Crash Dynamics Summary

Federal Aviation Administration

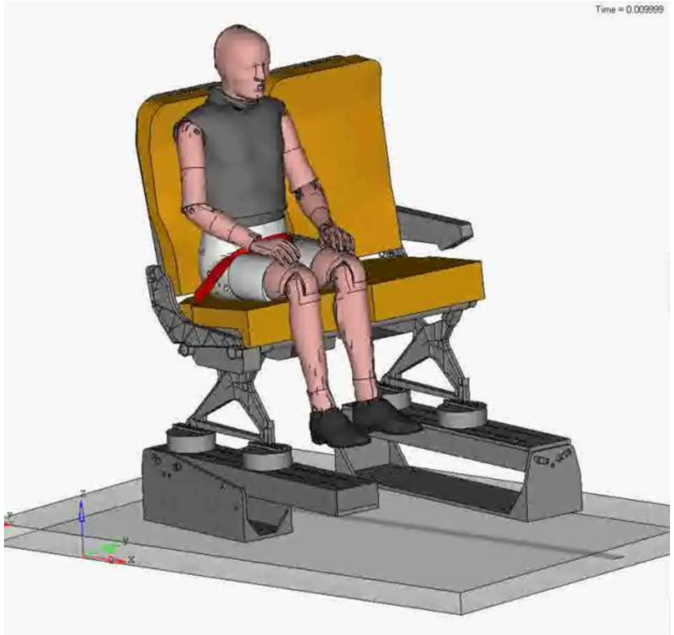
Presented to: FAA/EASA/Industry Composite Transport Fatigue, Damage Tolerance, Maintenance and Crashworthiness Workshop

By: Joseph Pellettiere, Chief Scientific and Technical Advisor for Crash Dynamics

Date: 19 May 2011

Overview

- **History**
  - Provide basis of regulations
- **Modeling and Simulation**
  - How to apply M&S to regulations



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History

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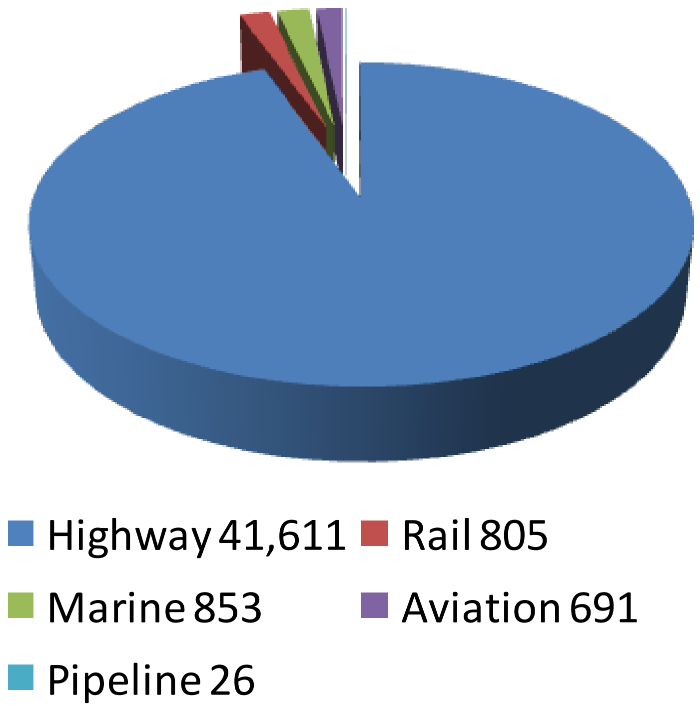
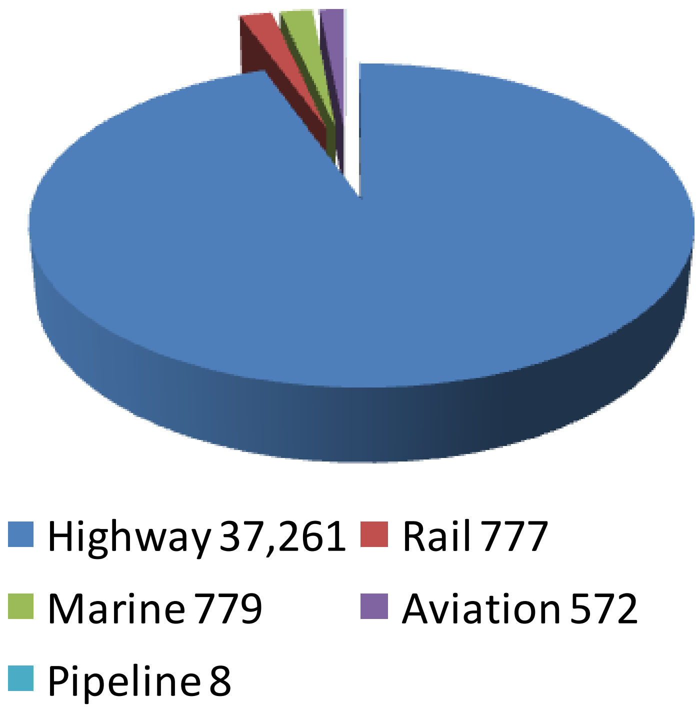
Total Transportation Fatalities

43,986 Total Fatalities in 1999 ***39,397 Total Fatalities in 2008***

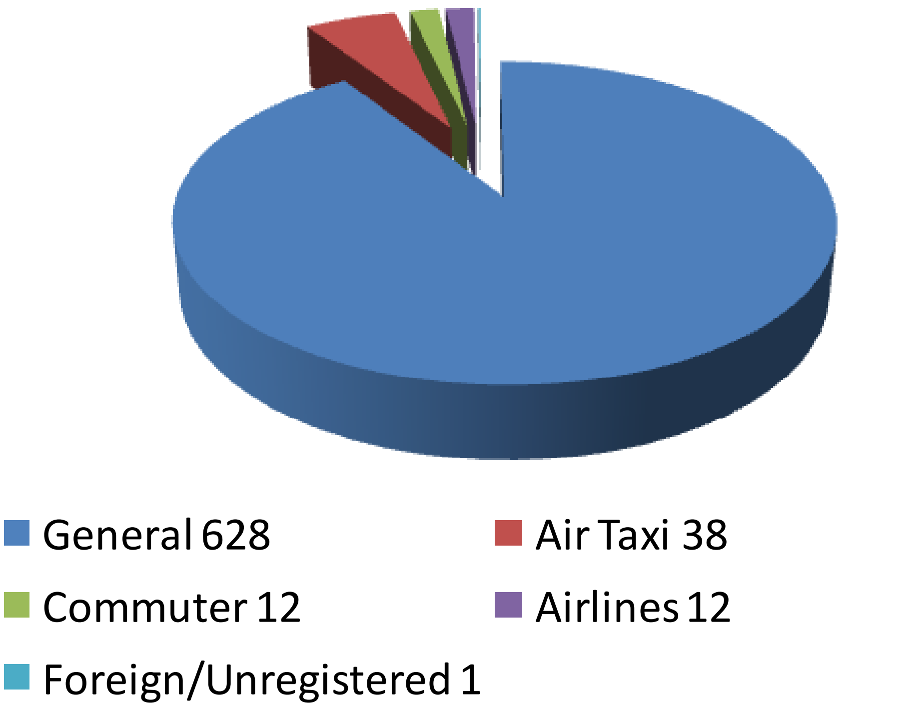
Aviation < 2%



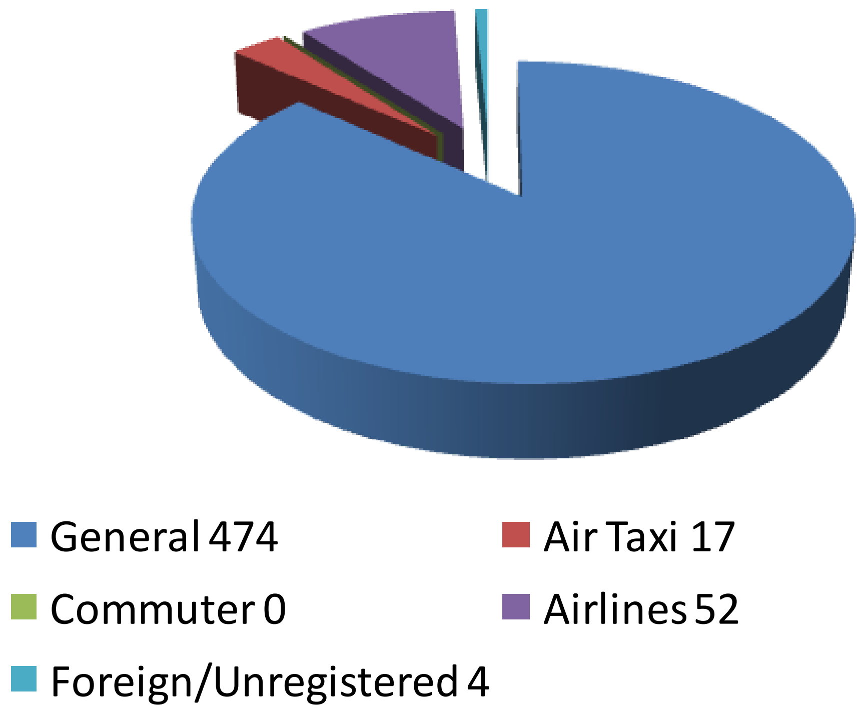


Aviation Related Fatalities

691 Aviation Fatalities in 1999



534 Aviation Fatalities in 2009



General Aviation ~ 90%

Performance Standards Developed for Each Aircraft Category

- **General Aviation Aircraft**
- **Rotorcraft**
- **Transport Category Aircraft**
- **Commuter Category Aircraft**

Rationale for Seat Dynamic Test Criteria

- **Static Tests**
  - Body blocks may apply an unrepresentative load distribution
- **Static Tests can only assess**
  - Structural adequacy of seat/restraint/attachments
  - Structural deformation

Rationale for Seat Dynamic Test Criteria

- **Dynamic Tests**
  - Anthropormorphic Dummy(s) apply a more representative load distribution
- **Dynamic Tests can assess**
  - Structural adequacy of seat / restraint / attachments
  - Structural deformation
  - Restraint system behavior and loads
  - Potential for Occupant Injury

The General Aviation Safety Panel

- **The General Aviation Safety Panel (GASP) was Instrumental in Formulating Dynamic Performance Standards**
- **Formed at the Request of the FAA Administrator**
- **Represented a Broad Constituency from the General Aviation Community**
  - Research
  - Regulatory
  - Manufacturers of G/A Products
  - G/A User Groups

GASP Objectives

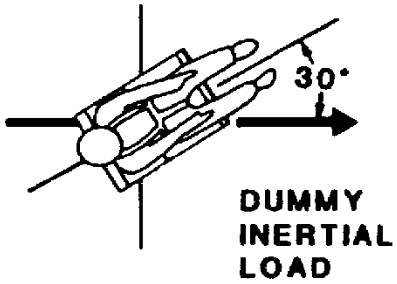
- Analyze Results of Existing Crash Dynamics Research
- Develop Crash Dynamics Design Standards
- Establish Milestones for Implementation of any Developed Recommendation

