Crashworthiness Research on Cabin Structure at JAXA

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Aviation Program Group
Japan Aerospace Exploration Agency(JAXA)

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in Atlantic City, New Jersey, USA

What is JAXA?

JAXA : Japan Aerospace Exploration Agency

Aims : JAXA will promote research and development in aerospace, deepen its intelligence, and contribute to achieving a safe and prosperous society.

Three Japanese organizations that had previously promoted separate research and development in aerospace were merged as JAXA on October 1, 2003. Through the merger of the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA) into a core space agency, JAXA will comprehensively promote all space development, from basic research to development and utilization.

Organization:

- JAXA
  - Office of Space Flight and Operation
  - Office of Space Applications
  - Institute of Aerospace Technology
  - Institute of Space and Astronautical Science
  - **Aviation Program Group**
    - Program Office
    - Aviation Program Systems Engineering Office
    - Safety and Quality Assurance Office
    - **Civil Transport Team**
    - Clean Engine Team
    - Supersonic Transport Team
    - **Operations and Safety Technology Team**
      - **Crashworthiness Section**
    - Unmanned and Innovative Aircraft Team

Aviation Program Group (APG)

Philosophy: To nurture the growth of the aviation industry and lay the groundwork for breakthrough for the future of air transport.

Two Basic Policies:

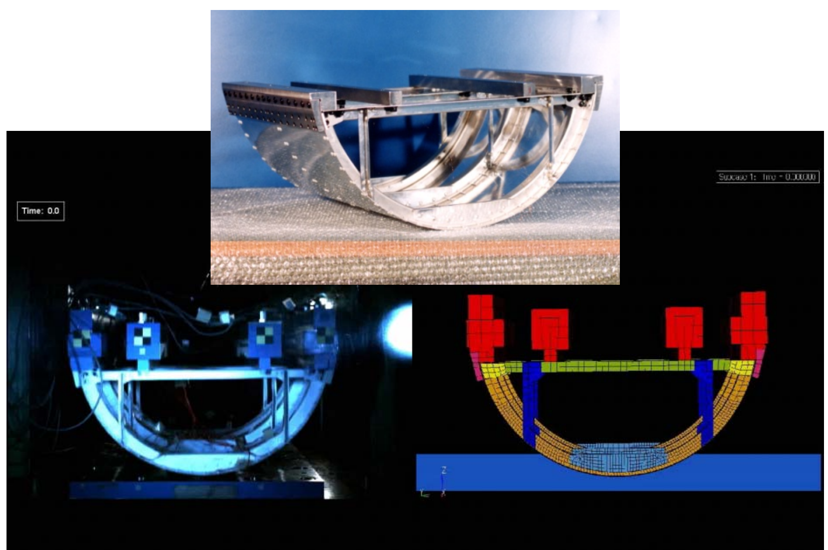
1. Responding to requests from society as a core organization in the aviation circles of Japan
2. Opening up the next generation through advanced technology development projects

Objectives of Crashworthiness Section

- Establish crash simulation technique on aircraft crashworthiness in Japan
- Improve cabin safety to improve survivability at crash accidents

