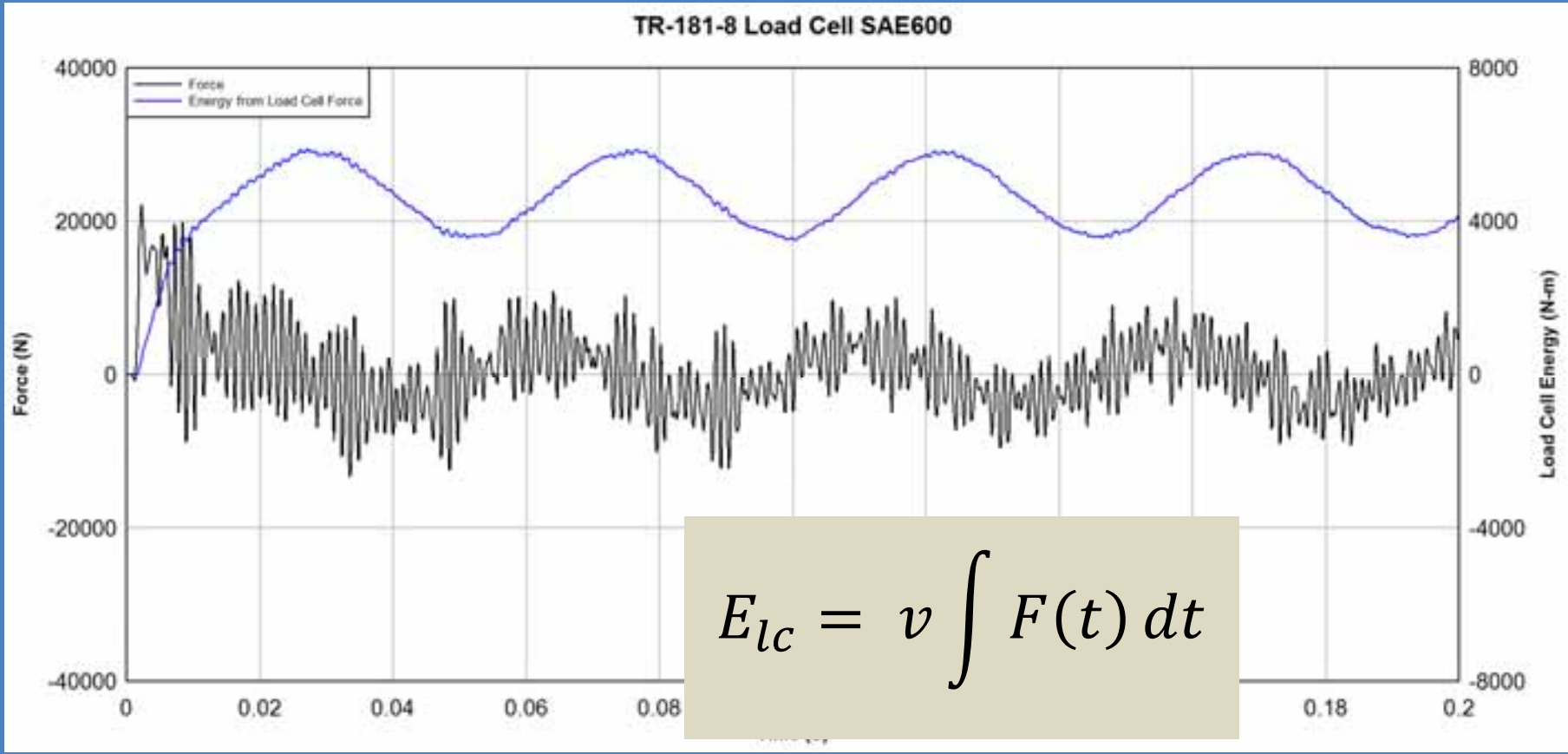
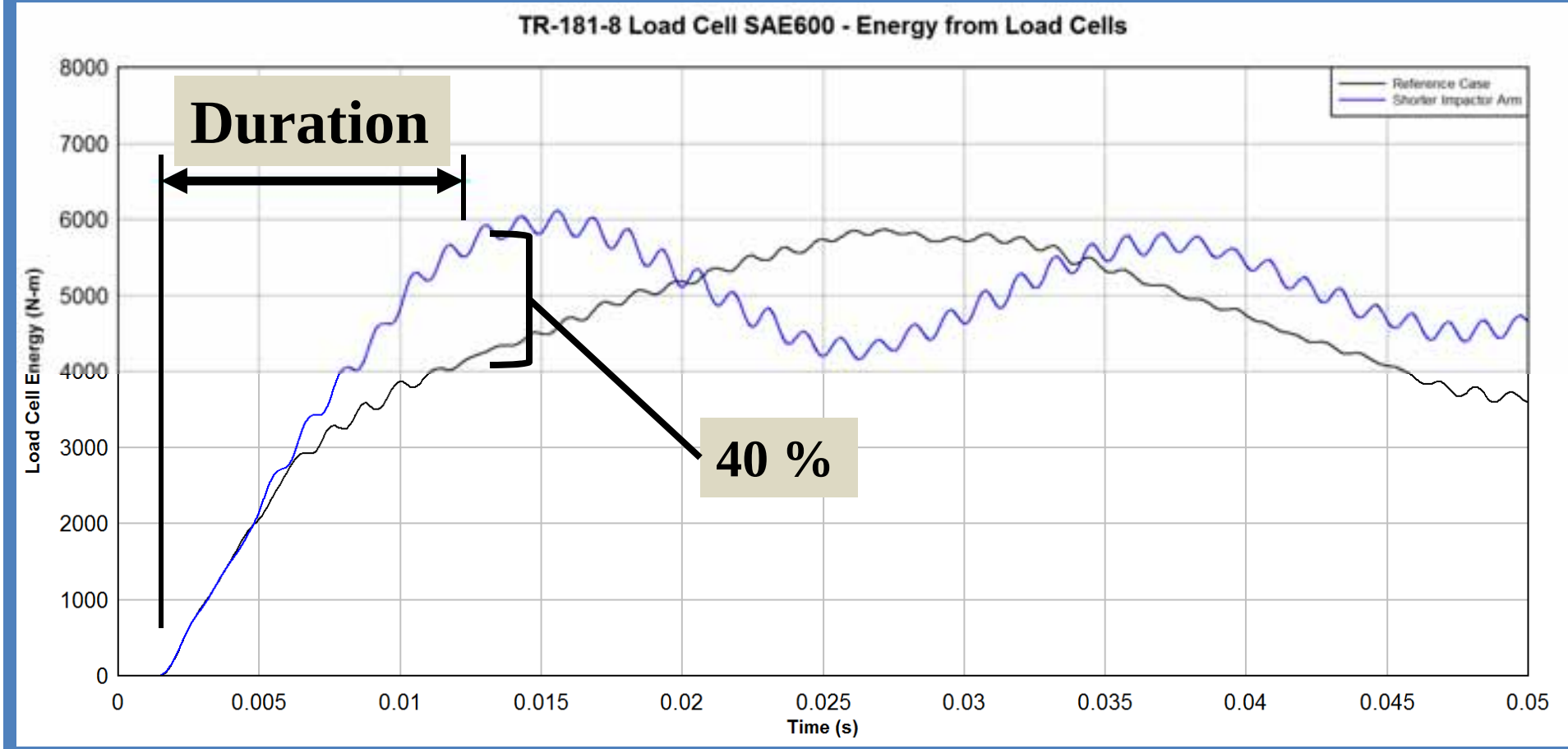


