the CertaSim SOLUTION™

Featuring:
The IMPETUS Afea Blast ATD in a Full Vehicle Model

Q3
2017

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CertaSIM, LLC is the official distributor of the IMPETUS Afea Solver® in North, Central and South America and provides technical support and training for the IMPETUS suite of software.

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News and Events

New Support & Training Office in Silicon Valley

CertaSIM is excited to announce the opening of a new Support & Training office in Saratoga, at the heart of Silicon Valley. "Since CertaSIM works with Next Generation Software, on the edge of technology we felt it was beneficial to have an office where things happen", says Dr. Morten Rikard Jensen, CTO of CertaSIM, LLC. He continues, "We believe that it is easier to attract engineers with the right background having this new location."

The address is: CertaSIM, LLC, Support & Training 18809 Cox Ave., Suite 150, Saratoga, CA 95070 United States. Drop by if you are in the neighborhood or give us a call at: +1-408-796-7488.

Engineering Mechanics Institute Conference (EMI 2017)

The EMI 2017 Conference was held this year in San Diego on June 4-7 and CertaSIM was there to present a paper authored by Dr. Wayne Mindle of CertaSIM and Dr. Anthony Rosato of the New Jersey Institute of Technology (NJIT). Dr. Rosato is a professor in the Mechanical Engineering Department and the Director of the NJIT Granular Science Laboratory. The conference topics covered many areas of mechanics and the paper presented by Dr. Mindle was titled, "**Modeling Particle Compaction of Granular Media with Next Generation Finite Element Technology**". Dr. Rosato has been doing research in granular media for much of his career and it was an honor to work with him on this paper. Here is the abstract for the presentation. Anyone interested in more details can contact CertaSIM:

Modeling Particle Compaction of Granular Media with Next Generation Finite Element Technology

In processes such as direction compression tableting in the pharmaceutical industries and the creation of pre-sintered green compacts, particle to particle contact deformation is a nonlinear dynamic process that is a function of the loading evolution, material properties and shape of the particles. While finite element methods have been applied to model deformable particles [1,2], its use has been limited to 2D simulations due to the high computational cost. While some understanding has been achieved via these simulations, it is necessary to model the full three-dimensional process in order to capture the actual physics of the phenomena. This can be done using the IMPETUS Afea Solver ® which has developed next generation fully integrated high-order solid elements and takes full advantage of GPU Technology for massively parallel processing on a standard workstation. Capabilities include distributions of particle size and shapes (including non-convex geometries), full interactions with external structures, a large number of particles, and particle fragmentation in a true 3D scenario. In order to demonstrate some of the capabilities of the method, we discuss a paradigm case study of the compaction of 500 μm spherical particles, which are created with cubic hexahedron elements that consist of 64 nodes and 64 integration points. The physical enclosure consisted of a 3 mm diameter by 6 mm tall cylindrical container with one open end. The assembly housed within the cylinder was created by stacking single layers of particles (with adjacent layers being slightly offset from each other), in which an individual sphere was comprised of seven cubic hexahedron elements. Compaction of the system was achieved by applying a vertical load via a rigid cylindrical plate to compress the particles to half the cylinder length (3mm) then slowly unloaded by moving the plate in the opposite direction. The simulation for a simple model with 444 uniform particles of diameter 0.5 mm required only 32 minutes to complete. Simulations conducted with a particle diameter of 0.375 mm (~1300 particles) increased the runtime time to ~3 hours.

ASME 2017 Pressure Vessels and Piping Conference

The ASME 2017 Pressure Vessels and Piping Conference was held in Hawaii on July 16-20. CertaSIM has been collaborating with the University of Nevada Las Vegas in the area of Hypervelocity. The laboratory at UNLV is an expert in performing hypervelocity experiments with their gas gun. This provided CertaSIM the opportunity to validate the IMPETUS GAMMA-SPH solver with accurate experimental results. A paper was presented at the conference titled, "**MODELING OF HYPERVELOCITY IMPACT EXPERIMENTS USING GAMMA-SPH TECHNIQUE**". Dr. Jerome Limido of IMPETUS Afea SAS in France was the lead author which also included Professor and Associate Dean for Research Mohamed Trabia and Professor Brendan O'Toole of UNLV, one graduate student, Dr. Wayne Mindle of CertaSIM and researchers from National Security Technologies, LLC. The experimental work was supported under a DOE contract through National Security Technologies, LLC. Dr. Trabia attended the conference and presented the paper. There were around 30 people that attended his session and the response was very positive. Anyone interested in the full paper can contact CertaSIM.

Proceedings of the ASME 2017 Pressure Vessels and Piping Conference
PVP2017
July 16-20, 2017, Waikoloa, Hawaii, USA

PVP2017-65517

MODELING OF HYPERVELOCITY IMPACT EXPERIMENTS USING GAMMA-SPH TECHNIQUE

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3rd Annual BMES/FDA Frontiers in Medical Devices Conference

The "Frontiers in Medical Device Conference" is a medical device conference sponsored by the Biomedical Engineering Society (BMES) and the Federal Drug Administration (FDA). The conference was held in Washington DC, May 16-18. CertaSIM, LLC had a booth at the conference, together with csimsoft, the developer of Trelis and Bolt (http://www.csimsoft.com).

csimsoft is a CertaSIM partner and their suite of pre-processors are world renown for building quality solid element meshes. We appreciate the many attendees that stopped by our booth to discuss simulation and the large interest that was shown for Trelis, Bolt and the IMPETUS Afea Solver®. This year we were handing out Amazon Echo Dots to the lucky winners of our drawing.

CertaSIM's Director of Marketing, Dr. Mindle, on the left, with one of the lucky winners, Dr. Afshari from Depuy Synthes Spine. CertaSIM and csimsoft were Silver Sponsors at the conference and gave a seminar on the importance of high order finite elements to accurately capture the geometry found in Medical Devices.

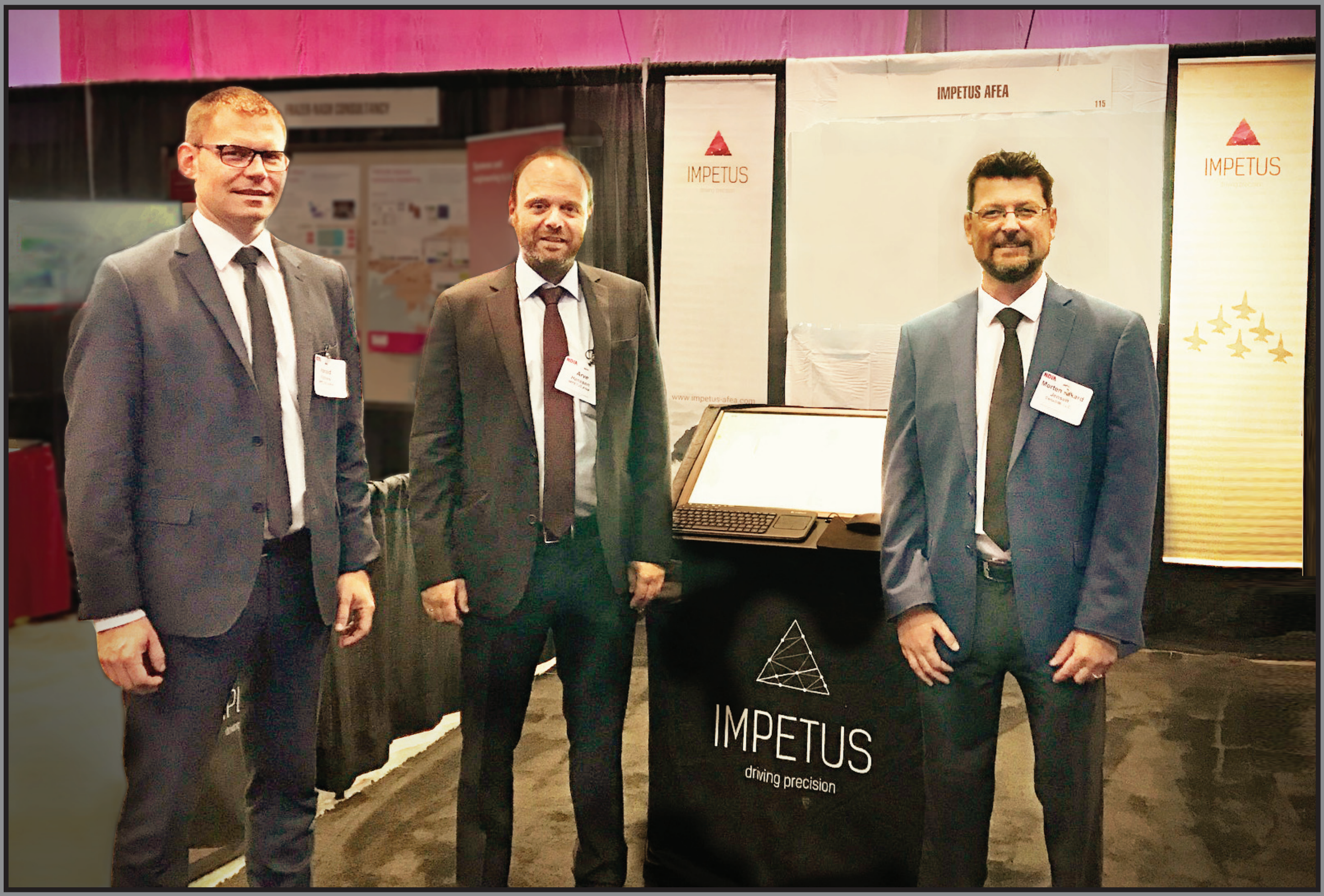
2017 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM MODELING & SIMULATION, TESTING AND VALIDATION (MSTV) TECHNICAL SESSION AUGUST 8-10, 2017 - NOVI, MICHIGAN

In collaboration with General Dynamics Land Systems, CertaSIM, LLC made a presentation at the GVSETS conference. It showcased both the experimental and numerical study of the IMPETUS Blast ATD. Topic for the presentation was: "**Calibration and Verification of Detailed Hybrid III 50TH Percentile Male Anthroporphic Test Device (ATD) Based on Extensive Mine Blast Tests**". The paper was well received by the community and the work is the foundation for modeling full vehicle blast tests including ATDs. A summary of the paper is provided later in the Journal.

