ANB70 - TRB Truck and Bus Safety Committee Meeting
JANUARY 24, 2012

SAFETY AND CRASHWORTHINESS PERFORMANCE OF PARATRANSIT BUSES

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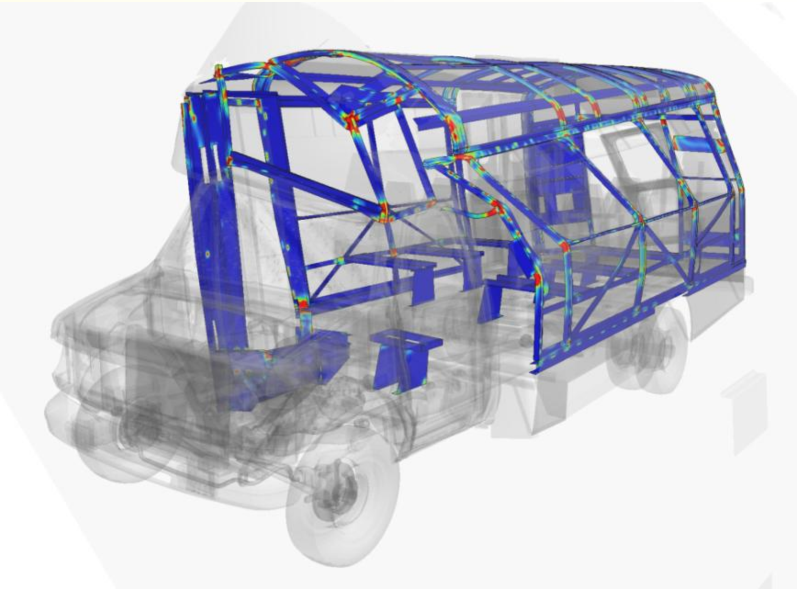


Project sponsored by: Robert Westbrook (FDOT Transit Administrator) and Erin Schepers
Transit Office, Florida Department of Transportation

RESEARCH BACKGROUND

- What are paratransit buses?
- How are they built?

- Which buses are stronger?

RESEARCH BACKGROUND

- Why is this research important ?

- Project goal: evaluate safety and rollover performance of a typical bus by using TWO popular, related standards

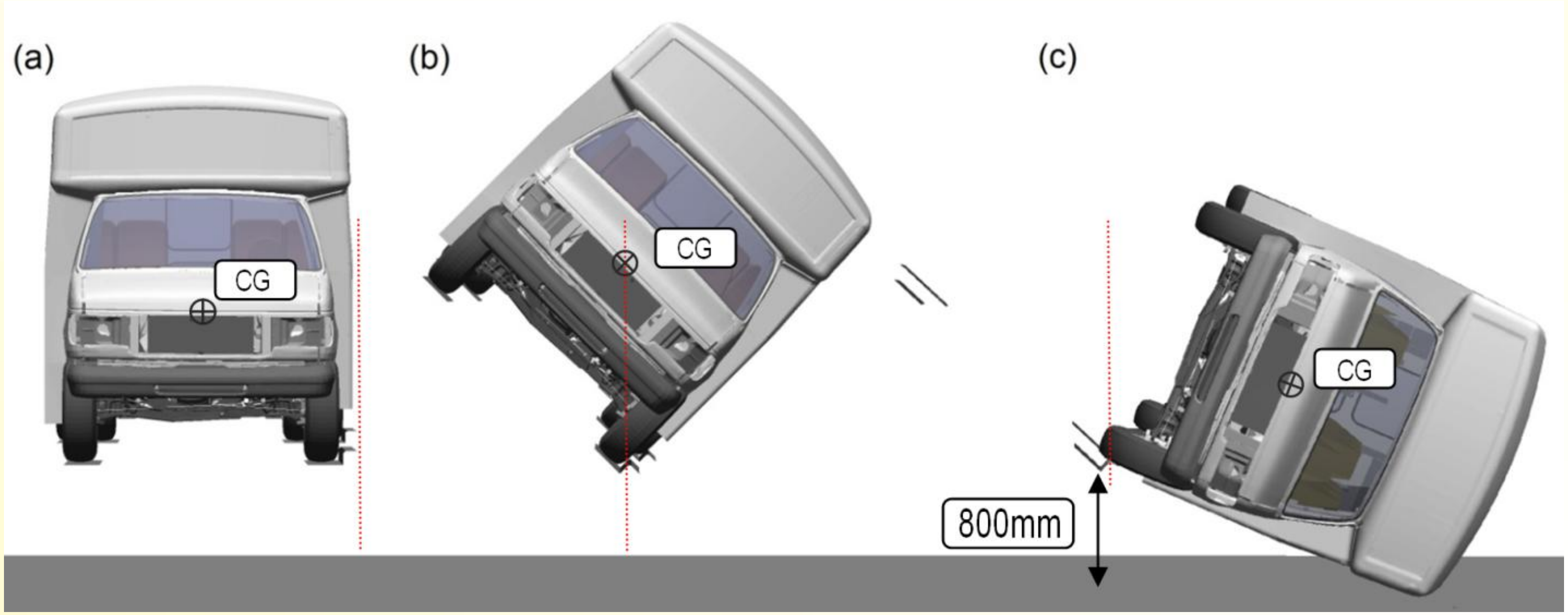
National:
FMVSS Standard 220:

- Vertical force equal to 1.5 UVW (Unloaded Vehicle Weight)
- Force applied through flat, rigid rectangular plate
- Vertical displacement of the plate < 5.125in
- Design strategy: strong roof bows with light wall columns

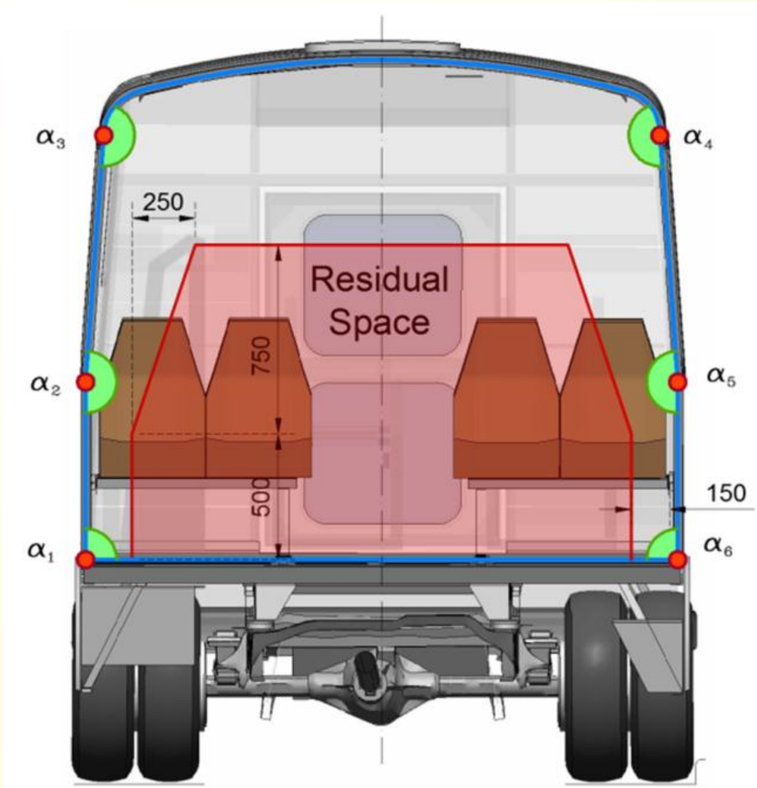
European:

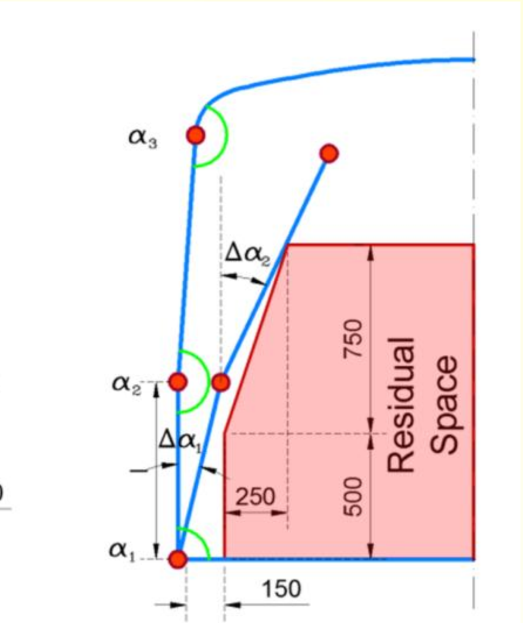
ECE Regulation 66

- Dynamic rollover test
- Bus on the tilt table (a) rotated into unstable equilibrium (b)
- Bus falls under its own weight into the 800mm deep ditch (c)
- Pass-fail criteria based on the concept of Residual Space (RS)
- RS can not be compromised by any structural part of the bus during and after the impact