$$E_{lc} = v \int F(t)\, dt$$

Reference Case and Shorter Arm

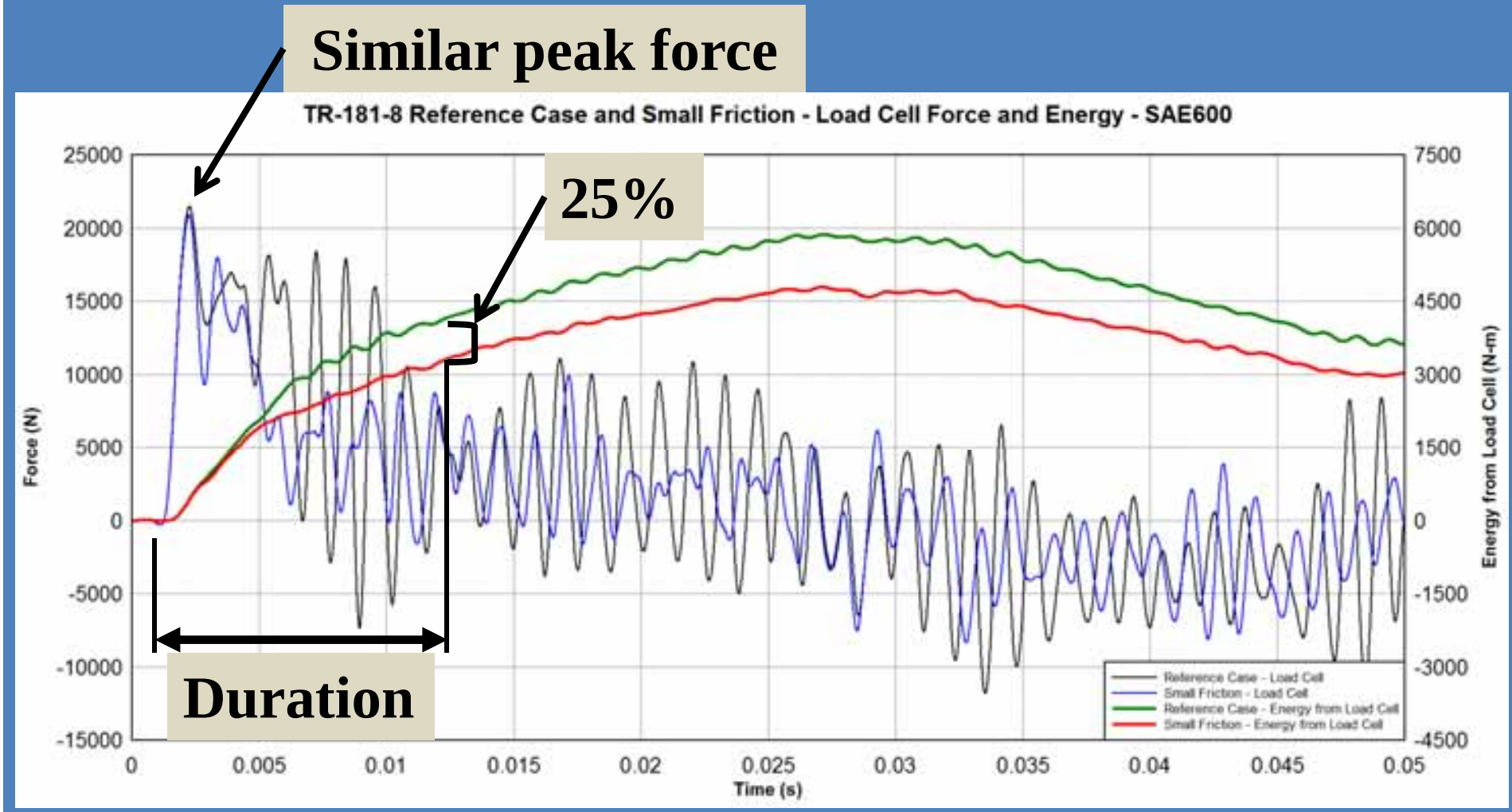


Reference Case vs Small Friction

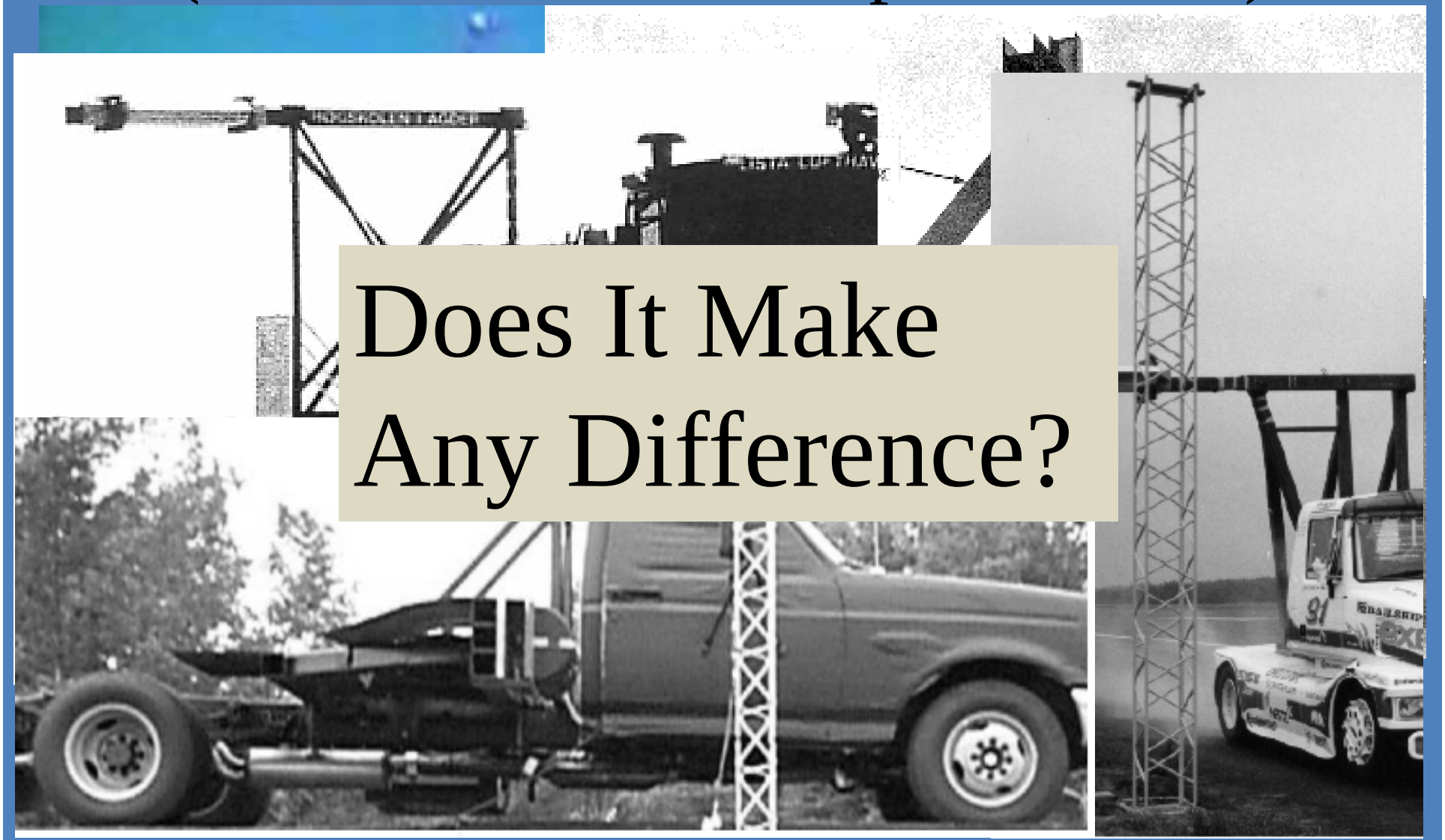
- Reference Case
  - Static Friction = 0.7
  - Sliding Friction = 0.4
- Small Friction
  - Static Friction = 0.1
  - Sliding Friction = 0.1

Recall the Reference Case

Reference Case vs Small Friction



