Roadmap to Close the Technology Gaps, Rev B
August 19th, 2015

Submitted to

Research Partnership to Secure Energy of America (RPSEA)
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Project Title: Development of Advanced CFD Tools for the Enhanced Prediction of Explosion Pressure Development and Deflagration Risk on Drilling and Production Facilities

Subcontract No.: 12121-6403-01

Subcontract Amount: $3,679,506

Dates of Performance: August 23rd, 2014 – September 30th, 2016

# 1. Background

As stated in the bid and award process, two major technology gaps currently present in Gulf of Mexico (GOM) drilling and production facilities are (1) the lack of detailed geometry information in the early design phase, which, when congestion due to small items is not integrated into the model when performing explosion studies, the design blast loads will be severely underestimated and (2) no adequate tools to predict the potential risks of DDT at these facilities, where the consequences of DDTs can be orders of magnitude larger than typical deflagrations.

As previously, stated the general methodology to be used to address these gaps are large scale testing and numerical CFD simulation experiments using the FLACS package.

# 2. Gap 1: Lack of Detailed Geometry Information

## 2.1. Overview

The first technology gap to be addressed will be the lack of detailed geometry information in the early design phase for topsides structures in the GOM. This has been identified as a major source of error when performing initial risk assessments during the design phase. At this point in the project design, there is little information about small diameter piping and congestion that can have a large contribution to the maximum overpressure load and DDT potential. This is unfortunate because when this information becomes available it is often laborious to go back and revise the designed layout.

## 2.2. Path to Close the Technology Gaps

The end goal to address the lack of detailed geometry available in design phase will be to come up with a methodology to add anticipated congestion to ensure that any explosion risk analysis will be representative of the final congestion, subsequent overpressure and DDT potential.

An Anticipated Congestion Methodology (ACM) has been developed largely for North Sea offshore platforms, not the GOM. The North Sea platforms are generally exposed to harsher weather conditions and tend to have more confinement than those present in the GOM. Therefore, the first step towards developing this methodology specifically in use in the GOM will be to obtain as-built geometries. Our initial target for will be approximately 4 platforms, if possible, from each of four partners for an approximate total of 16 as-built platforms. At the time of this report, two partners have been secured. This leaves us with a target of 8 platforms at present. A third cost share partner is in final negotiations and discussions continue with other interested parties. We are optimistic we will be able to achieve the target 16 platforms.

Subsequently, two different styles of numerical experiments will be conducted. The first one will be to run numerical experiments in a “top-down” approach. Starting with the as-built models, pipes will gradually be removed that are smaller than 2” diameter, then 4” diameter, all the way up to approximately 10” diameter pipes. This will allow us to demonstrate the level of detail necessary in the geometry model to obtain realistic overpressure results. Concurrently, we will populate the Concept or FEED phase geometries with anticipated congestion. Congestion will continue to be added to the models until the maximum overpressures are similar in magnitude to those obtained in the as-built models. From this study, an ACM methodology will be developed that will be specific to GOM offshore facilities

More specifically, the methodology consists of adding “AC blocks”, which are generic building blocks of specific process equipment, such as turbine generators. These “blocks” can be scaled and moved, but already have supporting piping and structure included in them to mimic the geometry in an as-built configuration. These blocks are typically added to geometries in the early design phase (Concept or FEED) to ensure that not only the final congestion levels but its relative distribution (meaning higher congestion around process equipment) are conserved in the model for explosion risk studies and the results will close to the “as built” geometry.

The goal of the work will be to determine necessary congestion levels for given “as built” geometries, provide a methodology using ACM to achieve the necessary levels of congestion, and determine the sensitivities of the explosion results to chosen ACM methodology (e.g., how would the results change if ACM varied by ±10%). The study will focus on both ventilation and maximum explosion loads.

### 2.3. Environmental Impact

As this task is based on computer simulations, there is no environmental impact. This study of these tasks will result in no physical emissions or environmental implications.

## 3. Gap 2: Lack of Tools to Predict DDT

### 3.1. Overview

The second addressed technology gap is the lack of adequate tools to predict the potential risks of DDT at drilling and production facilities. Currently, deflagrations are the main focus of explosion risk while evaluating oil and gas facilities. While this can be adequate for sparsely congested platforms dealing with lower reactivity fuels, such as methane or natural gas, it may be insufficient for modern platforms with high levels of congestion and the presence of highly reactive fuels such as ethylene.

Currently GexCon’s tool, FLACS has a module which can help predict the onset of a DDT through the use of the DPDX parameter. This is a non-dimensional spatial pressure gradient parameter. The values obtained from this parameter can help tell when a DDT is likely, but cannot directly calculate the resulting overpressures from a DDT. Current advanced 3D CFD tools, as well as, more simplified analytical models were developed on small to mid-scale experiments. It is, however, well known that the transition phenomenon does not easily scale to larger volumes, such as those associated with topside modules[1]. Therefore, large scale experimental testing will be conducted to create a database of information that will serve as a database for validation of new updated tools as they are developed.

