Section 2

PEAK FORCE AS A DEFINING CRITERIA FOR FRANGIBILITY

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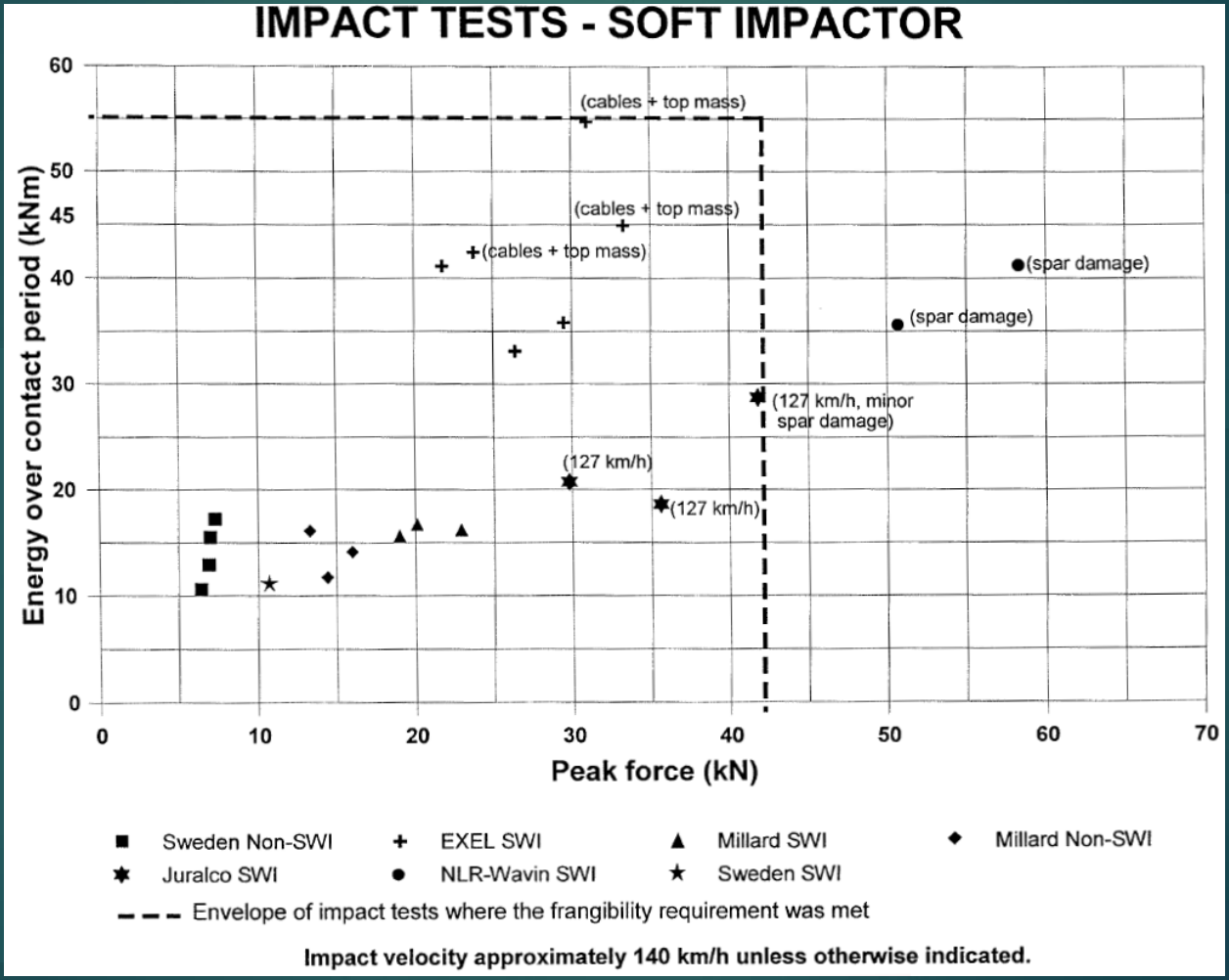
TRIDYNAMIC SOLUTIONS

Recommendation

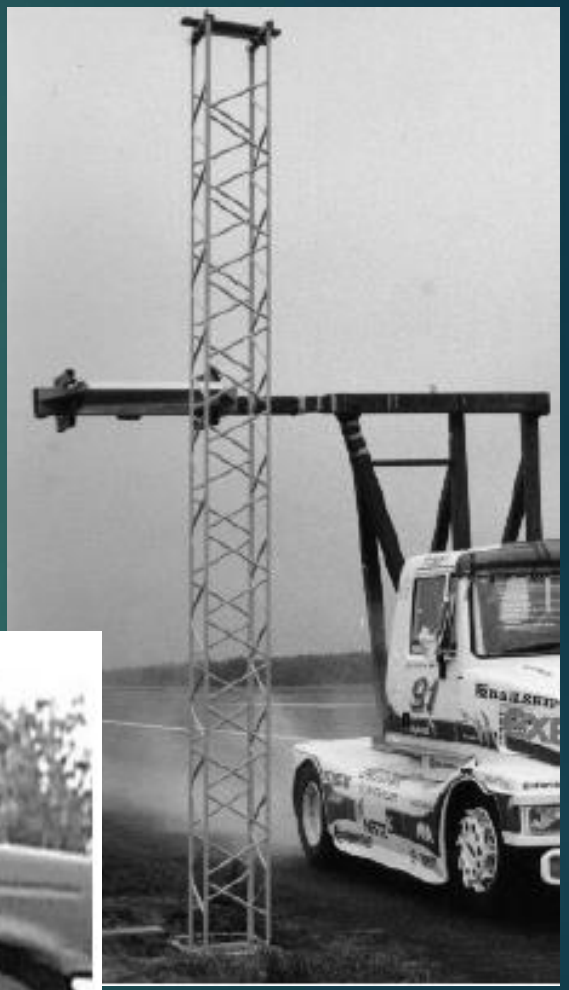
- Abandon peak force limit as an approval criteria