Early Pioneers

- **The Development and Application of Crash Dynamics Technology Fostered the Dynamic Performance Standards**
- **US Army's Aircraft Crash Survival Design Guide**
  - Hughes AH-64 Apache
  - Sikorsky UH-60A Blackhawk
- **FAA/NASA Crash Dynamics Research**

US Army Requirements

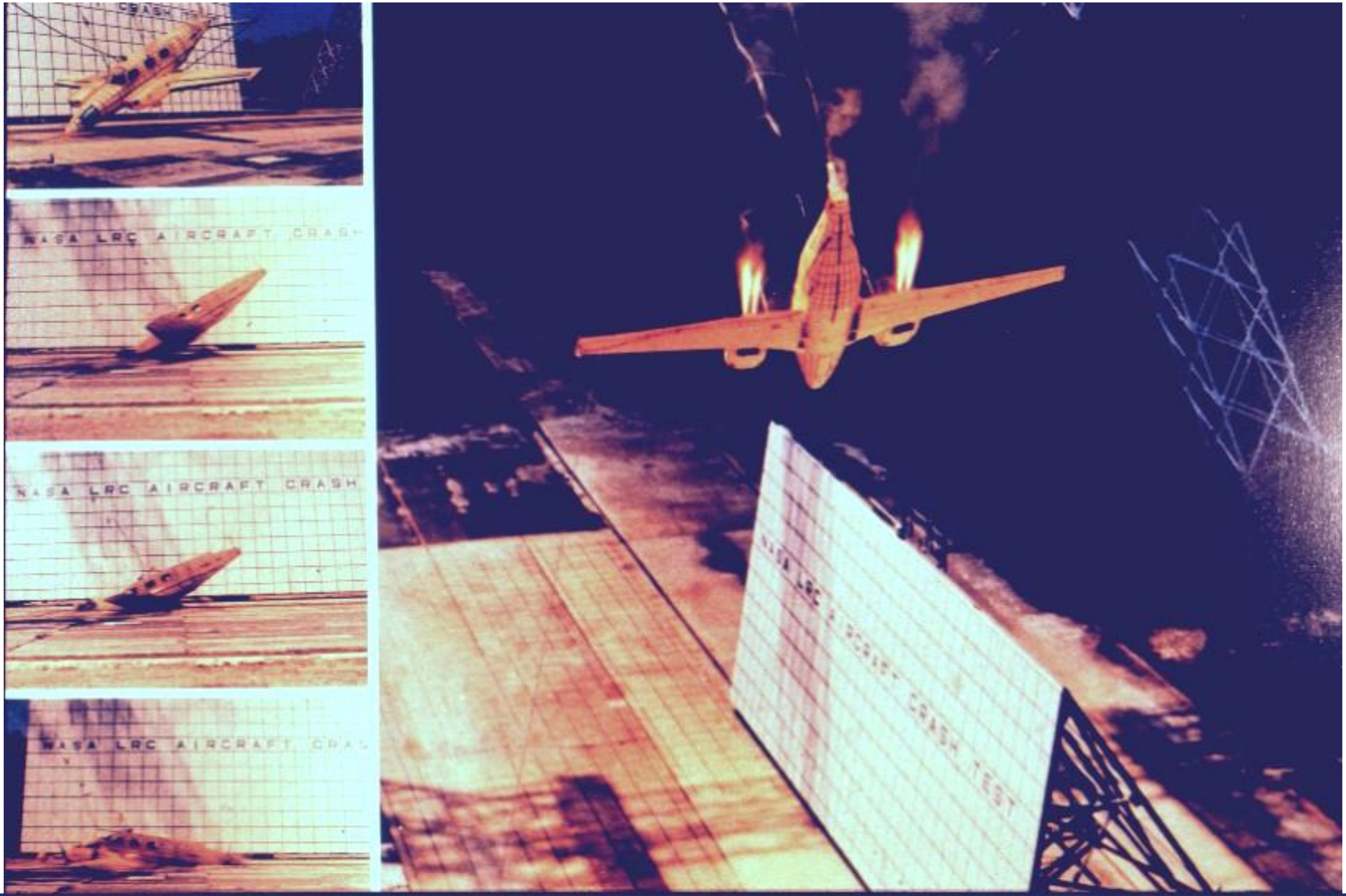
For Seats Having At Least 12 inches Of Vertical Stroke

TEST	CONFIGURATION	PARAMETER	COCKPIT SEATS LIMITS	CABIN SEATS LIMITS
2		t_1 SEC	0.066	0.081
		t_2 SEC	0.100	0.127
		G MIN	28	22
		G MAX	33	27
		ΔV MIN FT/SEC	50	50

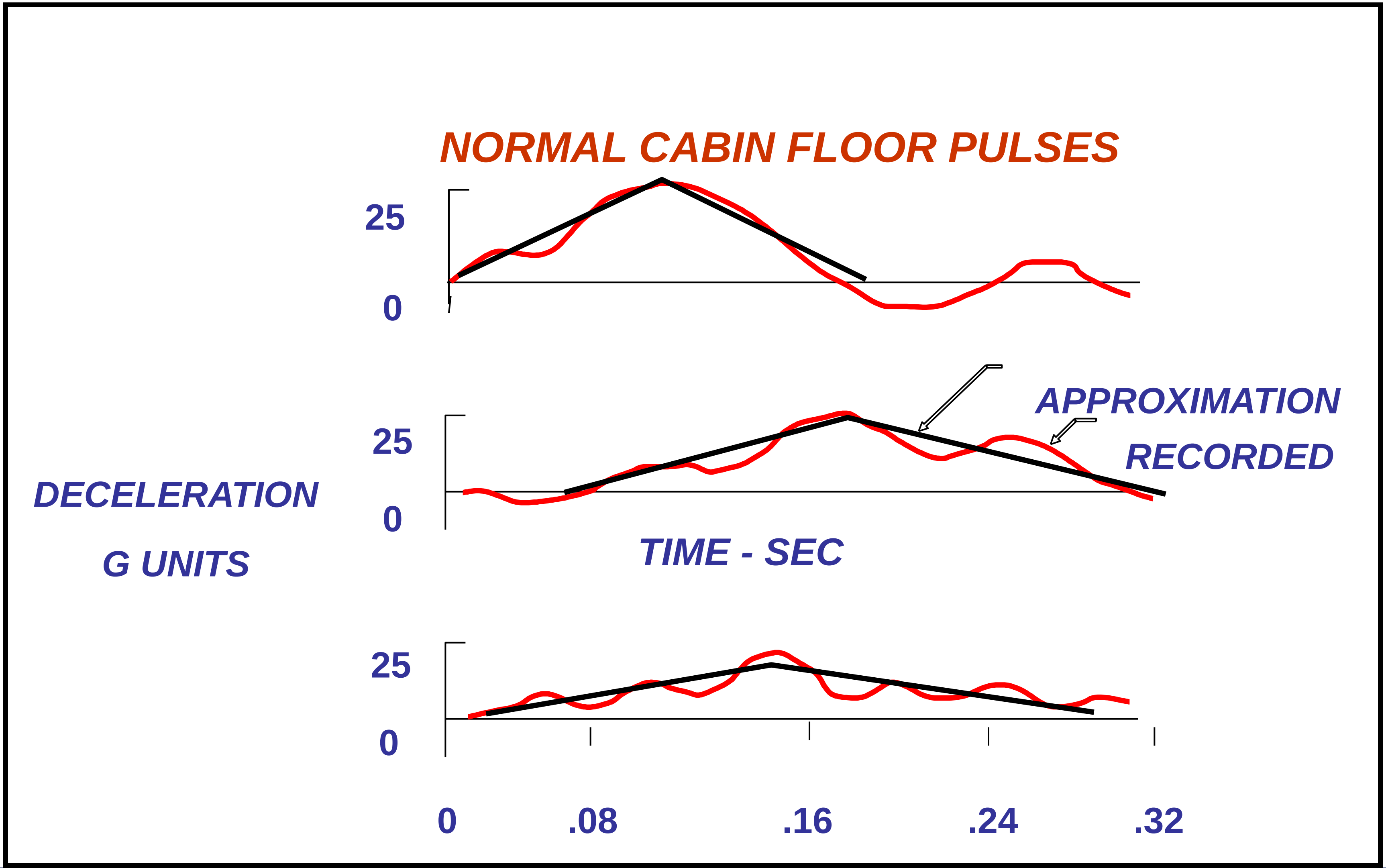
CREW SEATS: SHOULD MEET THE REQUIREMENTS OF MIL-S-58095
SEAT HEIGHT ADJUSTMENT TO BE AT THE FULL-UP POSITION
95th PERCENTILE ATD TO BE USED

CABIN SEATS: SHOULD MEET THE REQUIREMENTS OF MIL-S-85510
SEAT HEIGHT ADJUSTMENT TO BE AT FULL-AFT AND UP POSITION
95th PERCENTILE ATD TO BE USED

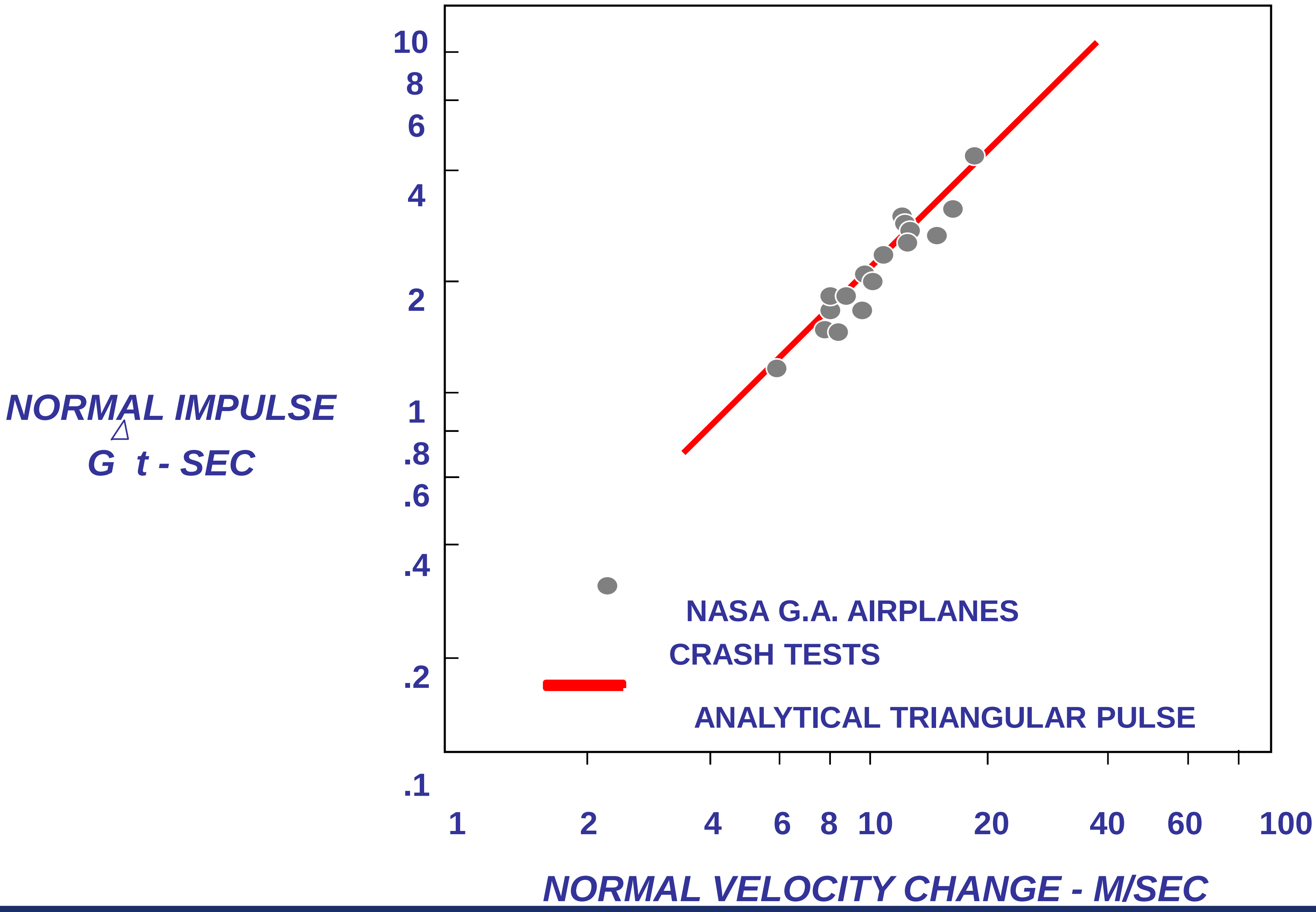
FAA/NASA General Aviation Airplane Impact Tests