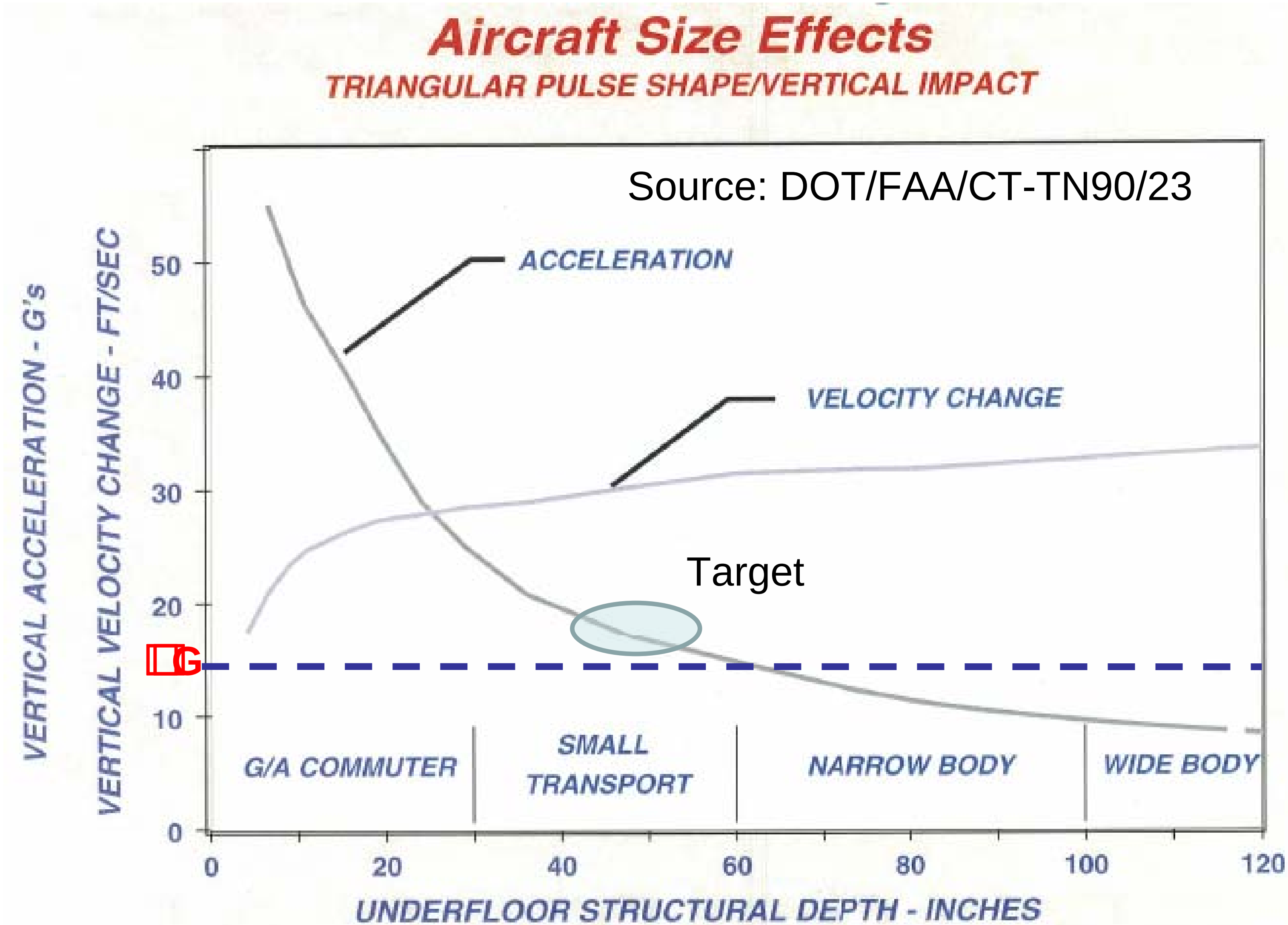
Components

Substructure



Full-structure

Motivation

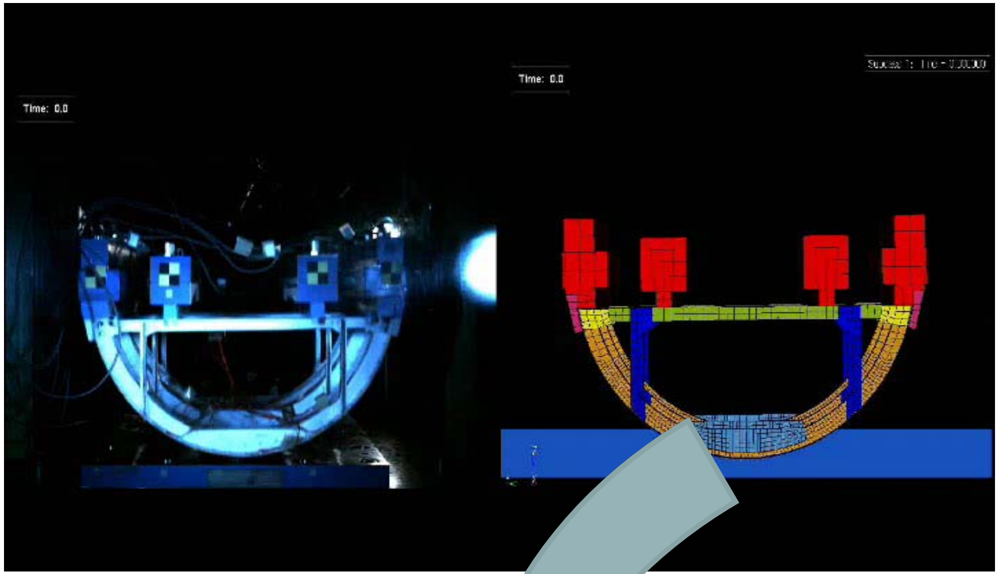


The more impact energy can be absorbed, the more cabin safety and survivability can be improved.

Our Research History

- Shock absorbing device research(1993-)
- Scale model of fuselage under-floor structure research (1998-2000, 2004-)
- YS-11 airliner fuselage section drop tests
  1st: Dec. 2001 2nd: Jul. 2002
- Seat test in ATR42-300 drop test - Jul. 2003
- MH2000 Helicopter full-scale crash test -
  Feb. 2004
- Retired YS-11 airliner fuselage section drop tests
  (Now we are planning)

Substructure(1)



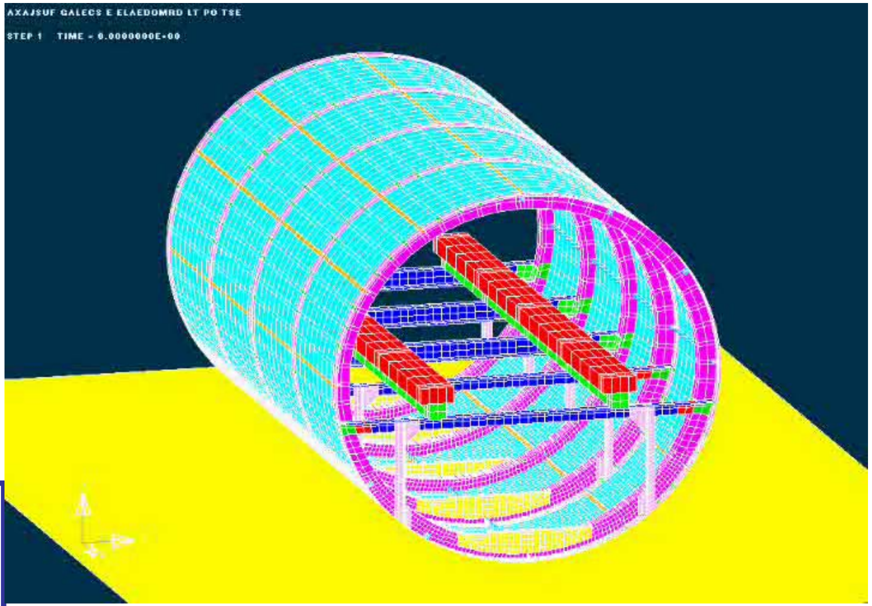
Experiment

Analysis

Underfloor Scale Structure Model

Built underfloor analytical model verified by real drop tests with underfloor scale model

Expanded

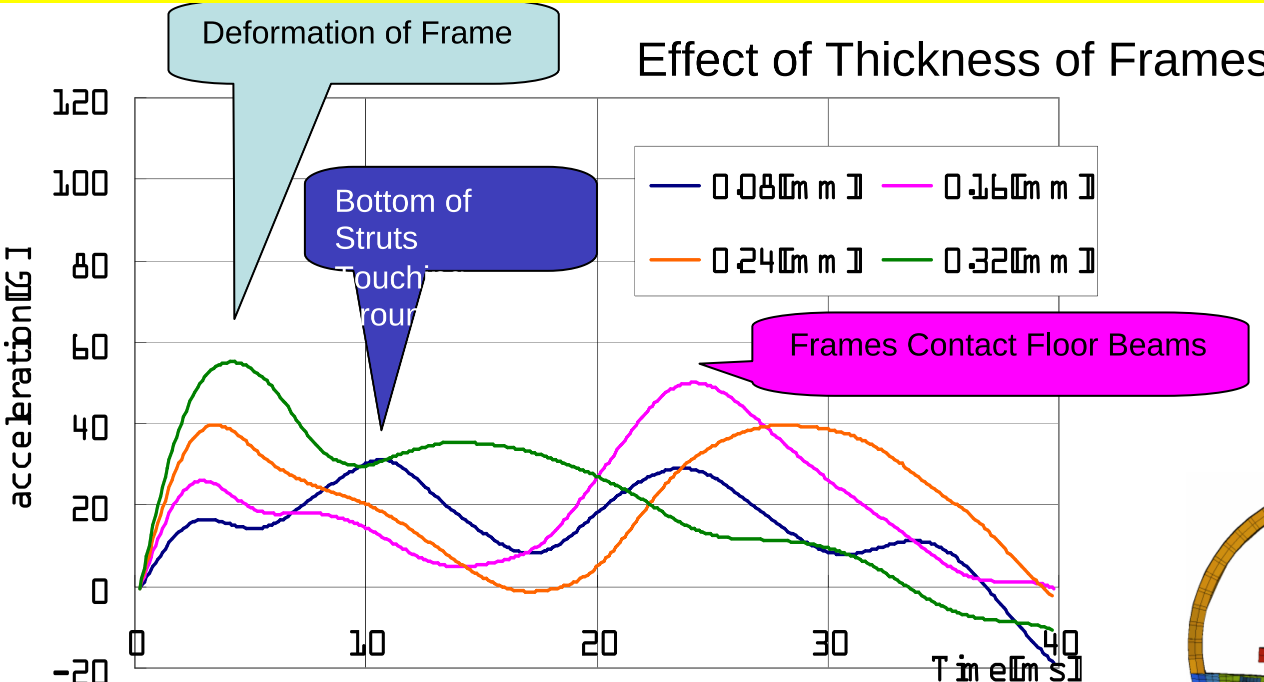


Fuselage Section Structure Scale Analytical Model

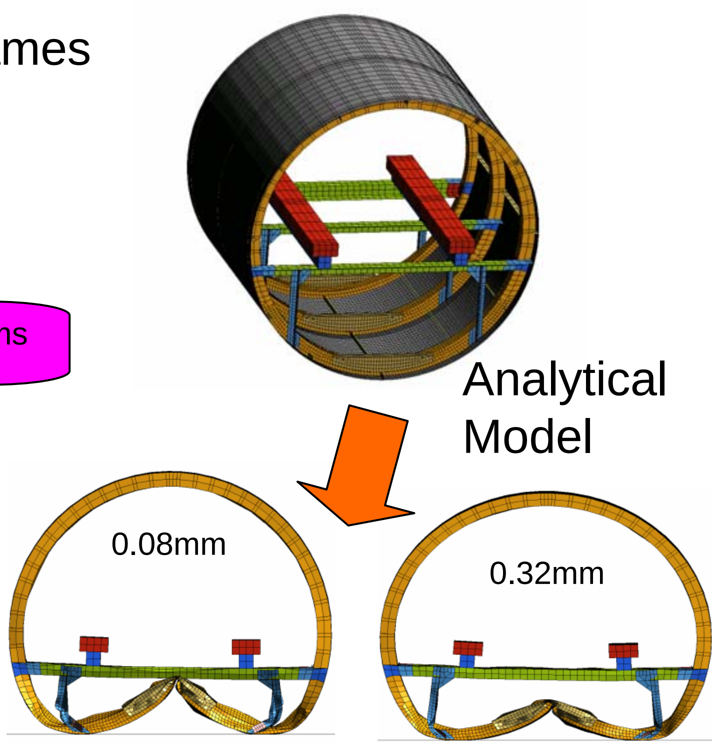
Substructure(2)

