# LS-DYNA® Aerospace Working Group and LSTC updates

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August 2019

# Introduction



- Livermore Software Technology Corporation (LSTC)
- LS-DYNA Aerospace Working Group
- LS-DYNA Aerospace Working Group – Subgroup Cabin Interiors
- LSTC v-ATD models (Christoph Maurath)
- Burns Seat Model (BSM) (Satish Pathy)

# Livermore Software Technology Corporation (LSTC)



lstc.com/corporate/profile

Livermore Software Technology Corporation

LSTC

Products ▼ Support ▼ Applications ▼ Sales Training ▼ Corporate ▼

## Corporate Profile

Headquartered in Livermore, California, Livermore Software Technology Corporation (LSTC) develops LS-DYNA and a suite of related and supporting engineering software products.

LSTC was founded in 1987 by John O. Hallquist to commercialize as LS-DYNA the public domain code that originated as DYNA3D. DYNA3D was developed at the Lawrence Livermore National Laboratory, by LSTC's founder, John O. Hallquist.

LSTC's headquarters comprises three buildings that house offices, meeting rooms, and a state-of-the-art training room with audio and video equipment.

A team of engineers, mathematicians, and computer scientists are engaged in the development of LS-DYNA, LS-PrePost, LS-OPT, LS-TaSC (Topology), and LSTC's Dummy & Barrier models for use in various industries, including Automobile Design, Aerospace, Manufacturing, and Bioengineering. LS-DYNA development is focused on one code methodology that includes Implicit, Explicit, SMP and MPP solvers. It is optimized on all platforms including clusters running Unix, Linux, and Windows operating systems.

LSTC is focused on technical excellence and support. The worldwide growth of the LS-DYNA user base is attributable to both the quality of LSTC's software and the extraordinary efforts regularly made by the technical staff to ensure customer satisfaction.

With regard to LS-DYNA pricing, LSTC consistently offers a more competitive product because 90% of the work force is solely dedicated to technical endeavors. LSTC directs its resources towards producing high quality software and supporting li-

# Livermore Software Technology Corporation (LSTC) Products



**LS-DYNA** (general-purpose finite element program)

- Explicit
- ALE
- CESE
- EM
- ICFD
- Thermal
- Implicit
- Chemistry
- Particle Methods
- NVH/Acoustics
- Composites
- Materials
- Elements
- IGA
- Controls
- Metal Forming
- Additive Manufacturing
- …