30th International Symposium on Ballistics

As a member of International Ballistic Society, CertaSIM's Dr. Jensen attended the 30th International Symposium on Ballistics in Long Beach, California, 11-15 September 2017. CertaSIM was in the IMPETUS booth to showcase the IMPETUS Afea Solver® and meet new and old colleagues from all over the world. The IMPETUS Afea HQ located in Norway was represented by Dr. Hanssen and Mr. Vistnes who showcased the IMPETUS interface. CertaSIM showed for the first time the three new brochures on ballistics and fragmentation simulations. It was a great event that allowed us to meet many of our customers in one place.

The Norwegian Defense Research Establishment and Nammo Raufoss had a paper and presentation entitled "Projected Area and Drag Coefficient of High Velocity Irregular Fragments that Rotate or Tumble (Article # 0396)" where the IMPETUS Afea Solver® was used to calculate the physical characteristics of fragments.



New Brochures

If you have not already received our latest brochures, please contact us! They highlight the use of the IMPETUS Afea Solver® for ballistics and fragmentation. One describes in general about modeling ballistics with IMPETUS, another one is a Case Study for modeling scoring of a copper bullet that was done in a collaboration project between US Army ARDEC Picatinny Arsenal and CertaSIM, LLC. The last new brochure lists the advantages of using IMPETUS for fragmentation simulation and showcases some of the unique features developed for this application.

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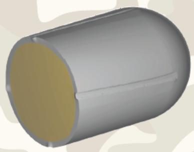
Scoring of a Bullet and Penetration of a Brittle Target

CASE STUDY

CertaSIM, LLC and the US Army ARDEC Picatinny Arsenal collaborated on a project to demonstrate the methodology to accurately model ballistic impact. The project involved a target plate made of brittle aluminum and a copper bullet. The simulation included both engraving of the bullet by the gun barrel "lands" and impact of the target.

The analysis was divided into two steps. The first step involved modeling the bullet as it travels down the gun barrel which cuts grooves into the bullet surface by the barrel "lands". This process is what causes the bullet to spin. The second step was impact of the target plate with the engraved bullet. In order to use the same bullet model for both steps it was necessary to mesh the bullet model with enough resolution to capture the engraving process and to refine the front of the bullet for impact of the target. The target is composed of brittle aluminum and so the classic method of element erosion is not appropriate because it will only create a plug that is pushed through the target. To obtain a realistic and accurate solution it was necessary to use the Node Splitting Algorithm developed by IMPETUS to model material fracture and fragmentation.

The bullet has a diameter of 0.25 inches and the motion is defined by a pressure history curve applied to backend of the bullet. The bullet travels inside the barrel and makes contact with the lands that have a width of 0.0106 inches. The bullet is modeled with two layers of cubic ASET™ Elements along the surface to capture the deformation and the core is represented by linear elements. The scoring of the bullet is clearly observed and the resulting engraving is very smooth which would not be possible if linear elements had been used for the bullet surface.



The impact with the aluminum target involves highly non-linear behavior both geometrically, materially and in the contact. The fragmentation of the plate is captured with node splitting. IMPETUS separates the damage criteria from the material model which makes modeling of damage very flexible since a damage model can be specified for any relevant material model. It is also very

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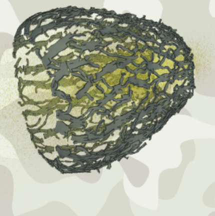
Modeling Fragmentation

Simulation of material fragmentation is difficult because it involves damage that exhibits very large non-linear deformation. Modeling with a Lagrangian approach requires Finite Elements that can handle this extreme case and the classic Finite Elements found in Legacy Solvers are not up to the task. This is why IMPETUS developed new Finite Element Technology to handle the task and provide accurate and robust elements designed specifically for Dynamic events that exhibit very large deformations. The ASET® Elements which includes quadratic and cubic Hexahedron, Tetrahedron and Pentahedron Elements are fully integrated so they eliminate the classic shortcomings of hourglass modes, element inversion, etc. They have been successfully applied to modeling warhead fragmentation. IMPETUS is a general purpose non-linear transient dynamic explicit Finite Element solver, a truly Next Generation Solver which also takes advantage of Next Generation Hardware "GPU Technology". GPU Technology provides massively parallel processing which is always load balanced unlike cluster based solutions and only requires a standard workstation or a single node of a cluster.



In the field of fragmentation analysis, the fragment size, velocity and mass is of vital importance. In fact, in experimental studies of fragmentation, the fragments are located, measured and weighed. During the tests, velocity and location are recorded as well. Thus, when a numerical tool is applied to simulate this event, it needs to have the ability to reproduce these key features. It is obvious that numerical ad-hoc eroding of elements and thus removing of mass in the model must be kept to a minimum. The approach used in IMPETUS for modeling fragmentation is the IMPETUS Node Splitting Algorithm, which splits elements along the length of the higher order elements and hence conserves the mass in the system. This feature can be added to any of the implemented damage criteria.

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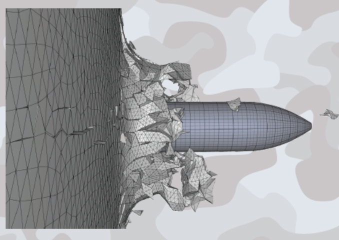
Modeling Ballistic Impact

The IMPETUS Afea Solver® leads the way to accurate modeling ballistic impact. The advanced Node Splitting Algorithm developed by the IMPETUS team provides an easy to invoke but accurate method to handle material fragmentation, a key component in ballistic impact. Accurate computations rely on efficient algorithms, robust high order solid elements and advanced parallel processing. This is why IMPETUS relies on GPU Technology for massively parallel processing on a standard workstation or a single node of a cluster.



The Advanced Element Technology, ASET™, at the heart of the IMPETUS Solver®, makes it possible to model the very large deformation that occurs from ballistic impact. The robust elements include accurate Hexahedron, Tetrahedron and Pentahedron quadratic and cubic element formulations. The Tetrahedron elements are unique because unlike classic finite element formulations, the IMPETUS Tetrahedron elements are accurate in both bending and plasticity and are particularly good for ballistic impact. Since these elements are fully integrated the pitfall of non-physical hourglass modes are avoided. The high order elements work in conjunction with a mesh smoothing algorithm to better capture the true physical geometry of a structure and leads to accurate geometrical surfaces to improve contact between parts.

To model impact of brittle materials requires modeling fragmentation and that is why the IMPETUS Node Splitting Algorithm is essential. IMPETUS has been used successfully to model impact and fragmentation of a reinforced concrete structure which included the deformation of the rebar cage.

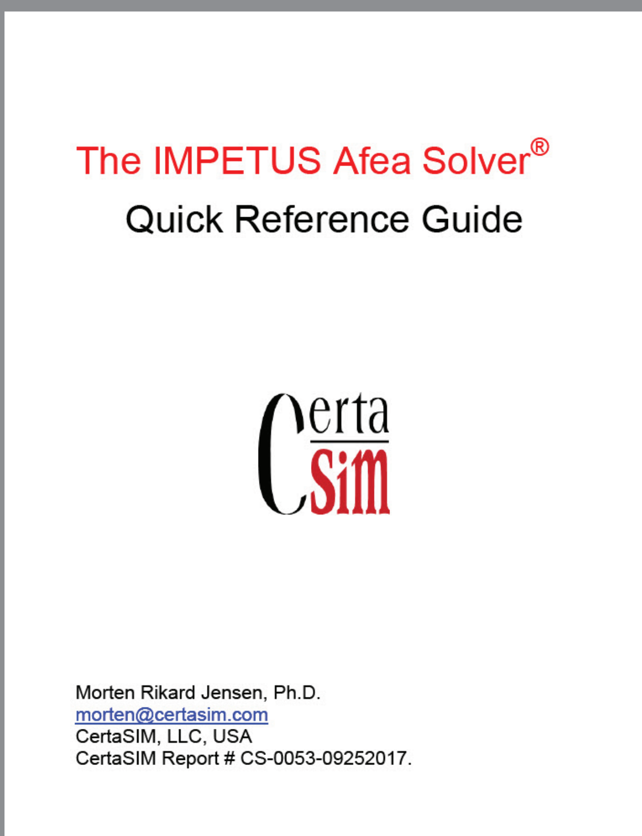
New Training Material from CertaSIM

At CertaSIM, LLC, we believe that good technical support is essential to customer success. A lot of effort and time is allocated to develop the best training material possible. For each application that the IMPETUS Afea Solver® is applied to, there must be material, either written or in another media form to disseminate the information to the user community. The number of applications and new customers are growing and so is the suite of training material. Two publications have just been released in new updated versions reflecting the newly developed GUI interface. The first one is "The IMPETUS Afea Solver® – Quick Reference Guide" which is a prerequisite to getting started as a new user. It explains how to model with IMPETUS, the different interfaces and some key features.

The second document is a new version of "The IMPETUS Afea Solver® – Tutorial – Example of Defense Applications". This tutorial consists of two booklets, one with model set-up and questions, complemented by an answer booklet as well as a set of command files. This format has proven to be very useful to new users of the software.