Impactor Assemblies – Various Tests (Data Used to Develop Standards)



Does It Make Any Difference?

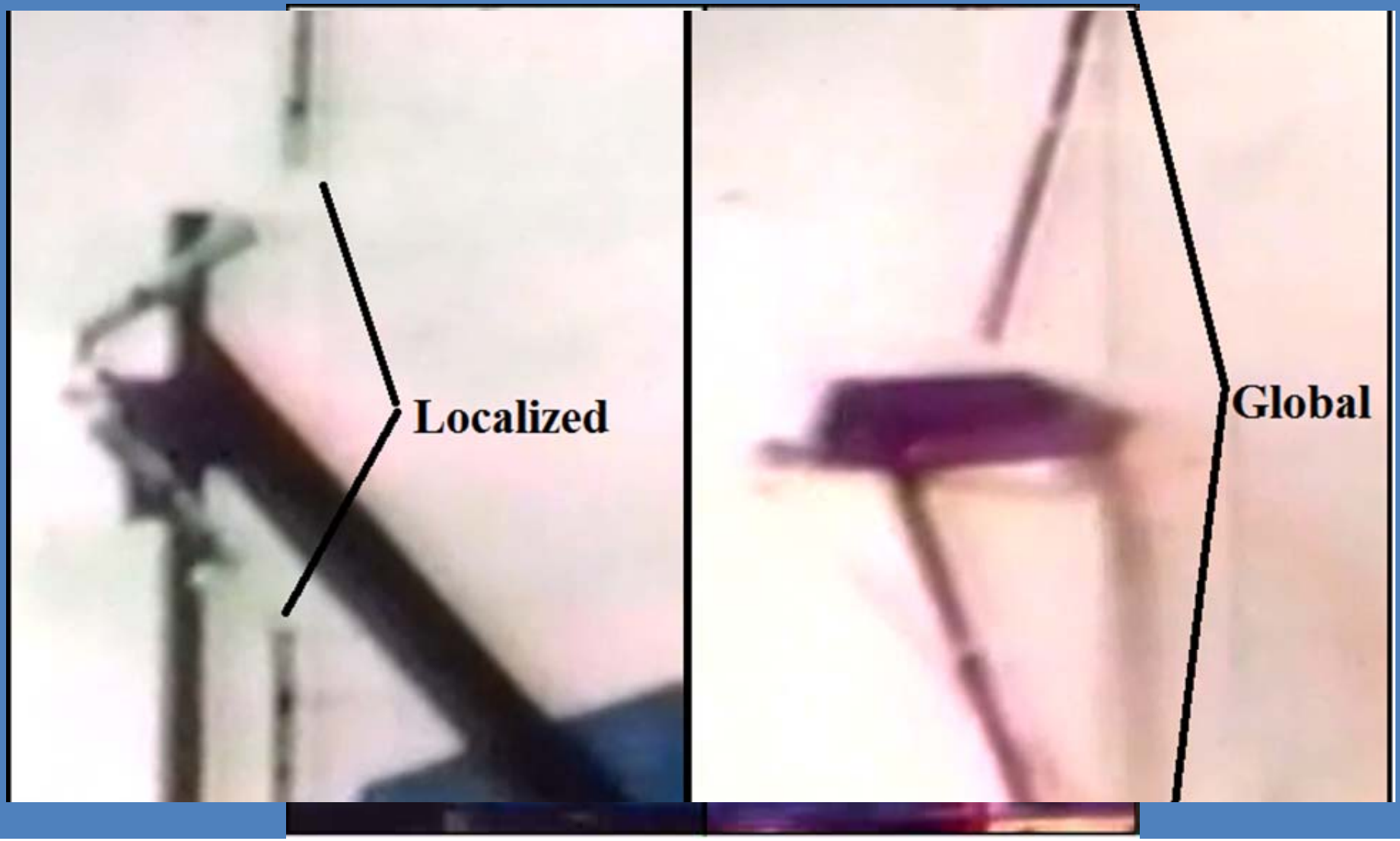
Variation from Test to Test

- Historically: What was done about
  - Reconciliation between various tests?
  - Variation in structural characteristics of impactor systems?
  - Treatment of friction and vertical forces in general?
  - Data smoothing and filtering?