**LS-PrePost**

*All LS-Dyna Pre & Post Processing*

**LS-OPT**

*Optimization Robustness*

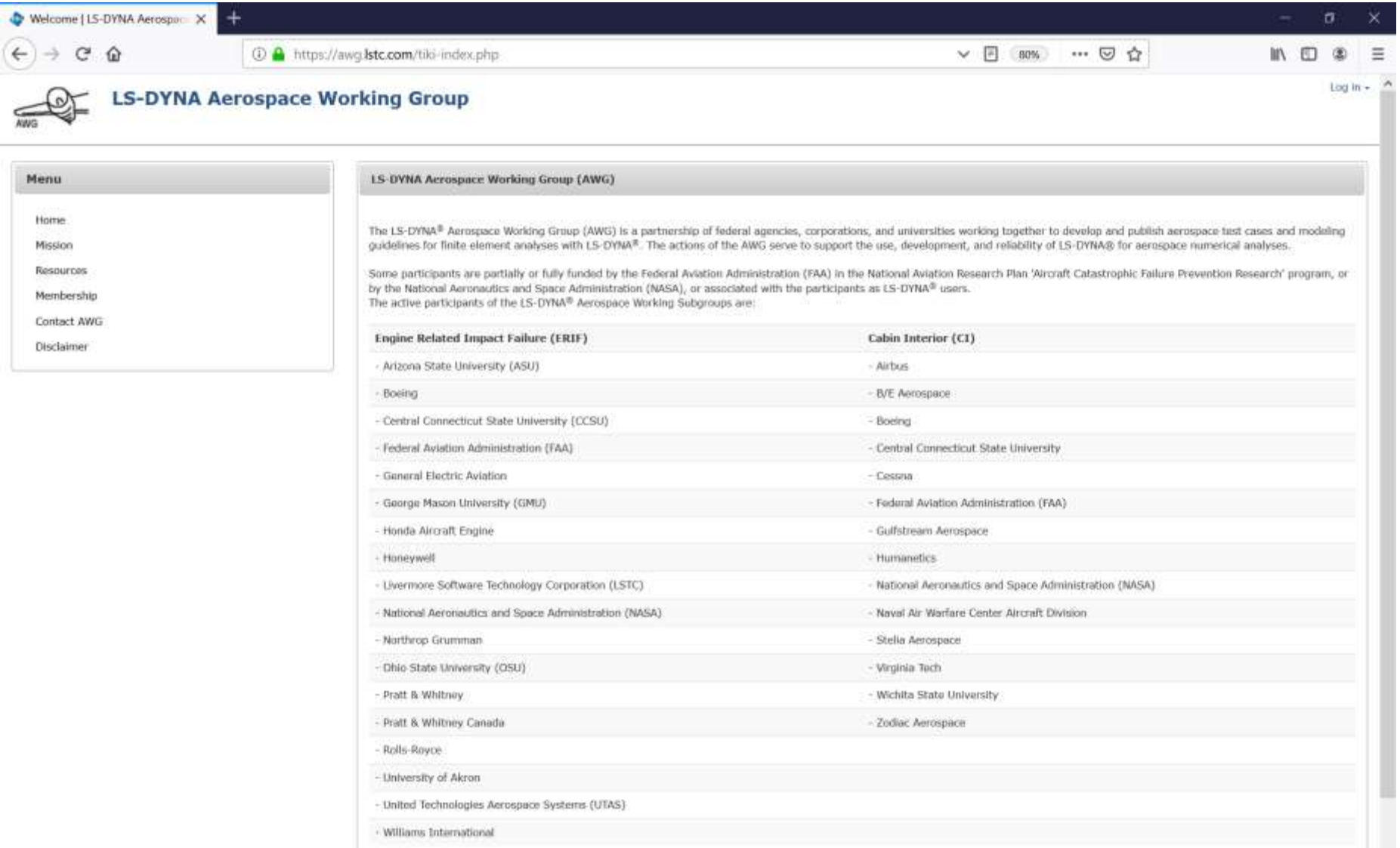
**LS-TaSC**

*Shape, Topology Optimization*

**v-ATD & Barriers**

*Validated barriers and Occupants models*

# LS-DYNA® Aerospace Working Group



## General

- Established around 2006
- partnership of federal agencies, corporations, and universities
- Some participants are partially or fully funded by the Federal Aviation Administration (FAA) in the National Aviation Research Plan 'Aircraft Catastrophic Failure Prevention Research' program, or by the National Aeronautics and Space Administration (NASA).

LS-DYNA® Aerospace Working Group

## Mission

- The mission of the Aerospace Working Group (AWG) is to develop and publish aerospace test cases and modeling guidelines for Livermore Software Technology Corporation's (LSTC) non-linear analysis program LS-DYNA®.
- The mission is achieved through the partnering of industry, government agencies, academia, and LSTC.
- The goal is to improve consistency and reliability of aerospace impact simulations with LS-DYNA®, thereby gaining regulatory agency acceptance of these simulations.

LS-DYNA® Aerospace Working Group

## Membership

- AWG subgroup participation is restricted to commercial aerospace companies with FAA certification requirements, related government agencies, and universities with projects funded by AWG organizations.
- AWG subgroup members will be active in all AWG subgroup activities, have login privileges to awg.lstc.com, be on the AWG subgroup mailing list, and attend meetings.
- The AWG subgroup mailing list is used to inform members of AWG subgroup activities and meetings.