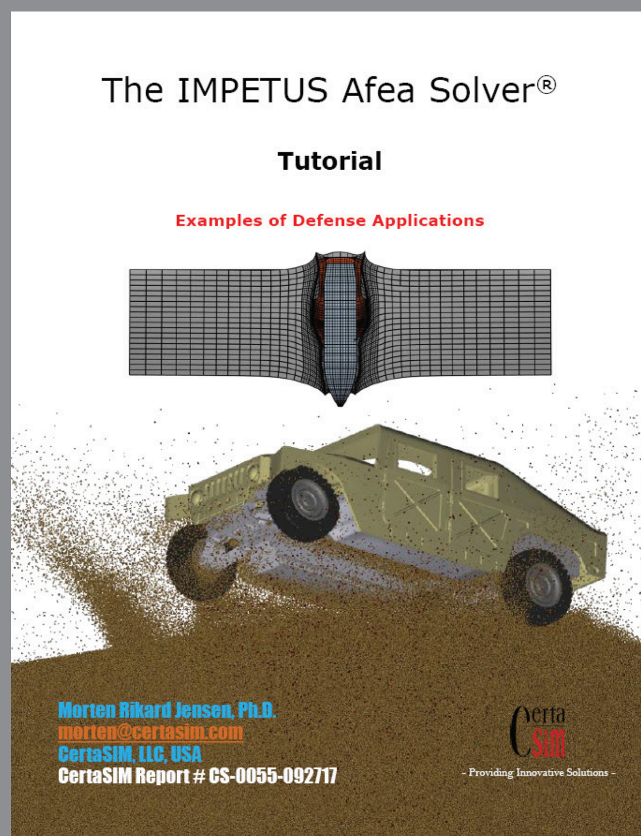
CertaSIM's Support & Training staff has also started a new Multi-Media Project that includes training videos on how to use IMPETUS, involving building models, running simulations and post-processing. The two first videos are out – showing the GUI interface and how to build an IMPETUS model from scratch.

More information about the new material can be obtained by contacting support@certasim.com.



The IMPETUS Afea Solver®
Quick Reference Guide

Morten Rikard Jensen, Ph.D.
morten@certasim.com
CertaSIM, LLC, USA
CertaSIM Report # CS-0053-09252017.



The IMPETUS Afea Solver®
Tutorial
Examples of Defense Applications

Morten Rikard Jensen, Ph.D.
morten@certasim.com
CertaSIM, LLC, USA
CertaSIM Report # CS-0055-092717

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References:

[1] M. R. Jensen, "The IMPETUS Afea Solver® – Quick Reference Guide", CertaSIM Report # CS-0053-09252017, 40 pages.

[2] M. R. Jensen, "The IMPETUS Afea Solver® – Tutorial – Example of Defense Applications", CertaSIM Report # CS-0055-09272017, 44 pages.

[3] M. R. Jensen, "The IMPETUS Afea Solver® – Tutorial – Example of Defense Applications - Answers", CertaSIM Report # CS-0055-09272017.A, 68 pages.

Latest Official Release of the IMPETUS Afea Solver®

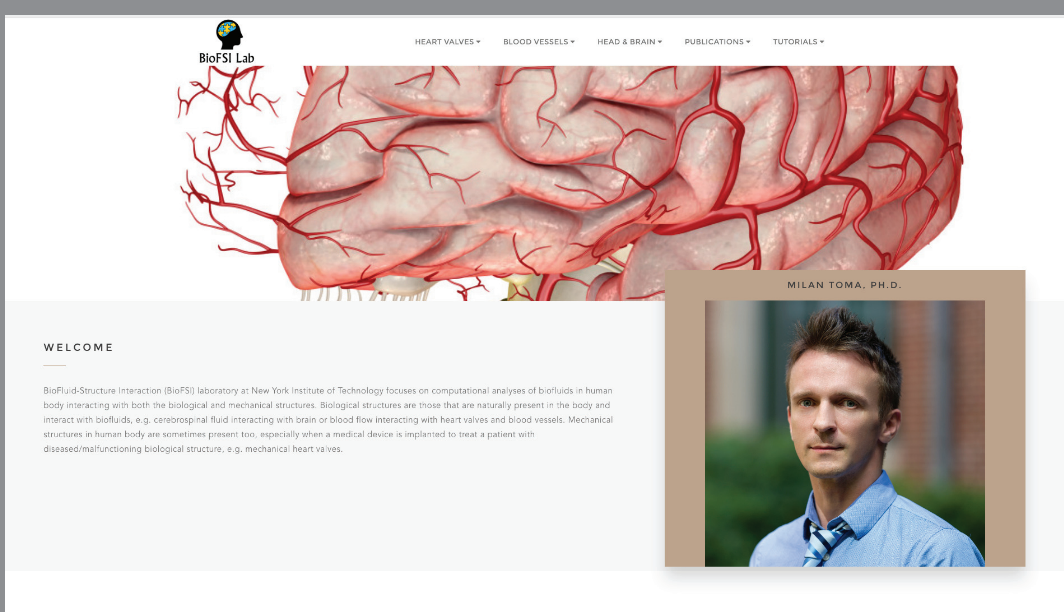
A new official QA'd version of the IMPETUS Afea Solver® has just been released. It is version 4.0.2279 for the Engine and version 4.3.0 for the GUI. The version includes many exciting new features many of which were beta tested by CertaSIM's users and found to be very useful. Some of the features are:

- *MAT_FABRIC: New material model for fabrics.
- *PARTICLE_DOMAIN: Added thermal velocity for complex burn laws.
- *CONNECTOR_GLUE_LINE: Improved interpolation between normal and shear loading.
- *CONTACT: More calculations done on GPU with new broad search algorithm.
- *CURVE: Using (optional) title as abscissa name in curve_X.out.
- *LOAD_AIR_BLAST: Tuned diffraction algorithm.
- *MAT_CERAMIC: Modified implementation for more flexibility in describing tensile fracture.
- *MAT_FABRIC: Added GPU support.
- *PART: Added user defined particle radius in element-to-particle conversion.
- *PARTICLE_DOMAIN: Modified element to particle conversion (look for overlap between particles and elements to prevent leakage).
- *PRESTRESS_BOLT: Improved algorithm to identify bolts/nuts.
- *REFINE: Improved algorithm for detection of through thickness direction.
- *RIGID_BODY_JOINT: Added user defined stiffness.
- Initialization: Better and faster memory handling.
- Multi-GPU: Better memory handling.

The new version can be obtained by contacting support@certasim.com.

BioFSI Laboratory Applies the IMPETUS Afea Solver®

"BioFluid-Structure Interaction (BioFSI) laboratory at New York Institute of Technology focuses on computational analyses of biofluids in human body interacting with both the biological and mechanical structures" as stated on their new website: www.tomamil.com.

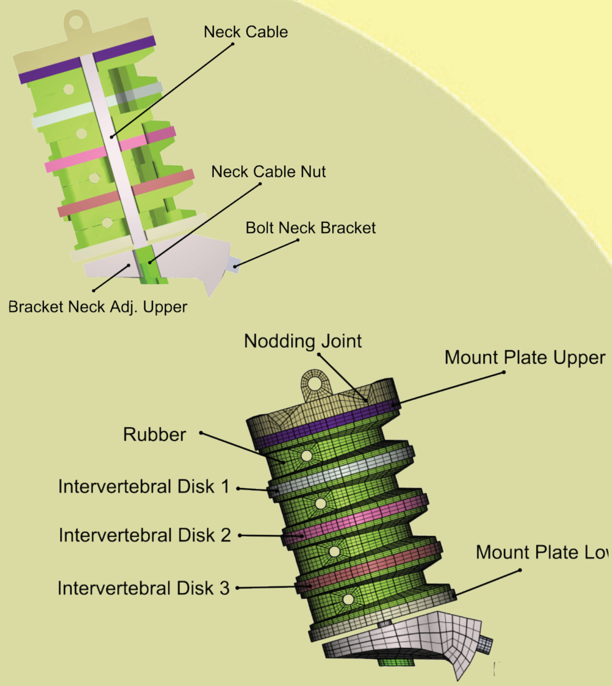


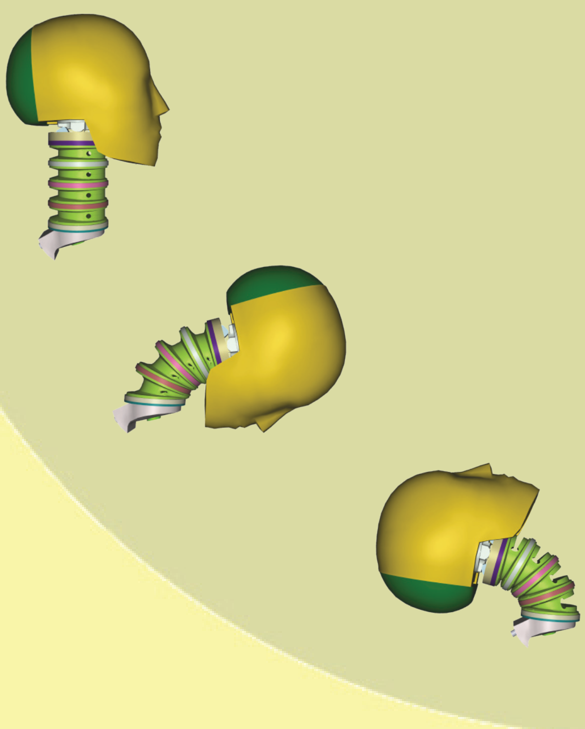
They use the IMPETUS Afea Solver® and it is very exciting to see Dr. Toma's important work and how the team utilizes IMPETUS in these complicated biomedical simulations.
Visit their new website for contact information, relevant publications and tutorials.