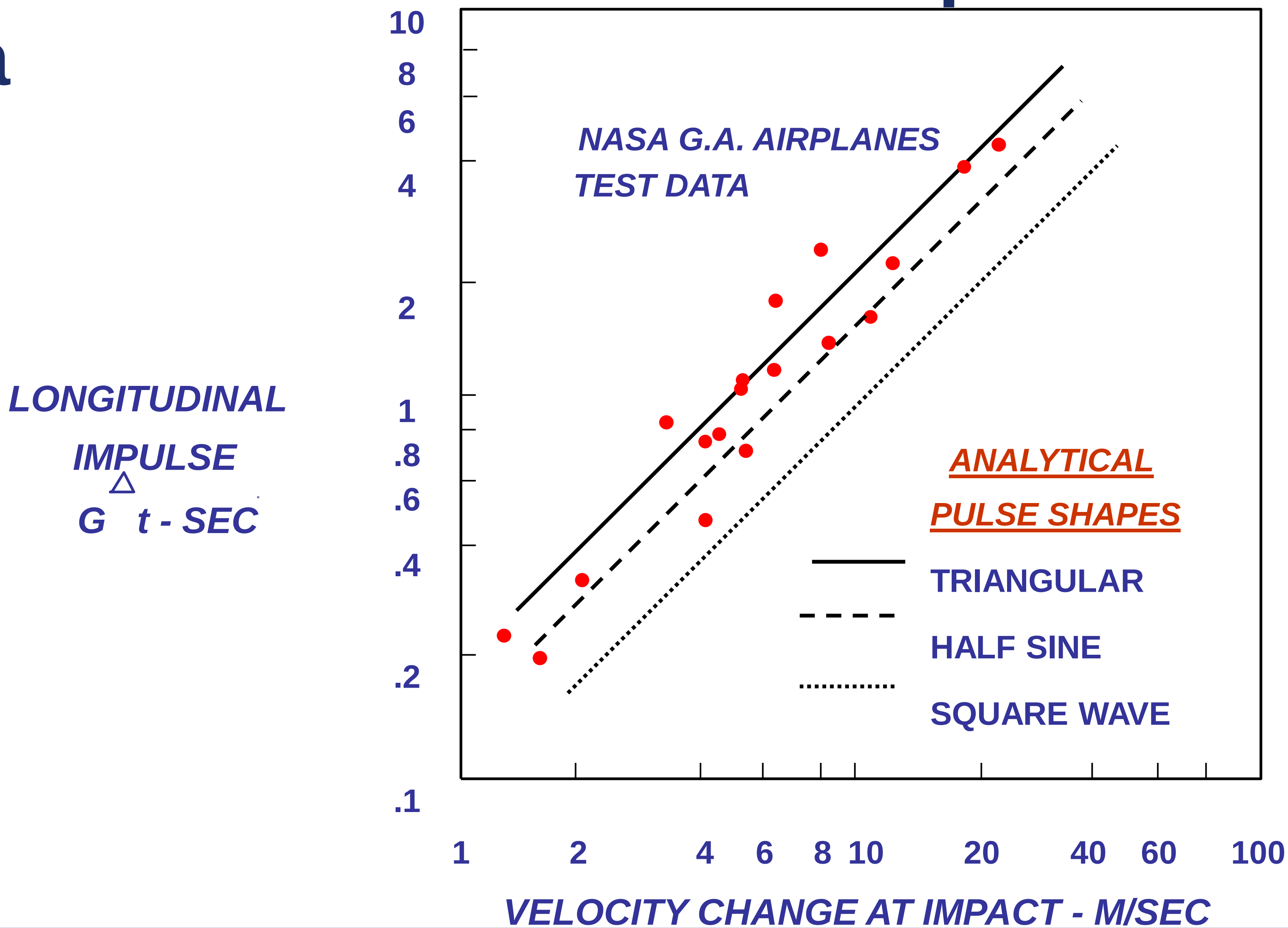
Example Time Histories



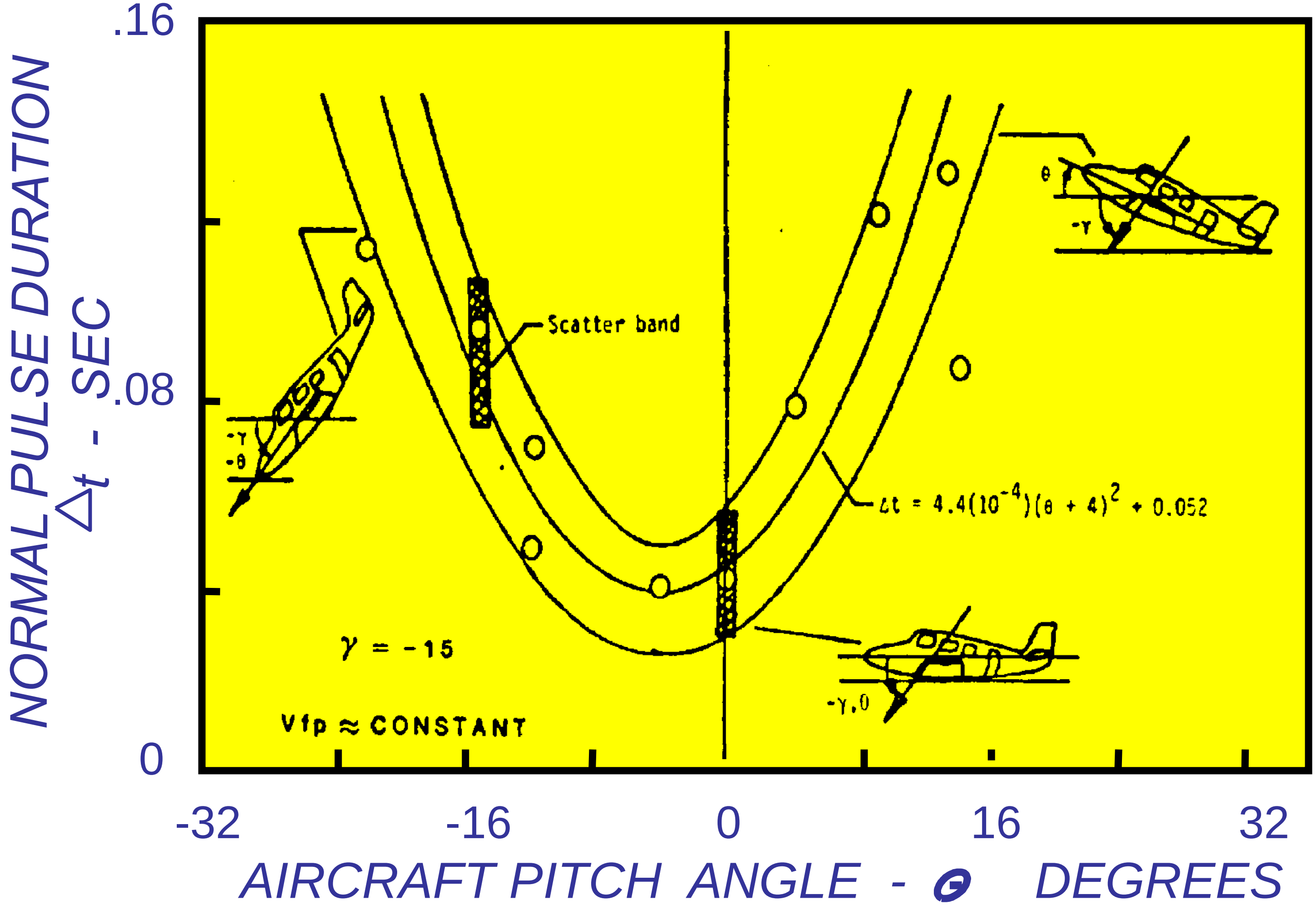
Experimental Normal Impulse Data



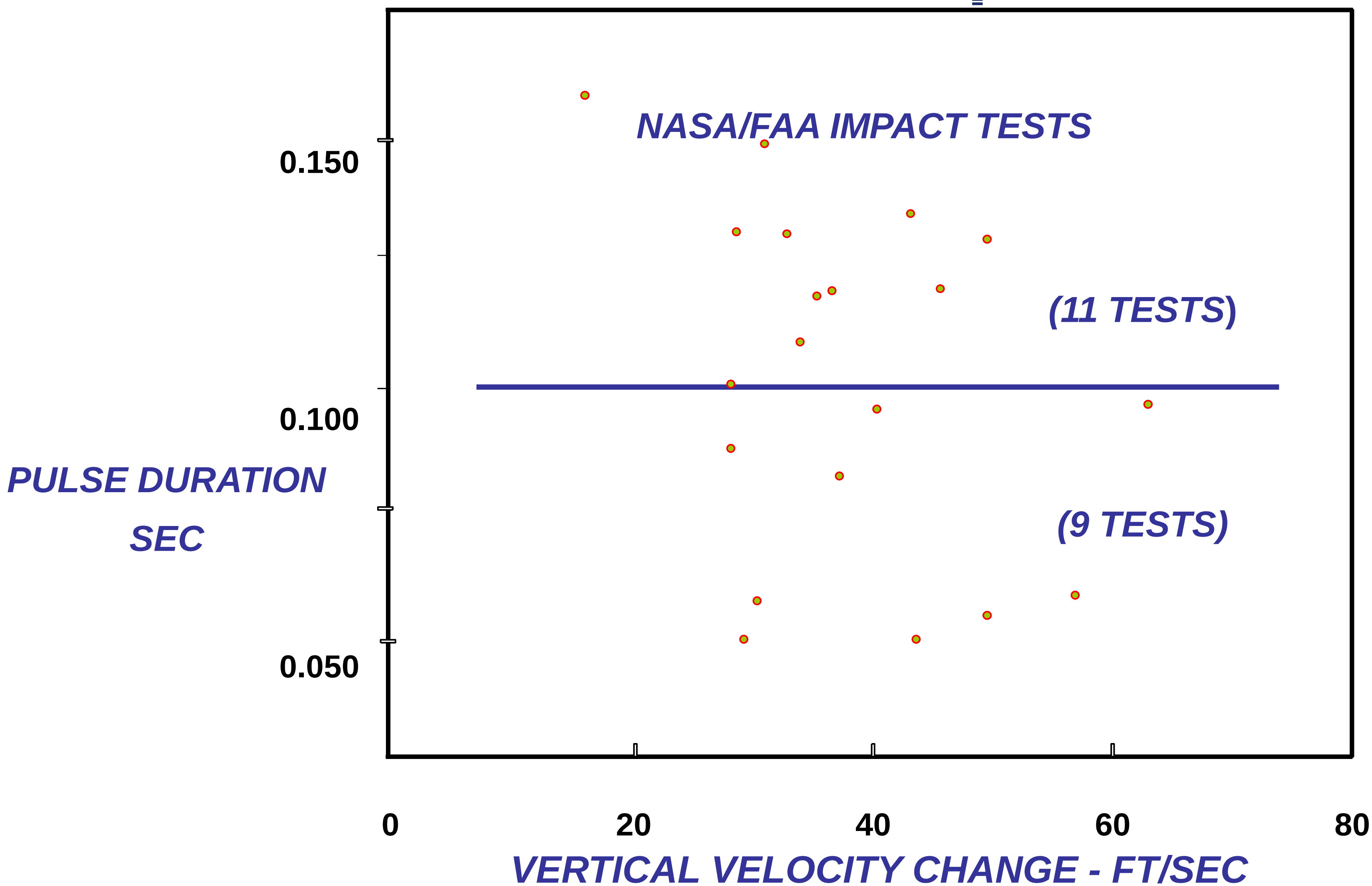
Experimental & Calculated Impulse Data



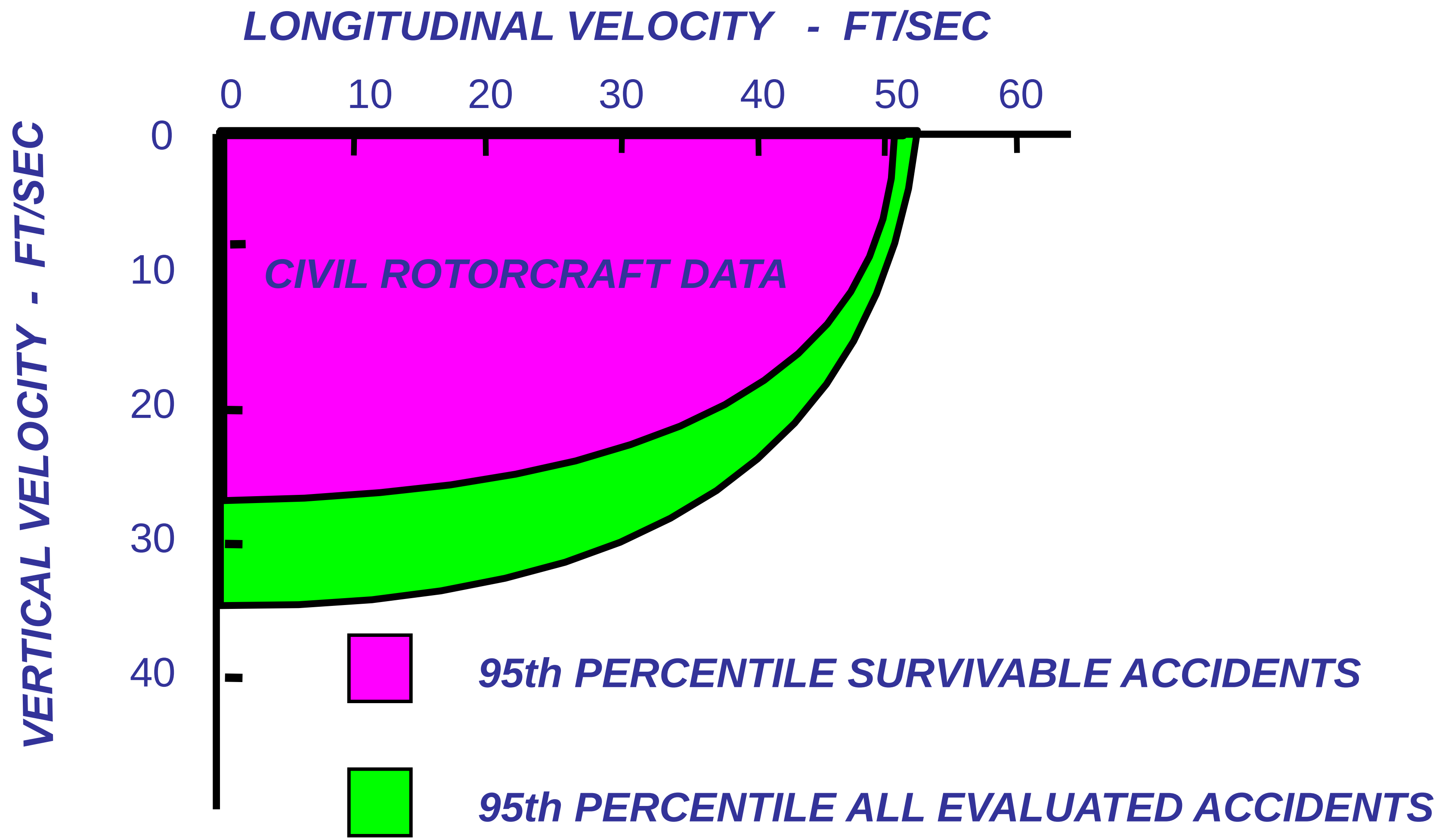
Impact Pulse Duration as a Function of Impact Attitude



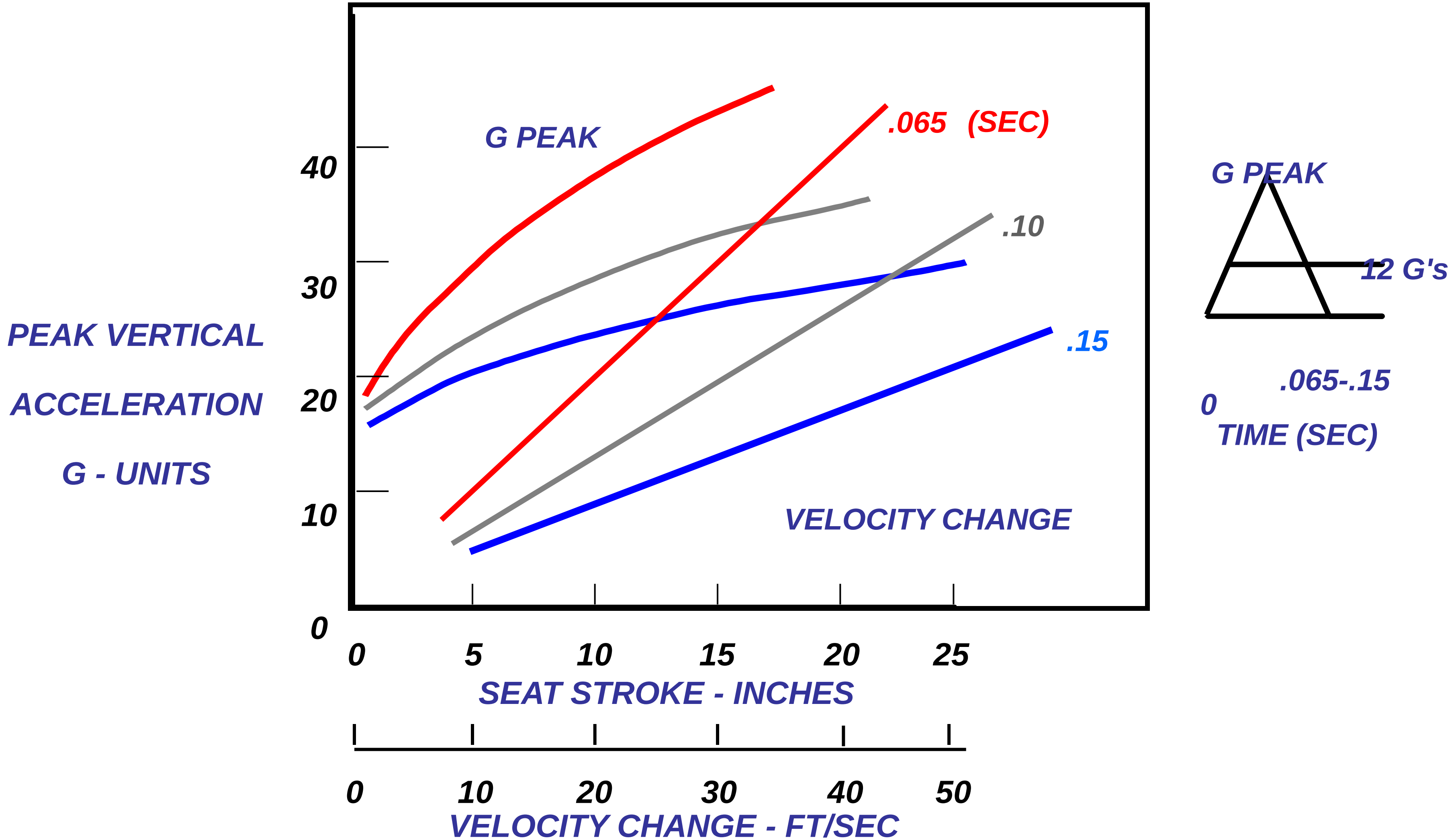
NASA/FAA Full-Scale Impact Tests



Accident Survivability for Longitudinal/ Lateral Impact Velocity Components



Peak Vertical Acceleration vs Velocity Change and Seat Stroke for Various Pulse Durations



GASP Established a Pass/Fail Performance Criteria

- **Performance Criteria Relates Selected Measured Dynamic Test Parameters to Injury Criteria**
- **Performance Criteria Evaluates the Seat/ Restraint System's Potential for Preventing or Minimizing Injuries from:**
  - Primary Impacts
  - Secondary Impacts
  - Occupant Skeletal Loads