Parametrical Study of Specifications of Components with Substructure Analytical Model

Effect of Thickness of Frames



Time History Curve of Acceleration



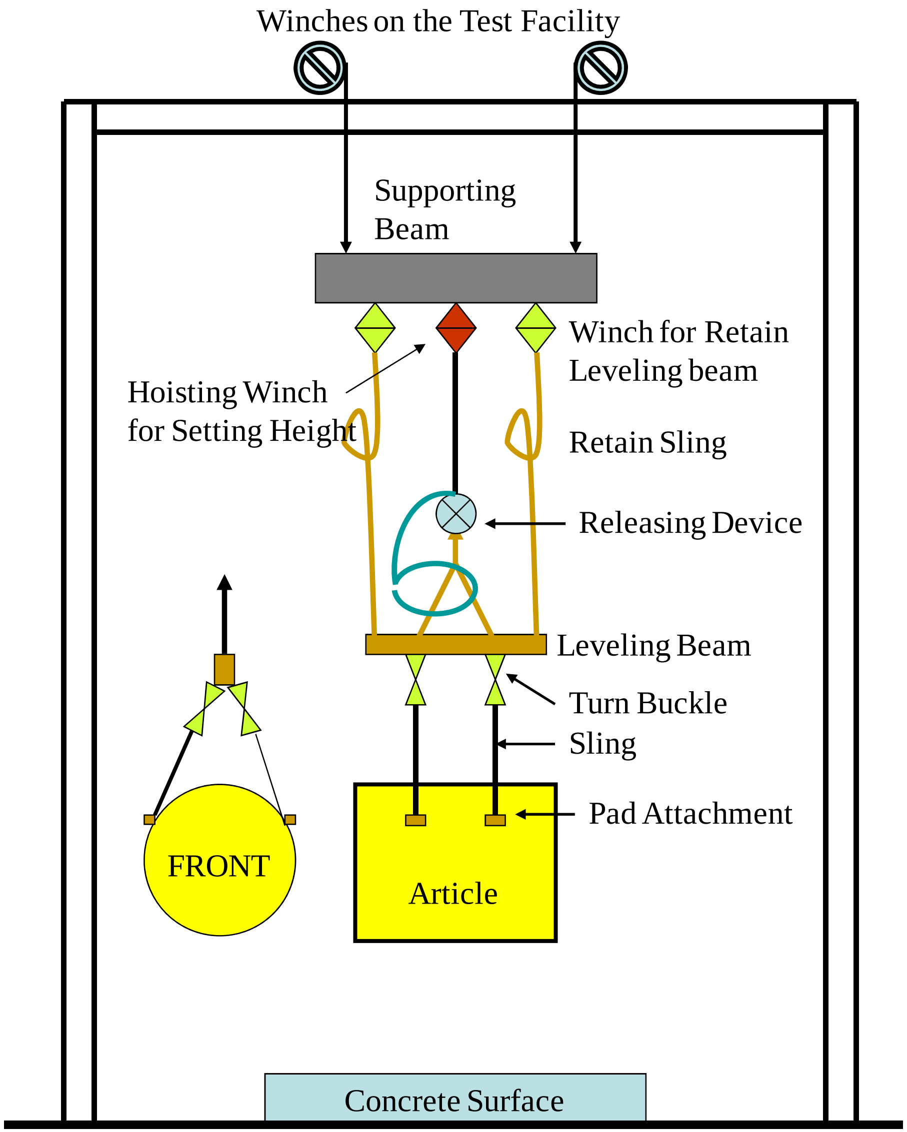
Deformations(Effect of Frame Thickness)

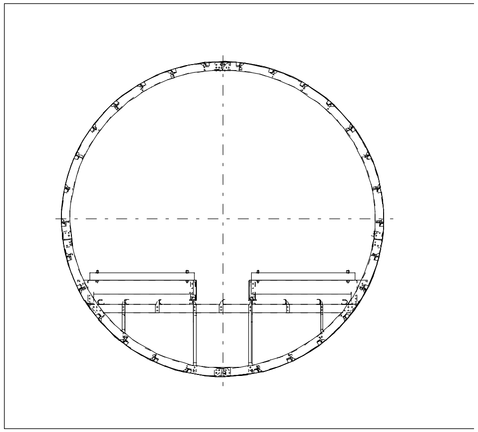
◆Governed impact failure mode changes with components stiffness distribution

◆Frames absorb larger impact energy than other components

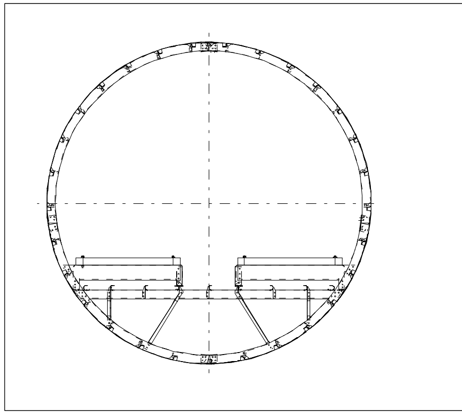
◆ Angle of attitude at the contact with ground has effects on crush results largely

Scale model fuselage section drop tests and analysis(1)





Basic-type



Improved-type

Seat and passengers substituted by corresponding weights.

These articles simulated conventional fuselage structure, not a specified aircraft.

Procedures of Test and Analysis

1. Pre-Analysis

2. Test of Basic-type Ariticle
 Drop Height:3.2m Impact Velocity7.9m/s(26fps)
 (Acc: 65, Strain: 63, High-speed Video: 3, VHS: 2)

3. Improve simulation model of improved-type article with the test results of the basic-type test

4. Test of Improved-type Article
 Drop Height: 1.9m Impact Velocity: 6.1m/s(20fps)
 (Acc: 65, Strain: 63, High-speed Video: 3, VHS: 2)

5. Post-Analysis for improvement accuracy

Scale model fuselage section drop tests and analysis (3)