Residual Space Concept



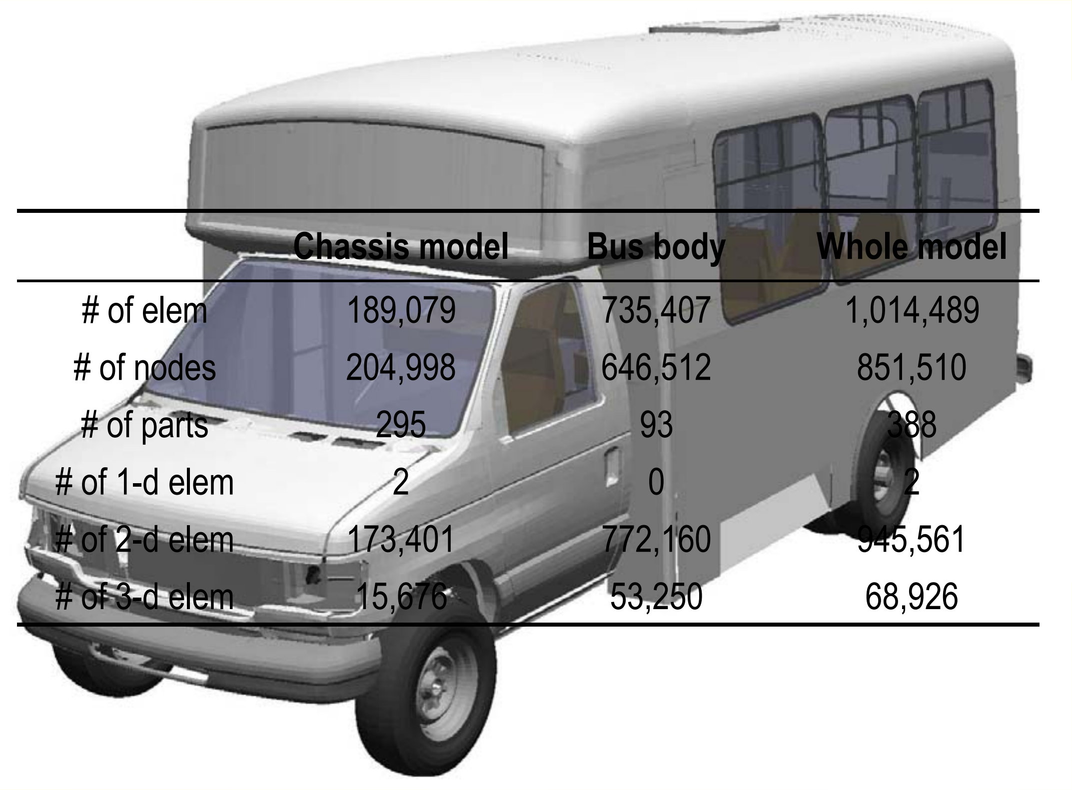


$$DI = \frac{l}{d} \cdot \tan(\Delta\alpha_1) + \frac{(h-l)}{d} \cdot \tan(\Delta\alpha_2)$$

- RS defined as a survival zone for passengers
- Deformation Index (DI) introduced by Florida Standard in addition to ECE-R66
- If the value of DI>1 than the bus fails the rollover test (Residual Space has been compromised)

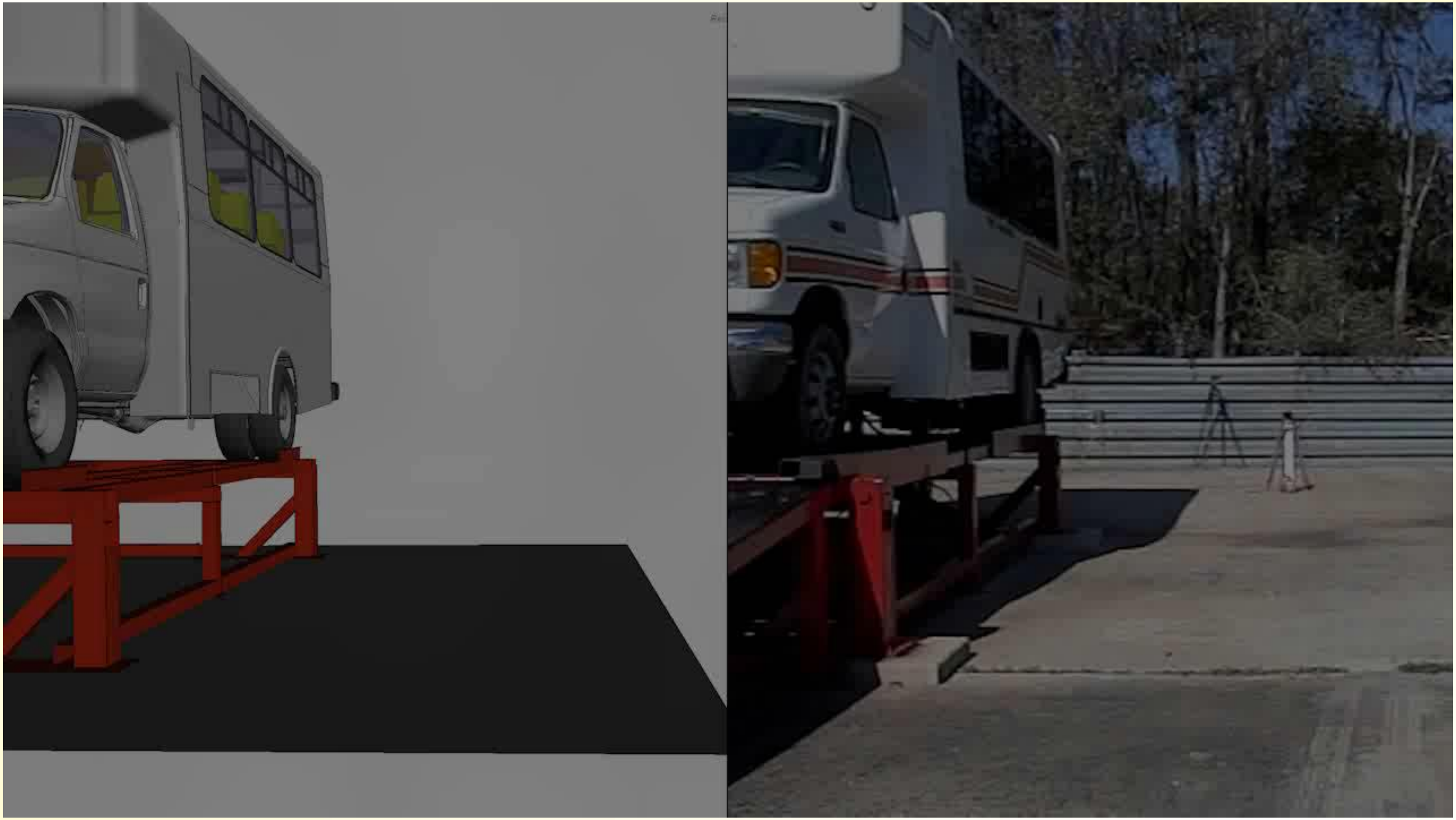
FINITE ELEMENT MODEL DEVELOPMENT

- Ford Econoline FE model
- Chassis E-150 to E-450
- AutoCAD 2D specs
- AutoCAD 3D model
- Full FE Model
- Exploded view
- Model summary