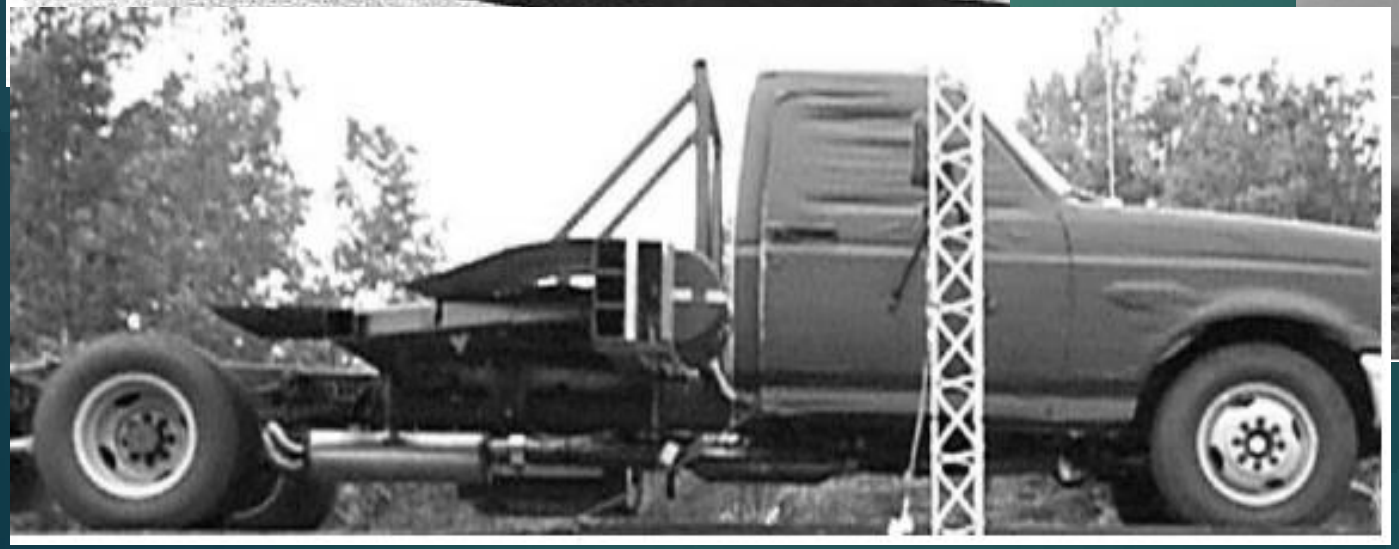
Force and Energy Limits

Frangible Aids Study Group ⇒ ICAO



Variation in Impactor Stiffness