LS-DYNA® Aerospace Working Group

## Structure

- Two public groups, one members only group
- Public groups:
    - Engine related impact and failure (ERIF)
        - Established around 2006
        - Focus on engine containments
    - Cabin interiors (CI)
        - Established around 2014
        - Focus on seat certification
- Members only group
    - *MAT_213 group
        - Composite material model development

LS-DYNA® Aerospace Working Group

## Output

- Test cases and test reports
  - 17 test cases (ERIF) and 2 test case (CI)
  - Input decks can be downloaded from the website
  - Test reports for LS-DYNA releases can be downloaded as well
- Material parameters sets
  - Aluminum 2024
  - Ti-6Al-4V
  - Ice
  - Kevlar
- Modeling guidelines document (MGD)
  - ~ 250 page document
  - Examples are available as well

LS-DYNA® Aerospace Working Group

## Website

- URL: https://awg.lstc.com
- Public and membership area
  - Content accessible to the public:
    - Test cases and test reports
    - Modeling Guidelines document (MGD)
    - Material parameter sets
    - LSTC tutorials
    - External reports (FAA reports)
  - Membership area
    - Content which is not yet approved to be public
    - member contact data
    - meeting agendas and meeting presentations
- Contact us

LS-DYNA® Aerospace Working Group

## Member contributions (examples)

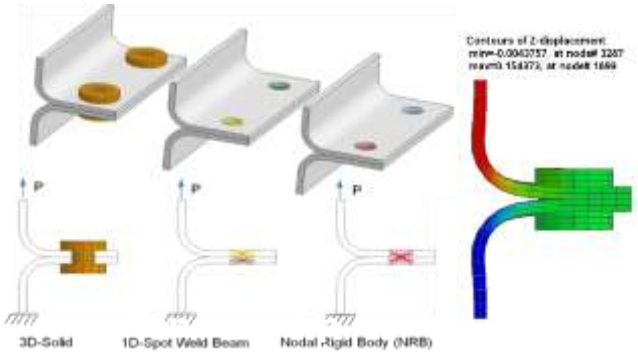
- FAA / NASA
  - Funding of various research projects
  - Funding website administration (Tom Vasko, CCSU)
- Universities (ASU, GMU, OSU, VT, WSU …)
  - Research projects (FAA / NASA funded)
- Industries
  - Contribution to Modeling Guidelines Document
  - Contribute test cases
- LSTC
  - Perform tests runs and publish test reports for all test cases (Juan Pu)
  - Host and maintain website
  - Add test cases to internal LSTC QA

LS-DYNA® Aerospace Working Group

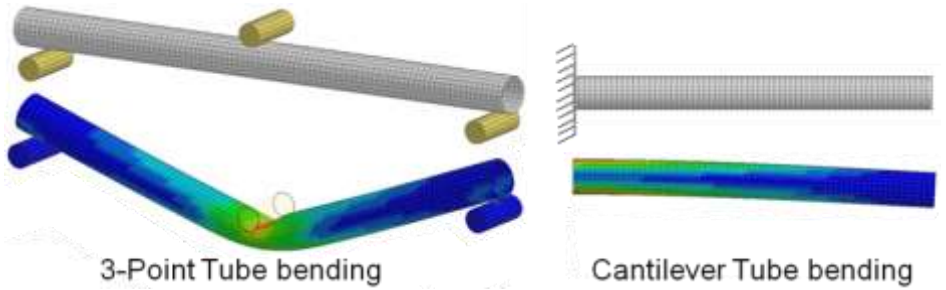
## Subgroup Cabin Interiors

- Primary Focus: Seat Certification by Analysis
- Organized by Joseph Pellettiere (FAA)
- 35 Active Members
  - 5 Government Representatives
    - NASA, FAA, Naval Air Warfare Center Aircraft Division
  - 8 Industry Representatives
    - Zodiac Aerospace, Gulfstream Aerospace, Collins Aerospace, Boeing, Airbus, Humanetics, HAECO Cabin Solutions
  - 4 University Representatives
    - WICHITA State, Virginia Tech, George Mason
  - 13 Delegates
  - 5 LSTC Members

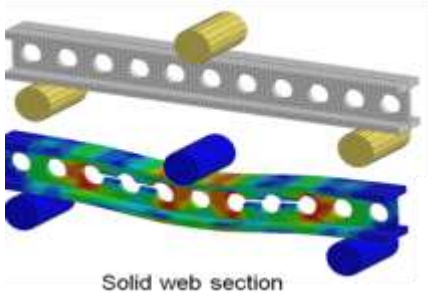
- Cabin Interior Test Cases in Development