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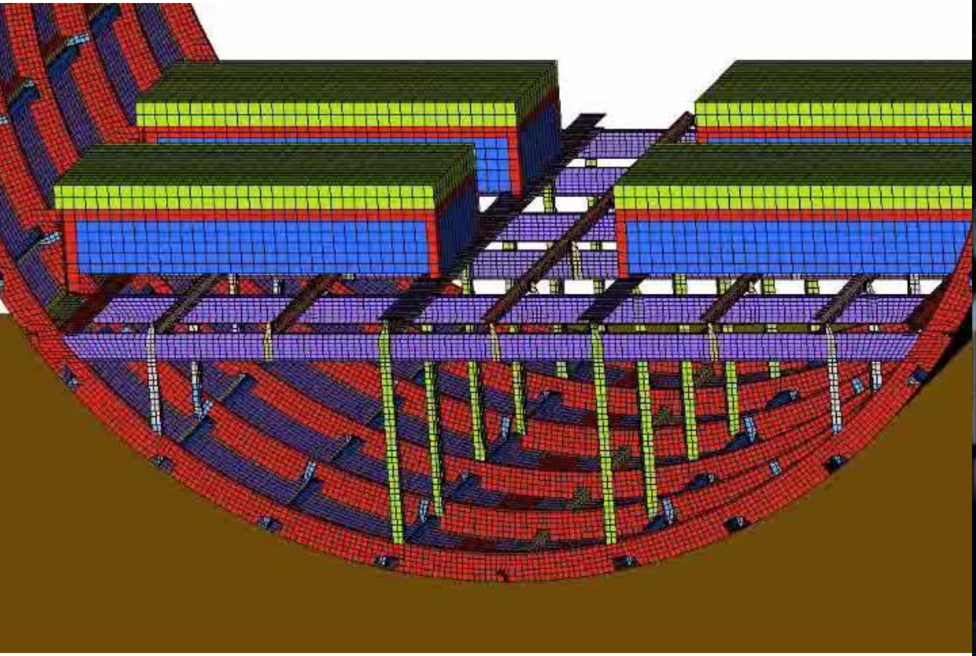
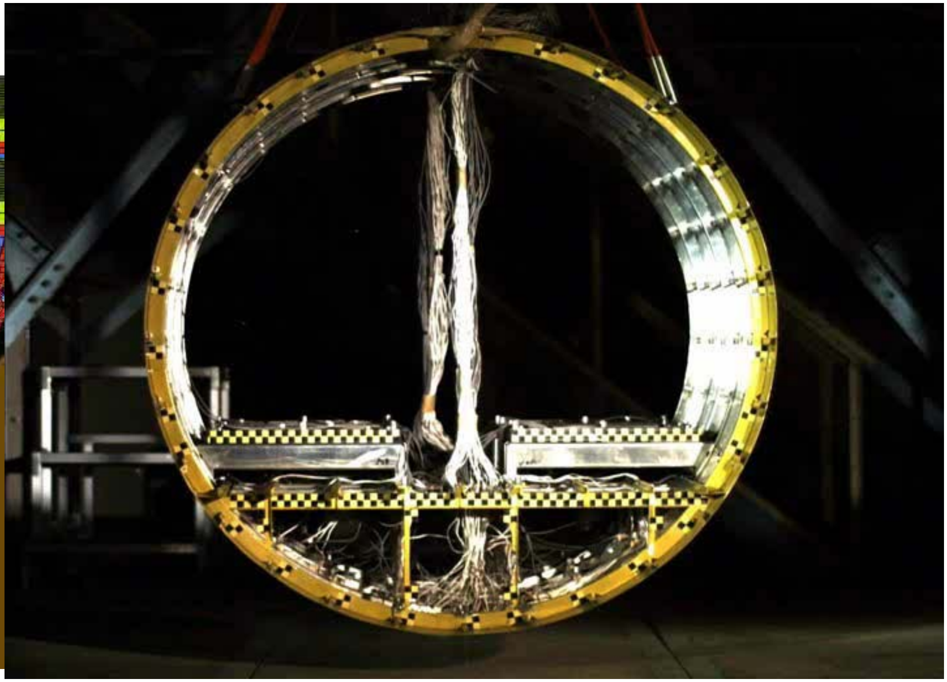
- **Pre-Analysis**

- **Basic-type Test**

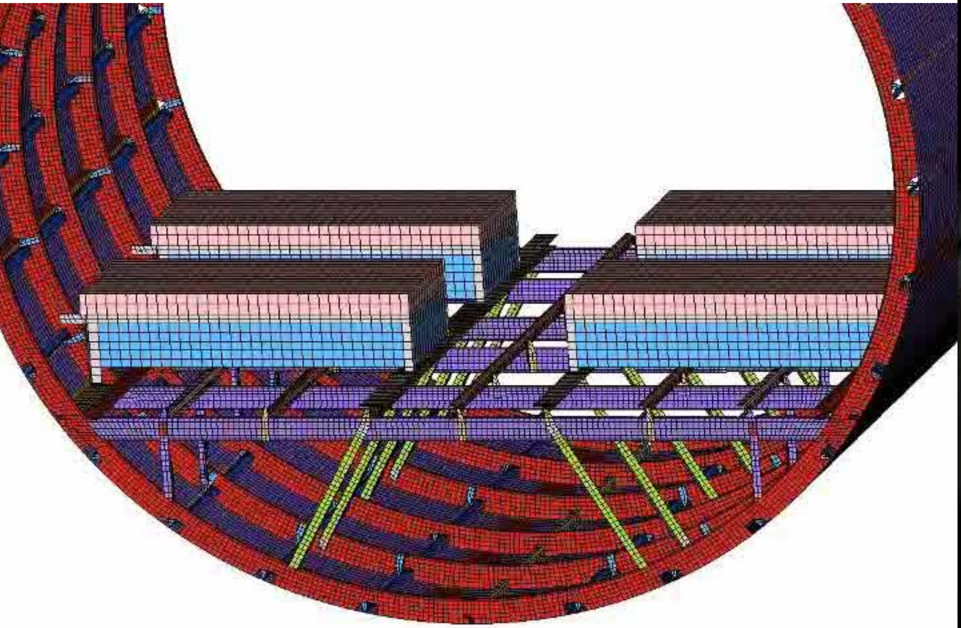




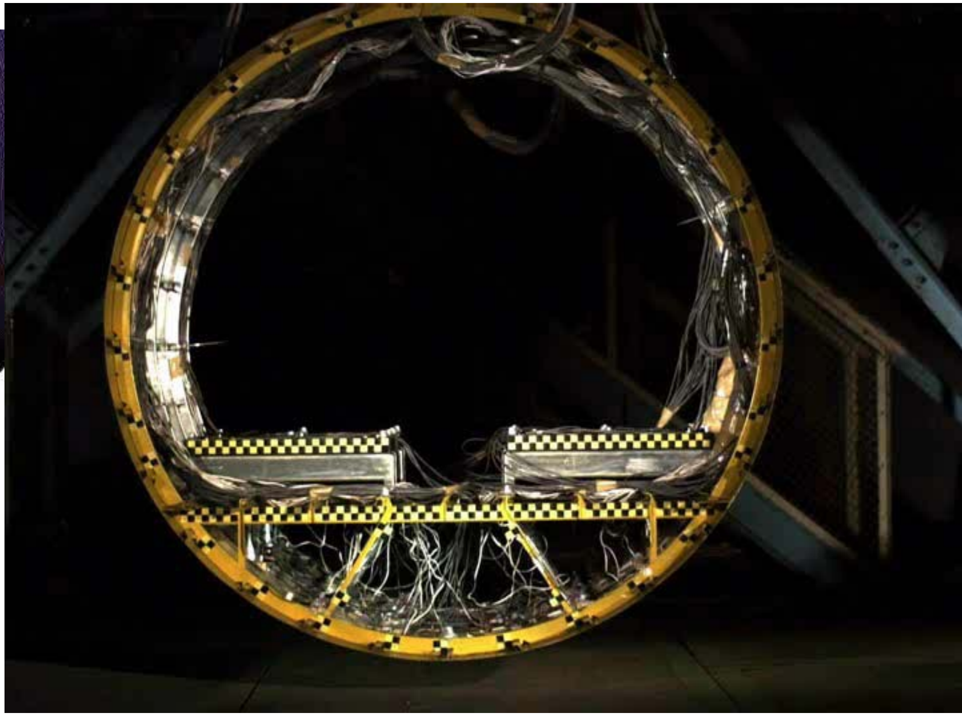
Drop Height: 3.2m Impact Velocity: 7.9m/s(26fps)

Scale model fuselage section drop tests and analysis (4)