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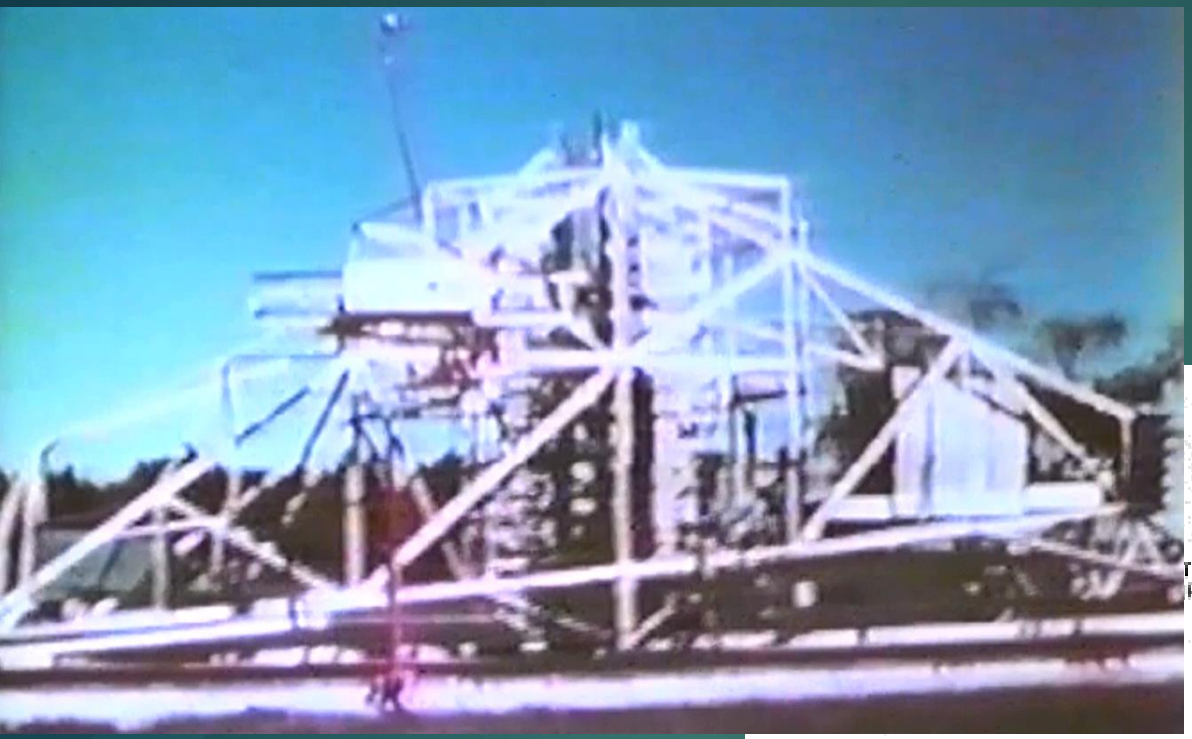
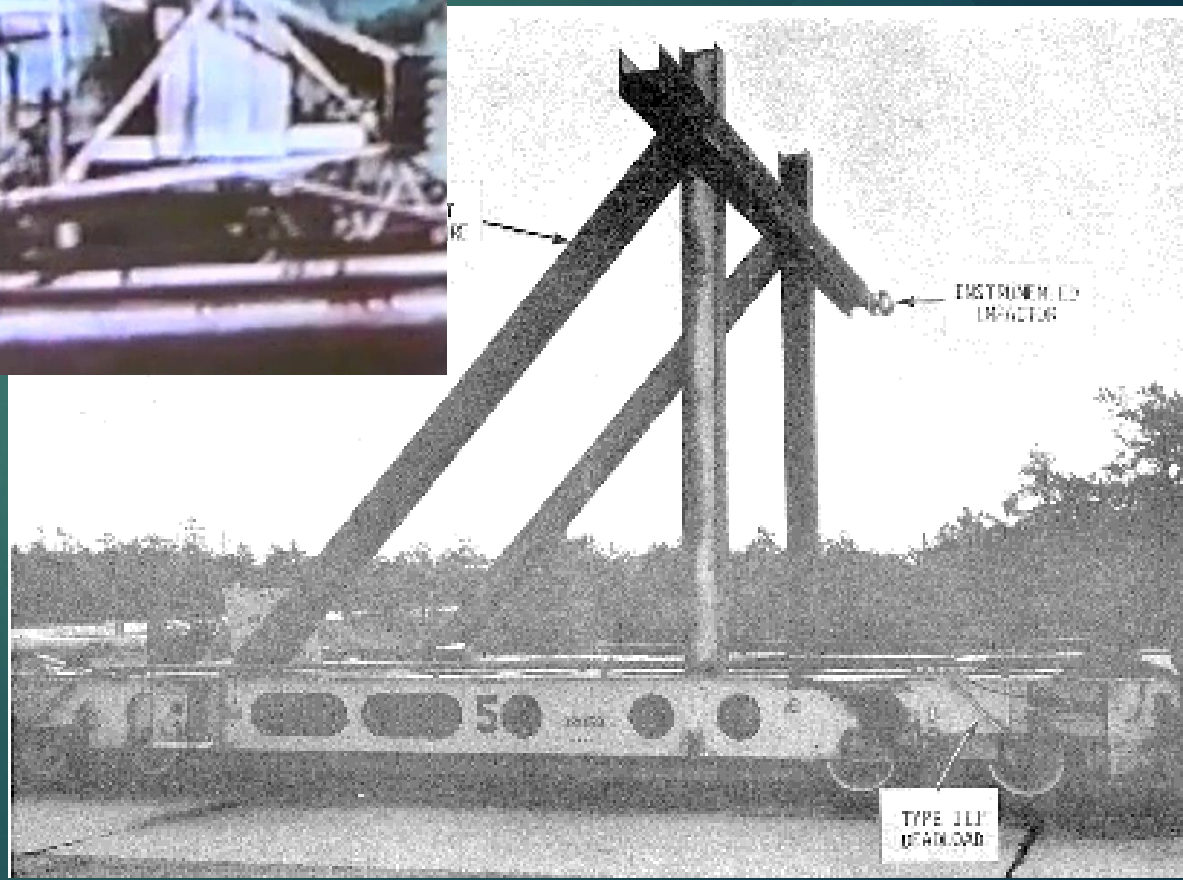
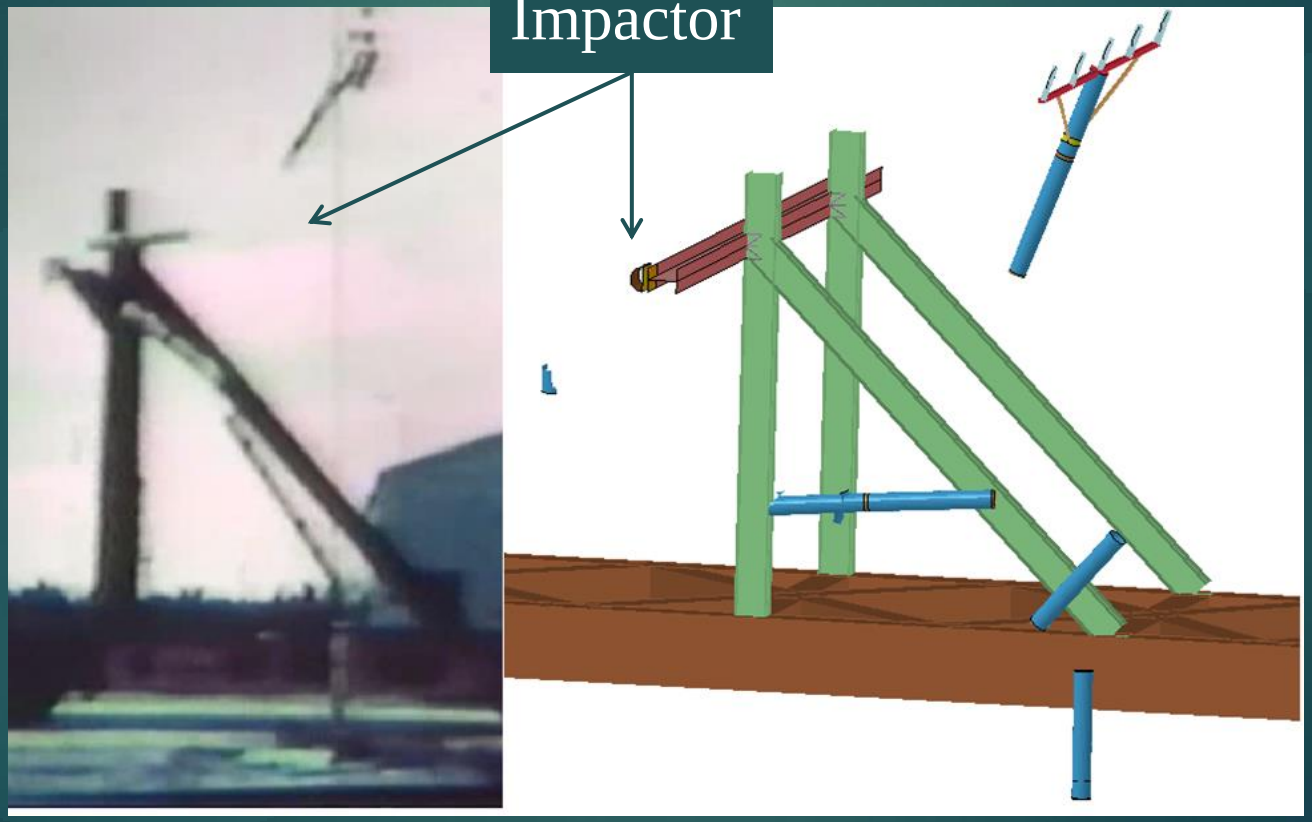