Rotorcraft

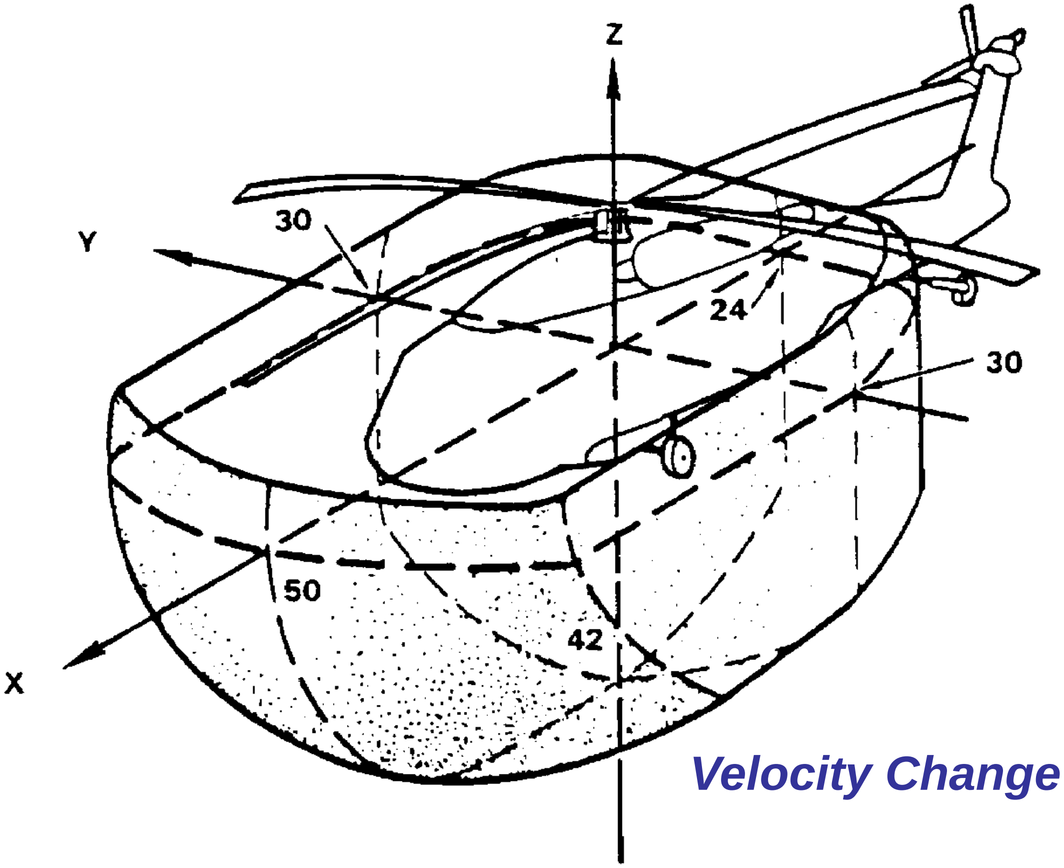
- **Technical Data Review**
- **Rotorcraft Accident Analysis**
- **Accident Scenarios**
- **Impact Envelopes**
- **Performance Criteria**
- **Dynamic Performance Standards**
- **14 CFR Part 27, Amendment 27-25**
- **14 CFR Part 29, Amendment 29-29**
  - Effective Date – December 13, 1989

MIL-STD-1290A

Crash impact design conditions with landing gear extended

Condition No.	Impact Direction (Aircraft Axes)	Velocity Change (ft/s)	Object/ Surface Impacted
1	Longitudinal (cockpit)	20	Rigid vertical barrier
2	Longitudinal (cabin)	40	
3	Vertical*	42	Rigid horizontal surface
4	Lateral, Type I	25	
5	Lateral, Type II	30	
6	Combined high angle* Vertical Longitudinal	42 27	
7	Combined low angle Vertical Longitudinal	14 100	Plowed soil

Design Velocity Change Envelope
95th Percentile Survivable Accident



Velocity Change - FT/SEC

Accident Frequency – Civil Rotorcraft

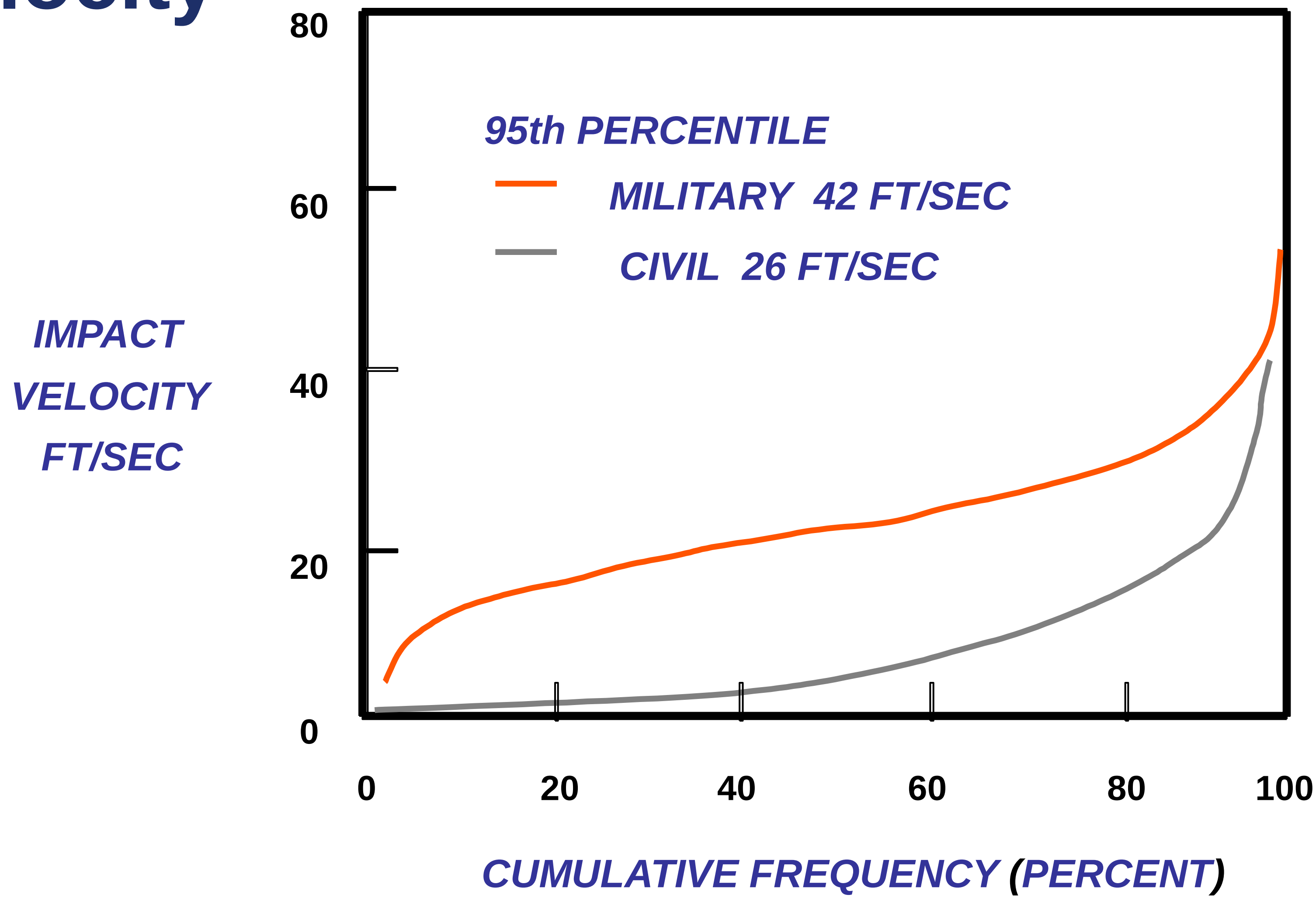
SCENARIO TYPE	DESCRIPTION	NO. OF ACCIDENTS	PERCENTAGE
1	HIGH VERTICAL IMPACT VELOCITY	70	29.2
2	HIGH LONGITUDINAL IMPACT VELOCITY	21	8.5
3	ROLLOVER	34	13.7
4	WIRE STRIKE	25	10.1
5	WATER IMPACT	24	9.7
6	HIGH YAW RATE	21	8.5
	ALL OTHERS	53	21.3
		248	100.0

Crash Hazard Ranking

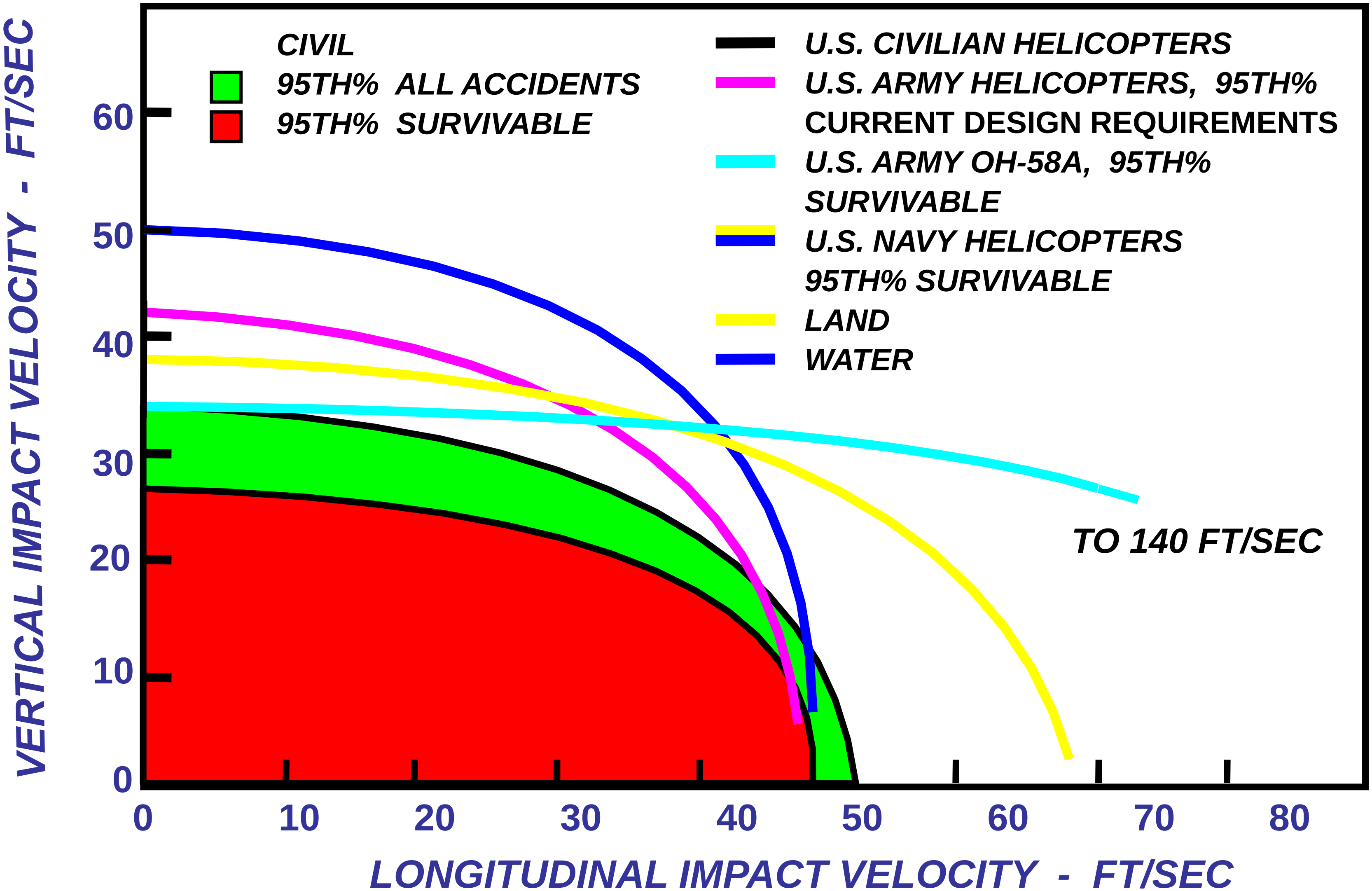
RANK-ORIENTED LISTING OF CRASH HAZARDS FOR THE CIVILIAN ROTORCRAFT FLEET

HAZARD No.	SIGNIFICANCE GROUP	DESCRIPTION	FREQUENCY INDEX	SEVERITY INDEX	ACCUMULATED AIS
1	2	BODY EXPOSED TO FIRE WHEN FUEL SYSTEM FAILED ON IMPACT	B	I	147
2	2	BODY RECEIVED EXCESSIVE DECELERATION FORCE WHEN AIRCRAFT AND SEAT ALLOWED EXCESSIVE LOADING	B	I	145
14	7	BODY EXPOSED TO CHEMICAL AGENTS ON IMPACT	E	III	1