ATD Calibration for Crash – Neck Flexion Test

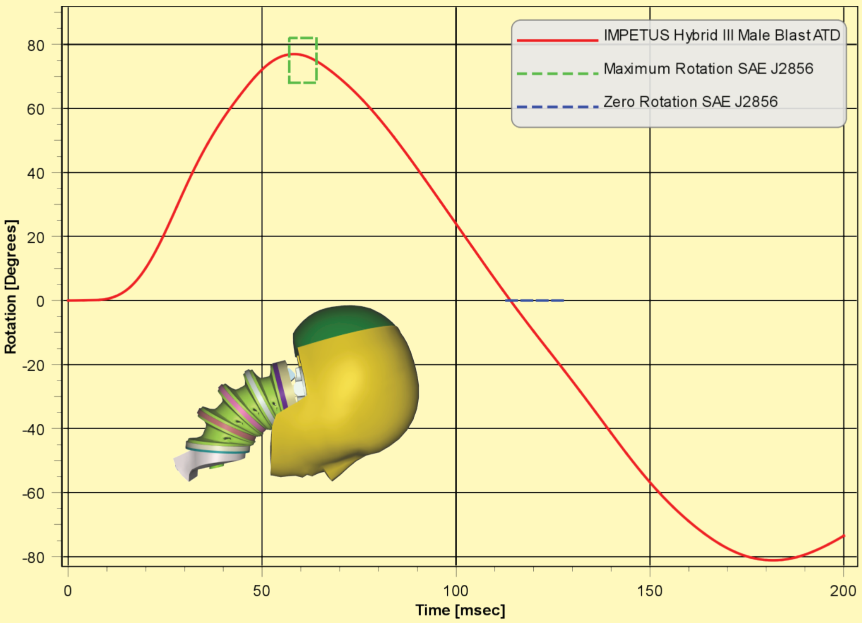
With today's continued military conflicts one of the most dangerous situations for our warfighters is the attack from an Improvised Explosive Devices (IEDs) which results in extensive damage to their vehicles. To develop better protection for the vehicles it is necessary to include the affect of blast loading on the warfighters that occupy the vehicle. This is accomplished by including an Anthropomorphic Test Device (ATD) as part of a physical test. For simulation this involves a computer model of the ATD. IMPETUS has developed a fully calibrated ATD model based upon the SAE standards but has, together with CertaSIM, extended the calibration to include the results from physical blast tests, which is something that has not been done before. This series of articles describes the different calibrations to the SAE standards; the following discusses the results for the Neck Flexion Test.

The Neck Flexion Test consists of the Neck and Head assembly mounted on a pendulum which includes the brackets. The Head assembly was discussed in Q1 2017 of the CertaSIM Solution Journal and also described in [1].





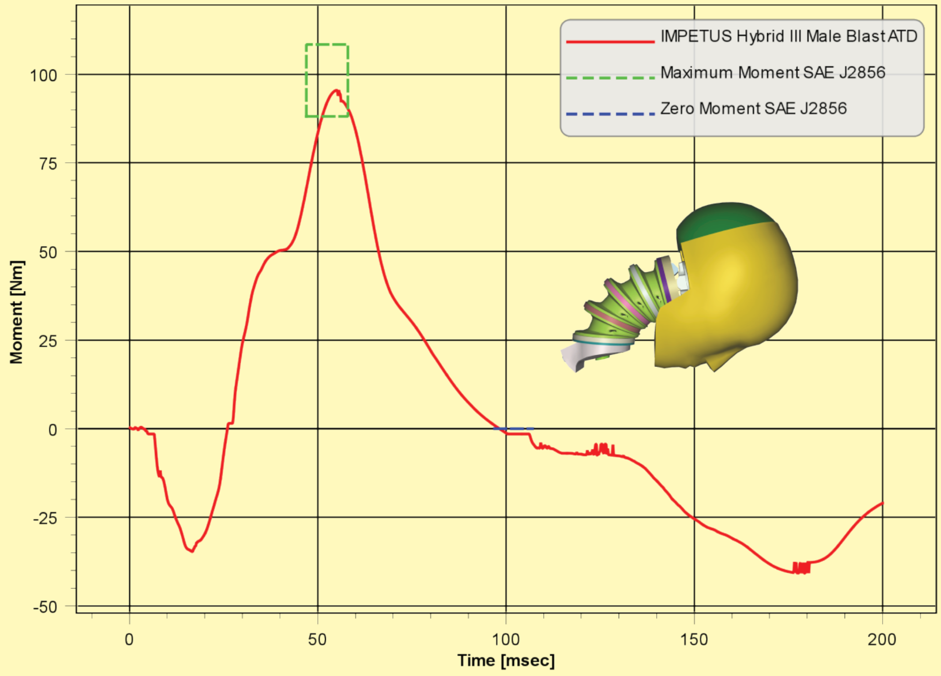
The test results in the neck initially bending forward then backwards.



SAE J2856 [2] is the standard on which this calibration is based. The pendulum is released to allow a free fall from a given height that makes it achieve a velocity between 6.89 m/s and 7.13 m/s. The pendulum is deaccelerated according to values in the SAE standard. In the numerical model the pendulum is not modeled but the Pad Sternum is used. The Pad Sternum is located in the lower Torso assembly which is the only part added besides the Neck and Head assemblies.

The performance specifications are given in [2] and covers rotation and moments. Rotation is related to a plane D which is defined as the horizontal plane through the base of the skull. Maximum rotation of the D-plane should be 64° to 78° with respect to the pendulum and must occur between 57 and 64 msec. Furthermore, the head rotation versus time curve must cross the zero angle between 113 and 128 msec. The values are found in the rigid.out file. The results are within the requirements.

There are also requirements for the computed moments where the maximum moment of the head around the global Y-axis must be between 88.1 N-m and 108.4 N-m occurring between 47 and 58 msec. Furthermore, the decaying part of the moment versus time curve must cross the zero axis between 97 and 107 msec when it crosses the axis for the first time. In the IMPETUS model this is found from values in the rigid_body_joint.out file. The Torque around the global Y-axis is plotted for the Neck Joint. It was found that the numerical results are within the requirements.



References:

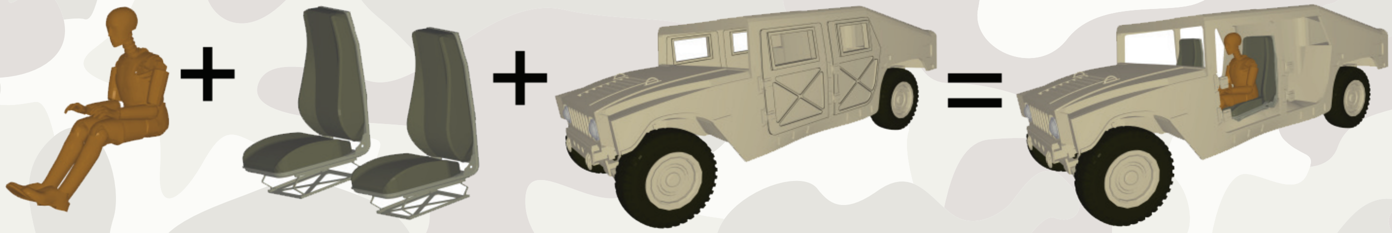
[1] M. R. Jensen, "The IMPETUS Hybrid III 50th Percentile Male Blast ATD", CertaSIM Report # CS-0052-09012017.

[2] SAE International J2856 September 2009, "User's Manual for the 50th Percentile Male Hybrid III Dummy".

Mine Blast Event of Full Vehicle Including Seated ATD

The development of armored vehicles requires a significant amount of component analyses but also a full vehicle blast event which includes an ATD to represent the warfighter. Development of such a model by CertaSIM, LLC is described in this article.

An armored vehicle has to be tested for blast response of occupants in the vehicle as per AEP-55 Volume 2 & 3 where the limits for the ATD responses are given [1, 2]. To satisfy these requirements for the IMPETUS Blast ATD a project modeling a full vehicle with a seat and the IMPETUS Blast ATD is underway. CertaSIM is funding the development work using the IMPETUS model of a HUMVEE. The CAD files for the seat were kindly provided by Armorworks. The seat fits into the HUMVEE and was meshed and modeled by MDG Solutions, Inc.



The model development required building the seat, connecting to the vehicle and seating the ATD. The latter is accomplished with a gravity loading simulation. After the seat model, a blast model was developed and preliminary results are being processed. Based on this work, rate sensitive foam models are being developed and tested. Future plans are to stress test this model to evaluate the response of the IMPETUS ATD. This is done by applying increased charge size for the IED to evaluate the numerical responses at the ATD sensor locations, e.g. Lumbar Spine Force and Lower Tibia Forces. The charge size should be larger than Level 4 as specified in STAGNA 4569 [3] since the current trend in the defense industry is to exceed this level. Often it is required that multiple ATD's are placed in the vehicle and the current model allows for two ATD's and can be increased to four. This will also provide a good benchmark for estimating the computational time when modeling a large realistic Finite Element Model. Other future plans for this model are to test different harness configurations and boot types. Planning for the latter has already begun.

More information about the new implementation and the research can be obtained by contacting support@certasim.com.

References:

[1] NATO/PfP, "Procedures for Evaluating the Protection Level of Armoured Vehicles – Volume 2: Mine Threat", August 2011, AEP-55, Volume 2 (Edition 2).
[2] NATO, "Procedures for Evaluating the Protection Level of Armoured Vehicles – Volume 3: IED Threat", AEP-55, Edition C Volume 3 (Part I), Version 1, Ratification Draft 1.
[3] NATO Standardization Agency, "STANAG 4569 (Edition 2) – Protection Levels for Occupants of Armoured Vehicles", 18/12/2012.