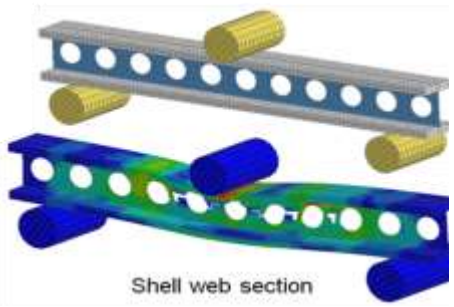



**Joint/Fasteners – Tension Loading**

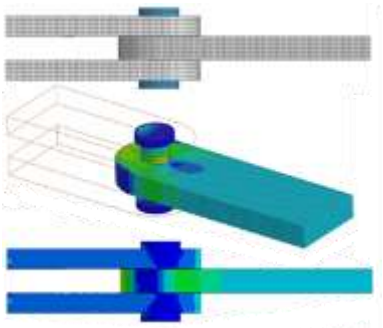



**Tube Bending**

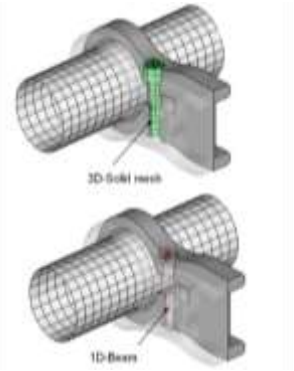



**I-Beam Web Section – Leg Structure – Solids vs Shells**



**Lug joint**



**Fastener Preload**



LS-DYNA® Aerospace Working Group – SG Cabin Interiors

# LSTC v-ATD models (Christoph Maurath)

- Available to current LS-DYNA licensees
- Can be downloaded through LSTC web site
- Support: atds@lstc.com
- http://lstc.com/products/models/dummies

# Released LSTC v-ATD models

| Detailed Models |
| --- |
| HYBRID III 5th |
| HYBRID III 50th |
| HYBRID III 95th (scaled) |
| HYBRID III 50th Lower Body |
| SID IIs D |
| EuroSID 2 |
| EuroSID 2re |
| USSID |
| HYBRID III 6-year-old |
| Free Motion Headform |
| Pedestrian Legforms |
| Pedestrian Headforms |

| Fast Models |
| --- |
| HYBRID III 5th |
| HYBRID III 50th |
| HYBRID III 95th |
| SID IIs D |
| HYBRID III 5th Lower Body |
| HYBRID III 50th Lower Body |
| HYBRID III 95th Lower Body |
| HYBRID III 50th standing |