Soft Impactor (Surrogate Wing)

- Comparable to actual wings
- Contrast 0.03” aluminum with 1” steel
- Strong recommendations throughout most of the history to use soft impactors
- “Abandoned” for the perceived convenience of reusable and relatively rigid steel impactors

Rigid versus Soft Impactor
TR-181-8 and TR-181-10



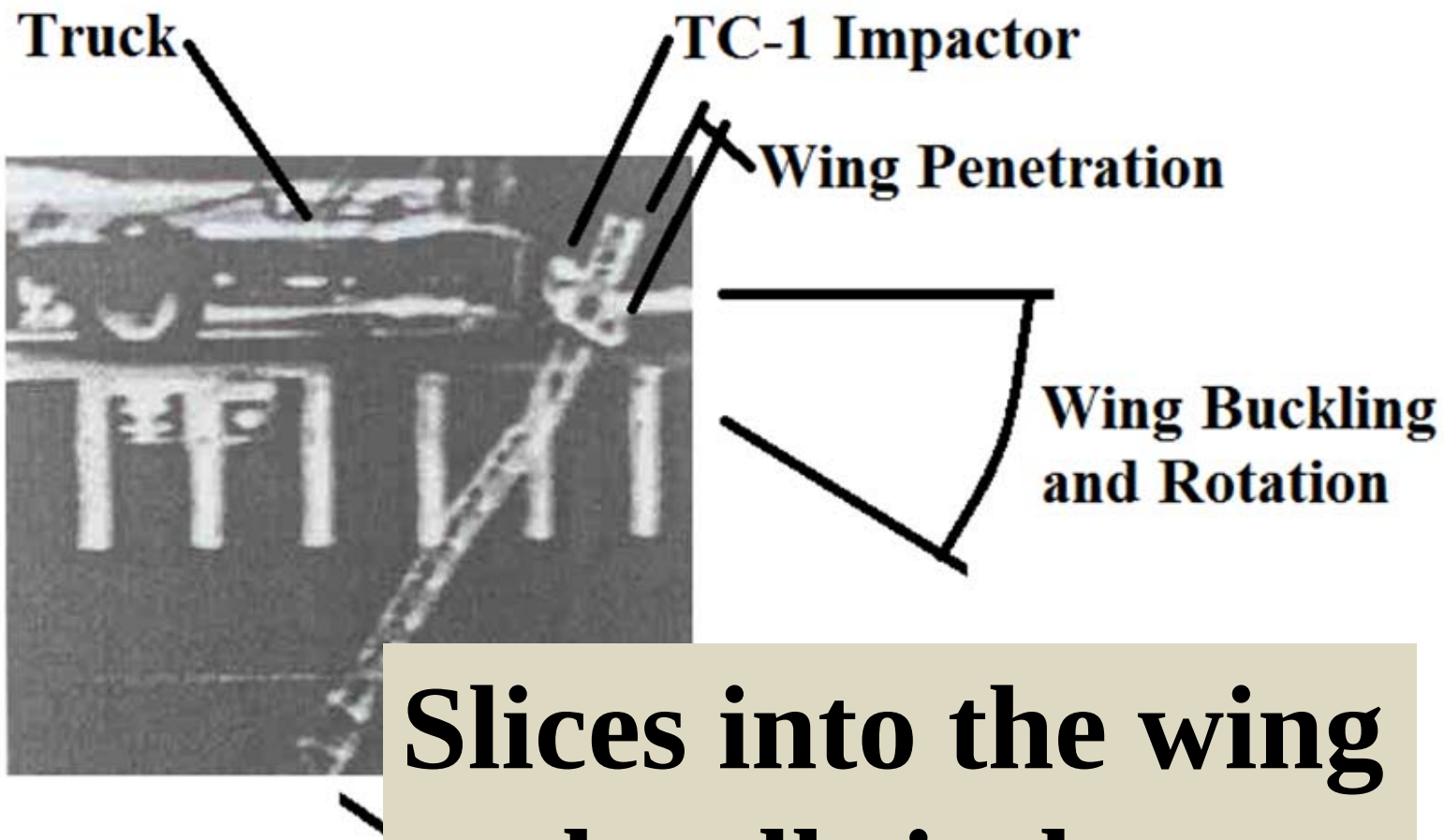
Soft versus Rigid Impactor

- Rigid impactor
  - Convenient
  - Faster turn-around
  - Cost benefit
- Soft impactor
  - More realistic particularly for device reaction
  - Visual inspection of damaged surrogate

Vertical Forces

- Vertical forces are present.
- Friction in a windowing system can make a difference in measured forces.
- How have they been accounted for?
- Should they be accounted for?

Vertical Forces



Slices into the wing and pulls it down.

Vertical Forces

Brace added to control pitch of impactor

Vertical Forces

- Rigid impactor
  - Device slides over the face of the impactor
- Soft impactor
  - Devices cut into and pull down
- Which is more realistic?

Vertical Forces

- Does using a rigid impactor mask the potential problem?
- Does simply adding braces mask the potential problem?
- Should they be accounted for?