Acknowledgement:

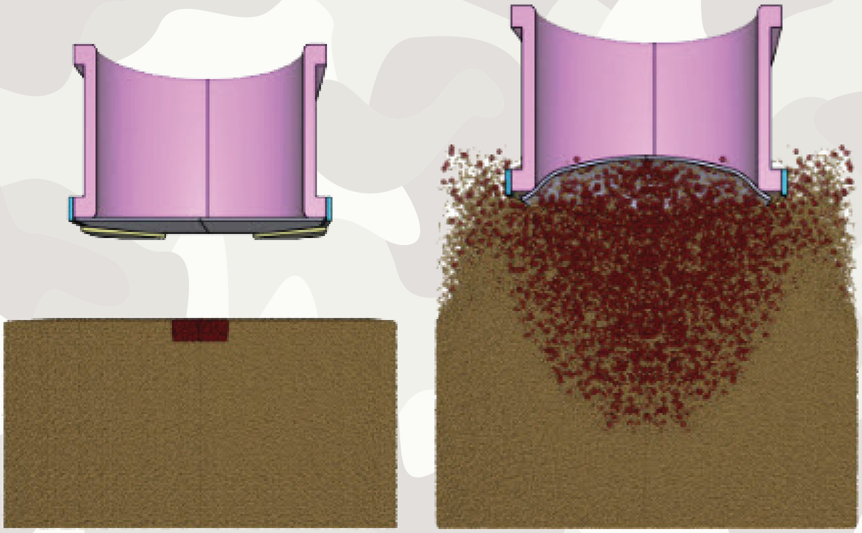
David Bosen and Dr. Ken Lou from Armorworks are greatly appreciated for providing the seat model and input during the building of the model. The general model development was performed by MDG Solutions, Inc.

Guidelines for Modeling Blast Loading

As an engineering analyst, non-linear dynamic Finite Element modeling of complex real engineering problems is not an easy task. Good documentation in various forms is essential to guide the analyst in the most effective way to use software. This includes model set-up and verification with experimental data. Both IMPETUS Afea and CertaSIM, LLC understand the importance of good documentation and the following is the Blast Loading guidelines that IMPETUS Afea has developed.

IMPETUS Afea AB, Sweden has developed a suite of Recommended Modeling Practices (RMP) for various applications. Currently, five of these are available and more are under development as the Solver expands into more application areas. The second of these RMP's is RMP002 that discusses the topic of close-range Blast Loading. More specifically, it relates to validation models from currently 11 different references of experimental blast loading that includes surface blast and buried mine blast. There is a large variation in High Explosive types, soil types, depth of burial, stand off distance, etc. thus covering a range of possible scenarios that are important to IMPETUS customers.

A selected group of these tests are included in the IMPETUS QA System, referred to as the "Verifier", before a new official release. The version control is also listed in the document. Currently, 57 test cases from RMP002 are included in the verifier which will flag warnings if the results are off target. The various tests are discussed in detail as well are the IMPETUS models. It should be mentioned that in general the pre-defined dry and wet soil models are used and thus the parameters are not fine-tuned to the specific soil but any discrepancy is clearly listed, acknowledging that the results could be improved with soil calibration based on, e.g., a rigid plate impulse test.



One of the test models is from [1] where a cylindrical charge is buried in a box filled with sand. A steel plate is placed above the box and the dynamic peak displacement is measured as Response Parameter which then is used to compare with the numerical results from the IMPETUS simulation.

In this case the IMPETUS results compare very well with experiments, especially when considering that the pre-defined dry soil model was applied.

Test	Sand			Simulation result	Error
	Type	Density (kg/m^3)	Discrete particles	(m)	(%)
1-2	dry	1620	1M	0.0883	-4.2
3-5	dry	1620	1M	0.0956	-6.0
6-8	dry	1620	1M	0.0650	-10.1
9-10	dry	1620	1M	0.0878	-4.8

It is strongly recommended to follow the guidelines in the report when modeling blast loading with the IMPETUS Afea Solver®.

The RMP002 – Blast Loading can be found at:

http://www.impetus-afea.com/support/documents/?doc=rmp/rmp002

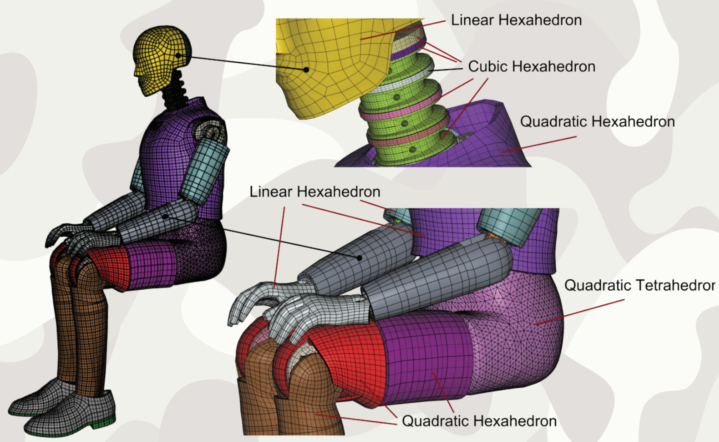
References:
[1] Björn Zakrisson, Hans-Åke Häggblad, Pär Jonsen, "Modelling and simulation of explosions in soil interacting with deformable structures", Central European Journal of Engineering, Volume 2, 2012, Pages 532-550.

Acknowledgement:
The help with the models and documentation for the RMP002 report from Marcus Menchawi, IMPETUS Afea AB, Sweden is greatly appreciated.

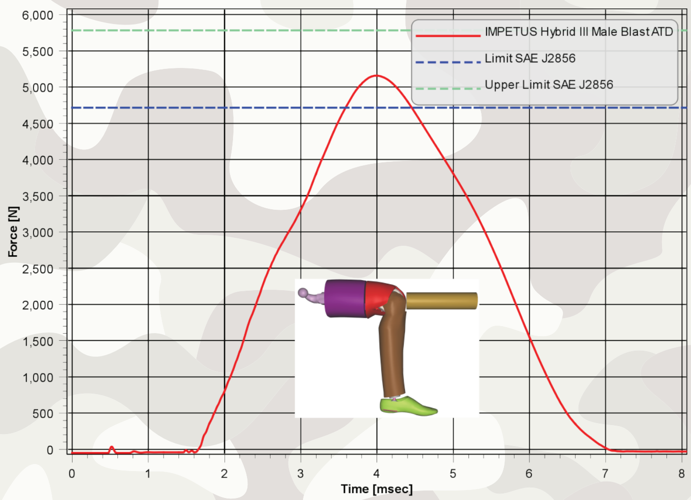
The IMPETUS Blast ATD: Experimental and Numerical Work

In order to represent the human in a vehicle incident, be it an automobile crash, airplane accident or blast load for military events, dummies also known as Anthropomorphic Test Device have been used both in experimental and numerical investigations. IMPETUS Afea and CertaSIM have for the last couple of years been working extensively on R&D projects related to this as have been illustrated throughout the issues of the "CertaSIM Solution Journal." The following describes the current status as presented at a recent military conference with emphasis on vehicle performance. Contributions were provided by General Dynamics Land Systems and CertaSIM, LLC.

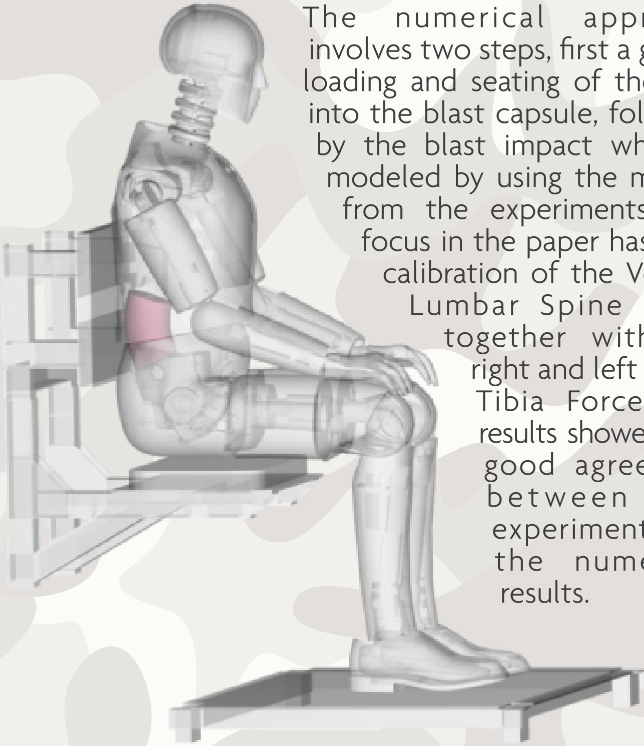
CertaSIM's, Dr. Morten Rikard Jensen presented work [1] related to mine blast at 2017 NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), August 8-10, 2017 – Novi, Michigan. The work was a collaboration with Mike Honaker, Manager, Mechanical Engineering, Advanced Products and Technology, General Dynamic Land Systems and Alexandre Boglaev, Senior Technical Specialist, Advanced Products and Technology, General Dynamics Land Systems. The work presented covers both experimental as well as numerical parts to calibrate the IMPETUS Blast ATD which is a Hybrid III 50th Percentile Male ATD. The first part of the project covers building of the virtual ATD based on drawings as well as determination of material properties for the different parts. The main part of this work was done by IMPETUS Afea AB, Sweden and the Norwegian Defense Research Establishment (FFI). This model takes advantages of the ASET™ family of High Order elements and throughout the ATD a mix of element types are used, e.g., Quadratic Tetrahedron for some parts and Cubic Hexahedron for others.



With the foundation work for the ATD finished, it was calibrated to nine different crashworthiness tests, two European [2] and seven tests according to the SAE J2856 [3]. Some of these tests have been and are currently shown in this Journal with more of them to come in future issues. For each of these tests there are criteria that have to be met, e.g., forces in specific locations or a sensor acceleration needs to be within a certain given band. Both the physical and the numerical ATD will have to follow the standard in order to be certified.

