Overview of LSTC's LS-DYNA® Anthropomorphic Models

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Abstract

The paper gives an overview of LSTC's LS-DYNA crash test dummy model development effort. The model development process is outlined. Details of all released models are presented. The development status of models currently under development is addressed. Outlook to future models is given.

Introduction

Crash test dummies, in technical terms usually called Anthropomorphic Test Devices (ATD), are life-size mannequins that measure forces, moments, and accelerations which can be interpreted to the extent of injuries humans would experience in impact conditions or other injury threatening conditions. Therefore, dummies should ideally behave like real human beings, but still be durable, able to be used repeatedly and generate reproducible results. They are equipped with numerous sensors to measure parameters, such as forces, moments, accelerations, and deformations. There are a large variety of crash test dummies available to represent the different sizes and shapes of humans. Different dummies are generally used for frontal, side, or rear impact directions.

Different techniques can be utilized to represent physical dummies in a computer model. Rigid body models with special joint definitions might be the least complicated technique. LS-DYNA itself includes two types of those models. They will not be covered in this paper. Please refer to the *COMPONENT section of the LS-DYNA Keyword User Manual [1] for details.

Dummies can also be modeled with a combination of some coarsely meshed deformable parts and other rigidized parts and sections. This approach simplifies the dummy and keeps the runtime low while providing reasonably good performance. LSTC's USSID and Rigid-FE models fall in this category.

Detailed or fully deformable dummy models have the advantage of being able to represent global and local deformations. They are most likely to perform just like the physical dummy since the least number of approximations are used. However, runtimes for these models increases due to the number of elements and the complexity of the model. Most of LSTC's anthropomorphic models are detailed models.

All of LSTC's publicly released models are distributed free of charge to licensees of LSTC's LS-DYNA software who are current with their annual license fees (Annual License) or maintenance fees (Paid-up License) [2].

Outline of Development Process

In the following section and also within LSTC's naming convention ALPHA versions refer to running models with fair correlation to test data and no documentation. BETA versions correlate well to the available test data and include documentation about the correlation and the dummy model in general. Final versions are versions of models that are not expected to go through any further major changes.

The development process for a new dummy model is outlined in Figure 1. It usually starts with LSTC identifying which model to develop based on customer needs and the availability of geometry data.

For some dummy models drawing packages are available and we rely on scanned geometry data only for outer parts and parts with shapes that cannot be generated from drawings only. For other dummy models we rely completely on scanned geometry from customers or collaborators.

The mesh of the model is then being generated. Most of LSTC's detailed models were meshed utilizing TrueGrid meshing software [5].

The build-up of the model with joints, connections and initial materials leads to a first running version.

Model certification tests are set up. At this point test data, mostly of certification tests, from customers is needed to compare the model to the results from the physical tests. Approximate materials for the model are generated to make it an ALPHA model.

In some cases an early ALPHA version is released to customers, who helped with the geometry or test data for this model. Feedback from those customers is implemented to later ALPHA versions. Iterations of certification simulations are run to improve the model response and calibrate the dummy model. In certain cases LS-OPT® is employed to optimize the materials. Sometimes a later ALPHA version is being released to all customers.

BETA versions go through several more iterations of certification and performance test runs to improve the model response. For the release of BETA versions documentation is added to the model file package. Customer feedback is implemented into the model. If available, data from physical material tests is implemented into the model. BETA model releases are supported by LSTC.

The final version of a model will be maintained and supported, but no iterations of certification test runs will be performed.

In case of regulation changes or changes in the design of the physical model, a final version model might be used as a basis for another ALPHA or BETA version of the modified physical dummy.