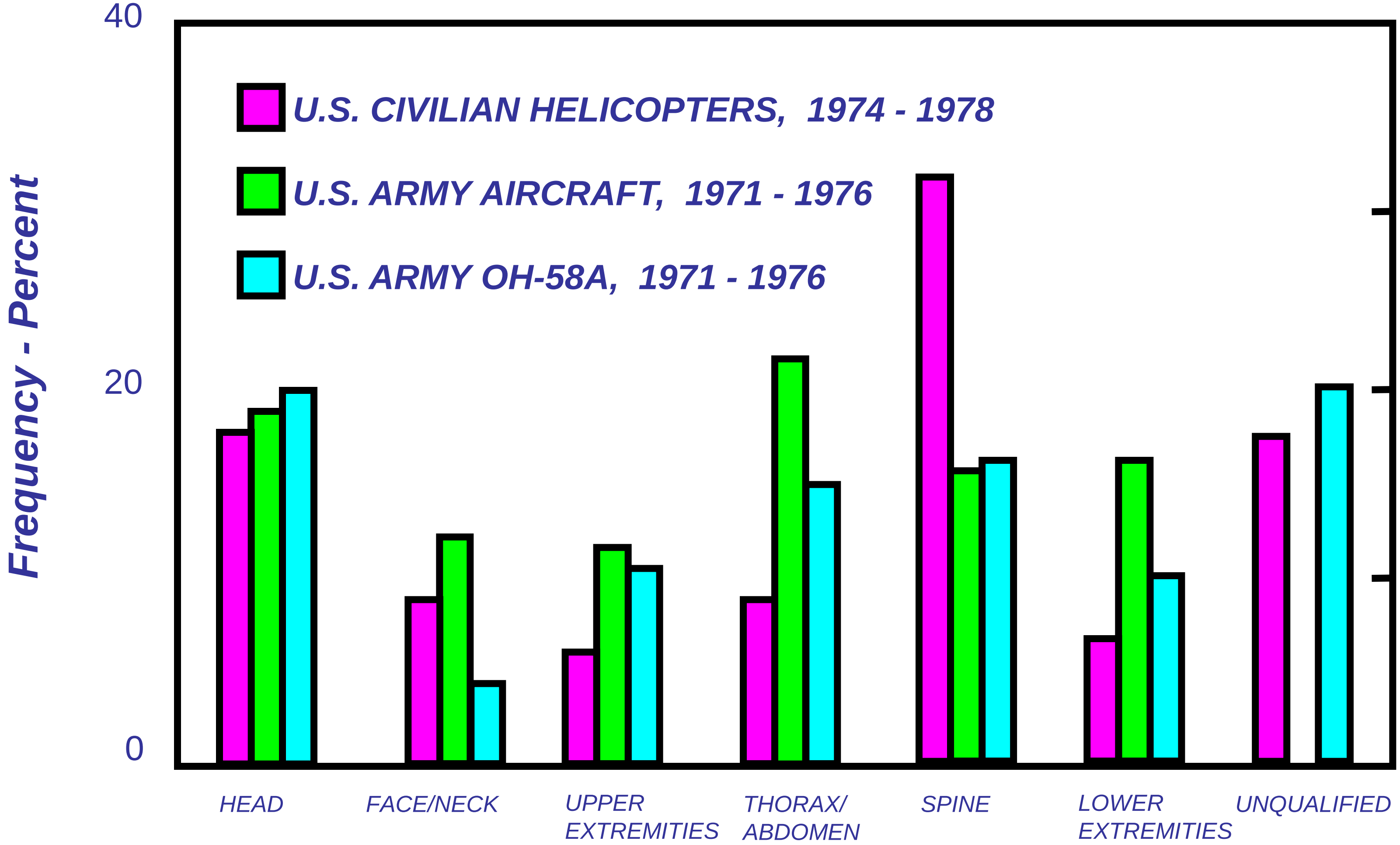
Occurrence of Vertical Impact Velocity



Civil and Military Comparison

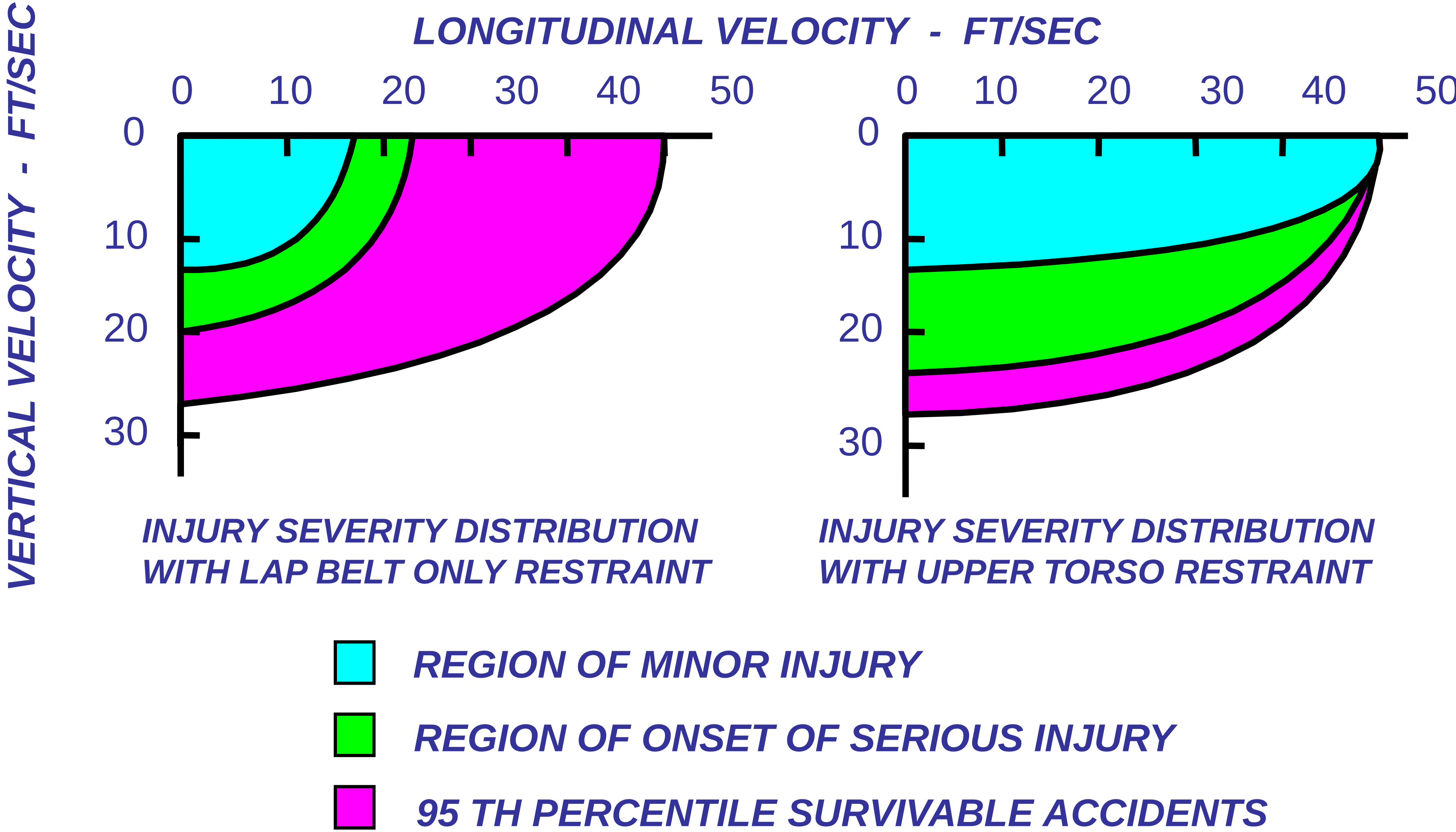


Injury Distribution Used to Select Injury Criteria



Frequency Of Major And Fatal Injuries To Each Body Region As Percentages Of Total Major And Fatal Injuries In Survivable Accidents

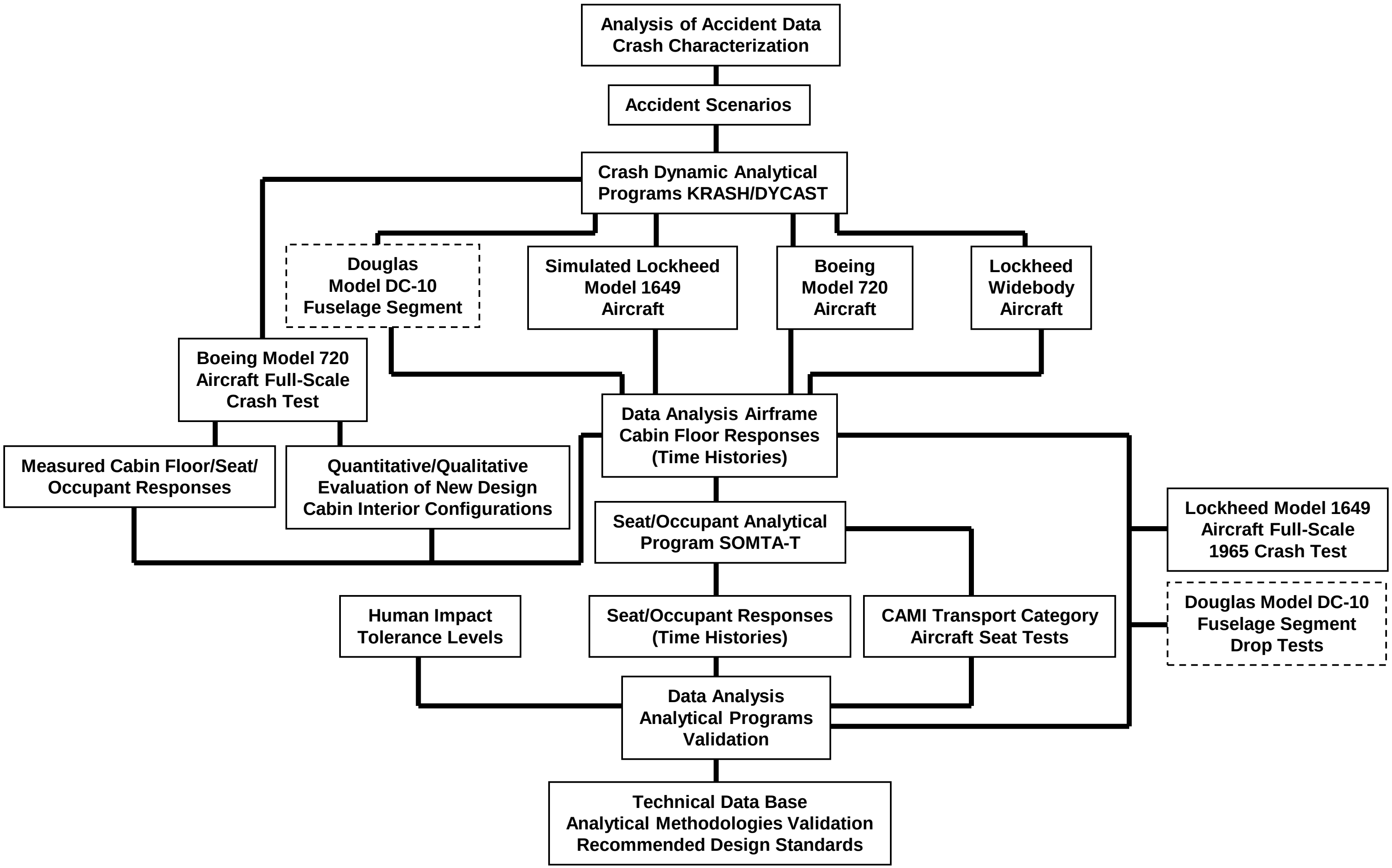
Upper Torso Restraint Raises the Onset Point for Serious and Fatal Injuries