Variation in Impactor Stiffness

Length of Impactor Arm



Variation in Impactor Stiffness

Length of Impactor Arm

- Simple change of impactor arm length

Measurement	Reference Case	Impact Arm Length x 0.5	Impact Arm Length x 1.5
Peak Impact Force (kN)	24.6	43.8	26.1
Time to Peak Force (s)	0.006	0.009	0.004
Maximum Energy (kN-m)	5.76	6.02	5.87
Time to Maximum Energy (s)	0.026	0.014	0.044

78% with one change in impactor dimension

Corresponding Energy change = 5%

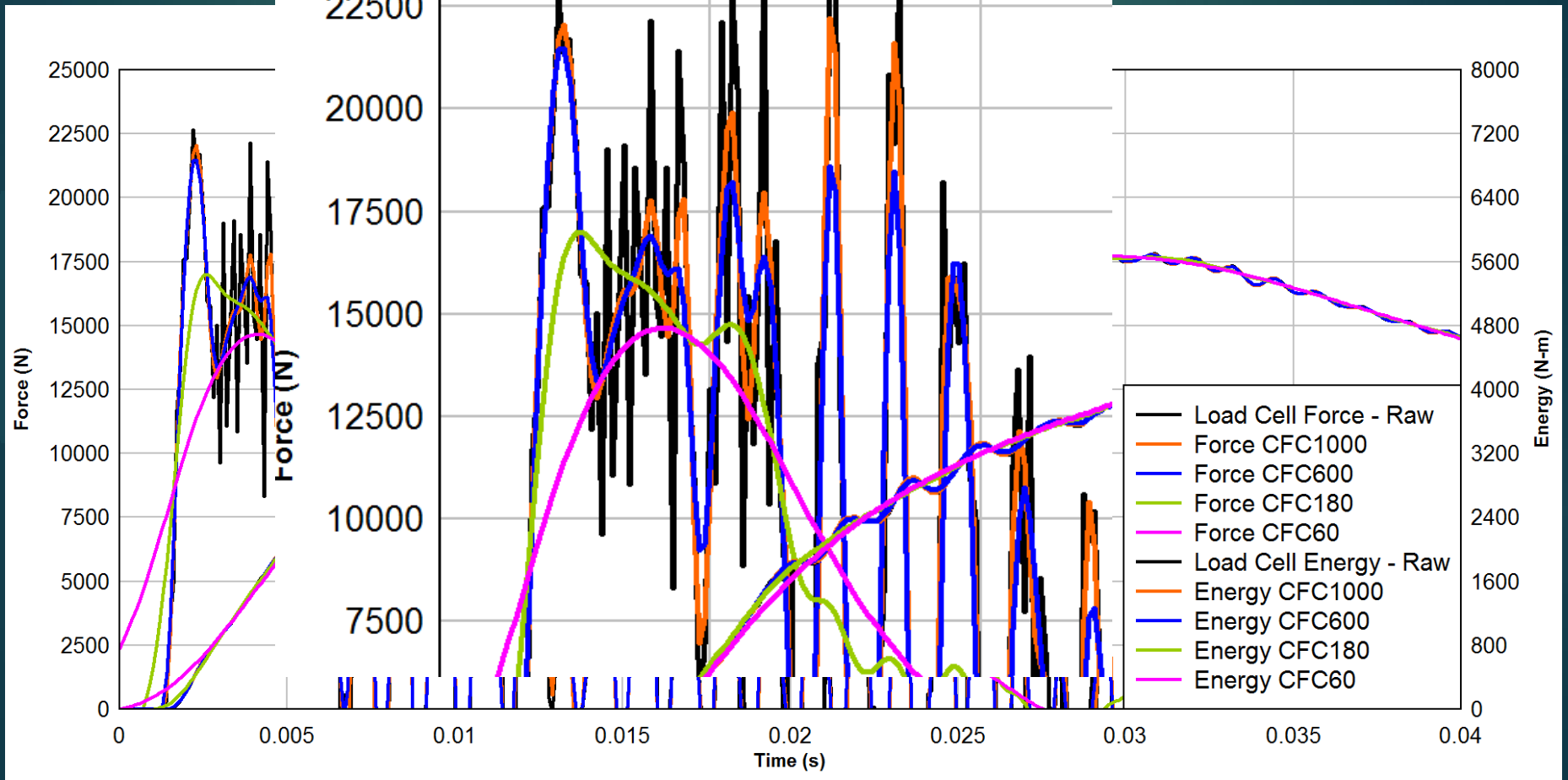
Data Measurement & Processing

- Historical sample rates
  - Potential comparison issues

Effective Sampling Rate (kHz)	Peak Impact Force (kN)	% Diff relative to 10 kHZ	Maximum Energy (kN-m)	% Diff relative to 10 kHZ
10	24.6	-	5.76	0
5	22.9	-6.9	5.88	+2.1
2	23.8	-3.3	6.16	+6.9
1	17.5	-28.9	5.24	-9.0