Improve simulatiuon model
Improved-type Model



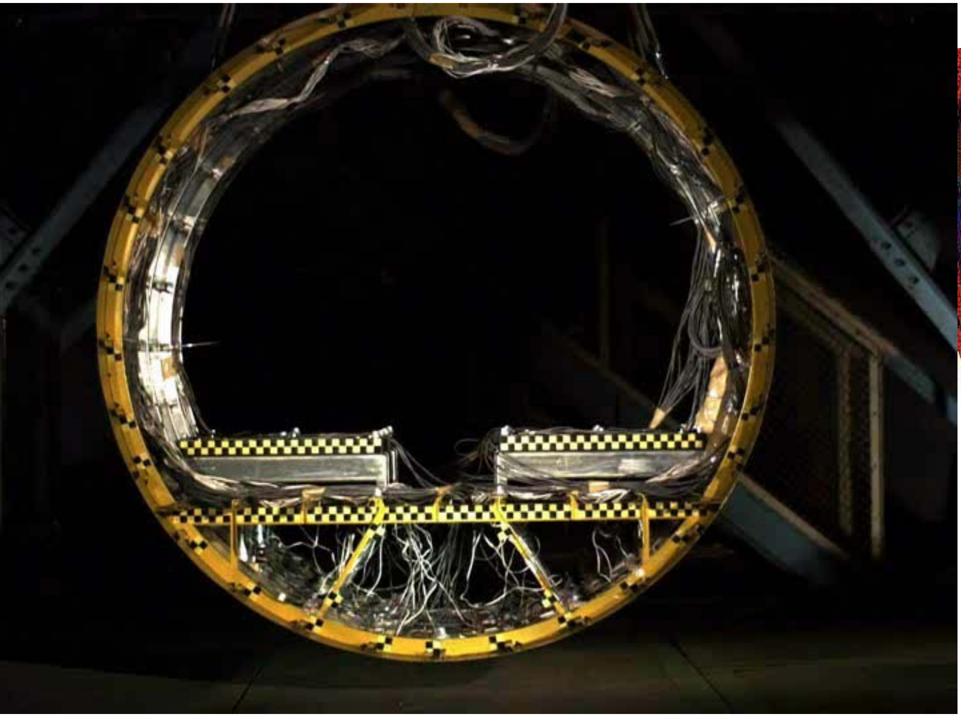
Improved-type test



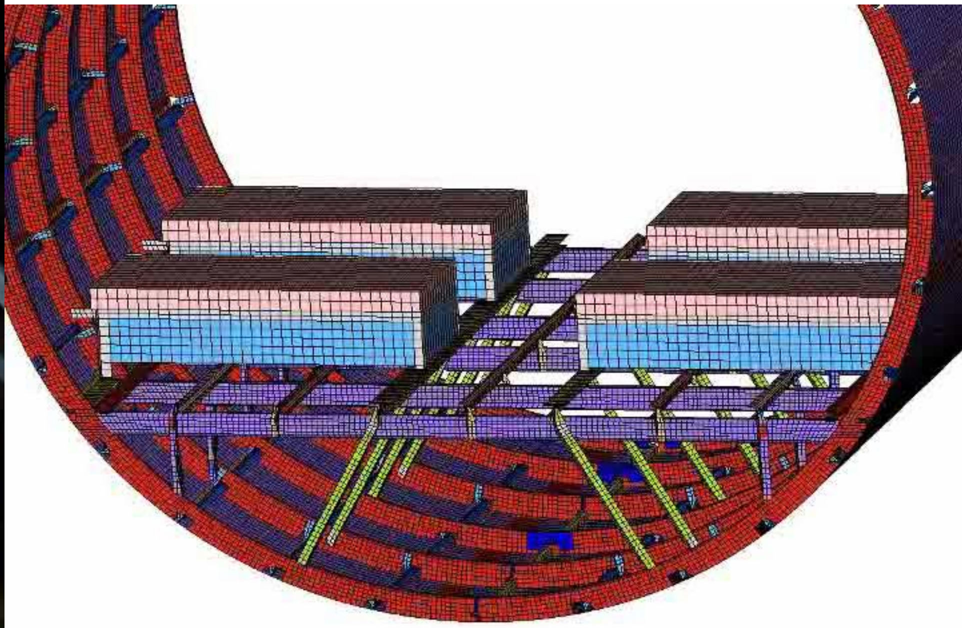
Drop Height: 1.9m   Impact Velocity: 6.1m/s(20fps)

Scale model fuselage section drop tests and analysis (5)

Improved-type test



Post Analysis



Drop Height: 1.9m   Impact Velocity: 6.1m/s(20fps)

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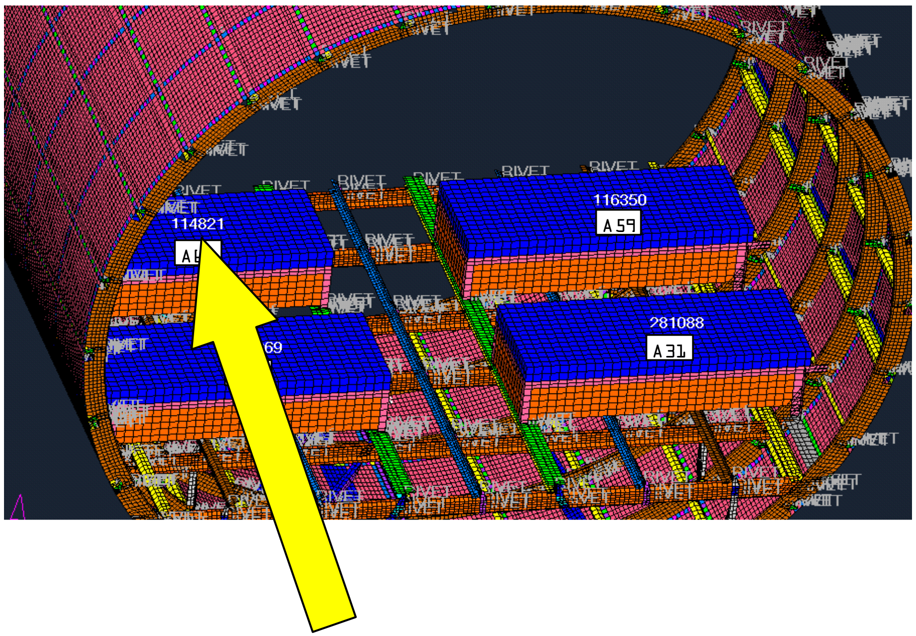
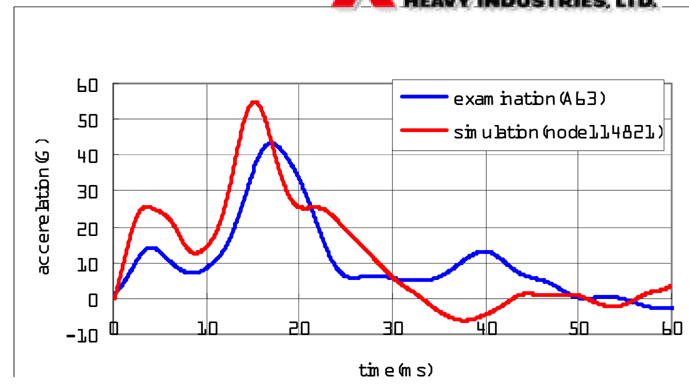
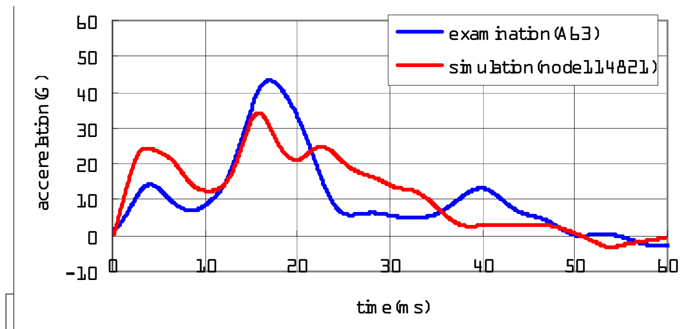
Comparing accelerations between test and analysis



