SAND2015-1701R

Project Accomplishment Summary

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Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation
Albuquerque, New Mexico

PROJECT ACCOMPLISHMENTS SUMMARY

Cooperative Research and Development Agreement (#1573.103)

between **Sandia National Labs** and **Lockheed Martin Corporation**

Note: This Project Accomplishments Summary will serve to meet the requirements for a final abstract and final report as specified in Article XI of the CRADA.

Title: Coupled Physics Modeling and Simulations

Final Abstract:

This project focused on incorporating the LMSSC-developed Coupled Damage and Reaction (CDAR) model into the current version of CTH, and making it available to Eulerian-Lagrangian coupled analyses through ZAPOTEC. The ZAPOTEC code was then updated with a new Lagrangian kernel, the Sandia-developed Sierra/SM module. In this project, Sandia and DOE received a state-of-the art constitutive model for modeling propellant damage and reactivity. This model will greatly enhance the ability to model a range of safety scenarios. LMSSC in turn has received an initial version of the Eulerian-Lagrangian coupling framework to use for modeling critical safety issues, and will receive the updated version once it is released. The public receives the benefit of future improved safety in missile/rocket systems.

Background:

Assessment of solid rocket motor (SRM) responses to mechanical/thermal hazards is an on-going concern, and new systems are required to demonstrate benign responses as part of the development program. Full-scale testing is not only extremely expensive but also poses serious challenges with regard to range safety. Many of these issues may be addressed with modern continuum-based physics codes running on parallel Linux computing clusters. The most challenging problems require coupled physics modeling capabilities that do not yet exist, e.g., coupled propellant and missile structure modeling with propellant reactive response due to impact hazards. An extension of such a capability would be to predict the violence of a thermal initiation event due to slow or fast cook-off. Sandia has extensive experience in coupled physics modeling, while Lockheed Martin has extensive experience in the problem at hand, making this a promising collaboration on an important problem.

Description:

To assess solid rocket propellant responses to mechanical impact hazards, LMSSC has developed the Coupled Damage and Reaction (CDAR) constitutive model implemented in SNL's CTH Eulerian shock physics code. CDAR models the propellant's viscoelastic deformation, damage, distention, reactive sensitization due to damage, and ultimately reactive responses up through full detonation. It is a multiphase material physics model and is well-suited for implementation in an Eulerian framework. In realistic hazard scenarios, structural components can play key roles with regard to propellant response, but unfortunately, Eulerian codes such as CTH cannot model structural components with the required fidelity.

For modeling structural component responses, Lagrangian formulations as manifested in more traditional finite element codes are more appropriate. SNL has developed a prototype coupling between CTH and their in-house finite element code, PRONTO, in the form of a code called ZAPOTEC. CTH computes the stress fields acting on the structural components with approximate motions computed as well. These loads are then applied to the structural components in PRONTO, and the motions are computed more accurately

through the Lagrangian finite element solver. The motions computed by PRONTO are used to refine the material locations/interfaces in the CTH mesh.

More recently, Sandia has constructed Sierra, a new finite element framework. Sierra provides an expanded computational framework for generalized finite element calculations with an advanced database structure that enables complex mesh modification. Individual physics modules have been constructed to utilize these framework/database capabilities. Of interest to this project is the Sierra/SM module, which covers all of the features available within PRONTO and adds significant additional capabilities as well, especially in modeling material failure and fracture.

Under a separate IRAD effort, SNL upgraded the CTH component of ZAPOTEC to include the latest version of the CDAR model provided by LMSSC. This code has been provided to LMSSC for evaluation, and consulting has been provided in the use of this version. Under this IRAD, ZAPOTEC has been updated to use the Sierra/SM module instead of PRONTO. This makes the many improvements of Sierra/SM available for use in ZAPOTEC.

Benefits to the Department of Energy:

Earlier versions of the CDAR model had been incorporated into CTH, and had been used for DOE problems where there were concerns with the sensitivity of explosives. It has also been used for other explosive sensitivity problems in DOE/DOD shared activities. Including the latest version of this model enables more effective modeling of this key issue. Furthermore, coupling this model with the ZAPOTEC code enables the modeling of explosive detonation in a wider range of cases of interest. Updating of the ZAPOTEC code to use the Sierra/SM module improves robustness of solution on the Lagrangian portion of the computations, as well as enabling more advanced modeling of material failure and fragmentation.

Economic Impact:

The code will undergo substantial testing in the application space of interest in the near term, but once its utility has been demonstrated it will be used on full system calculations at LMSSC. These new capabilities will allow improved assessments of mechanical hazards to solid motor systems while minimizing the costs of full-scale testing. These capabilities will put Sandia/DOE and LMSSC far ahead of all competition in this technological arena. It is expected that this capability will allow for reduction in the expenses associated with full-scale hazards testing, thus, improving LMSSC's ability to compete for new missile system contracts.

Project Status:

This portion of the project has been completed.

ADDITIONAL INFORMATION

Laboratory/Department of Energy Facility Point of Contact for Information on Project

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Company Size and Points of Contact

Lockheed Martin Space Systems Company, 14,000 employees, $8.3 billion net sales (2012)
Contact: Erik Matheson
Work phone: (408)756-0896
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CRADA Intellectual Property

None

Technology Commercialization

No product is expected to be commercialized as a part of this project.

Project Examples

There is a range of technical presentation that could be made available to provide additional information about the use of this technology.

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This summary has been approved for public release by Sandia and Lockheed Martin Corporation

Sandia National Laboratories

By _____ 9/23/13
Gene Hertel — Date
Principal Investigator

Sandia National Laboratories

By _____ 8.22.13
Manager — Date
WFO/CRADA Agreements

Lockheed Martin Corporation

By Erik R. Matheson 11/18/13
Title: Fellow — Date

In order to expedite the process, if we do not receive your signed reply by 11/01/2013 we will assume your concurrence for the release of this document to the public.