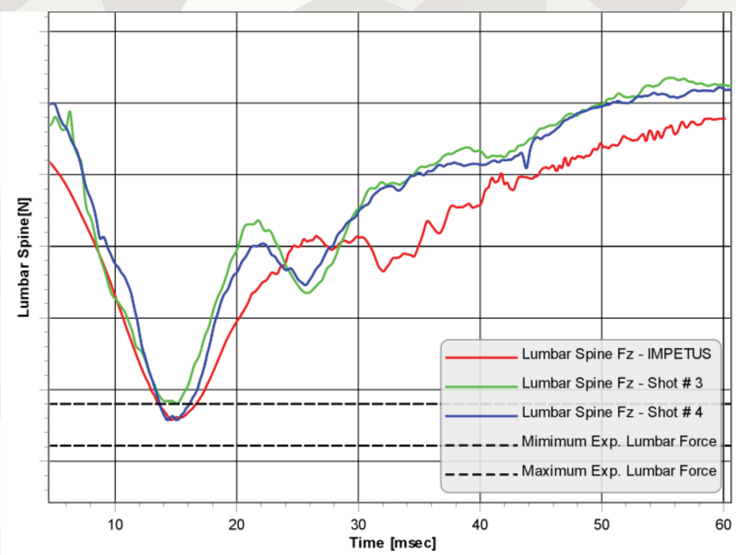


With a successful calibration for these 9 tests, the results from the vertical load in a mine blast event can now be studied. CertaSIM, LLC funded three days of live blast testing of a physical ATD at the General Dynamics Edgefield Test Center in South Carolina. The ATD was fully equipped with data acquisition hardware to gather the necessary response data that is used to a calibrate the numerical model. The experimental data showed excellent repeatability.



The numerical approach involves two steps, first a gravity loading and seating of the ATD into the blast capsule, followed by the blast impact which is modeled by using the motion from the experiments. The focus in the paper has been calibration of the Vertical Lumbar Spine Force together with the right and left Lower Tibia Force. The results showed very good agreement between the experiments and the numerical results.

This is ongoing work but these preliminary and very reasonable results will lead to a promising final calibration. Current work is calibration of the Pelvis Acceleration and verification of the Dynamic Response Index (DRIz). Next step is to model the set-up where the Tibia angle is modified to 110°. Experimental data was obtained for both seating positions. The final step will be to place the ATD in a vehicle in a seated position with an under-belly IED loading. This will cover many different scenarios, such as multiple ATD's, different seats, comparison to experimental data, etc. Preliminary modeling efforts have all begun as shown on the front page of this issue and results were presented earlier in the journal.



The full version of the article can be requested by contacting sales@certasim.com as well as the more detailed documentation found in [4].

References:

[1] M.R. Jensen, M. Honaker and A. Boglaev, "Calibration and Verification of Detailed Hybrid III 50th Percentile Male Anthroporphic Test Device (ATD) Based on Extensive Mine Blast Tests", 2017 NDIA Ground Vechicle Systems Engineering and Technology Symposium (GVSETS), August 8-10, 2017 – Novi, Michigan.

[2] DIRECTIVE 96/79/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 1996 on the protection of occupants of motor vehicles in the event of a frontal impact and amending Directive 70/156/EEC.

[3] SAE International J2856 September 2009, "User's Manual for the 50th Percentile Male Hybrid III Dummy".

[4] M. R. Jensen, "The IMPETUS Hybrid III 50th Percentile Male Blast ATD", CertaSIM Report #CS-0052-09012017.

Craig Newman, Chief Engineer, Military Product Engineering, Navistar Defense, LLC, Madison Heights, MI, USA

Craig Newman is Chief Engineer at Navistar Defense and has wide ranging experience in vehicle design, including civilian, commercial, and military vehicles. After his graduation from Michigan State University in 1982, he worked as a project engineer for General Motors in a variety of roles, including conducting vehicle modeling and simulation on multiple product lines. From 1989 to 2009, he blended his M&S activities with design, test, development, sales, and program management activities at MascoTech, Hartwick Professionals, and Cascade Engineering, leading projects in the areas of vehicle performance, crashworthiness, metal forming, and plastic injection molding. From 1997 to 2000 he was chief engineer for the General Motors funded X-Game concept SUV. Currently, he is a chief engineer with Navistar Defense. We are very honored that Mr. Newman accepted our invitation to write this article in which he discusses the evolution of engineering analysis capabilities and how it has been integrated into vehicle design throughout his long and successful career.

"Fresh out of college, I began my career as an automotive engineer for General Motors. Assigned to the Milford Proving Grounds, I was one of many participating in the development of what was then referred to as the N-car. The N-car was a front drive, mid-size vehicle platform that was to be shared by Pontiac, Buick, and Oldsmobile.

General Motors designated their vehicle platforms with letters of the alphabet. There were fleets *of vehicles numbering in the hundreds at the Milford Proving Grounds. Around the clock, vehicles of every different configuration and letter of the alphabet were abused on the proving ground durability routes. Other vehicles were put through the paces of the ride and handling road systems. In similarly large numbers, there was a steady stream of vehicle crashworthiness tests being conducted.*

At the time, it was the norm to spend a billion dollars or more and every bit of five years to develop and tool a mass produced automobile. It was commonplace to spend hundreds of thousands of dollars on a prototype vehicle and then completely destroy it in milliseconds in a barrier event to assess occupant performance. In the multi-year development of the N-car, there were more than 250 barrier tests conducted. A large number of these tests were one and done. The N-car reached the marketplace in 1985.

Challenged in the marketplace to maintain sales and profitability, General Motors constantly sought new technologies that held the promise of reducing vehicle program and development costs. One of these technologies was finite element modeling and analysis. Commencing in the 1970s, finite element analysis (FEA) at General Motors and in the automotive industry using the National Aeronautics and Space Administration's (NASA) NASTRAN software, was growing in use and application. It was used (and continues to be used) successfully for a number of linear static, buckling, and normal modes problems.

As component and vehicle level analysis began to provide better direction, there was an urgency to expand capabilities to more vexing full vehicle problems. Inside the General Motors Research Laboratories and at the US Government Lawrence Livermore National Laboratory, advancements were being made in non-linear implicit and explicit dynamic software to solve classes of problems that existing software could not.

My first exposure to Livermore's DYNA3D was in 1987 when some of my fellow analysts began using the software to try to analytically correlate progressive crush of automotive structures in a rear impact event. I observed what they were doing and realized this was a paradigm shift that was going to change the way automobiles were developed. I wanted to be part of this sea change and began to work with the software.

It was not easy. In fact, at times it could be maddeningly frustrating. After weeks of painstaking model construction, success was measured in FEA runs that after two weeks or more of processing on our computers, did not return a fatal error. The run resulted in an answer. It might not have been the right answer, but it was an answer and the job didn't bomb.

The software was not yet mature and new lines of code were written daily to address issues. Analysts were learning as well. Our early efforts did not lead the design. Analysts couldn't be depended upon to respond in a timely fashion, nor promise to meet timelines because they were just as likely to unknowingly cause a run fatal error as the software. But we still believed that we were onto something that when we figured it all out, was going to be the engineering holy grail: better, cheaper, and faster than anything that came before. Perhaps most importantly, we knew better analysis results would lead to better cars and save lives.

Over time, the software and users got better. Each successive year, "crash" models became larger, more complex, and more accurate. Models weren't limited to the vehicle structures. Soon anthropomorphic dummies and belt systems were modeled and added to push the development farther and faster. Computers also got faster and more powerful. Software became more efficient and parallelized. Within 10 years of my first exposure, analyst's models were no longer trailing the design, they were leading them. It became the norm to develop vehicle crashworthiness characteristic performance using virtual methods and use physical testing for validation. Even as the automotive industry was tasked with requirements for new types of impacts, the size of the barrier fleets grew smaller and smaller as the software and users became better and better.

Though I am no longer in the auto industry, a colleague recently told me that prototype vehicle crashworthiness fleets have been trimmed in size by more than 80% compared to my early career experience. By my estimate, the savings associated with 200 fewer prototype vehicle builds and test costs for a given platform approaches the $100 million range. Additionally, development that once took five years, is now three. Apply that to car and truck platforms across the industry and the savings is in the billions of dollars. A study by the Council on Competitiveness in Washington, D.C. found that the use of DYNA3D and similar programs results in approximately $14 billion annually in cost savings for U.S. companies by significantly reducing testing. I would expect that a significant chunk of that figure is related to the number of automobile crash tests no longer needed to be performed to validate and improve vehicle crashworthiness.

A paradigm shift had indeed taken place. The application of computer modeling and simulation that began as a government laboratory code revolutionized the way the industry developed vehicle crashworthiness performance and resulted in tremendous savings in time and money.
In 2009, I moved to Navistar Defense and was part of the team that was tasked to develop armored vehicles with improved blast survivability. The process and tools to evaluate blast performance were similar to my earlier crashworthiness experience in the automotive industry. There was some usage of modeling and simulation and heavy reliance on testing. For modeling and simulation, the daunting issue of the weeks and months to build the model and produce a result were hugely problematic when lives were concurrently being lost in war zones.

Improvised Explosive Devices (IED's), as a mechanism to inflict harm on soldiers and civilians alike, have become the preferred method of destabilizing countries and in waging guerilla wars. In 2012, Lieutenant General Michael Barbero, commander of the United States (US) Pentagon Joint IED Defeat Organization (JIEDDO) stated that the spread of terrorist networks and the related proliferation of IEDs are growing around the globe.