Sampling rate => missed peak force
Much less effect on energy

Data Filtering



Data Filtering

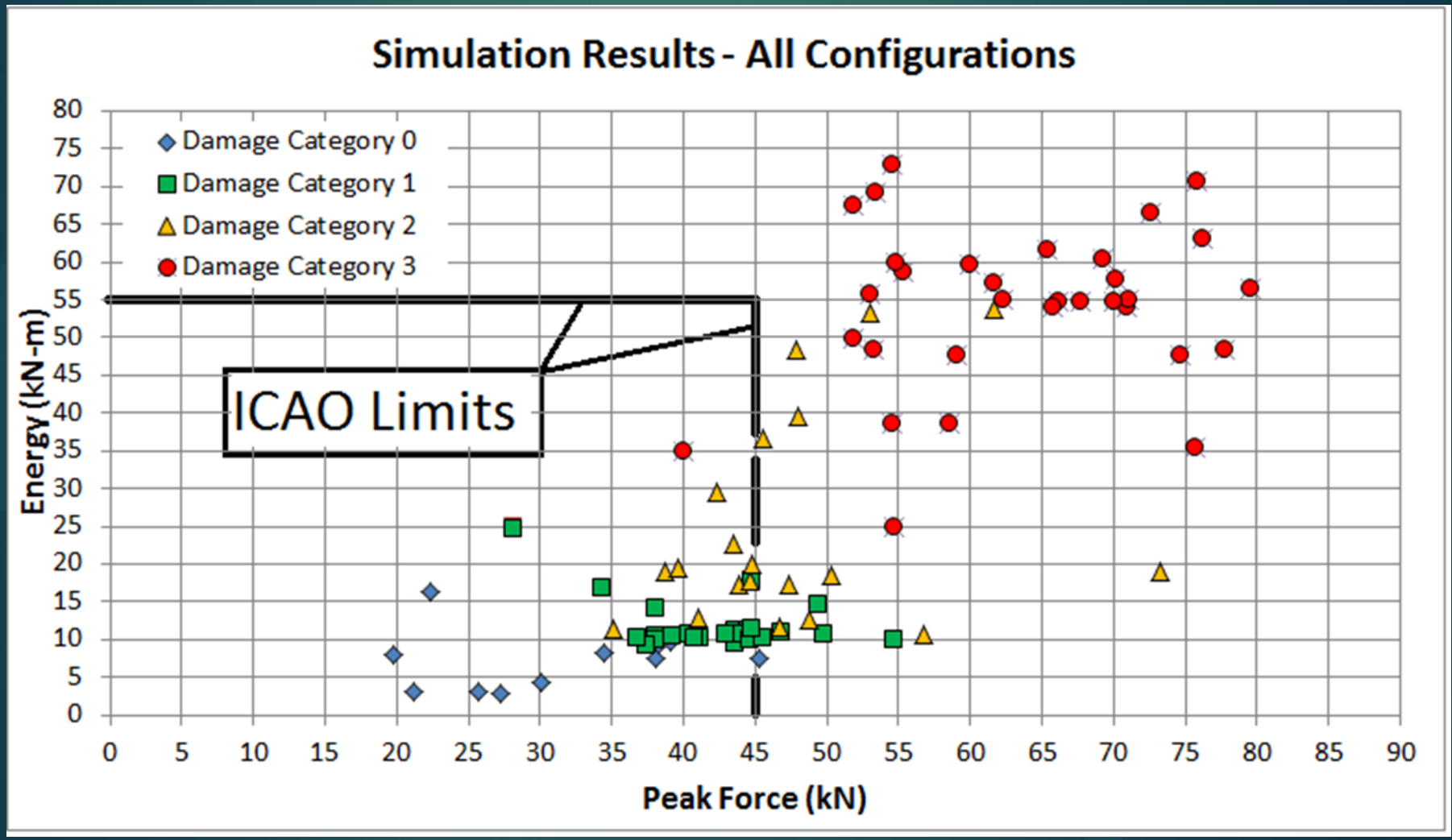
Measurement	Reference Case	CFC			
		1000	600	180	60
Peak Impact Force (kN)	24.6	22.2	21.5	17.0	14.7
Time to Peak Force (s)	0.006	.006	0.001	0.001	0.003
Maximum Energy (kN-m)	5.76	5.75	5.75	5.74	5.70
Time to Maximum Energy (s)	0.026	0.026	0.026	0.026	0.026

Peak Force very sensitive to filtering

Energy shows little sensitivity

Force Limit

- Not a good indicator of wing damage.



Abandon Peak Force Limit

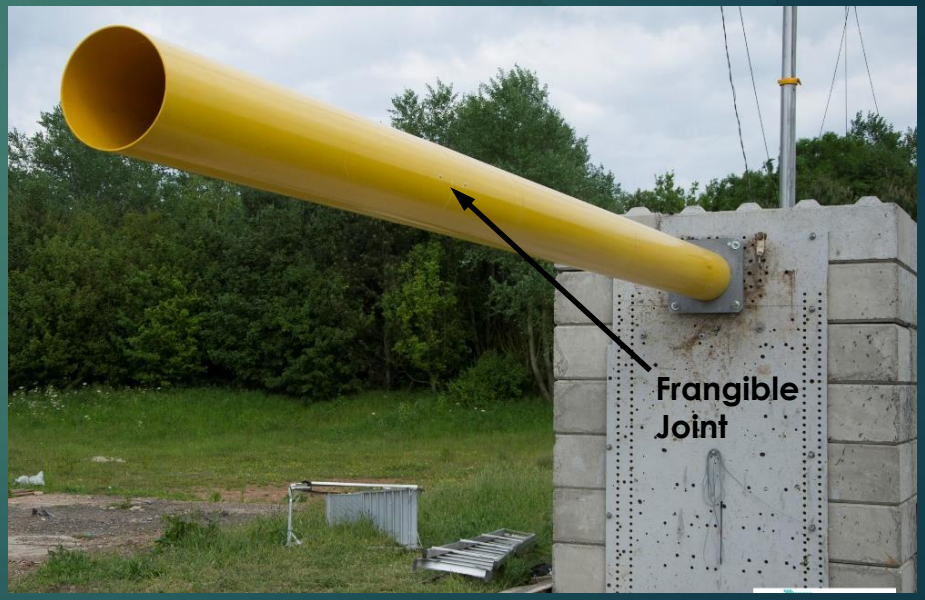
- Peak force measurement lacks the consistency between test configurations required to be suitable for frangibility assessment.
- Energy calculated from force measurements is far more consistent.