Impact Location

Current standard

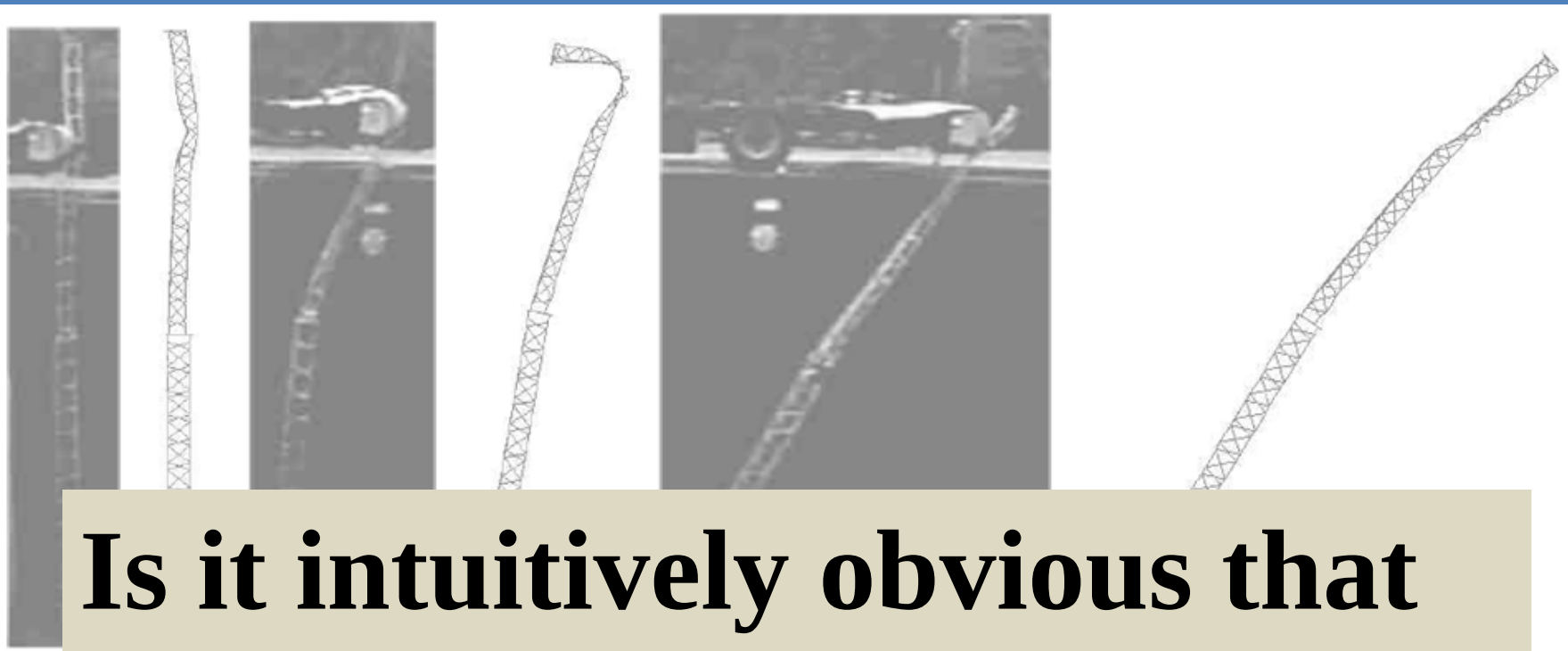
- Top 12 m required to be frangible
- Test impact height 1m from the top

Why just at 1 m?

Impact Location

- Windowing systems
  - Proximity to joints
  - Also proximity to joints in a truss

Impact Height – Wrap and Slide



Is it intuitively obvious that impact lower on the tower could make a big difference?

Impact Location

Test impact height 1m from the top

Why?