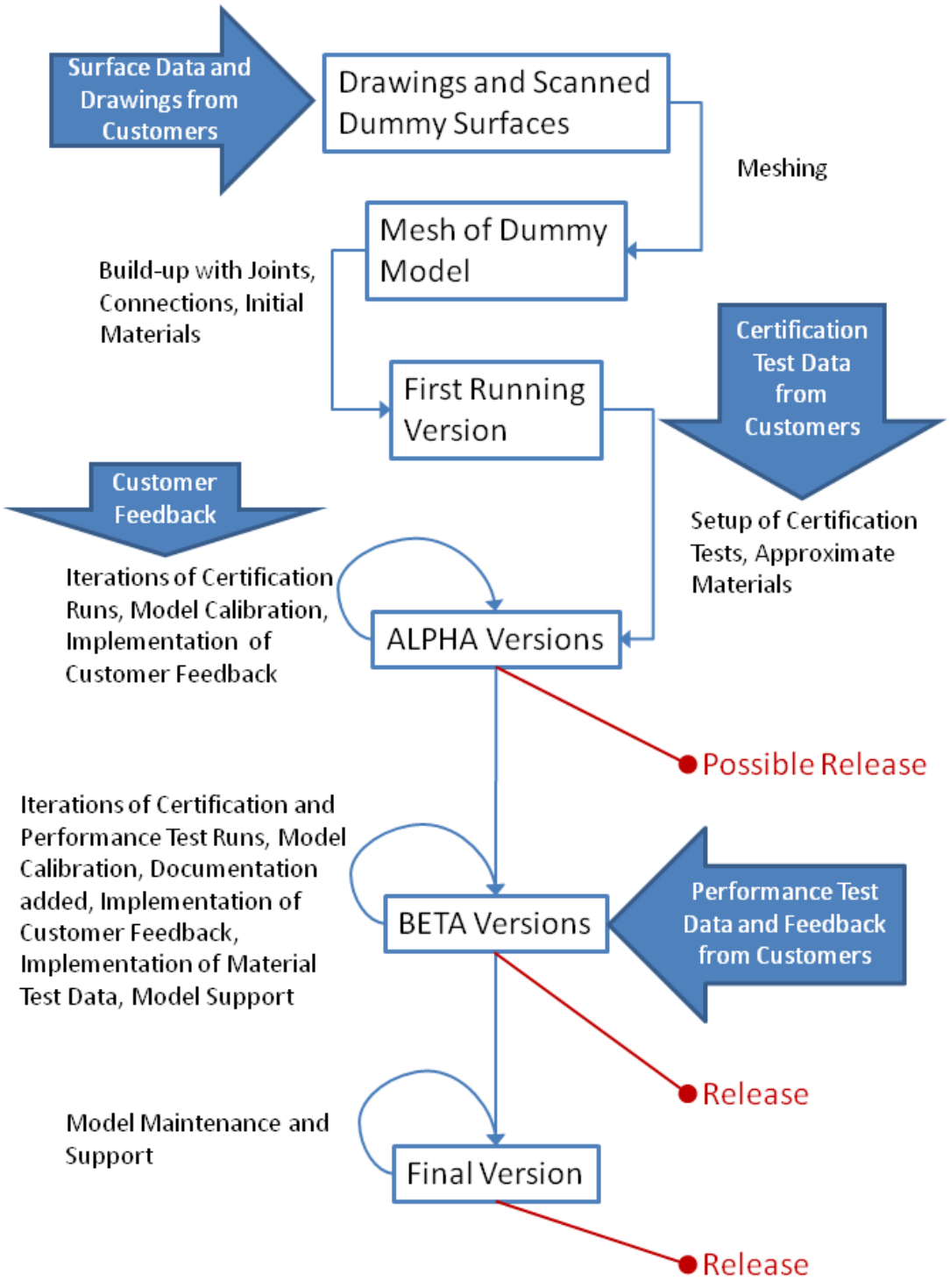

Figure 1: Development Process Flowchart

Currently Available Anthropomorphic Models

The following models are currently released and can be obtained from LSTC's ftp site or through your LS-DYNA distributer. For further details about the individual model, please refer to the documentation included in a package with the keyword file of the model [2].

The first four models, including Hybrid III Rigid-FE adult, Hybrid III Rigid-FE 50th male standing, USSID, and SID-IIs D Rigid-FE are partially rigidized and coarsely meshed to archive short runtimes. The other mentioned models are detailed models.

Hybrid III Rigid-FE adult models

These models include a 5th percentile female, a 50th percentile male, and a 95th percentile male version of the Hybrid III dummies. They are based on simple models that were originally developed in the mid 1990ies. In the last several years the models' run stability and response performance were significantly improved and customer feedback was incorporated. Since the last release the models have been further improved based on comparisons to data from physical sled tests. New versions will be released in the near future.

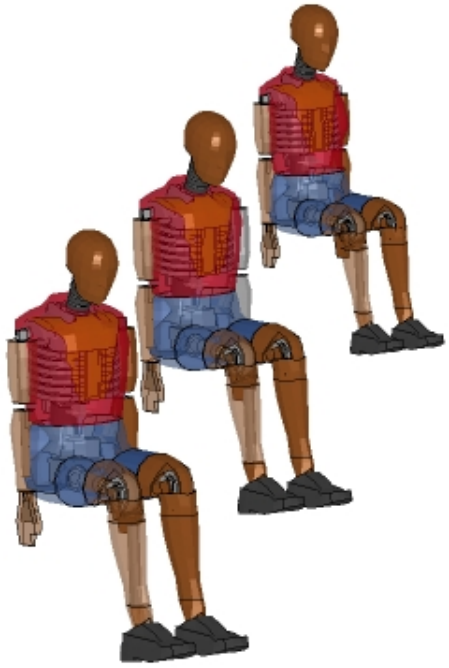

Figure 2: Hybrid III Rigid-FE adult models

Hybrid III Rigid-FE 50th male standing

This model is a standing version of the Hybrid III 50th percentile male dummy. Based on the original sitting 50th percentile Hybrid III, the spine, pelvic bone, pelvic flesh, and upper leg flesh have been modified for this model. The initial version has been release and currently we are searching for calibration data and await customer feedback.