- WorldSID 50th
- Hybrid III 3-year old
- Hybrid II

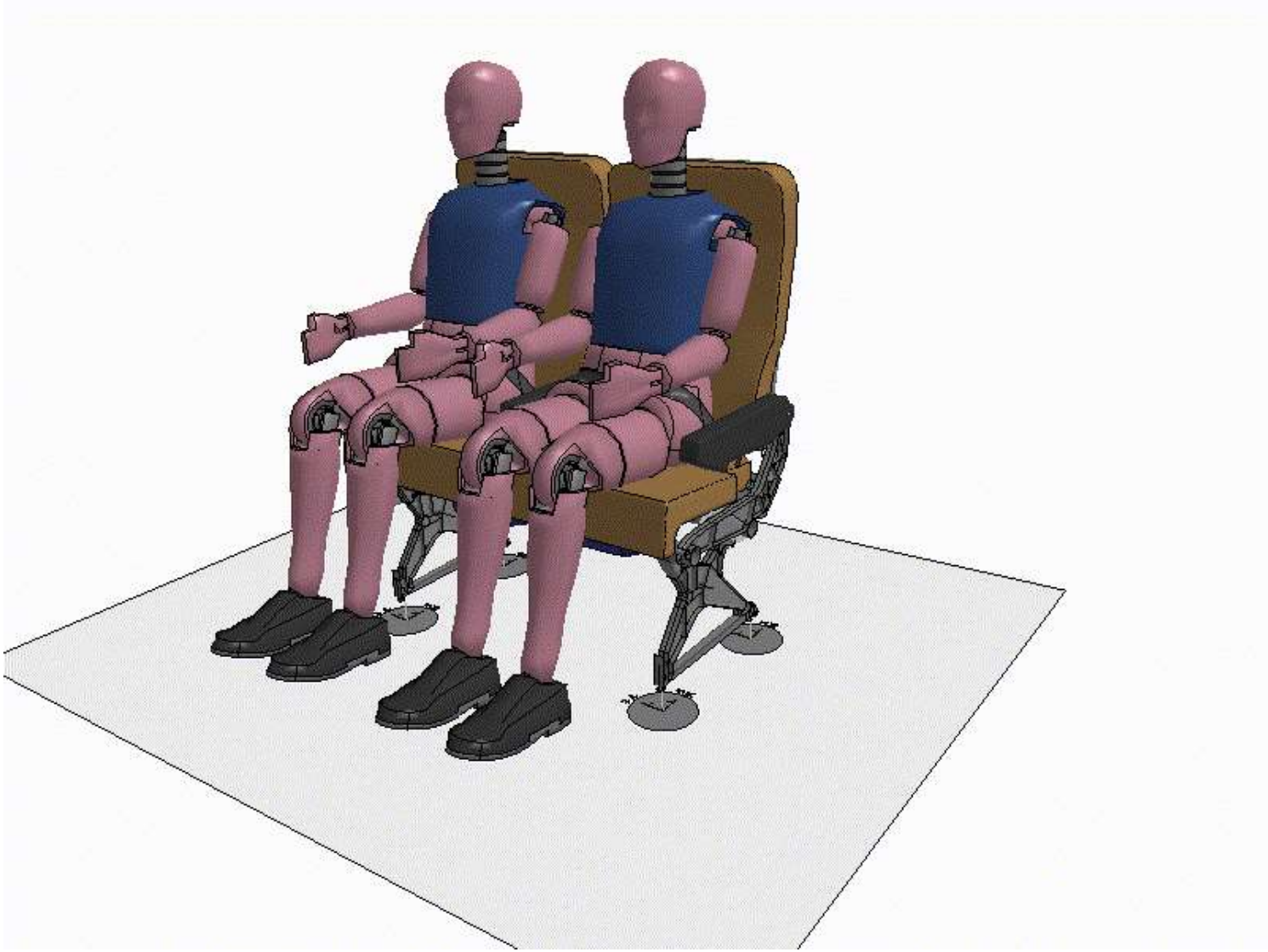
First version of WorldSID 50th detailed model was released in June 2018

# Development Hybrid II - Status



| Calibration Test | | Parameter | Requirement | Simulation | % Error | Comments |
|---|---|---|---|---|---|---|
| Head Drop | | Resultant Acc (G) | 210 – 260 | 230.2 | -- | Currently Working |
| | | Lateral Acc (G) | -10 – 10 | -7.3 | -- | |
| | | Above 100G level (ms) | 0.9 – 1.5 | 1.7 | 13 | |
| Neck Pendulum | | Maximum rotation (degrees) | 68° ± 5° | 51 | 19 | Currently Working |
| Thorax Impact | 14 fps | Force (N) | < 6450 | 5450 | -- | Done |
| | | Max Deflection (mm) | < 28 | 23 | -- | |
| | 22 fps | Force (N) | < 10008 | 9810 | -- | Done |
| | | Max Deflection (mm) | < 43.18 | 36.9 | -- | |
| Limbs (Knee Impact) | | Maximum force (N) | 8230 – 11120 | 10500 | -- | Currently Working |
| | | Above 4450N level (ms) | > 1.7 | 1.3 | 23 | |
| Sled Test (2, 3 and 4 point belt) | | | | | | Yet to start |

# Burns Seat Model (BSM) – A Study by Satish Pathy (LSTC)



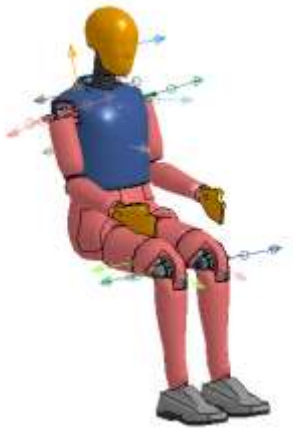
# Burns Seat Model (BSM)