Questions and Concerns

Seeking to Clarify and Improve

Questions and Concerns
Current Example

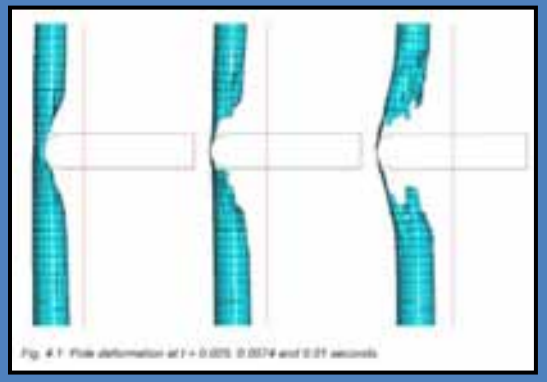
Clint Rooks

SES Evolution In Testing

Current ICAO and FAA Criteria

2006 ⇨

2006 ⇨



2007 ⇨

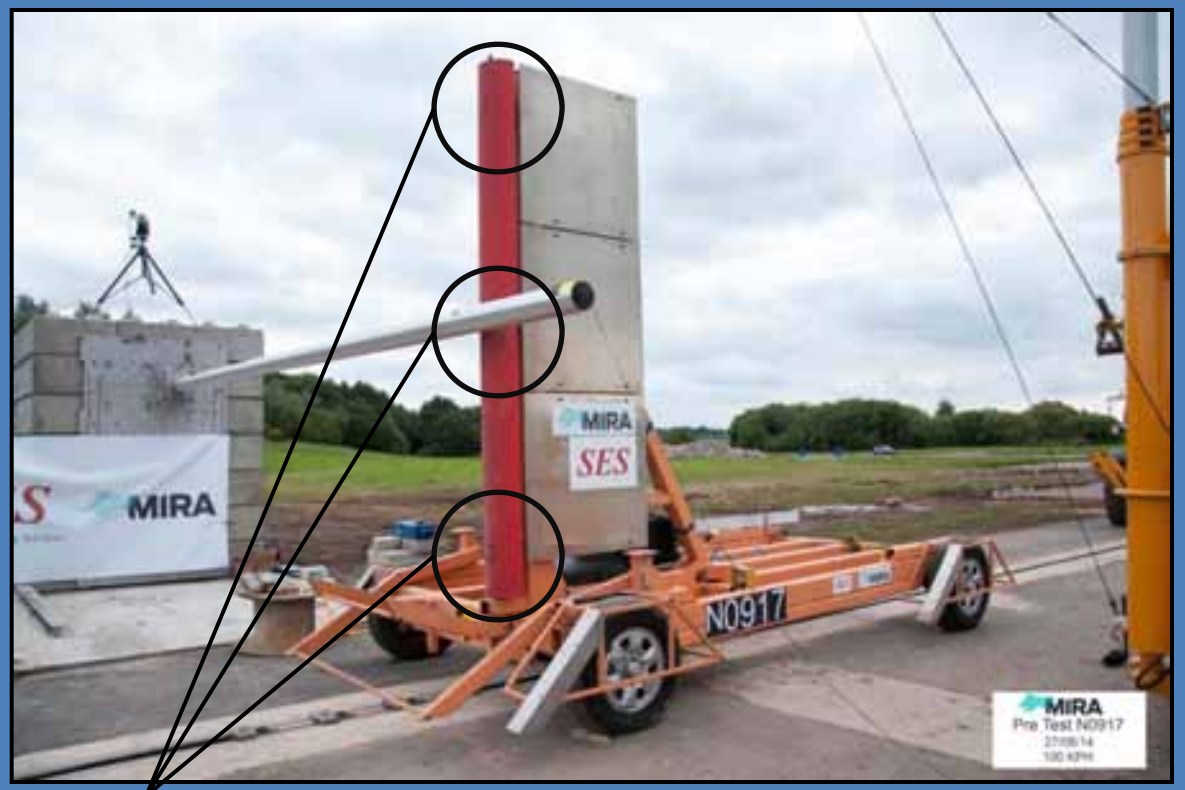
2009

2010 ⇨

Present

Standard Test Setup Development

- **Rail Guided Impactor System**
- **Increased Safety and Repeatability**



Primary Instrumentation

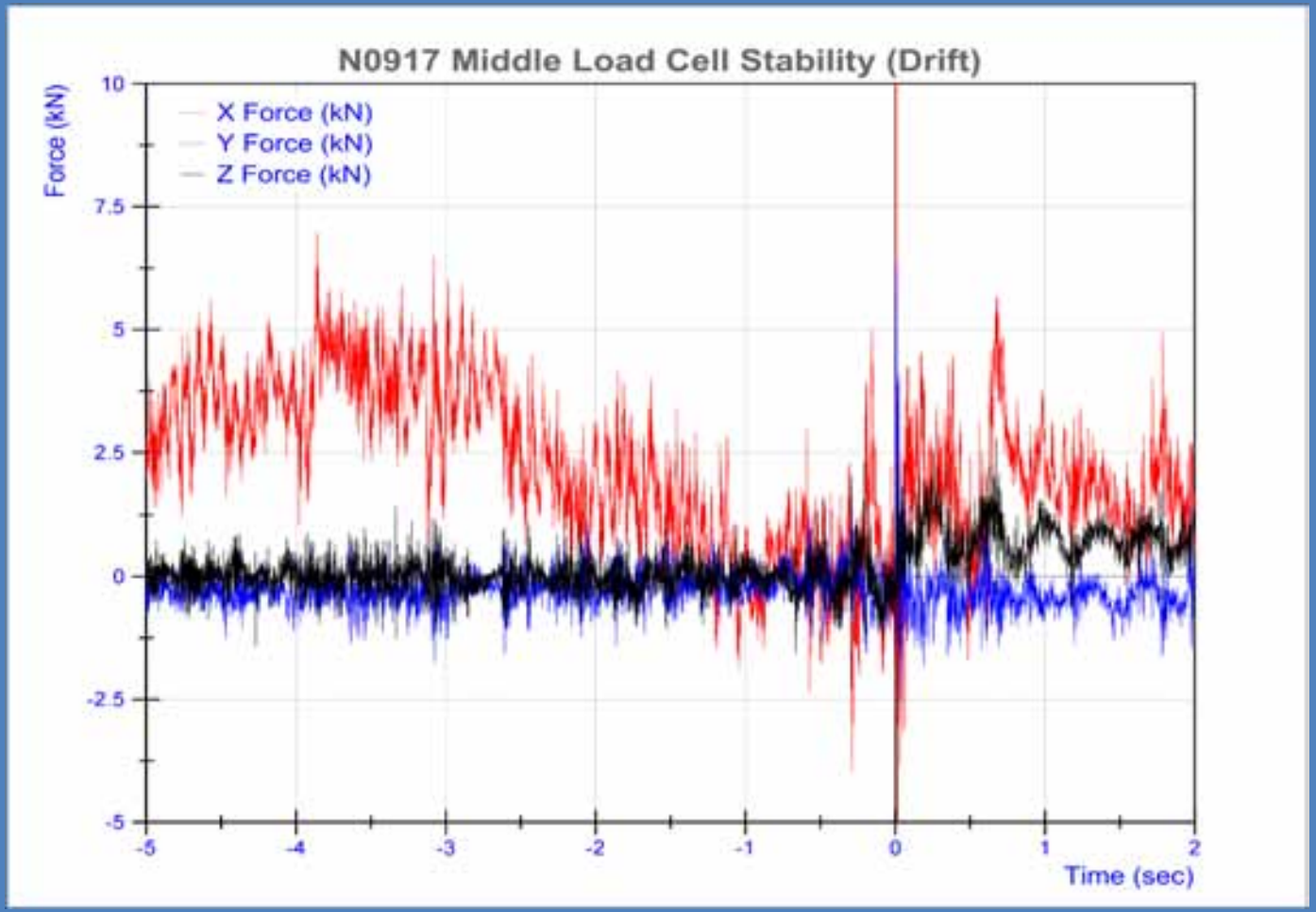
53

Speed Tolerance Testing

- **Current requirement is 140 km/h with no defined deviation**
- **Conduct 18 tests on aluminum and composite structures to define a standard test impact speed and allowable deviation**
  - **Completed 2 of 18 tests Aug 2014**