Figure 3: Hybrid III Rigid-FE 50th male standing

USSID

The model of the USSID is based on a publicly available model from the National Highway Traffic Safety Administration (NHTSA). Its jacket, arm and pelvic foam discretization have been improved. The material data for the foam parts was also improved. A single global contact was implemented. In the latest version a positioning tree for LS-PrePost® was added.

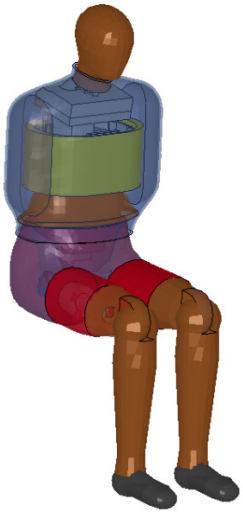

Figure 4: USSID

SID IIs D Rigid-FE

The reduced model of the SID IIs is based on our detailed model (see below). Most parts are significantly simplified to achieve faster runtimes compared to the detailed version. The initial version has recently been released.

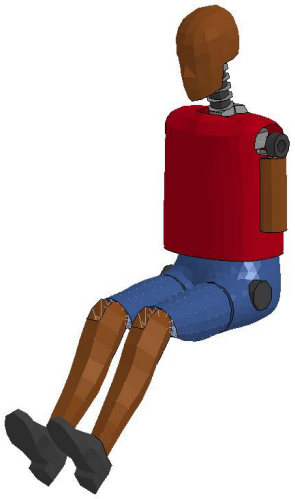

Figure 5: SID-IIs D Rigid-FE

Hybrid III 50th percentile male

The detailed model of the Hybrid III 50th percentile male dummy is a joint development with the National Crash Analysis Center (NCAC) at The George Washington University in Washington, D.C.

An initial ALPHA model was released in summer of 2009. Since then the correlation to test data from calibration tests and also performance tests has been significantly improved.

Figure 6: Detailed Hybrid III 50th male

SID IIs D

The detailed model of the SID IIs revision D was initially released in 2008. Since then customer feedback has been incorporated and the model was rereleased. Currently a second round of customer feedback is being utilized to improve the model.

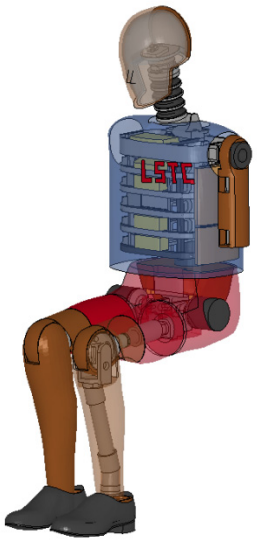

Figure 7: Detailed SID IIs revision D

EuroSID-2re/EuroSID-2

The EuroSID 2re and EuroSID 2 dummy models are jointly developed with DYNAmore GmbH in Germany.

Both are detailed models and were released in 2009. Currently we are awaiting customer feedback on the models.

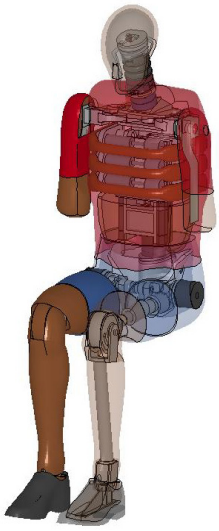

Figure 8: Detailed EuroSID 2re

Free Motion Headform

The latest released version of the Free Motion Headform includes a different way of head skin to skull interaction compared to earlier versions. Further, the material representing the head skin now incorporates data from physical material tests.

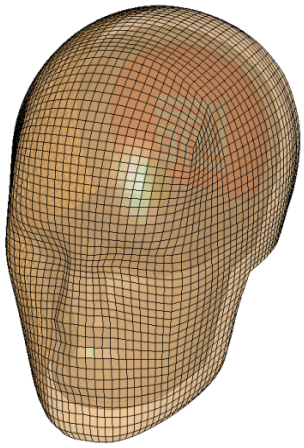

Figure 9: Free Motion Headform

Pedestrian Legforms

The Pedestrian Legform Impactor models were originally developed in 2001 based on EEVC WG 17 recommendations. Recently, both the Upper Leg Impactor and the Legform Impactor have been updated and revalidated according to European regulation 631/2009.