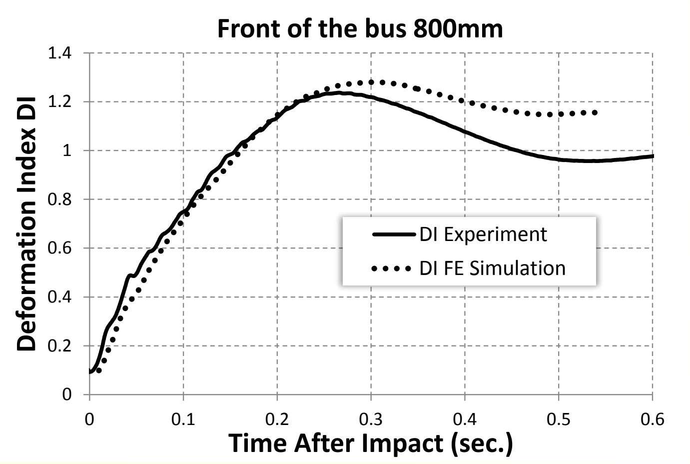
	Chassis model	Bus body	Whole model
# of elem	189,079	735,407	1,014,489
# of nodes	204,998	646,512	851,510
# of parts	295	93	388
# of 1-d elem	2	0	2
# of 2-d elem	173,401	772,160	945,561
# of 3-d elem	15,676	53,250	68,926