Ben Griffiths

SELECT ENGINEERING SERVICES

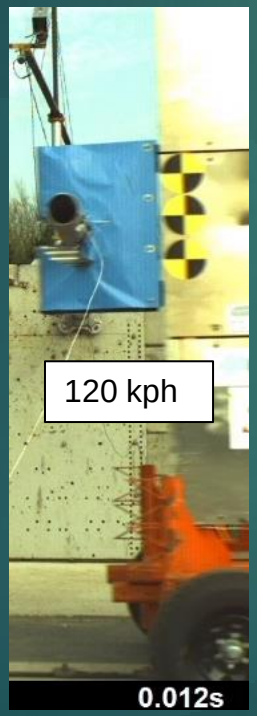
Air Force Testing

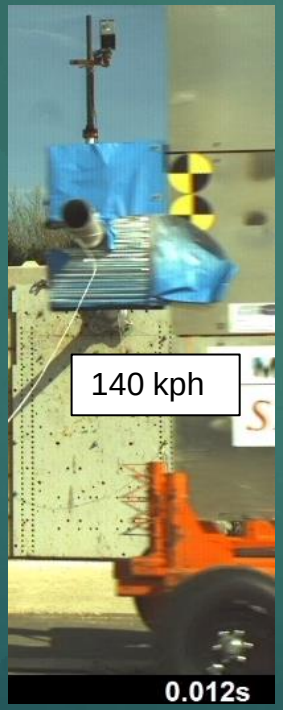
- 2 pole types - Aluminum and FRP
  - Not actual products
  - Frangible joint added to FRP pole by cutting 2 m from free end, inserting sleeve, and securing with screws.



Air Force Testing

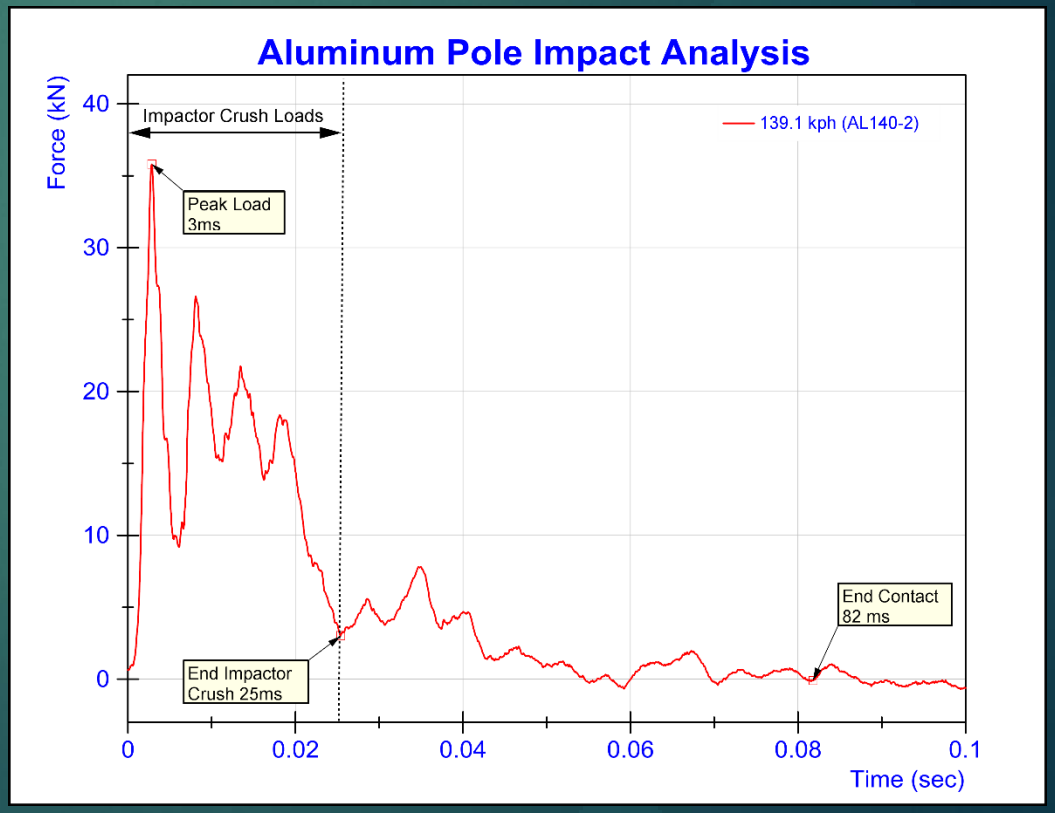
- 100, 120, and 140 kph test speeds
- Honeycomb impactor for all tests





Impact Analysis

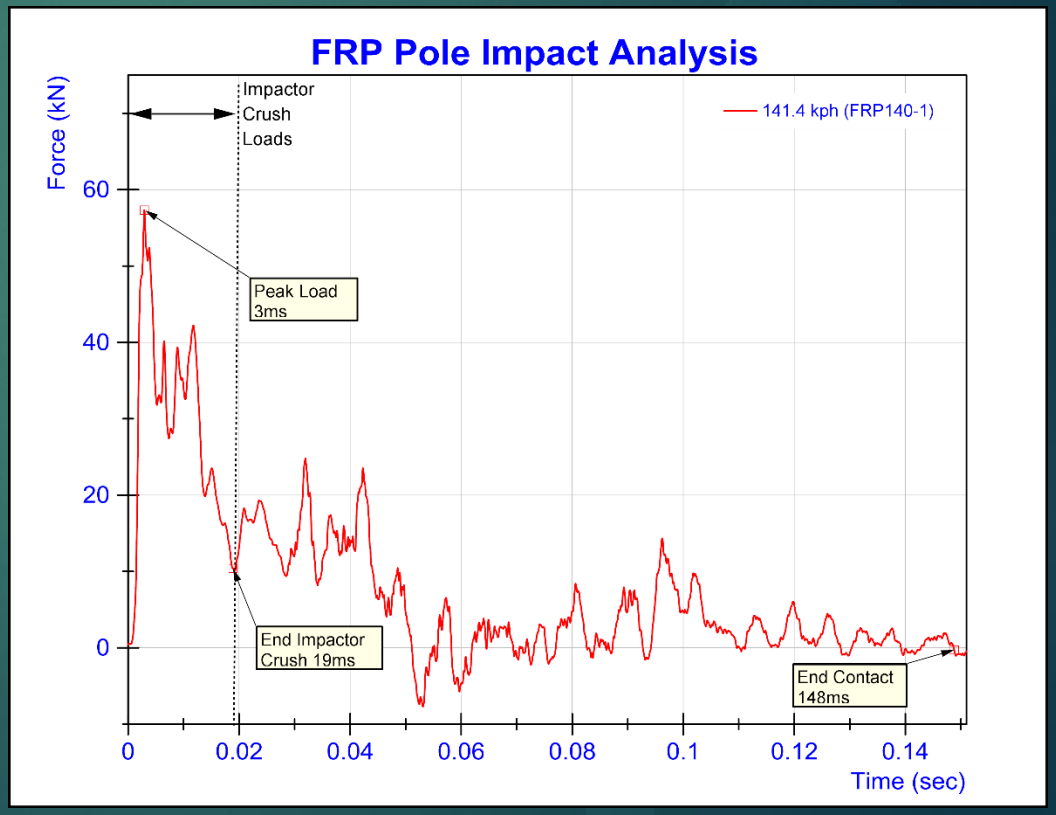
- Aluminum pole
  - Peak load at 3ms
  - Impactor crush for 25ms
  - Contact for 82ms