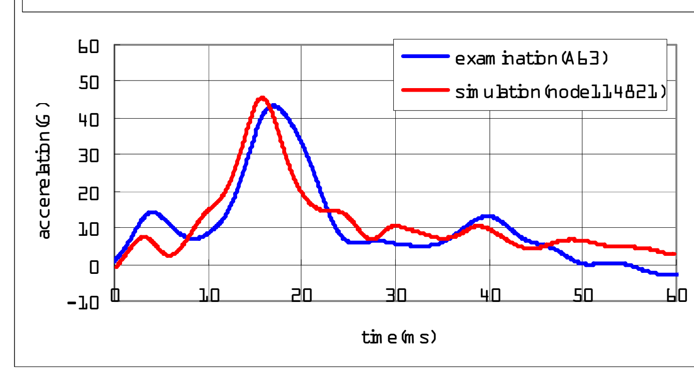
Pre-test



Improved after 1st test



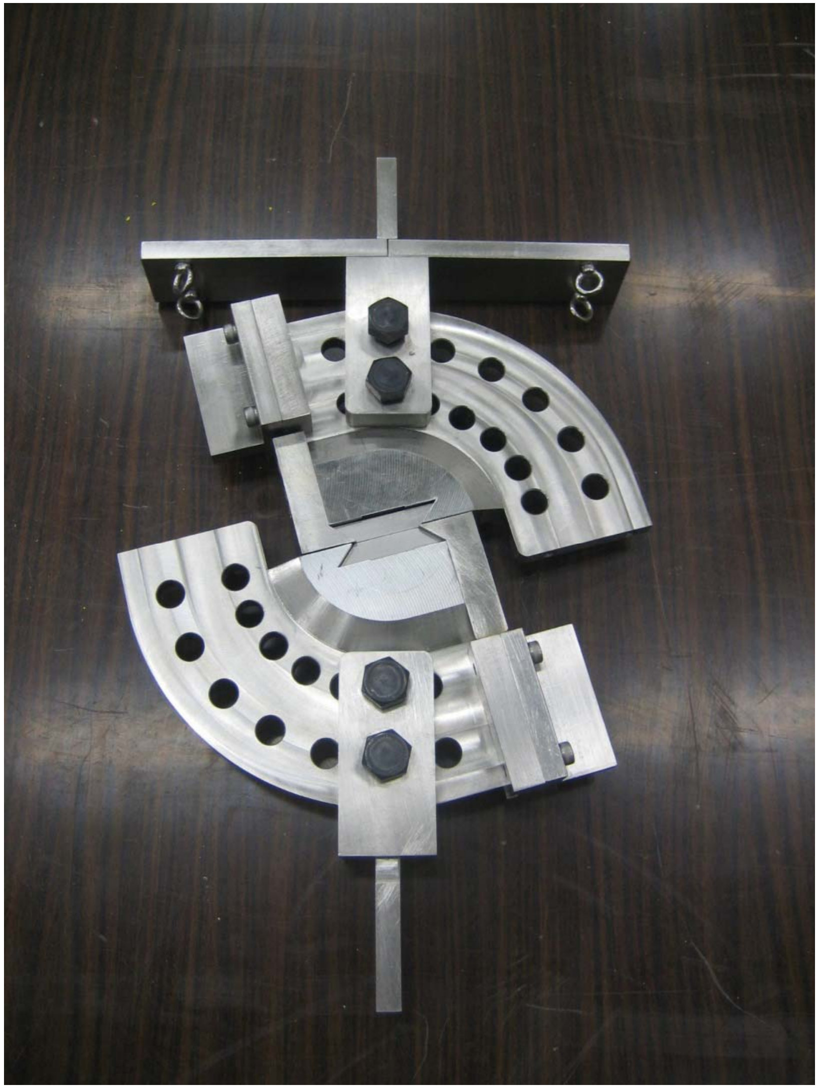
Post Test



Compare accelerations on Weight

In graphs, blue lines: test, red lines: analysis

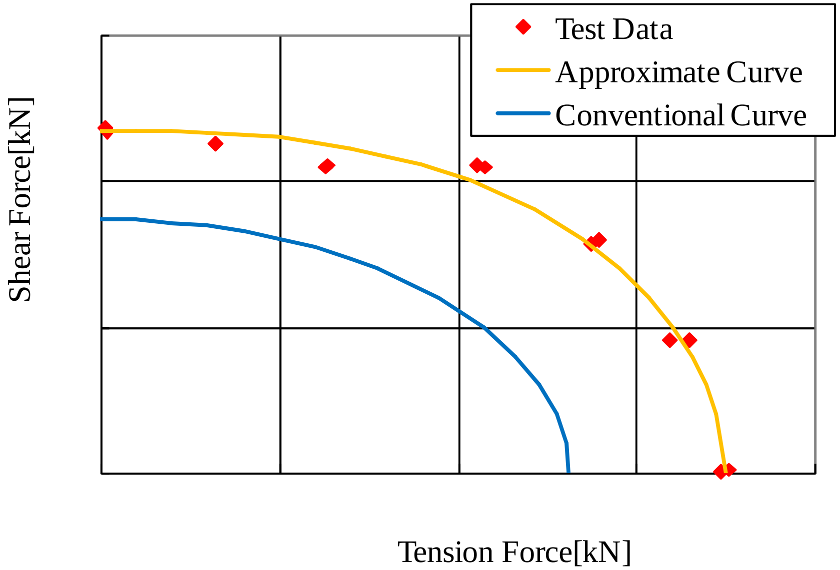
Rivet Modeling



Make a Rivet Model for Crash Simulation with LS-DYNA in order to improve accuracy of simulation.

Use Modified ARCAN method like ONERA method.

$$\left(\frac{|f_n|}{S_n}\right)^a + \left(\frac{|f_s|}{S_s}\right)^b \geq 1$$



Fuselage Section of YS-11 Drop Tests (1)

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A NAMC YS-11 A-200

Specifications

Fuselage Diameter : 2.88 m

Max.T/O Weight : 24.5 ton

Passengers : Max. 64

Wing Span : 32.0 m

Overall Length : 26.3 m

Tail Height : 9.0 m

Cruising Speed : 450 km/h

First Flight : 8/30/1962

Fuselage Section of YS-11 Drop Tests (2)

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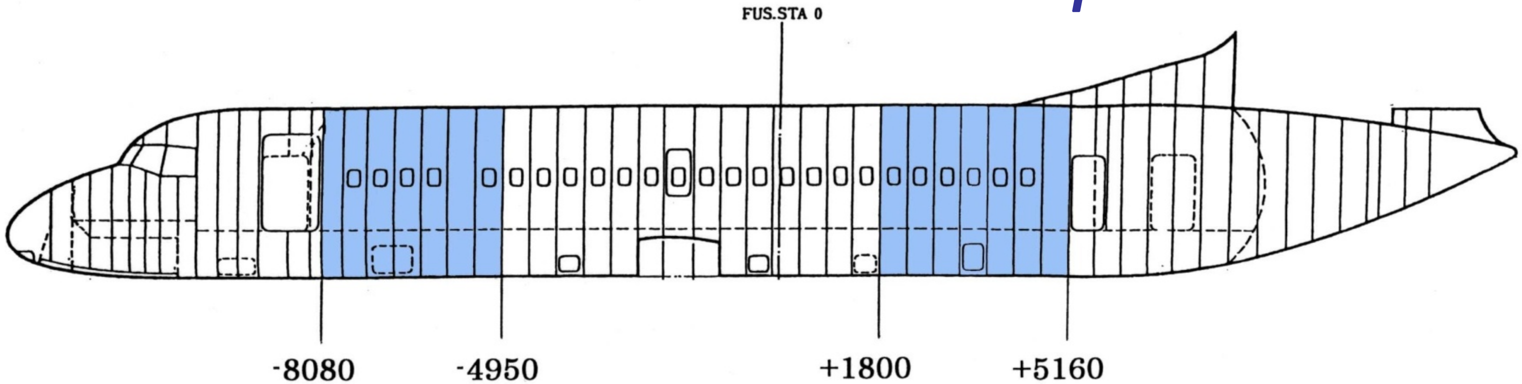
Fuselage sections for vertical drop tests