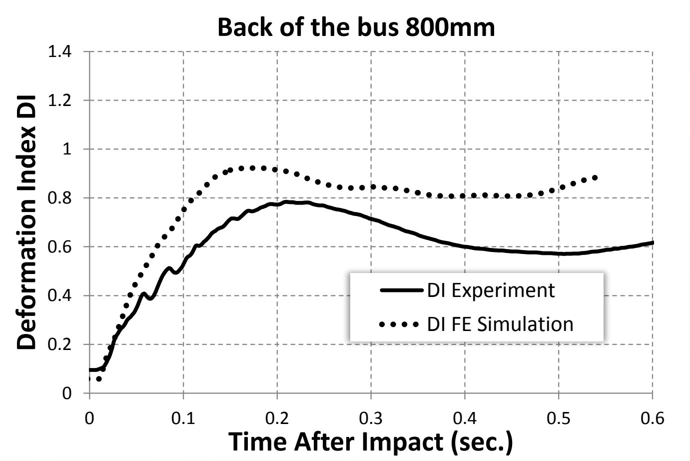
VALIDATION OF FE SIMULATION

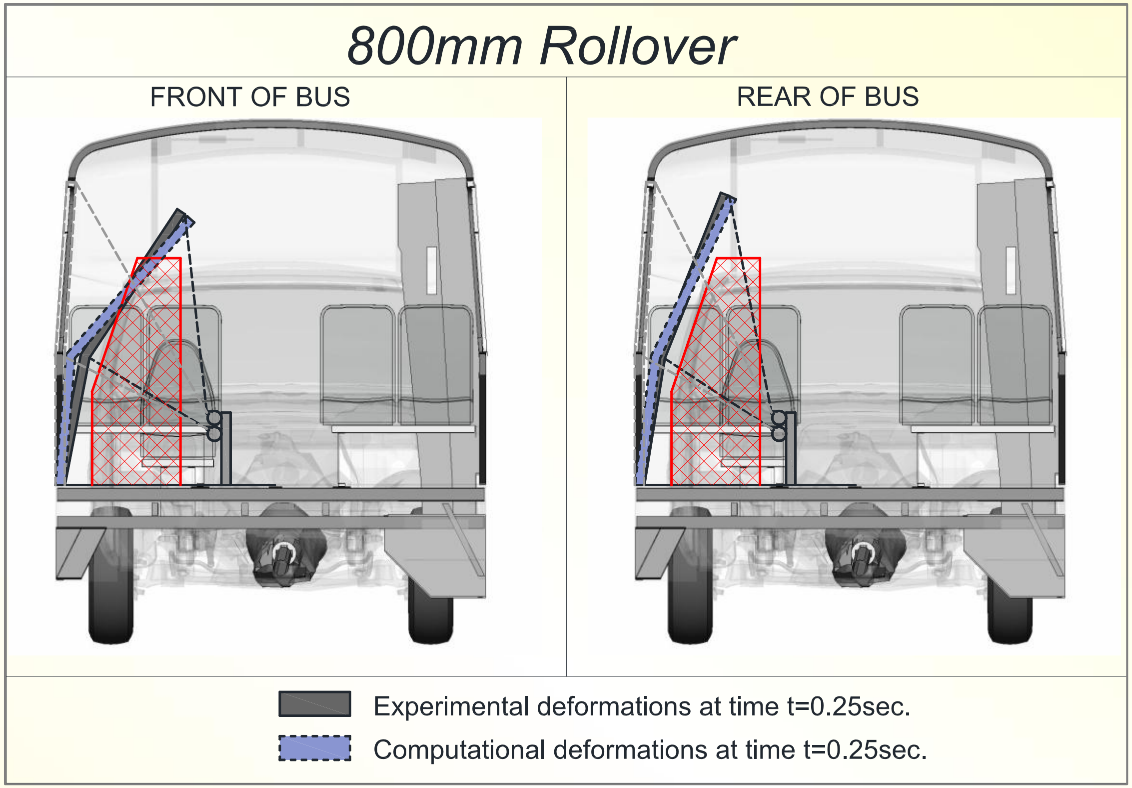


- Comparison of a full scale rollover test with a FE model simulation

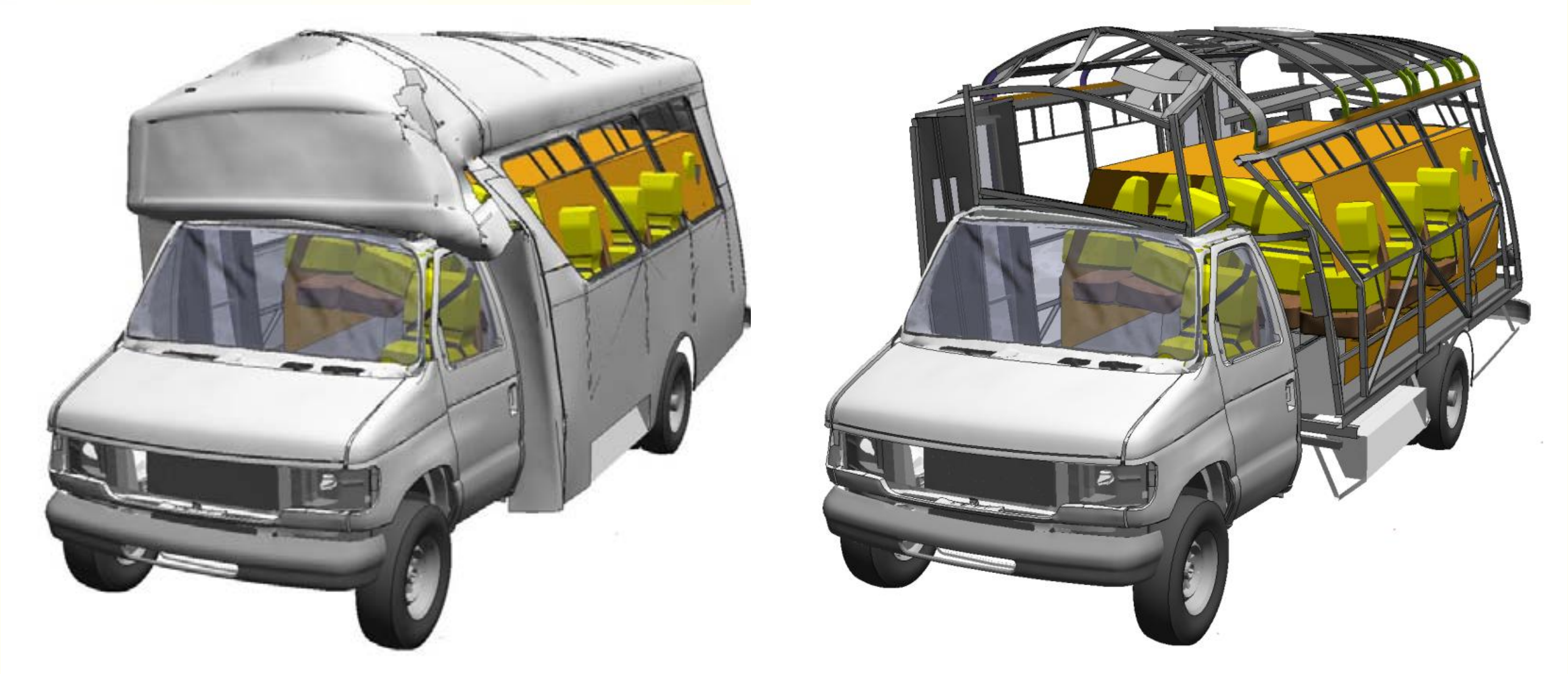
VALIDATION OF FE SIMULATION



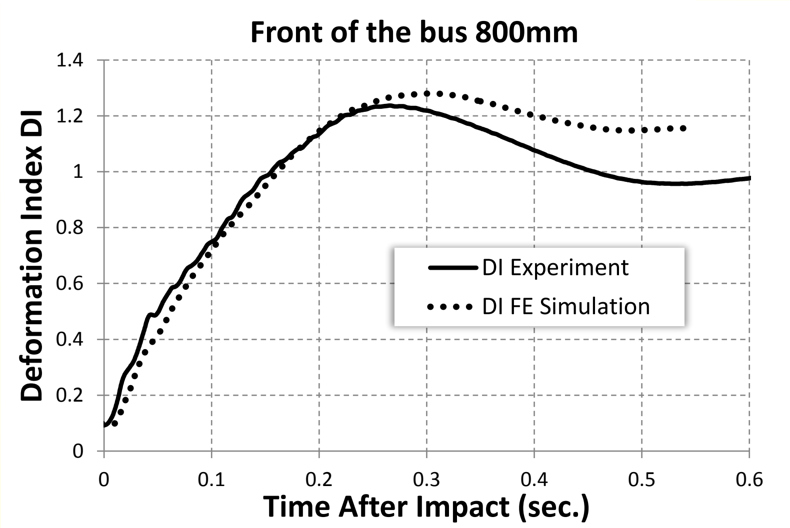




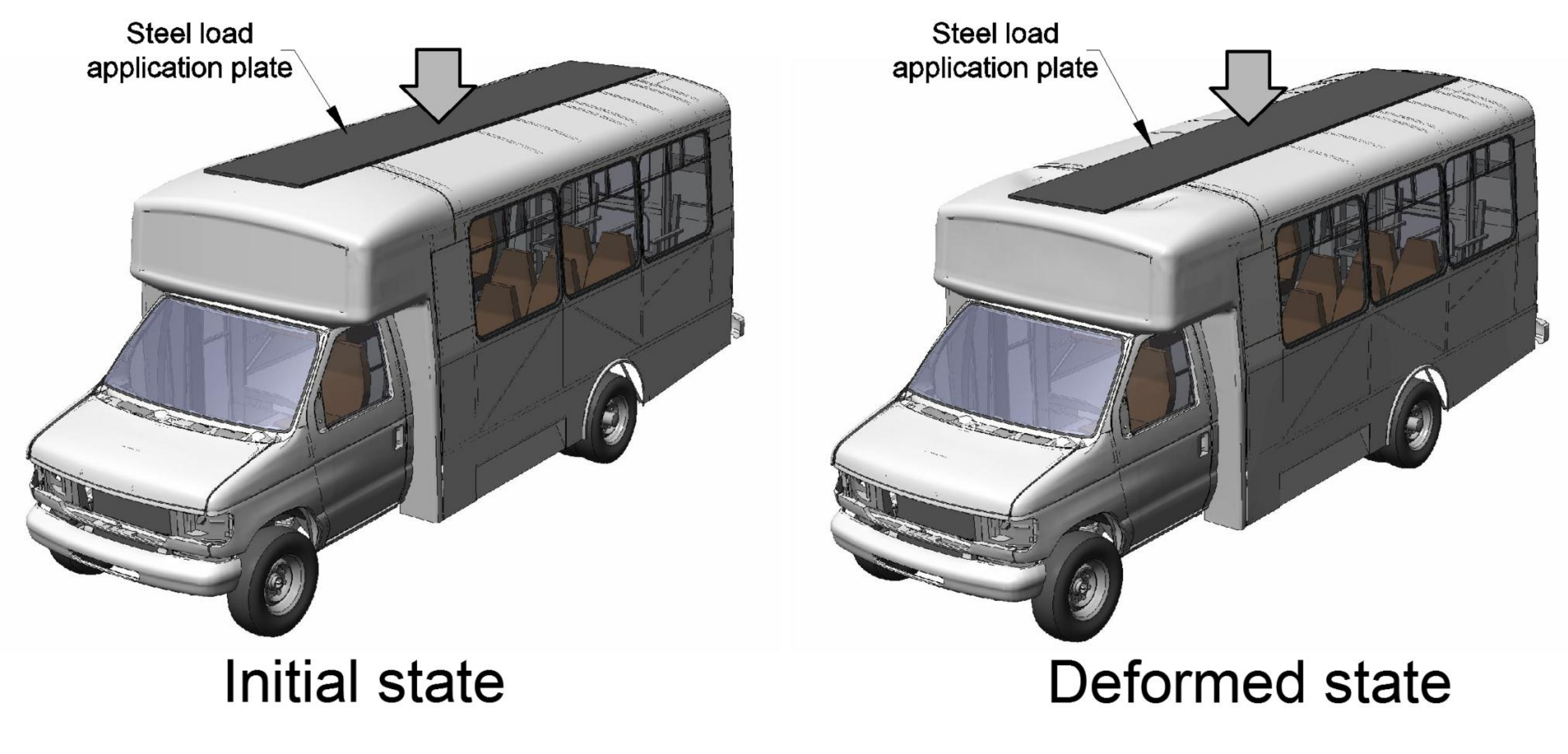
ECE-R66 FE MODEL SIMULATION - RESULTS



- Investigated bus **failed** the ECE-R66 rollover test
- Excessive side walls deformations lead to the penetration of bus structure into the residual space
- DI exceeds the value of DI>1.20



FMVSS 220 FE MODEL SIMULATION



- Evenly distributed load of 1.5 UVW (68,219 N) was applied to the roof structure of the bus
- Force application plate deflection was monitored during the loading procedure

FMVSS 220 vs ECE-R66

for a selected Paratransit Bus

FMVSS 220

ECE-R66

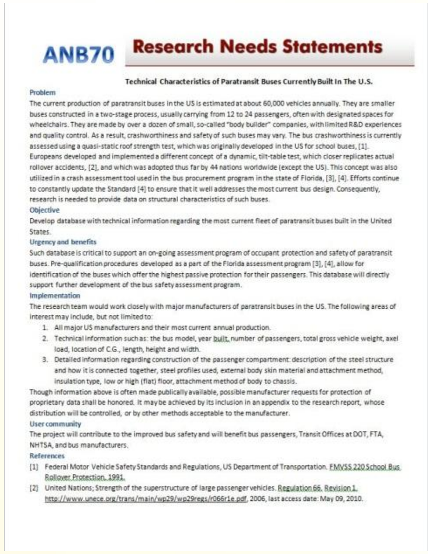
- Selected paratransit bus **passed** FMVSS 220 test
- Roof structure deformed only by 4.76in (limit 5.125in) under the load of 1.5 UVW
- Strong roof bow structure supported all the prescribed load

- Selected paratransit bus **failed** ECE-R66 rollover test
- Deformation Index reached a pick value at DI=1.23
- Strong roof bow structure did not prevent failure during dynamic rollover test

For further reference please refer to the 2011 TRB paper:
"COMPARISON OF ECE-R66 AND FMVSS 220 TESTS FOR A SELECTED PARATRANSIT BUS"

RESEARCH NEEDS STATEMENT

- State of Florida buys 300-350 paratransit buses annually
- The bus type considered is the most popular
- Would like our research to have broader (national) impact.
- What are the most popular paratransit buses built, sold and operated in the US?
- Research Needs Statement developed and supported by ANB70



ANB70 **Research Needs Statements**

Technical Characteristics of Paratransit Buses Currently Built In The U.S.