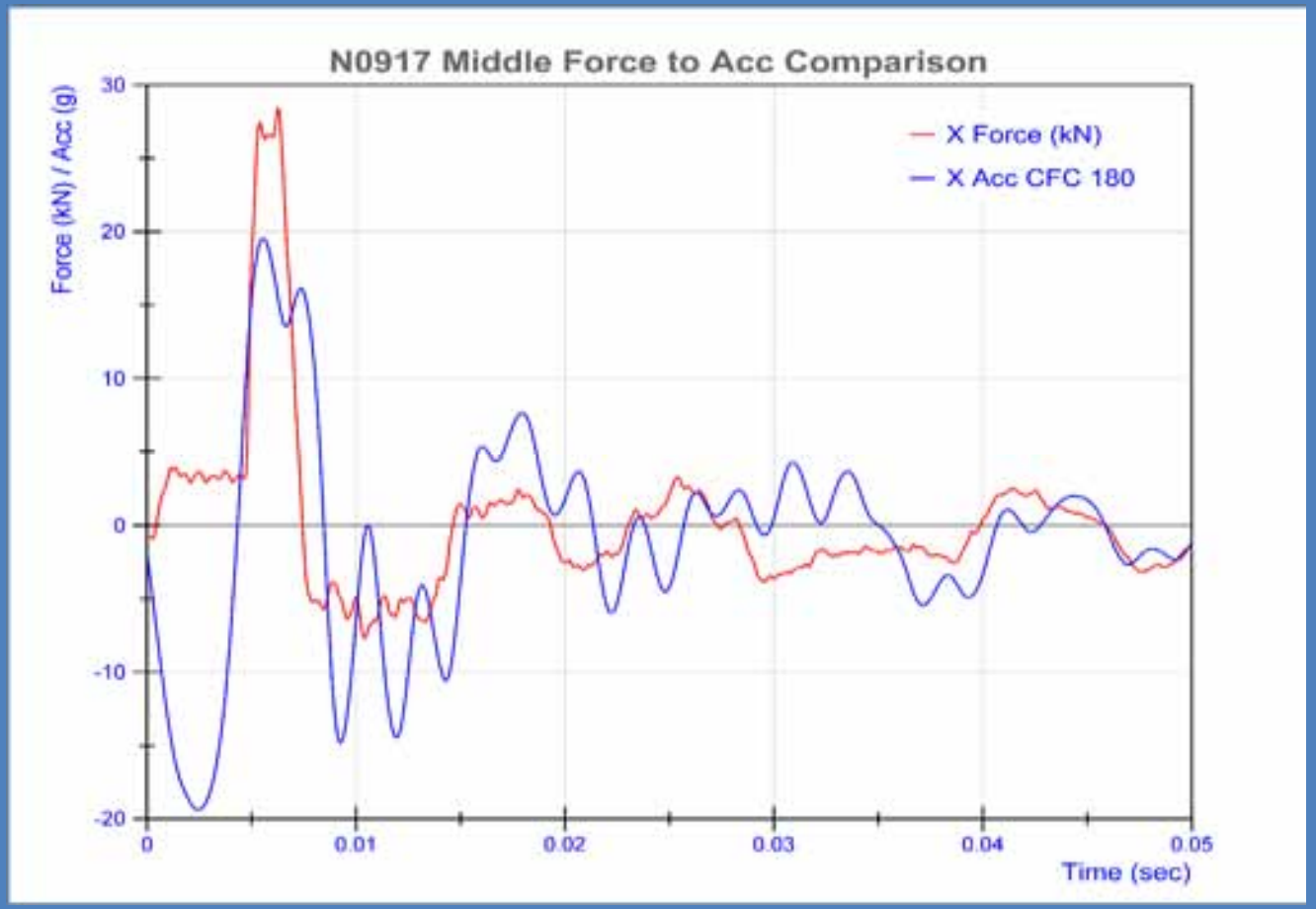
Lessons Learned

- **Rigid impactor with large mass has dramatic influence on recorded data**



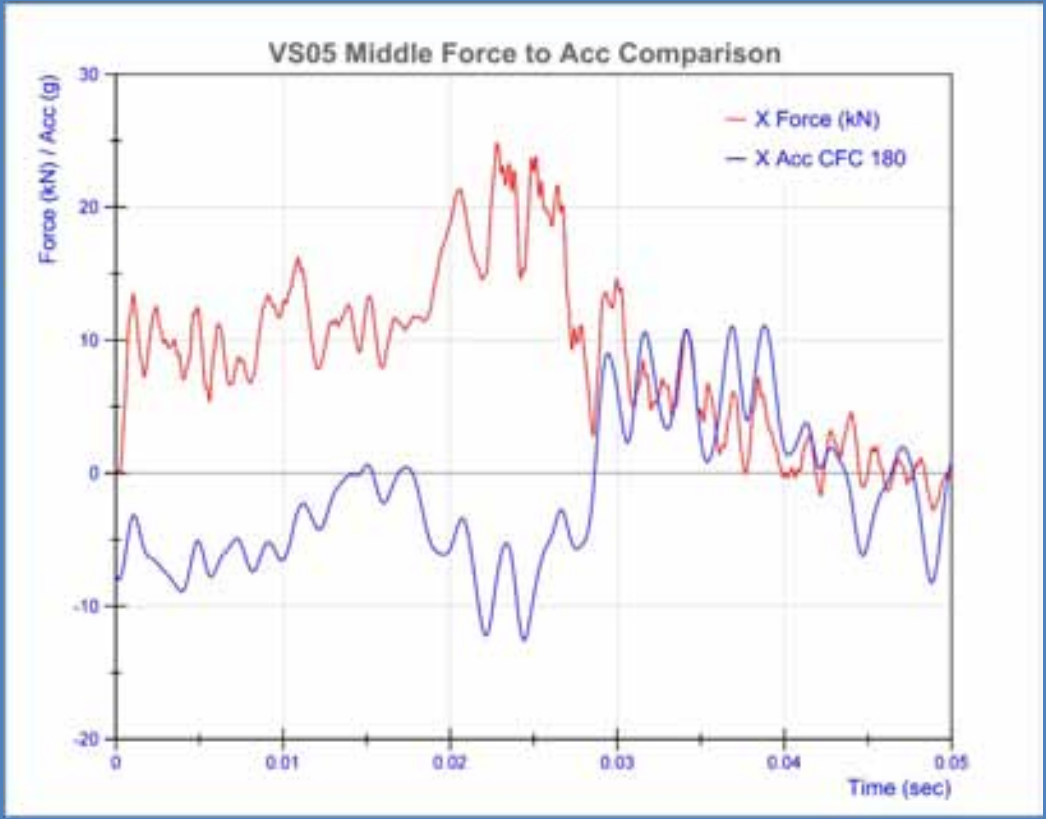
Lessons Learned

- **Positive accelerations with compressive loads**
  - **Start to pick up resonant frequency**