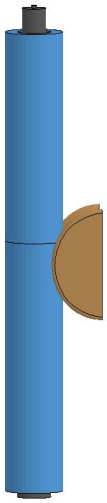

Figure 10: Pedestrian Legform Impactor

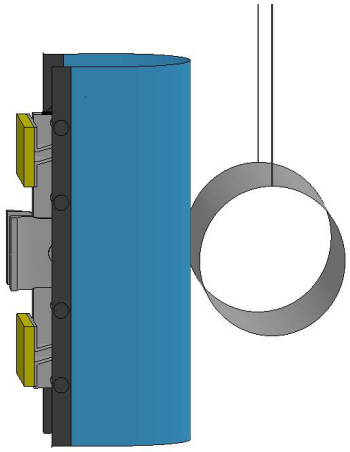

Figure 11: Pedestrian Upper Leg Impactor

Models in Development

The following dummy models are in various stages of their development.

Hybrid III 5th percentile female

The detailed model of the detailed Hybrid III 5th percentile female dummy is a joint development with NCAC.

We are in the final steps of the evaluation of the model and a first ALPHA version will be released in the near future.

Figure 12: Hybrid III 5th percentile female

Hybrid III 95th percentile male

The detailed model of the 95th percentile male Hybrid III dummy is a joint development with NCAC.

Currently the model is in the buildup and early calibration phase.

Hybrid III three-year-old

The detailed model of the Hybrid III three-year-old dummy is in the build-up and early calibration phase.

Figure 13: Hybrid III three-year-old

Hybrid III six-year-old

The mesh of the detailed model of the Hybrid III six-year-old dummy is almost completed and the model build-up will start soon.

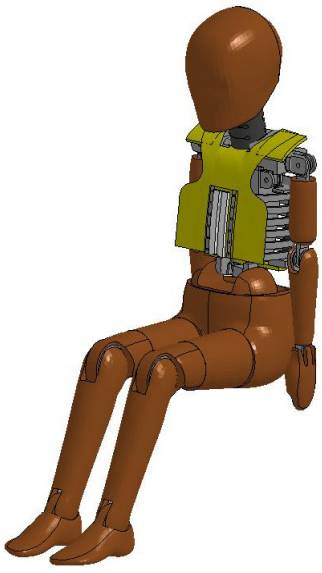

Figure 14: Hybrid III six-year-old

BioRID II

At time of submission of this paper, the detailed mesh of the spinal column of the BioRID II dummy model is complete. Every part of this complex spine is represented by a separate part in the mesh.

Soon we will receive surface scans of the rest of the dummies thorax and will continue building the mesh.

The extremities of this dummy, including legs, feed, arms, and head are from the Hybrid III 50th percentile male and will be copied from our detailed model of that dummy.

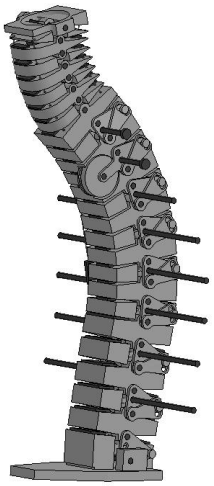

Figure 15: BioRID II spine

Future models and Conclusions

A brief outline of the general development process of LSTC's LS-DYNA anthropomorphic models was given. The currently available models and the models in development were presented.

Details about individual models, their development process, and certification test results can be found in the documentation accompanying the models.

All available models can be obtained through LSTC's ftp site: http://ftp.lstc.com/user/ or through your distributor.

We will continue to support and improve our existing models and to develop new models in future. Currently the following models are in the planning phase:

- WorldSID
- Flexible Pedestrian Legform Impactor
- Q6 Child Dummy
- Q3 Child Dummy

We endeavor to make the models as complete, accurate, reliable, and easy to use as possible. Suggestions and comments should be e-mailed to support@lstc.com. Please report any errors encountered in either the documentation or results immediately to LSTC through your site focus.

Parties interested in aiding with the development or improvement of any dummy model, please contact us at atds@lstc.com.

References

[1] "LS-DYNA® Keyword User's Manual Version 971," Livermore Software Technology Corporation, Livermore, California.
[2] http://ftp.lstc.com/user/ , LSTC's ftp site
[3] http://ecfr.gpoaccess.gov/ , Electronic Code of Federal Regulations, Title 49, Part 572
[4] http://eur-lex.europa.eu/ , European pedestrian safety regulation
[5] www.truegrid.com, **True*Grid*®** is a Registered Trademark of XYZ Scientific Applications, Inc.