Since 2001, insurgents have relentlessly used IEDs against US and NATO (North Atlantic Treaty Organization) forces in Iraq and Afghanistan. IED attacks have taken a toll on the warfighter and changed the equipment and methods used to confront the insurgency. A 2012 research study reported the number of IED attacks in Afghanistan increased 400 percent from 2007 to 2011. The number of US personnel killed as a result of these IED attacks also increased by 400 percent (Figure 1) and those *wounded increased by 700 percent (Figure 2). IEDs were the number one cause of death among all troops in Afghanistan. In 2010 alone, there were 14,661 IEDs planted in Afghanistan resulting in 3,366 US casualties.*

Figure 1: US Military Personnel Killed in Action in Afghanistan as a result of IED Attacks Source: iCasualties.org

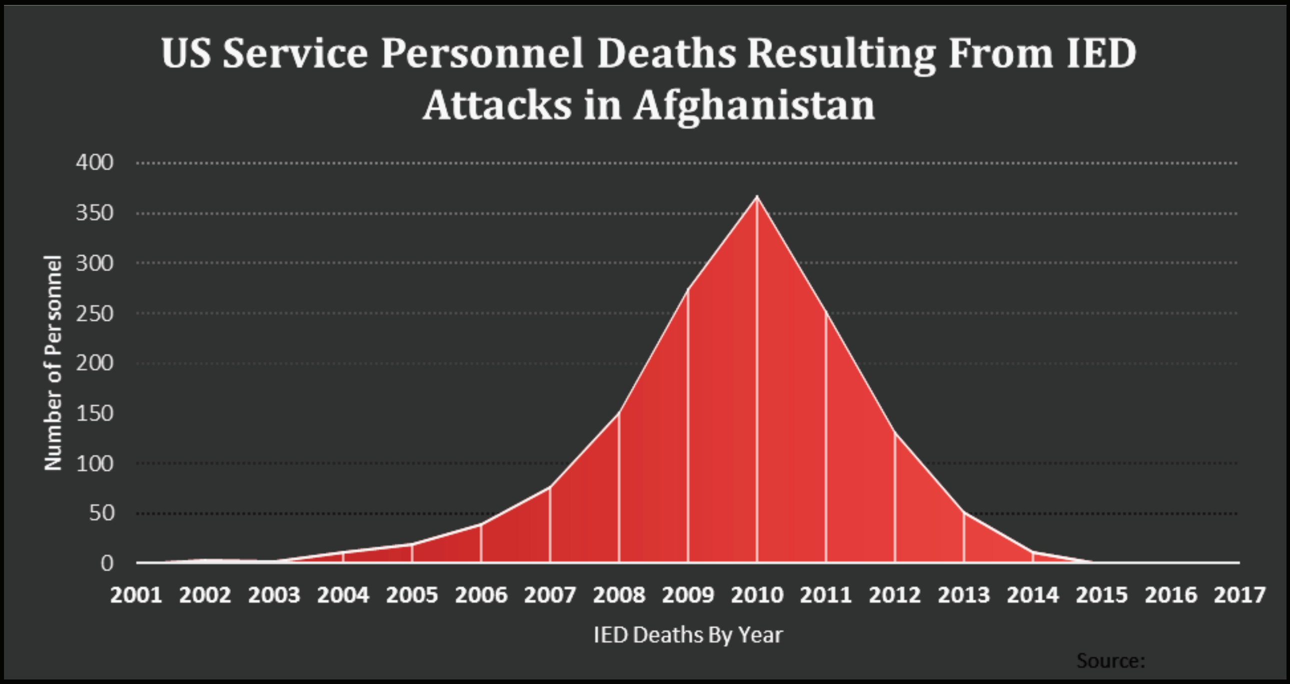
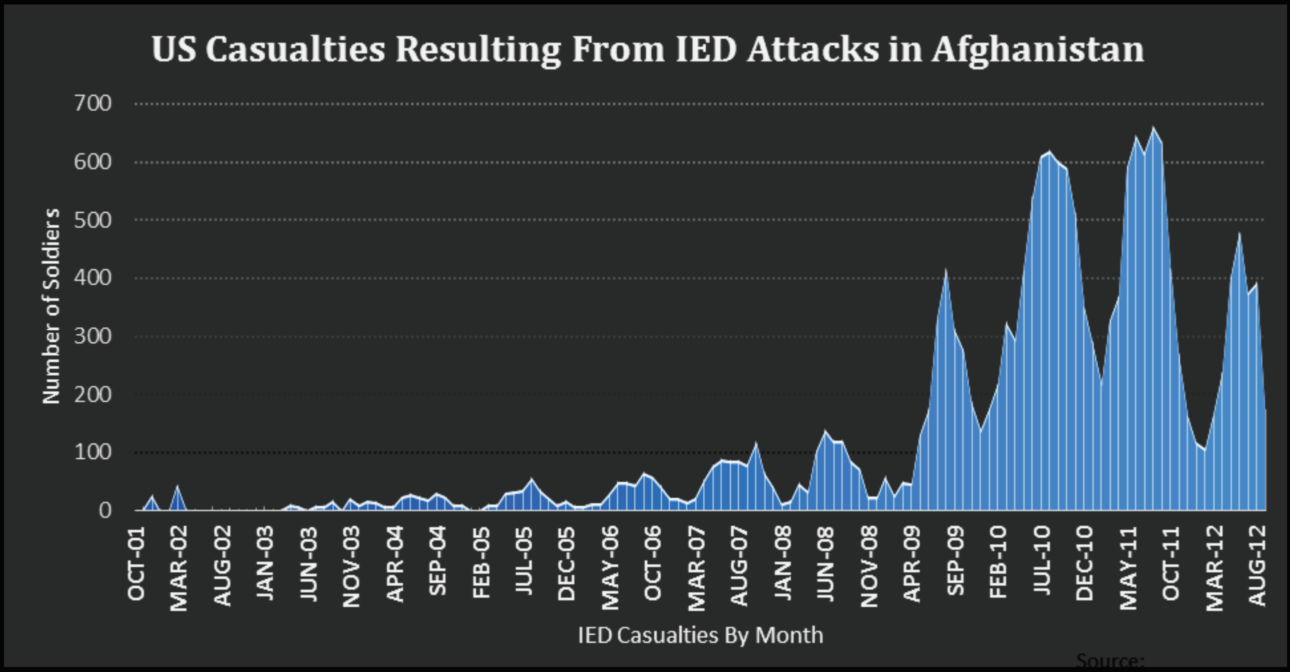


Figure 2: US Military Personnel Wounded in Action in Afghanistan as a result of IED Attacks Source: iCasualties.org



The cost of dealing with the IED threat is both immediate and enduring in human and financial terms. There are also tremendous societal financial cost burdens for individuals and governments tasked with the long-term care of IED event survivors. As a result of the wars in Iraq and Afghanistan, the Costs of War Project by the Watson Institute for International Studies at Brown University reports that US military medical and disability claims will cost taxpayers $1 trillion through 2053.

At Navistar Defense, survivability is our top priority. We are heartened when we hear of service personnel who survive an IED attack in our vehicles. We are disheartened when we learn of service personnel who do not fare well as the result of an attack. We take losses personally.

As we observed along with our customers the increase in the number and explosive yield of insurgent IED attacks, we responded (and continue to do so). Investments were made in our computer simulation hardware and software allowing Navistar Defense to create higher fidelity models yielding better correlated vehicle blast results. Significant time was spent by our people to gain a deeper understanding of the physics of blast and apply that understanding to the computer models they were exercising. Navistar Defense blast tested numerous bucks, prototypes, and production vehicles in a simulation and test cycle of engineering improvement. Ultimately, these efforts developed a formidable team possessing the knowledge and tools used to build the most survivable wheeled vehicle in the US military's fleet: the MaxxPro MRAP (Mine Resistant Ambush Protected) with the survivability upgrade kit. This vehicle has made a difference in occupant survivability and is now being sought by our coalition partners for their personnel.

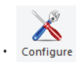
Using our automotive crashworthiness based development process, we get results. Our challenge is that blast has significant complexities beyond vehicle crashworthiness, and we struggle with our tools to build models and generate results in a timely fashion that contain the complete physics of a blast event. We needed to be faster and correlate to the real world events.