## 3.2. Path to Close the Technology Gaps

This project will utilize SRI's 480-acre Corral Hollow experiment site (CHES) to build the test facility and conduct large-scale experiments to acquire data that will be used to validate the FLACS DDT onset prediction capability. The key measurements for validation will be flame speed and blast overpressure. These tests will be conducted with homogeneous mixtures of methane-air, propane-air, and ethylene-air, which represent significant industrial gas explosion hazards. It is critical to demonstrate validation with fuels of different reactivity: low (methane), medium (propane), and high (ethylene).

Three general congestion levels will be used, "low", "medium", and "high" with the three fuels mentioned above. These congestion levels will be designed such that stoichiometric mixtures of ethylene, propane and methane detonate at the "low", "medium" and "high" congestion levels respectively. These experiments will be conducted at various fuel concentrations ranging from fuel-lean through stoichiometric to fuel-rich.

With these results the road map to close the technology gaps will be addressed through development of updated CFD tools and simple empirical correlations. These tasks will make large scale test data available to developers to validate technological advances against.

[1] van Wingderden, K., Middha, P., Hanser, O.R., (2008) On the possibility of DDT in vapor cloud explosions. Loss Prevention Symposium 2008, 59-67

FLACS R&D is an ongoing process with team members constantly working to update, improve and validate the CFD package. These tests will allow for validation of their efforts. The approach to improving the predictive capabilities of FLACS will be to make fundamental improvements to the modeling of turbulent flow and combustion, including the representation of sub-grid objects and their influence on the turbulent length scale used by the combustion model. These planned model improvements are likely to influence all simulation results for explosion scenarios in congested geometries. Once complete, FLACS will be updated for release at these scales for homogeneous mixtures (ideal vapor clouds).

The data acquired in the large-scale experiments will be used to develop empirical correlations for DDT onset predictions in large geometries and ACM in GOM structures, which will expand the range of applicability for at least 3 additional simplified explosion models.

### 3.3. Environmental Impact

As the path to help reduce this technology gap is through large scale testing, there are some environmental concerns. However, these concerns are minimal and generally only involve release of carbon dioxide ($CO_2$) into the atmosphere.

The combustion of the three fuels previously listed will be conducted at varying concentrations, from fuel lean through stoichiometry, to fuel rich. Currently, the estimated quantity of each fuel to be consumed is 3,500 lbs. for a total of 10,500 lbs. The results of this work will result in an estimated 15.5 tons of $CO_2$ that will be released into the atmosphere. To the best of our ability, no EPA standard was found that regulates $CO_2$ emissions as part of scientific explosion or combustion testing. As a comparison, based on our calculations, the other tests of interested outlined in the Concept Report under the Literature Review section have produced the following amounts of $CO_2$:

- HSE – BFETS Tests: 11 tests with natural gas, approximately 6.5 tons of $CO_2$ released from 2.3 tons of fuel
- British Gas – 45m Rig: 10 tests with natural gas and propane, approximately 8 tons of $CO_2$ from 2.5 tons of fuel.
- British Gas – Midlands: 13 tests with natural gas, propane and butane, approximately 4.5 tons of $CO_2$ released from 1.5 tons of fuel

Beyond the carbon dioxide release, there will be a minimal amount of other impacts. There will be minimal waste generated by the project as all of the developed structures will remain in use beyond the life of this project. There will be general municipal waste of approximately 500 lbs. The majority of this will be plastic sheeting used to contain the flammable vapor in the experimental rig prior to ignition during the experiment.

The tests will be conducted a SRI's CHES facility. This is a 480 acre facility located about 20 miles from Livermore, CA. The actual site within the facility is not located near any sensitive environmental areas. The nearest body of water is 9 miles away and there will be no run-off from the types of experiments being conducted.

From a safety standpoint there is a flammability hazard associated with the fuels being studied, however there is no toxic or environmental hazard associated with any of them. They are all generally already present in our atmosphere.

There may be times off added noise, however the general ambient noise level would remain at its current level. Beyond that, this project will not require permits with respect to any major environmental laws such as the Resource Conservation and Recovery Act (CERCLA), the Toxic Substance Control Act (TSCA), the Clean Water Act (CWA), the Clean Air Act (CAA), the Floodplains and Wetlands Regulations, the National Historic Preservation Act (NHPA) or the Coastal Zone Management Act (CZMA).

## 4. Conclusions

This document has covered the two major technological gaps currently present in the GOM drilling and production facilities. To address the lack of detailed geometry technology gap, this project will perform numerical CFD simulations on a variety of platforms. The relevant tasks will have no environmental impact. To address the lack of tools to predict DDT, large scale experiments involving methane, ethylene and propane will be conducted. These tests will have minimal environmental impact, with the largest concern being the release of approximately 15 tons of carbon dioxide over the course of project.