*Unfiltered data

Impact Analysis

- FRP pole
  - Peak load at 3ms
  - Impactor crush for 19ms
  - Contact for 148ms



*Unfiltered data

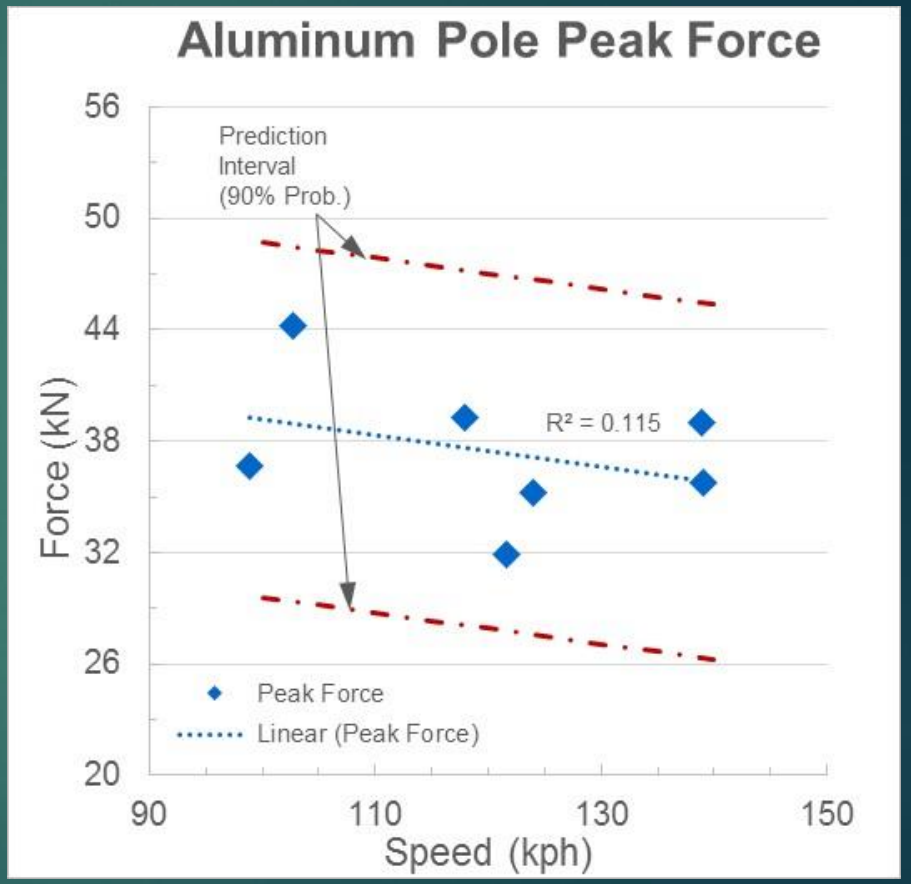
Data Filtering

- Standard for data filtering in automotive crash testing is the SAE J211
  - 4 filter classes
  - No significant effect on Energy
  - Significant effect on Peak Force below CFC600
- Recommend requiring raw data submission

Aluminum and FRP Pole Tests		
Filter Class	Max % Diff. from Raw	
	Peak Force	Energy
CFC1000	**1.31**	**0.00**
CFC600	**2.41**	**0.00**
CFC180	**12.98**	**0.13**
CFC60	**48.87**	**1.13**

Peak Force

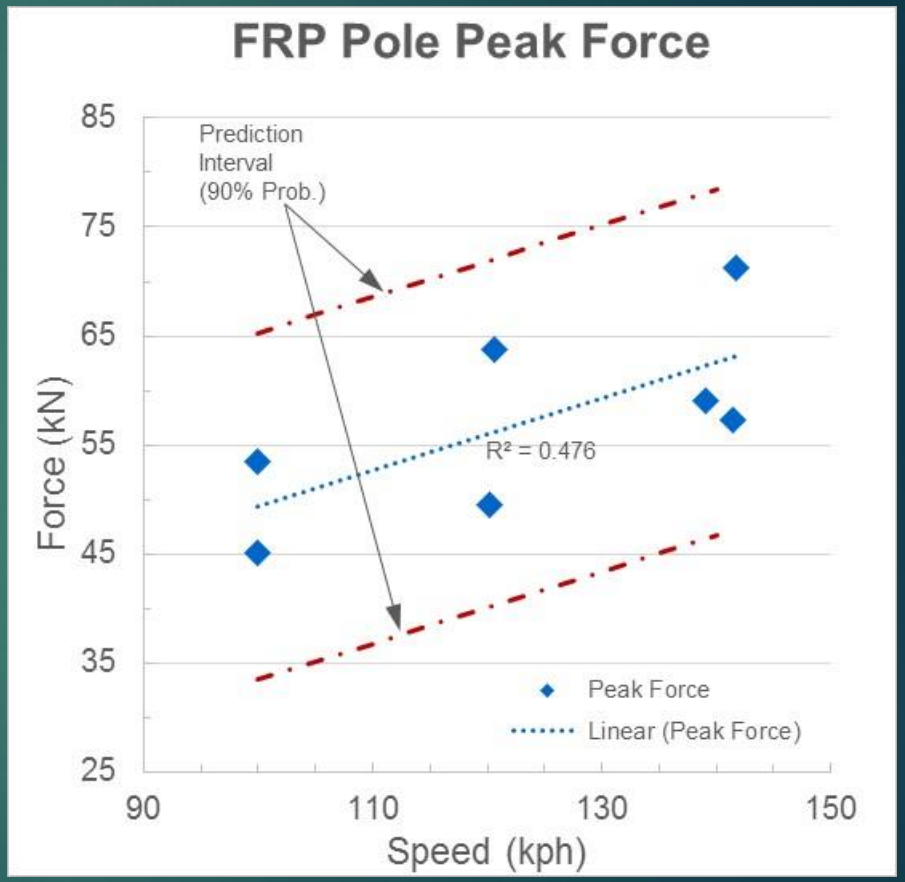
- Aluminum poles
  - Large variation
  - No clear correlation to speed
  - Prediction interval @ 140 kph:
    - 35.8 kN ± 25.7%