Test article	FWD Section(2nd)	AFT Section(1st)
Longitudinal Length	3.13 m	3.36 m
Weight (incl. ATDs)	1600 kg	1510 kg
Number of Seats	6 twin-seats	4 twin-seats and 2Equiv.Weights
Passenger Dummies	12 by ATDs	8 by ATDs and 4 by Equiv. Weights
Impact Velocity	7.4 m/s (25 ft/s)	6.1 m/s (20 ft/s)
Impact Energy	47 kJ	28 kJ
Test Date	Jul. 5th, 2002	Dec. 20th, 2001

Fuselage Section of YS-11 Drop Tests (3)

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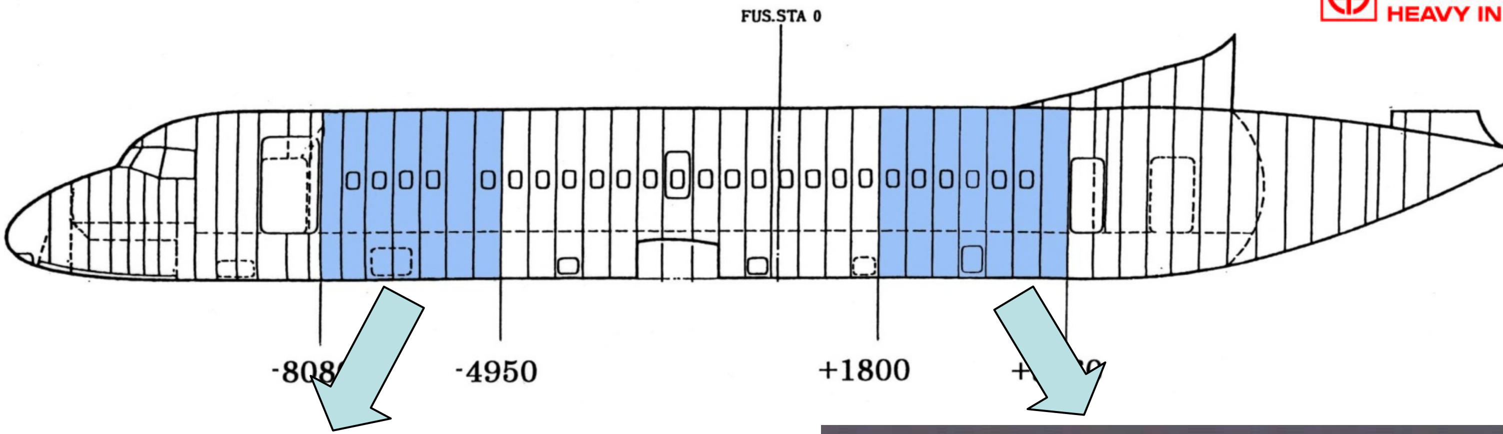


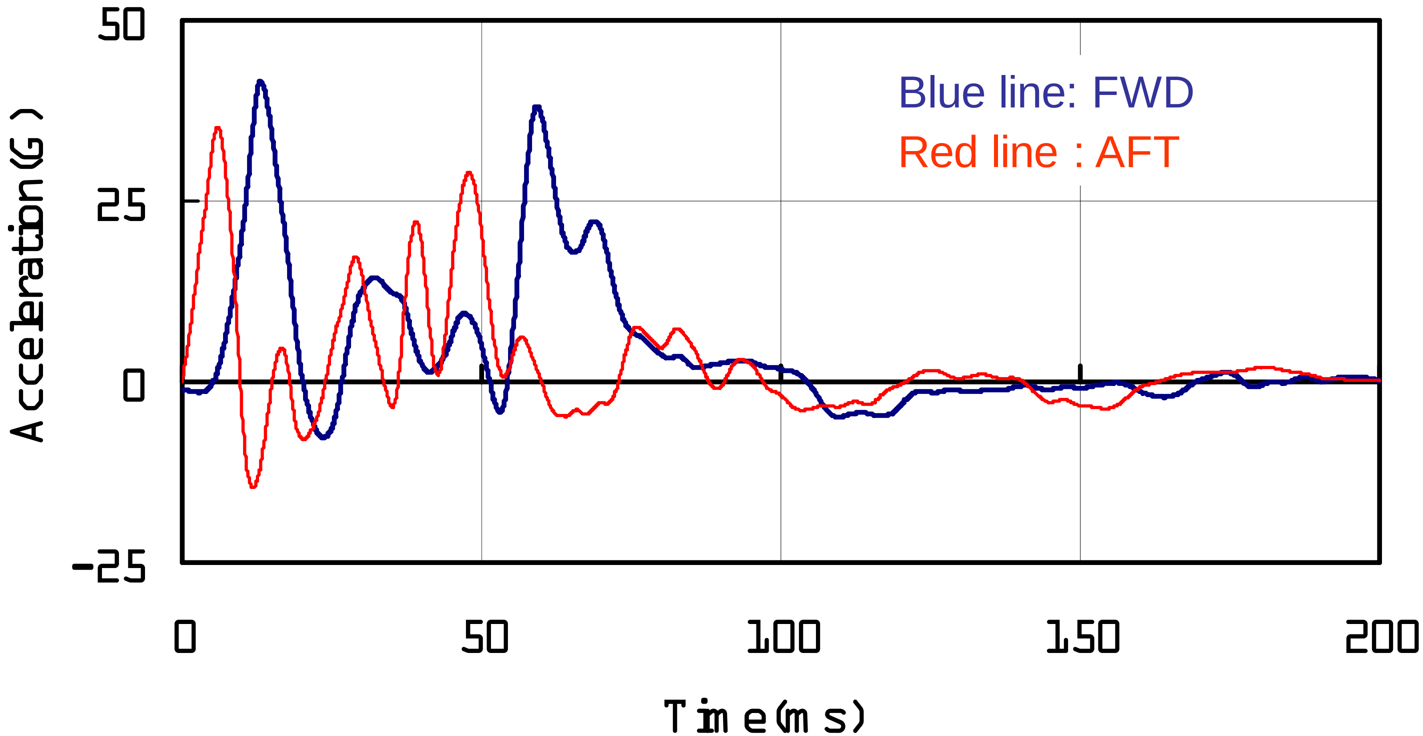
(a) FWD Section
2002.7.5

(b) AFT Section
2001.12.20

Fuselage Section of YS-11 Drop Tests (4)

Typical Vertical Accelerations at Seat Rails
(Left-hand side and window side)

CFC60



Although impact energy of the FWD test was 1.7 times as much as that of the AFT test, the peak acceleration of the FWD test was 1.2 times as much as that of the AFT test.

If underfloor structure absorbs large impact energy, the accelerations on the floor can be reduced.