Problem

The current production of paratransit buses in the US is estimated at about 60,000 vehicles annually. They are smaller buses constructed in a two-stage process, usually carrying from 12 to 24 passengers, often with designated spaces for wheelchairs. They are made by over a dozen of small, so-called "body builder" companies, with limited R&D experiences and quality control. As a result, crashworthiness and safety of such buses may vary. The bus crashworthiness is currently assessed using a quasi-static roof strength test, which was originally developed in the US for school buses, [1]. Europeans developed and implemented a different concept of a dynamic, tilt-table test, which closer replicates actual rollover accidents, [2], and which was adopted thus far by 44 nations worldwide (except the US). This concept was also utilized in a crash assessment tool used in the bus procurement program in the state of Florida, [3], [4]. Efforts continue to constantly update the Standard [4] to ensure that it well addresses the most current bus design. Consequently, research is needed to provide data on structural characteristics of such buses.

Objective

Develop database with technical information regarding the most current fleet of paratransit buses built in the United States.

Urgency and benefits

Such database is critical to support an on-going assessment program of occupant protection and safety of paratransit buses. Pre-qualification procedures developed as a part of the Florida assessment program [3], [4], allow for identification of the buses which offer the highest passive protection for their passengers. This database will directly support further development of the bus safety assessment program.

Implementation

The research team would work closely with major manufacturers of paratransit buses in the US. The following areas of interest may include, but not limited to:

1. All major US manufacturers and their most current annual production.
2. Technical information such as: the bus model, year built, number of passengers, total gross vehicle weight, axel load, location of C.G., length, height and width.
3. Detailed information regarding construction of the passenger compartment: description of the steel structure and how it is connected together, steel profiles used, external body skin material and attachment method, insulation type, low or high (flat) floor, attachment method of body to chassis.

Though information above is often made publically available, possible manufacturer requests for protection of proprietary data shall be honored. It may be achieved by its inclusion in an appendix to the research report, whose distribution will be controlled, or by other methods acceptable to the manufacturer.

User community

The project will contribute to the improved bus safety and will benefit bus passengers, Transit Offices at DOT, FTA, NHTSA, and bus manufacturers.

References

[1] Federal Motor Vehicle Safety Standards and Regulations, US Department of Transportation. FMVSS 220 School Bus Rollover Protection. 1991.

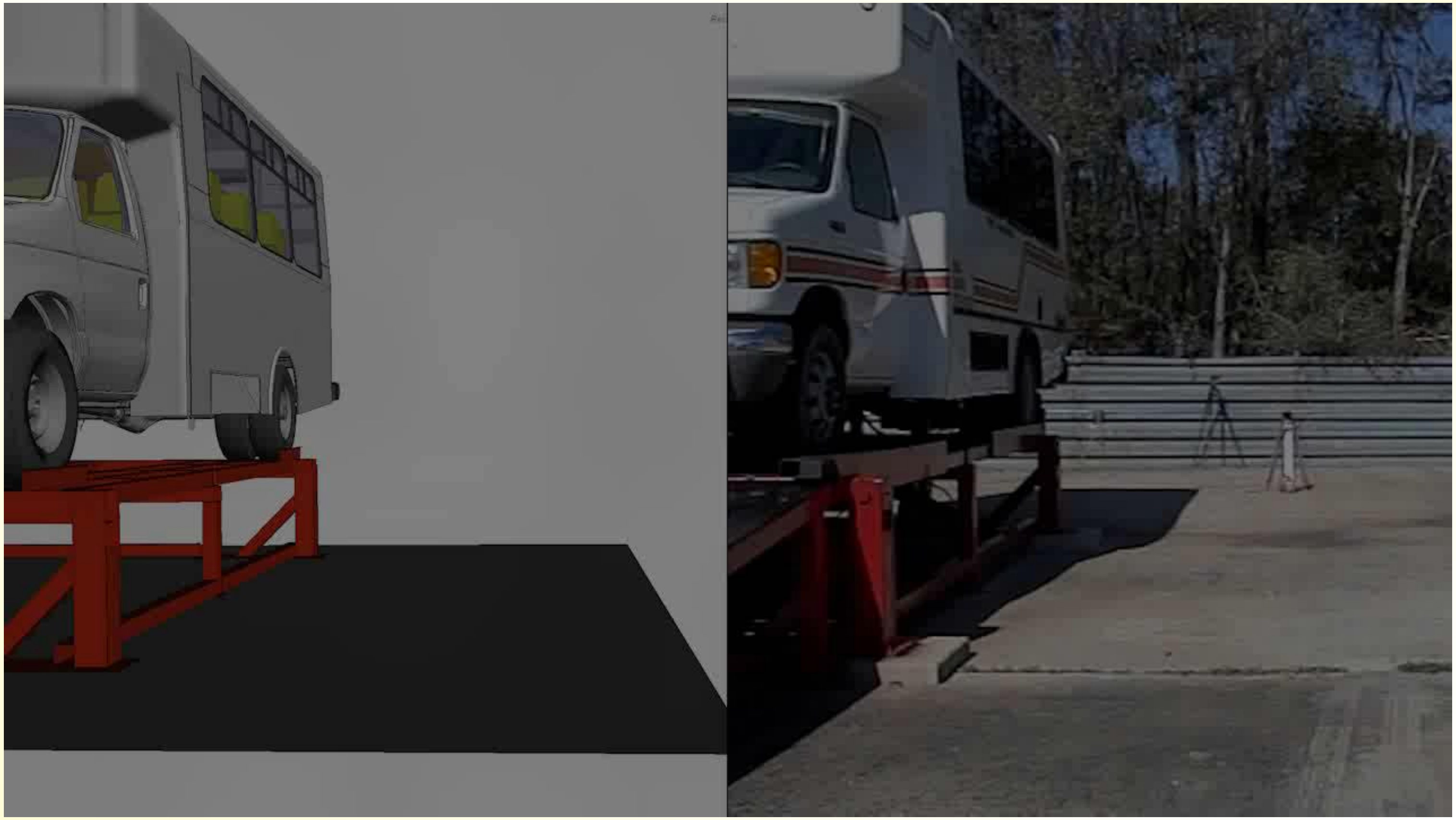
[2] United Nations; Strength of the superstructure of large passenger vehicles. Regulation 66. Revision 1. http://www.unece.org/trans/main/wp29/wp29regs/r066r1e.pdf, 2006, last access date: May 09, 2010.