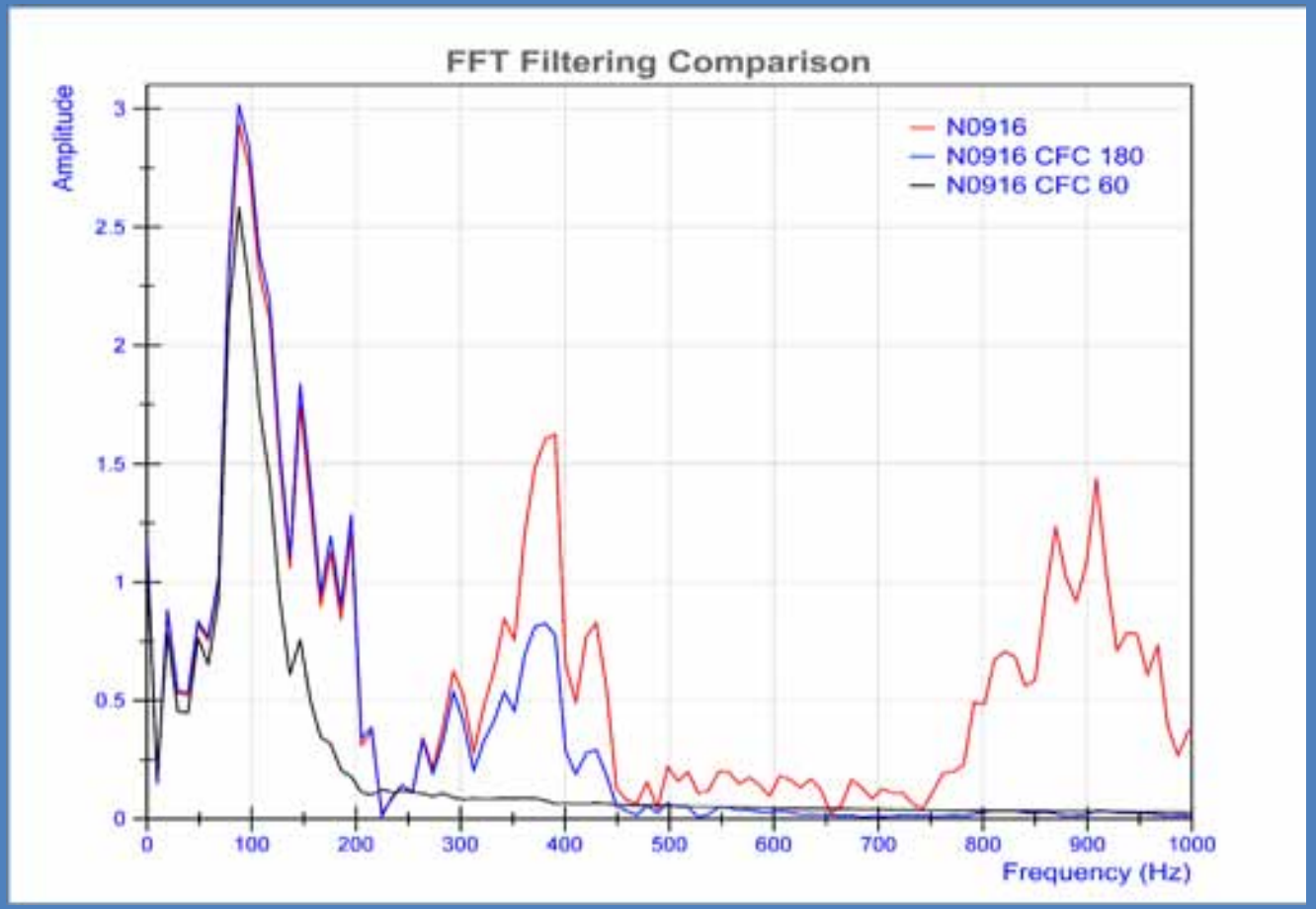
Lessons Learned

- **Same positive acceleration with compressive loading with different test setup**



Lessons Learned

- **Filtering data drastically influences results of data**
  - **No standard filtering method described for this type of test**



Impactor Redesign

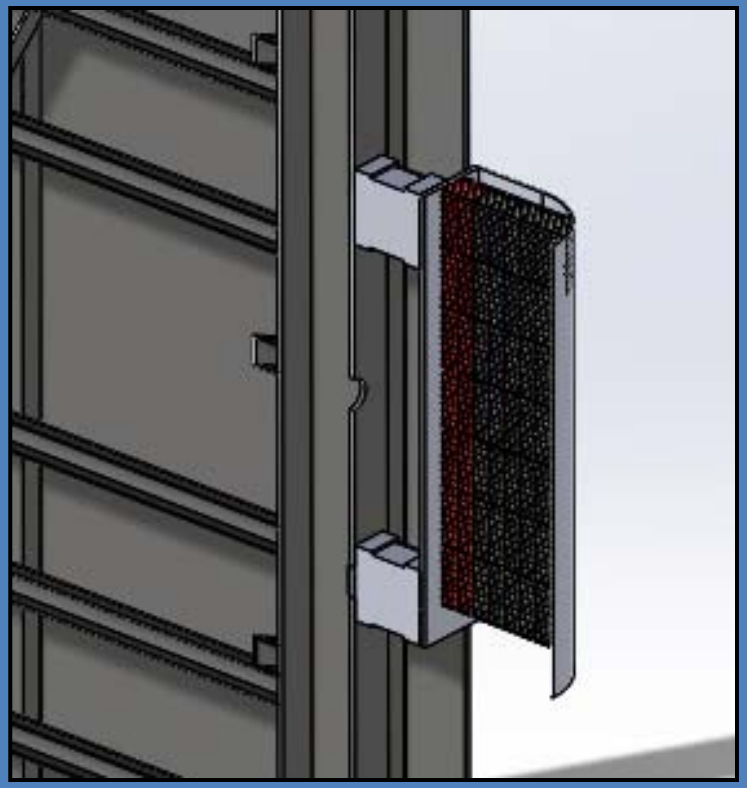
Design Considerations

- **Representative of Aircraft**
  - **Past: Piper Navajo, Piper Aztec, Beech Queen Air**
  - **Current: FAA Simulations with Piper Navajo**
- **Crush Strength Limitations**
- **Materials**
  - **Aluminum Honeycomb, Aircraft Components, Crushable Tubes etc.**
- **Overall Dimensions**
  - **Skin Thickness**
  - **Individual Segment Length**
- **Instrumentation and Location**
  - **Tri-axial Load Cells, Compression only, Accelerometers etc.**
- **Post Processing and Evaluation**
  - **Filtering, Peak Force, Energy Calculations**

Soft Impactor

Single Structural Member Concept

- **Need to reduce the mass in front of instrumentation**
  - **Honeycomb concept**
  - **Mechanical dampening**



Soft Impactor

Multiple Structural Member Concept

- **ILS Glide Slope Impactor Concept**

Questions
or
Comments?