- Burns Seat Model was developed by National Institute for Aviation Research (NIAR)
- This seat is an outdated design and the FE model was build from drawings and images
- Physical test data is available
- Model was provided as a test case to the AWG SG CI
- The model was chosen by the CI group to exercise different modeling and analysis methods

# Analysis goals



- A first investigation of this model was performed by Satish Pathy (LSTC) and Thomas Borrvall (DYNAmore Nordic)
- Goal was to explore the possibility to simulate the pre-loading part of the seat using LS-DYNA's implicit solver
- Focus on decrease wall clock time of calculations compared to current methods (dynamic relaxation)
- Details in: Satish Pathy and Thomas Borrvall , "Numerical Simulation of Aircraft Seat Compliance Test using LS-DYNA® Implicit Solver", 15th International LS-DYNA Conference, Detroit, MI, 2018



# Model Setup

- As stipulated in the FAA's 14 CFR 25.562, seat attachments are deformed to simulate the floor deformation after a crash.

- One side of the seat rails is subjected to a $10^0$ roll
- The other side of the seat rails is subjected to a $10^0$ pitch

- This pre-deformation results in pre-stressing the seat and increases bending moment in transverse members of the seat.

- All the above pre-loading is done with dummies seated, hence the contribution from dummy mass has to be considered.

# Simulation Setup

The simulation was carried out in three steps

1. Gravity load was applied
2. Roll left mounts by $10^0$
3. Pitch right mounts by $10^0$

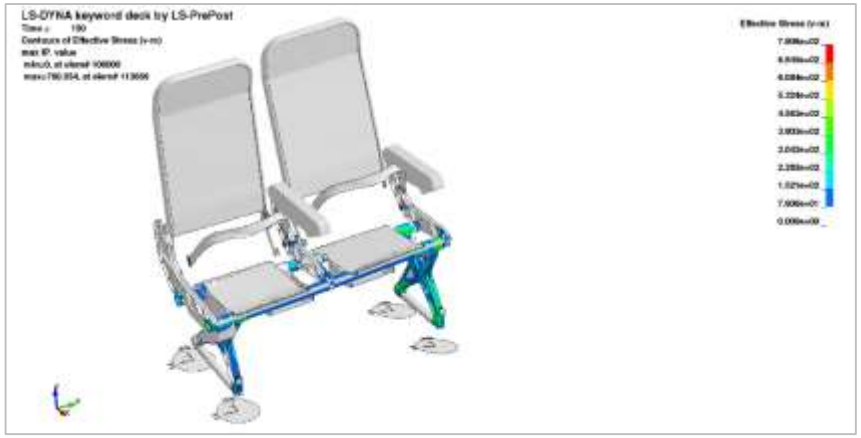
Two tests were performed

- Flexible v-ATD model
- Rigid v-ATD “shell” model
  - Mass and C.O.G was corrected

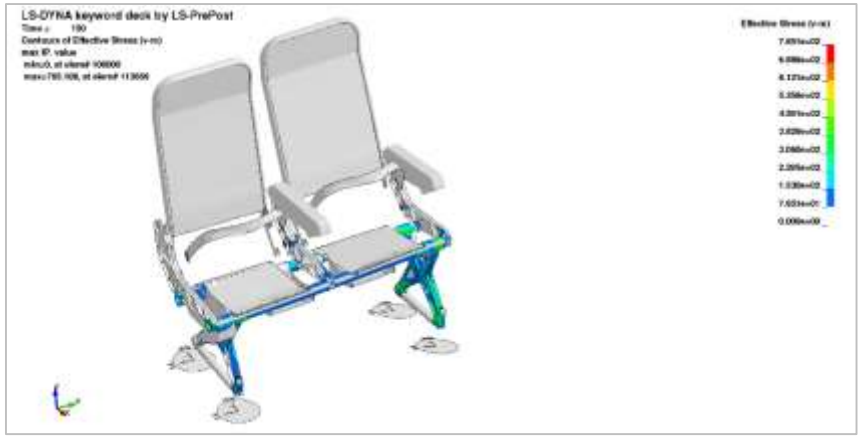
Analysis were performed with an LS-DYNA MPP executable utilizing 24 cores