[3] "Comparison of ECE-R66 and FMVSS 220 Tests for a Selected Paratransit Bus", Bronislaw Gepner, Christopher Rawl, Leslaw Kwasniewski, Cezary Bojanowski and Jerry W. Wekezer. Paper number 11-1802, 90-th Transportation Research Board Annual Meeting, Session 600, Final Program, page 178, Washington, D.C. January 23-27, 2011.

[4] Crash and Safety Testing Standard for Paratransit Buses Acquired by the State of Florida. http://www.tripsflorida.org/pdfs/Crash%20and%20Safety%20Testing%20Standard.pdf. Revision 2.01, August 10, 2007, last access date: February 9, 2011.

Estimated funding:	$50K
Research period:	12 months
Sponsoring Committee:	ANB70, Truck and Bus Safety
Date posted:	03/02/2011
Last modified:	03/02/2011
Index terms:	paratransit buses, current US fleet, bus structure, technical data.
Sponsoring Committee:	ANB70, Truck and Bus Safety
Date Posted:	03/04/2011
Date Modified:	03/05/2011
Index Terms:	Paratransit services, Paratransit vehicles, Bus transportation, Buses, Crashworthiness, Highway safety, Rollover accidents, Vehicle safety, Vehicle design,

QUESTIONS?



Standard:

Crash and Safety Testing Standard for Paratransit Buses Acquired by the State of Florida, approved by the Transit Office Florida Department of Transportation August 10, 2007 http://www.tripsflorida.org/pdfs/Crash%20and%20Safety%20Testing%20Standard.pdf

Peer reviewed journal publications:

"Crashworthiness Assessment of a Transit Bus", Leslaw Kwasniewski, Hongyi Li, Ravi Nimbalkar and Jerry W. Wekezer. Elsevier International Journal of Impact Engineering. (Article also published online via ScienceDirect: http://authors.elsevier.com/sd/article/S0734743X05000709). Hard copy: Volume 32, Issue 5, pp. 883-888, May 2006.

"Assessment of Passenger Security in Paratransit Buses", Andrzej Morka, Leslaw Kwasniewski and Jerry W. Wekezer. Journal of Public Transportation, Special Issue: Transit Safety and Security, http://www.nctr.usf.edu/jpt/pdf/JPT%208-4S%20Morka.pdf, ISSN 1077-291X, Volume 8, No. 4, pp. 47-64, October 2005.

"Material and Structural Crashworthiness Characterization of Paratransit Buses", Mark F. Horstemeyer, Hongyi Li, Jeff Siervogel, Leslaw Kwasniewski, Jerry W. Wekezer, Brian Christian, Garry Roufa. International Journal of Crashworthiness. http://www.informaworld.com/smpp/content~content=a783389084~db=all~order=page, pp. 509-520, Volume 12, Issue 5, 2007.

"Structural Response of Paratransit Buses in Rollover Accidents". Krzysztof Cichocki, Jerry W. Wekezer. International Journal of Crashworthiness. http://www.informaworld.com/smpp/content~content=a782255138~db=all~order=page , Vol. 12, No. 3, pp. 217-225, 2007.

"Crash and Safety Assessment Program for Paratransit Buses", Leslaw Kwasniewski, Jeff Siervogel, Cezary Bojanowski, Jerry W. Wekezer and Krzysztof Cichocki. Elsevier International Journal of Impact Engineering. http://dx.doi.org/10.1016/j.ijimpeng.2008.05.003. DOI information: 10.1016/j.ijimpeng.2008.05.003, Vol. 36, Issue 2, pp. 235-242, February 2009.

"Safety Assessment of Wheelchair Occupants in Paratransit Buses", Cezary Bojanowski, Leslaw Kwasniewski, Jerry Wekezer. International Journal of Human Modeling and Simulation. Vol. 1, No. 2, pp. 174-196, November 2008.