Fuselage Section of YS-11 Drop Tests (5)

Simulation Results

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Forward Section

25 ft/s impact velocity

Full-Scale Crash Test of MH2000 Helicopter (1)

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Nagoya Aerospace Systems Works

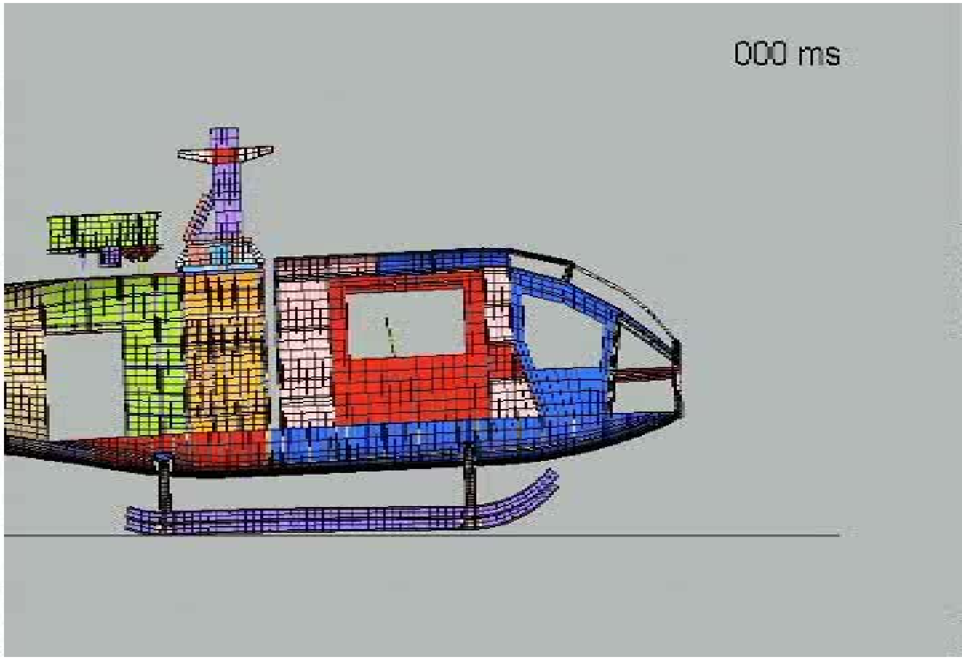
Overview Video Picture of the Crash Test

Conducted on February 25th, 2004.

Offered by MHI

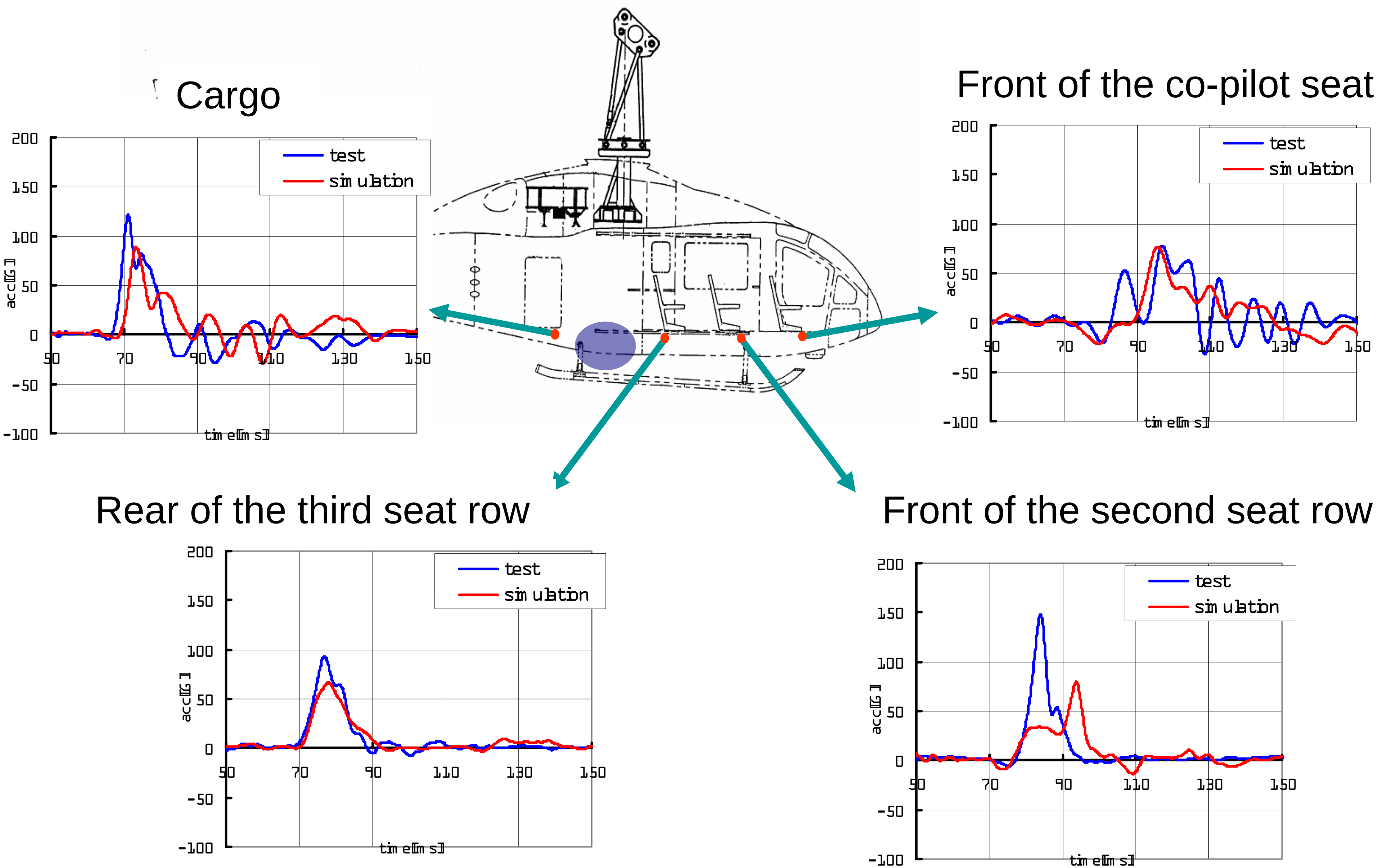
Full-Scale Crash Test of MH2000 Helicopter (2)

Simulation Result of Crash Test as of now



Numerical Simulation with LS-DYNA

Results : Acceleration responses (Left keel beam)



Objects of Research with Retired YS-11

Type: YS-11A-500
First FLT March 12^{th} 1973
Total FLT Hour 57,002 Hour
Total FLT Cycle 57,273 Cycle

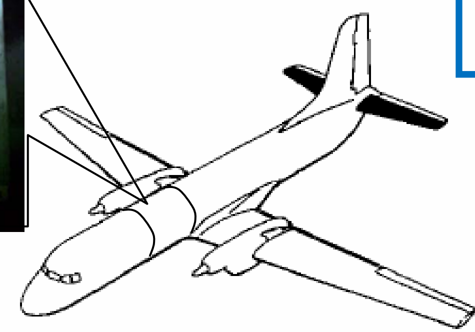
Length 26.3m	Width 32.0m
Height 8.98m	
Main Wing Area 95.0m^2	Aspect Ratio 10.8
External Diameter of Fuselage 2.88m	
Max. Taking off Weight 25,000kg	
Max. Landing Weight 24,500kg	
Max. Payload 7,038kg	Passengers Max. 64
Cruising Velocity 472km/h	Range 2,242km

Objects

- Acquisition of fatigue data for design of new transport and improvement of continuing aviation safety
- Research for application of new composite material to new transport
- Verification Test of impact simulation of bird striking and tire bursting

And…

Crashworthiness Research on Retired YS-11



Retrofit under floor structure of fuselage section

↓

Vertical Drop Test

↓

Verification

Target:

Components (Shock Absorbing Devices), Structural Configuration, Composite Materials, Shock Absorbing Materials, etc.

Schedule:

2007	2008	2009	2010	2011	2012	2013
Preparation & Pre-Analysis (2007–2010)				Verification & Post-Analysis (2011–2012)		
			Test (2010–2011)			

Proposition:

Test bed for crashworthiness test in cooperation research with domestic and overseas universities and research institutes.

Summary

◆Introduce crashworthiness research activities of our section

◆Propose cooperation research
by using the retired YS-11 fuselage sections

If anyone is interested in cooperation research with us by using the retired YS-11 articles, please contact me. shouji@chofu.jaxa.jp

Thank you for your attention!