# Results – Stress distribution on Seat frame



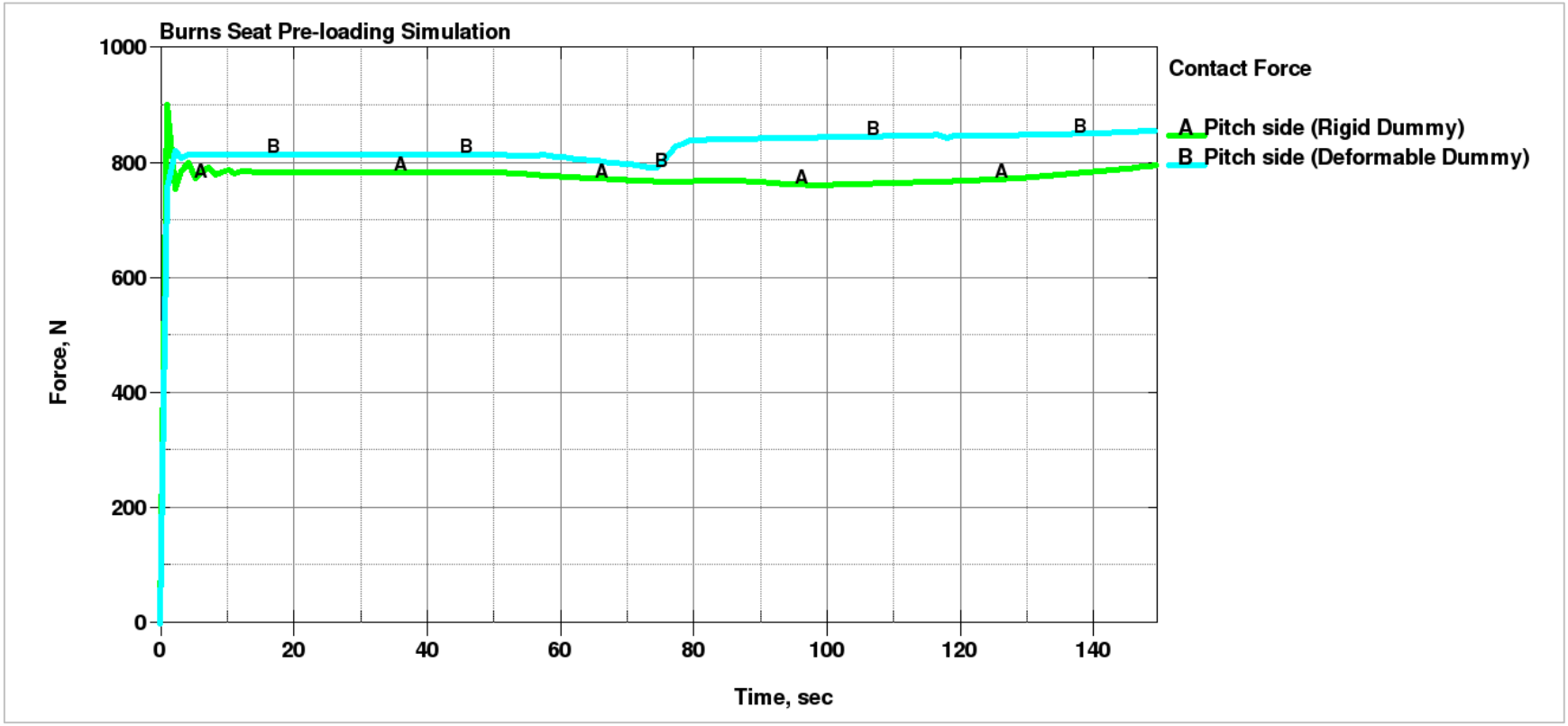



Stress Distribution on seat frame w/ Deformable Dummy

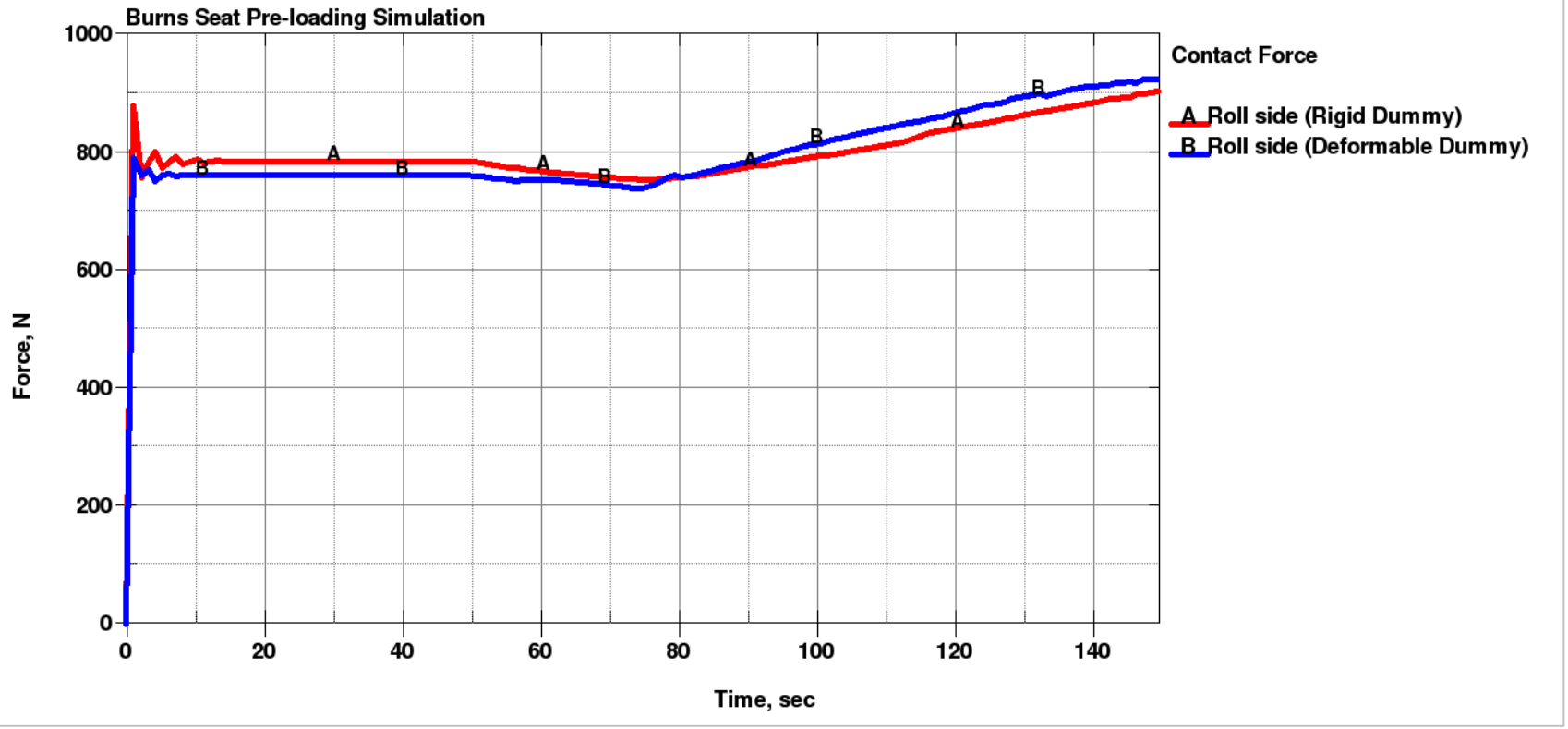



Stress Distribution on seat frame w/ Rigid Dummy “Shell”

# Results – Contact forces on v-ATD



# Results – Contact forces on v-ATD



# Conclusion

- This FE model was developed by NIAR, the implicit version of the same is available to download from awg.lstc.com (member area)
- Implicit simulation with fully functional dummy took ~31hrs (24 cores) for the full simulation
- Implicit simulation with rigid dummy shell took ~3hrs (24 cores) for full simulation
- If the model is developed keeping implicit in mind, one can solve the pre-loading part of the seat successfully and possibly with more accuracy.
- Based on the results, it appears we can perform the pre-loading of the seat using a rigid dummy shell (?)

# Future Work

- To validate the changes made in the dummy model and release a implicit version of the same. These validation efforts include running the model through a series of certification/calibration tests.
- Will continue to work with AWG's cabin interiors group to refine this method

Thank you for your attention