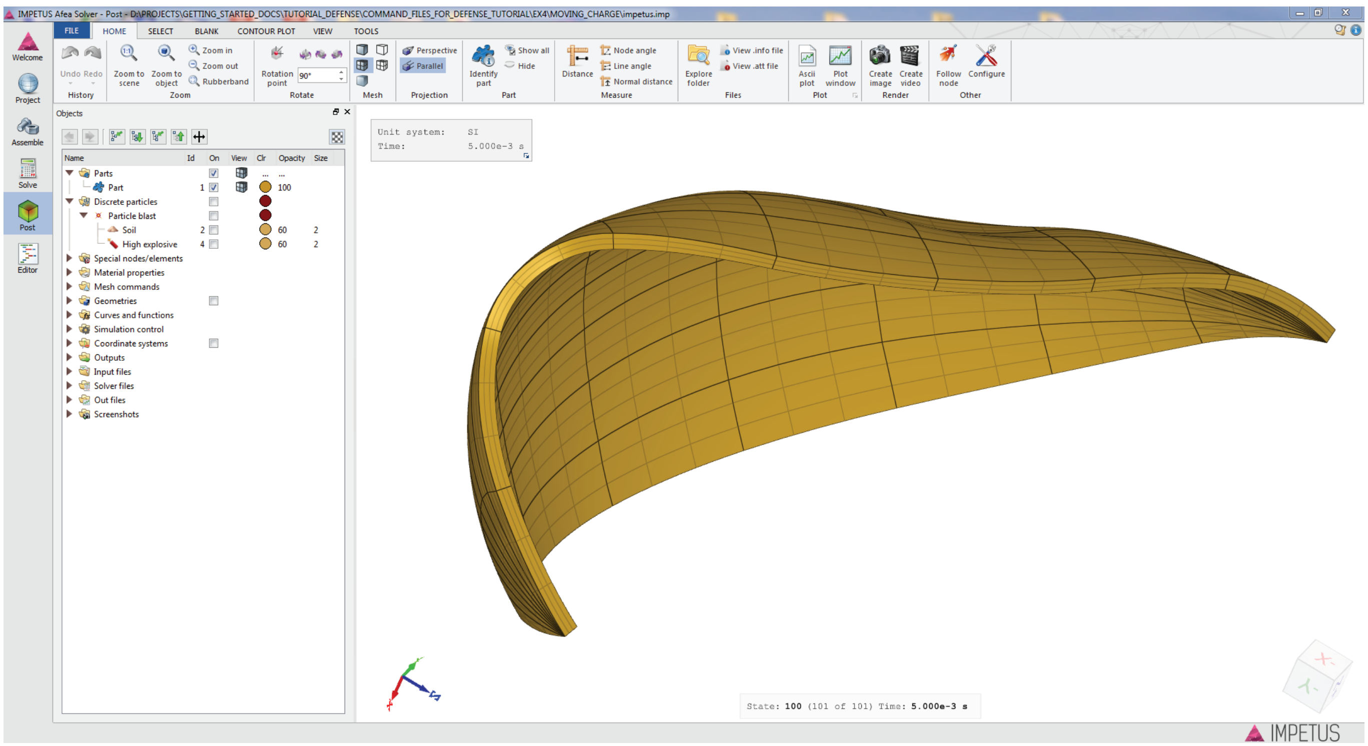
Recently, Navistar Defense collaborated with MDG Solutions in the modeling and simulation of a vehicle subjected to a buried mine blast using the IMPETUS Afea Solver. The Navistar Defense team is not easily impressed, but the IMPETUS Solver is a game changer. Because modeling is done differently and geometry details can be eased, the time to construct the model was approximately 75% less than our estimate using traditional methods. Model run (clock) times were equally impressive. Where previously a single ALE (Arbitrary Lagrangian-Eulerian) or DEM (Discrete Element Method) finite element analysis would require a week or more of run-time on one of our computers using our existing software, we were able to simultaneously run two simulations in less than a day on a GPU-based platform. Best of all, the true physics of the air, soil, and structure interactions were being captured and we were seeing excellent results and behavior right out of the gate. Taken as a whole, the IMPETUS Afea Solver is a disruptive technology.

As in 1987, as I witnessed Livermore's DYNA3D and felt I was seeing a paradigm shift in improving vehicle crashworthiness software and its use to develop better, faster solutions, I believe we are now looking at a similar paradigm shift in the way we develop products better able to withstand IED attacks, buried mine detonations, or a myriad of other similar blast events with the IMPETUS Solver. By replicating the physics, the IMPETUS Solver technology allows the engineer to understand what is happening and identify potential vulnerabilities before products are tested and built. Having this tool means engineering analysts can lead the design team with accurate results, evaluate more iterations, and come up with solutions that produce better occupant performance outcomes in much less time – a perfect combination. Two of the guiding principles of Navistar's business culture are "Better Every Day" and "Hours Not Days." We take these principles seriously and they guide our actions. Our products must constantly improve and do so quickly because the young servicemen and servicewomen who rely on our trucks to provide protection in hostile places deserve nothing less than our very best. We see the IMPETUS Afea Solver as a tool to help us do just that."

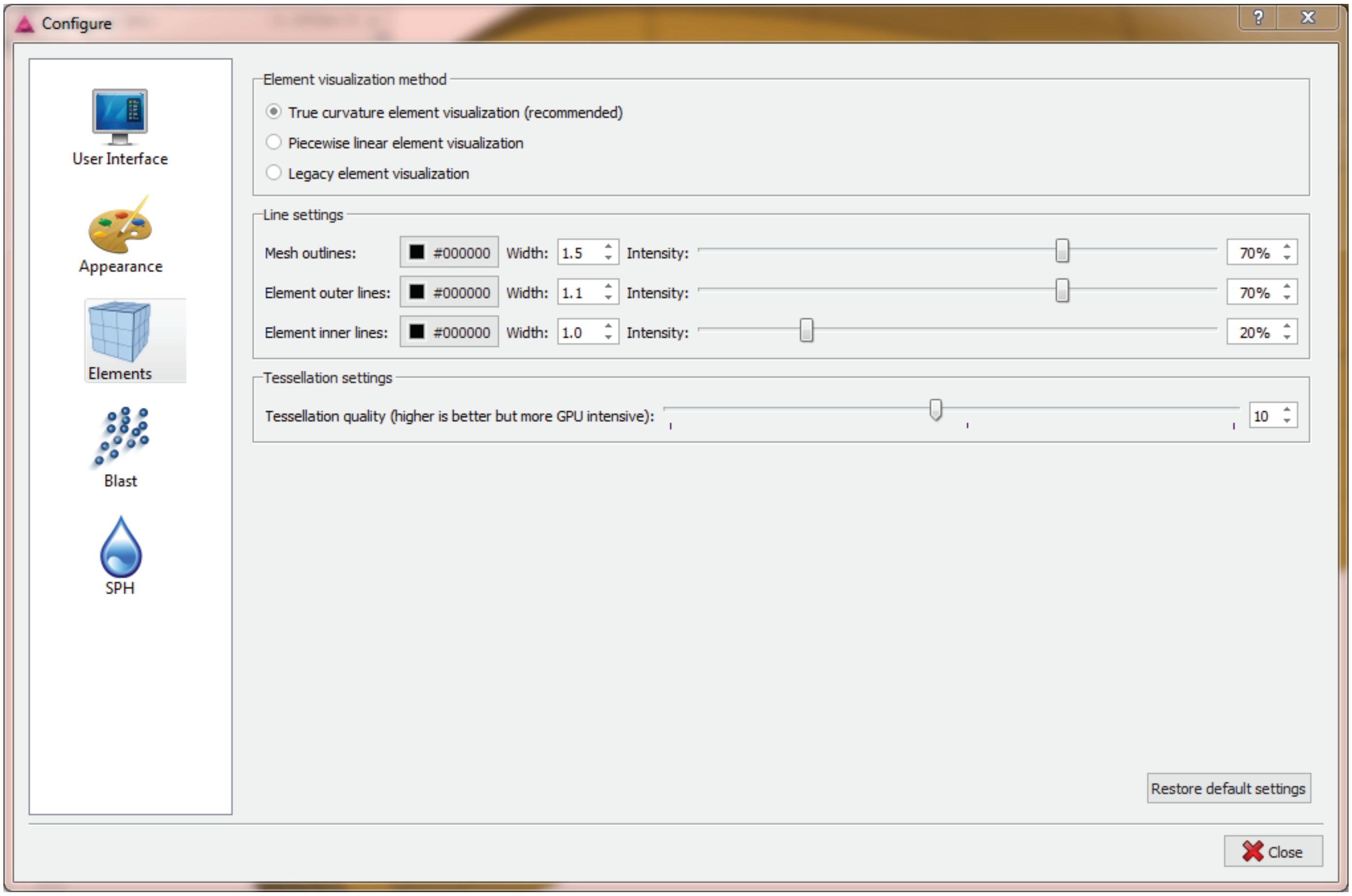
Showing the Real Geometry in the IMPETUS Afea Solver GUI

It is well known that with the ASET™ Family of High Order elements the finite element mesh can be smoothed to obtain a more realistic and accurate geometry of a structure eliminating the facetted geometry that is created with traditional linear elements found in Legacy Codes. These correct surfaces are then used in the contact algorithm which leads to more accurate solutions. Until now the IMPETUS Afea Solver GUI has only showed linear lines between the element nodes, where in fact the geometry is actually curved. This is no longer the case, the IMPETUS GUI has been improved with the latest graphic libraries from NVIDIA that allow for the actual curvature to be visualized.

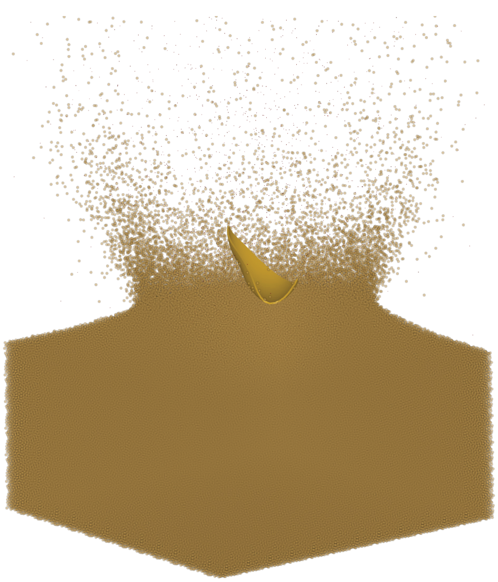
In the IMPETUS Afea Solver GUI use the Configure Icon under Other in the Top Menu. 



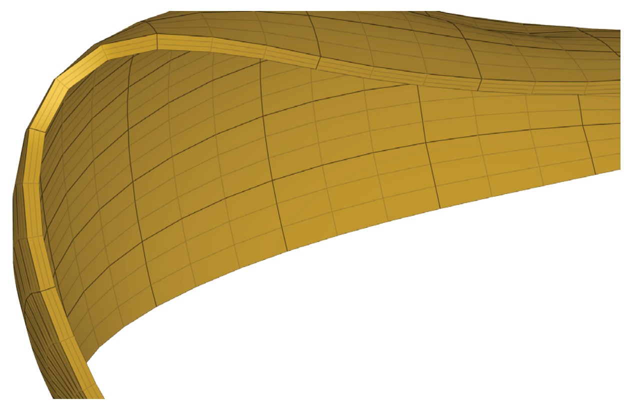
Now the Configure Menu will appear and here Elements should be clicked. 



In this menu select True curvature element visualization. This will now visualize the real curved geometry for the elements. As an example consider a plate set-up where a large blast load is applied leading to a heavily deformed plate.



A zoom on the curved part shows the linear lines.



If the True curvature option is selected, one sees a significant difference.