Transport Category Aircraft

- **Accident Data Review**
- **Full Scale Tests**
- **Parametric Studies (KRASH)**
- **Controlled Impact Demonstration (CID)**
- **Performance Criteria**
- **Seat Dynamic Test Series**
- **Transport Category Aircraft Seat Dynamic Performance Standards**
- **14 CFR Part 25, Amendment 25-64**
  - Effective Date – June 16, 1988

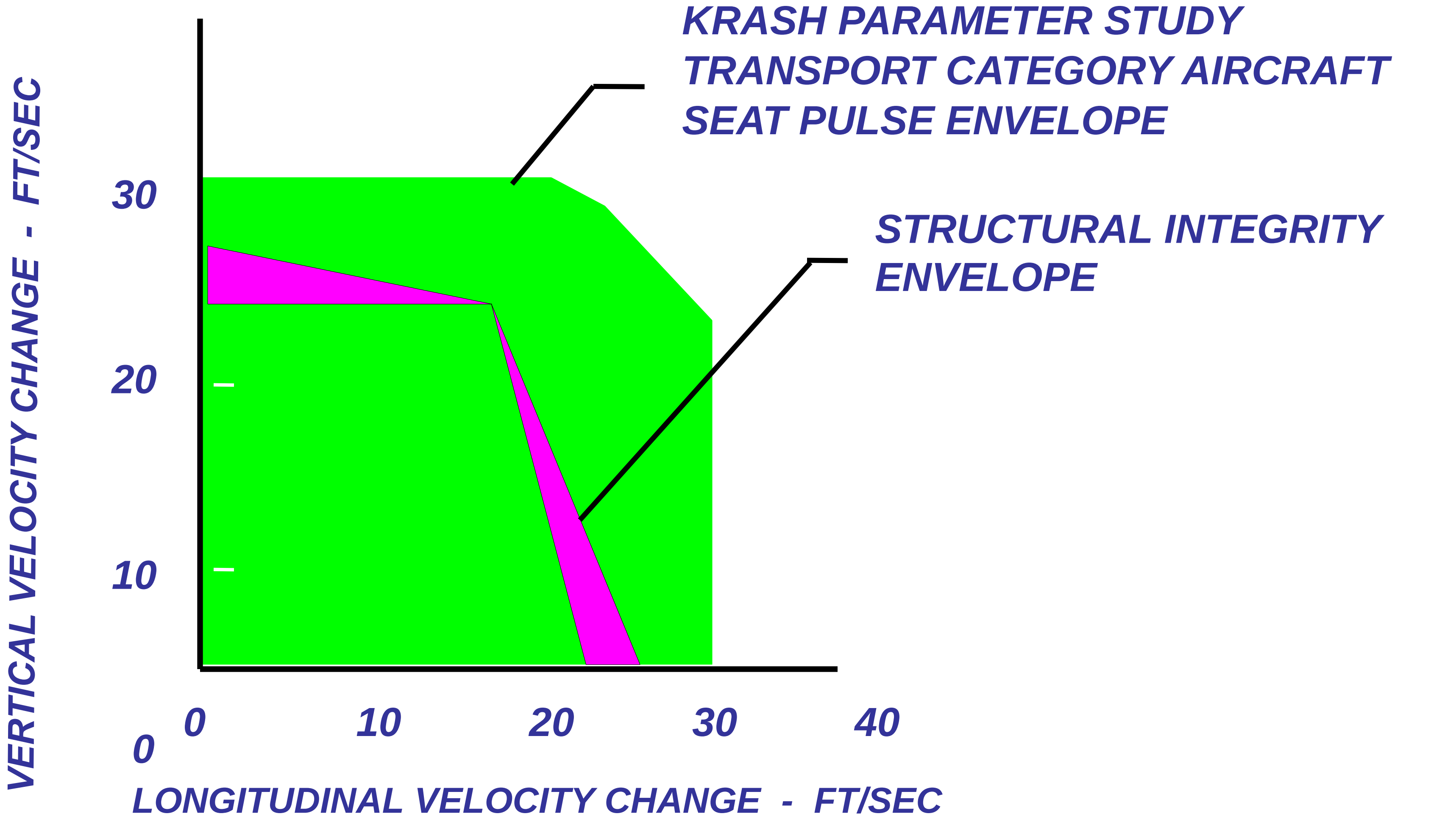
Crash Dynamics Program Plan



Candidate Crash Scenarios

CANDIDATE CRASH SCENARIO	IMPACT CONDITIONS	ACCIDENT TYPE	TERRAIN	HAZARD
GROUND-TO-GROUND, OVERRUN	LOW SINK SPEED LOW FORWARD VELOCITY SYM. A/P ATTITUDE GEARS EXTENDED	TAKEOFF ABORT LANDING OVERRUN	RUNWAY HARD GROUND	DITCH MOUND SLOPE SLAB LIGHT STANCHION
AIR-TO-GROUND HARD LANDING	HIGH SINK SPEED AND LANDING VELOCITY SYM. A/P ATTITUDE GEARS EXTENDED	HARD LANDING UNDERSHOOT	RUNWAY HARD GROUND	NONE
AIR-TO-GROUND IMPACT	HIGH SINK SPEED AND LANDING VELOCITY UNSYM. A/P ATTITUDE GEARS EXTENDED/RET	UNCONT/CONT GRD COLLISION STALL UNDERSHOOT	WOODED HILLY	TREES SLOPES BLDGS

Structural and Seat Test Velocity Change Envelopes



Fuselage Section Drop Tests

Provide Basic Airframe Data

- **Lower Fuselage Crush Characteristics**
  - Stress analysis
  - Static tests
  - Section drop tests
- **Obtain Load/Deflection Experimentally**
- **Address Failure Modes**
- **Verify Analytical Predictions**
- **Input for Aircraft Models**
- **Investigated Both "Hard" and "Soft" Sections**

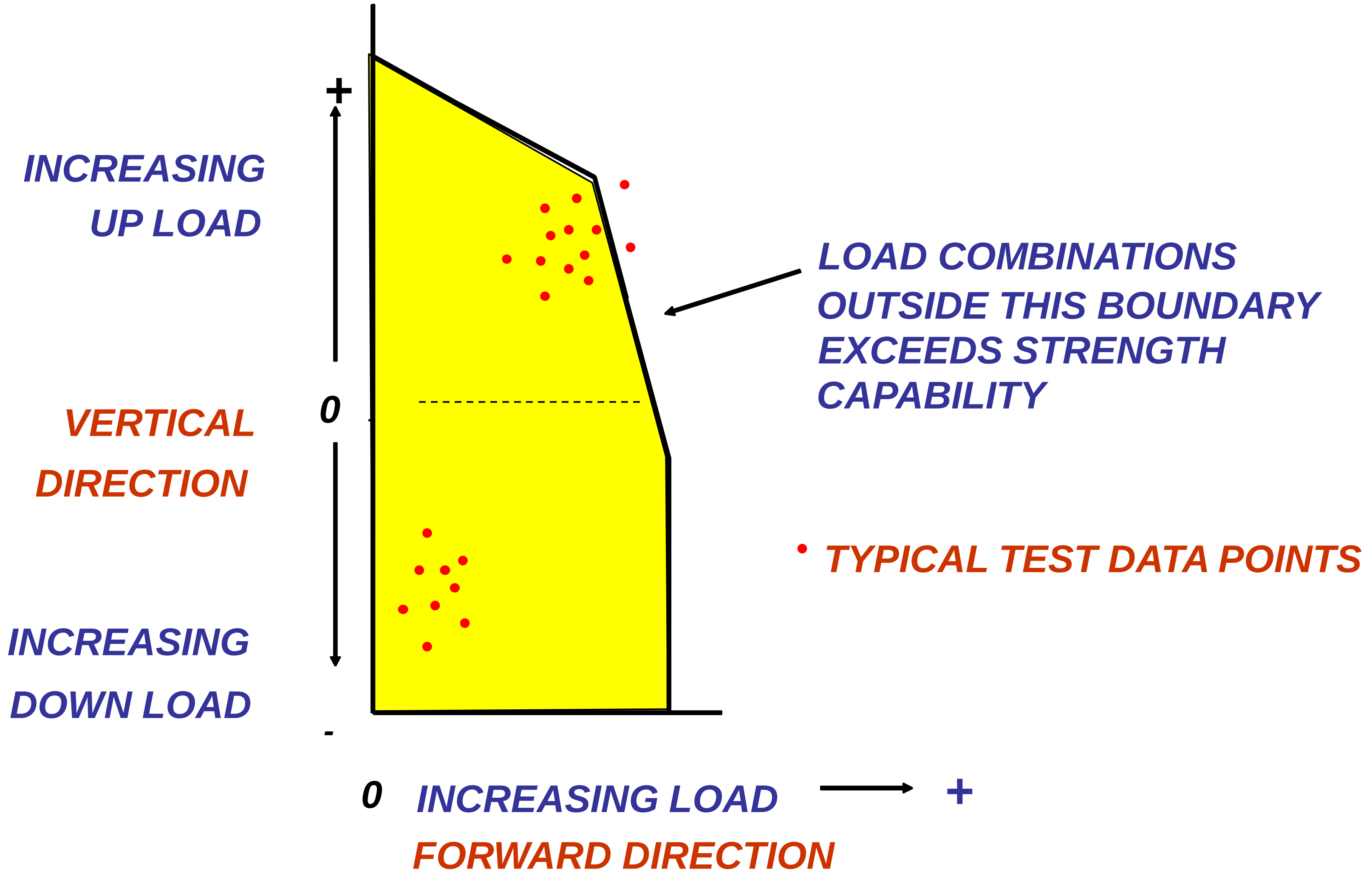
FAA/NASA Full-Scale Airframe Impact Tests