*Unfiltered data

Peak Force

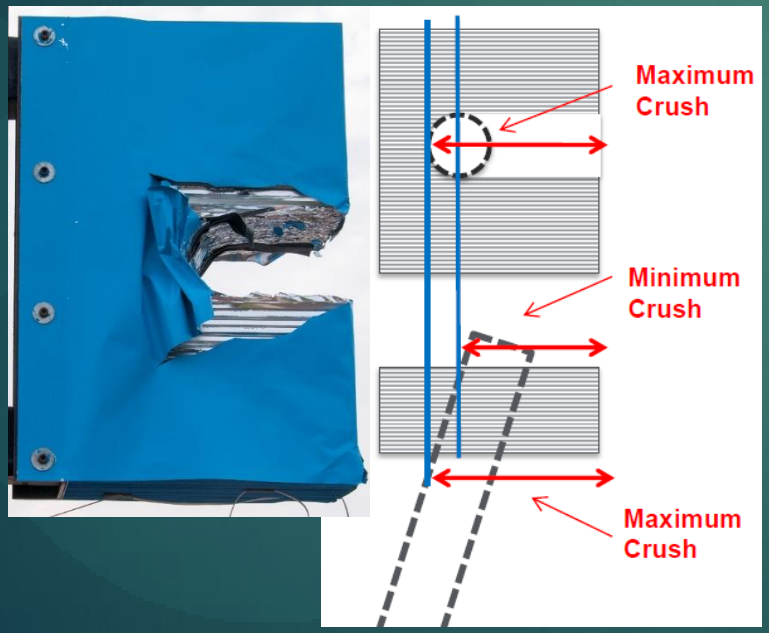
- FRP poles
  - Large variation
  - Correlation to speed questionable
  - Prediction interval @ 140 kph:
    - 61.7 kN ± 26.1%



*Unfiltered data

Honeycomb Crush

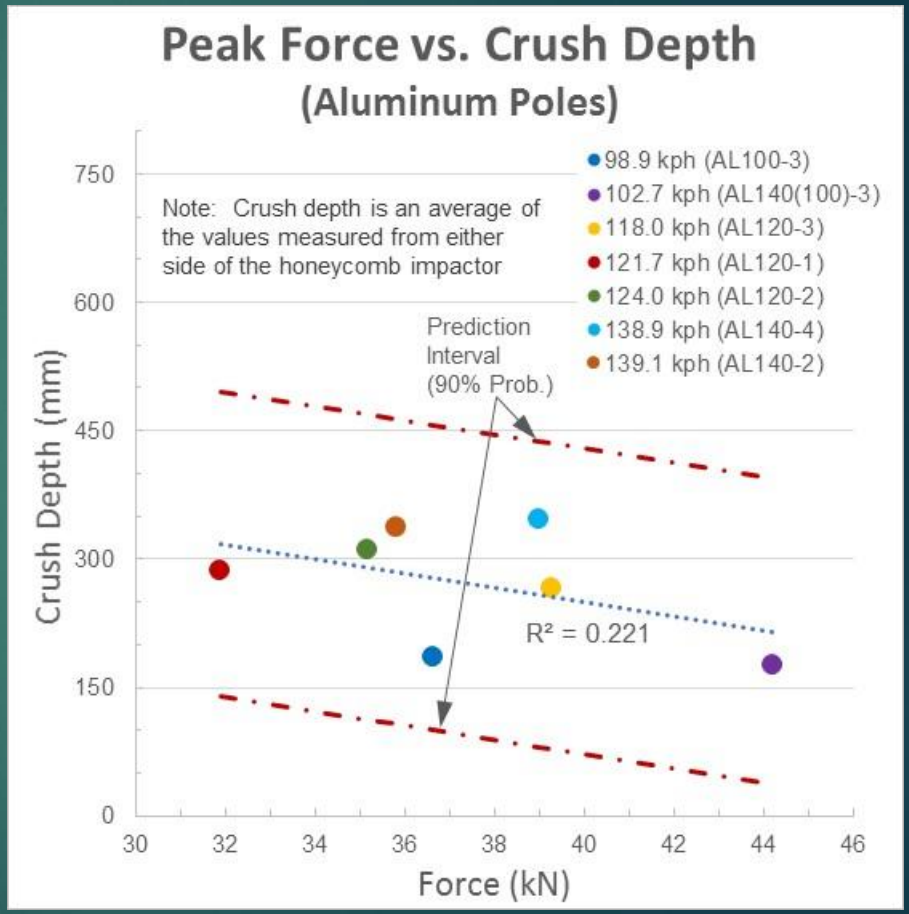
- Aluminum Pole
  - Consistent profile
  - Measurable depth



- FRP Pole
  - Complicated profile
  - Difficult to measure

Peak Force

- Aluminum poles
  - Large variation
  - No clear correlation to Crush Depth
  - Likely that there is no wing damage correlation
  - Prediction interval @ 37.5 kN:
    - 272 mm ± 51.8%



*Unfiltered data

Peak Force

- ICAO
  - "4.3 …the maximum impact load may adversely affect the structural integrity of the aircraft."

Summary

- Peak force is inconsistent between test configurations
- Peak force is not repeatable within a given test configuration
- Peak force is not directly relevant to level of wing damage

Recommendation

- Abandon peak force limit as an approval criteria