AIRPLANE TYPE	TEST SPECIMEN	TEST CONDITION
NARROW BODY	FORWARD FUSELAGE SECTION	VERTICAL IMPACT 20 FPS
NARROW BODY	CENTER FUSELAGE SECTION	VERTICAL IMPACT 20 FPS
NARROW BODY	FORWARD FUSELAGE SECTION WITH CARGO	VERTICAL IMPACT 20 FPS
NARROW BODY	AFT FUSELAGE SECTION WITH CARGO	VERTICAL IMPACT 35 FPS
WIDE BODY	AFT FUSELAGE SECTION	VERTICAL IMPACT 20 FPS
WIDE BODY	FUSELAGE SECTION WITH CARGO	VERTICAL IMPACT 25 FPS
NARROW BODY	FULL AIRPLANE LAURINBURG	VERTICAL IMPACT 17 FPS
NARROW BODY	FULL AIRPLANE - CID	VERTICAL IMPACT WITH FORWARD VELOCITY 17.3 FPS/141.5 KTS

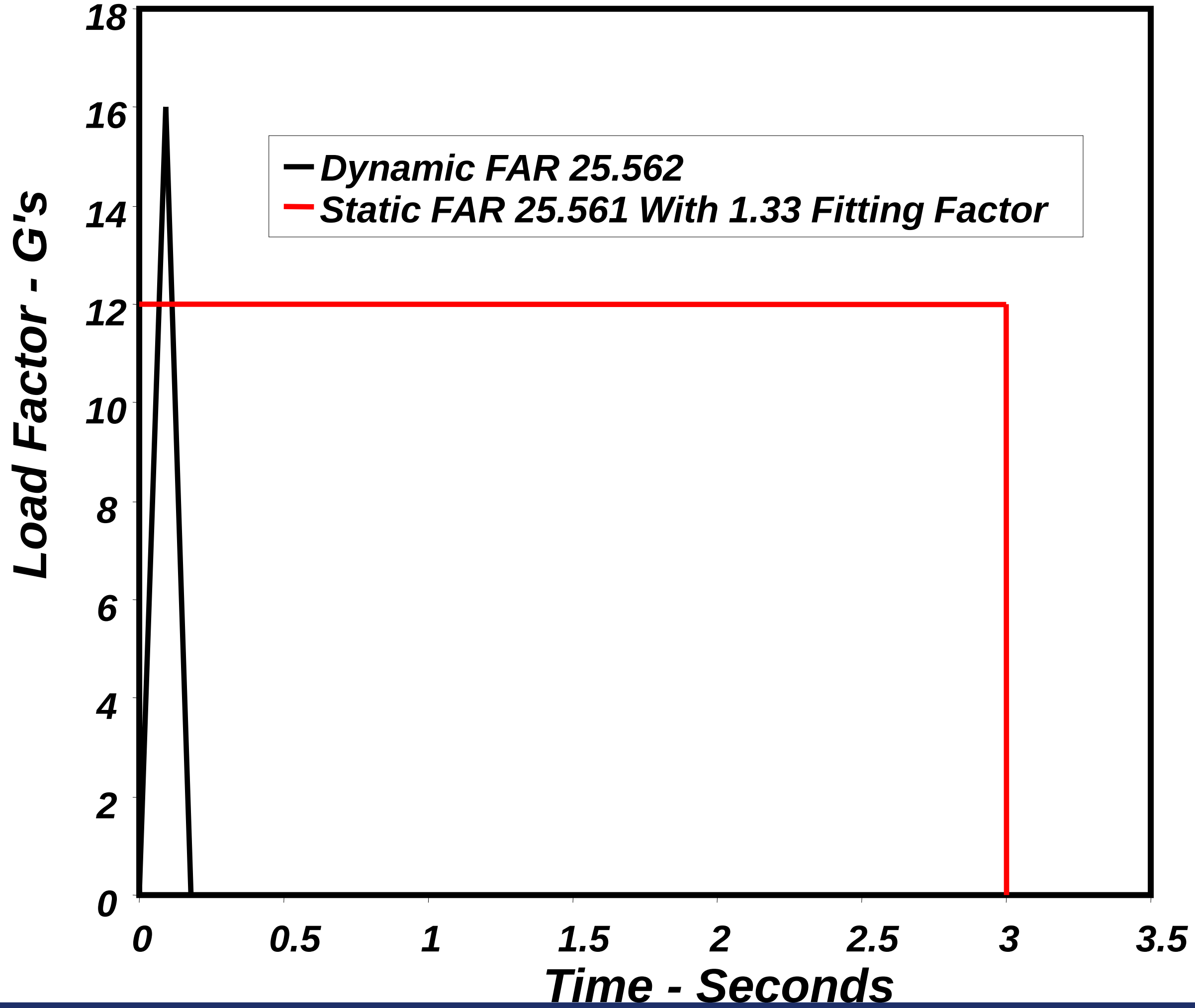
Transport Category Aircraft Longitudinal Impact Tests

TEST PROGRAM	PEAK LONGITUDINAL ACCELERATION G's	LONGITUDINAL VELOCITY CHANGE FT/SEC
MODEL 1649	10	26
CID	2 - 4	8
FAR PART 25	16	44

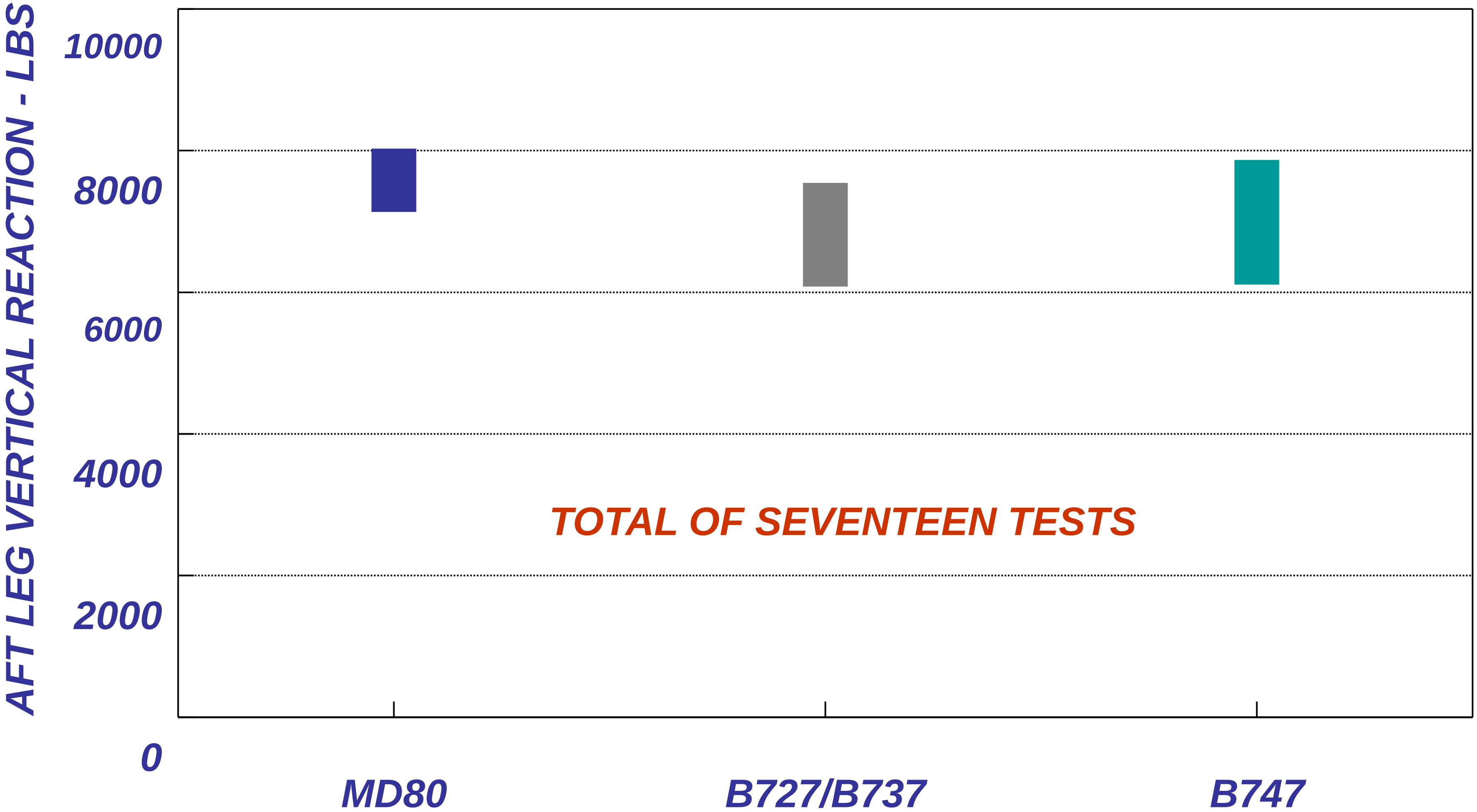
Typical Floor Track Strength Envelope



Static/Dynamic Load Factor Requirements



16 G's/44 fps Nominal Impact Test



Two Distinct Dynamic Test Conditions

- **Combined Vertical/Longitudinal**
  - Velocity change not less than 35 fps
    - Vertical 30.3 fps
    - Longitudinal 17.5 fps
    - Peak Deceleration 14 G's minimum
  - Evaluates spinal loads and injury
- **Longitudinal**
  - Velocity change not less than 44 fps
    - Peak deceleration 16 G's minimum
  - Assess occupant restraint system
  - Assess seat structural performance

Current Regulations

14 CFR 23.562 Emergency Landing Conditions
Amendment 23-50 Effective Date March 11, 1996

14 CFR 25.562 Emergency Landing Conditions
Amendment 25-64 Effective Date June 16, 1988

14 CFR 27.562 Emergency Landing Conditions
Amendment 27-25 Effective Date December 13, 1989

14 CFR 29.562 Emergency Landing Conditions
Amendment 29-41 Effective Date November 28, 1997

Performance Standards Summary

DYNAMIC TEST REQUIREMENTS	PART 23	PART 25	PART 27	PART 29
TEST 1				
TEST VELOCITY (FT/SEC)	31	35	30	30
SEAT PITCH ANGLE (Degree)	60	60	60	60
SEAT YAW ANGLE (Degree)	0	0	0	0
PEAK DECEL. (G's)	19/15	14	30	30
TIME TO PEAK (Seconds)	0.05/0.06	0.08	0.031	0.031
FLOOR DEFORMATION (Deg.)	NONE	NONE	10 PITCH/ 10 ROLL	10 PITCH/ 10 ROLL
TEST 2				
TEST VELOCITY (FT/SEC)	42	44	42	42
SEAT PITCH ANGLE (Degree)	0	0	0	0
SEAT YAW ANGLE (Degree)	10	10	10	10
PEAK DECEL. (G's)	26/21	16	18.4	18.4
TIME TO PEAK (Seconds)	0.05/0.06	0.09	0.071	0.071
FLOOR DEFORMATION (Deg.)	10 PITCH/ 10 ROLL	10 PITCH/ 10 ROLL	10 PITCH/ 10 ROLL	10 PITCH/ 10 ROLL
QUANTITATIVE COMPLIANCE CRITERIA				
MAX HIC	1000	1000	1000	1000
LUMBAR LOAD (lb)	1500	1500	1500	1500
STRAP LOADS (lb)	1750/2000	1750/2000	1750/2000	1750/2000
FEMUR LOADS (lb)	N/A	2250	N/A	N/A

Conclusions

- **Recommendations based on**
  - Accident data
  - Parametric studies
  - Existing guidelines
  - FAA/NASA research
- **General Aviation Crashworthiness Project**
  - NTSB confirmed GASP recommendations
- **Continued testing beyond initial development**