Progress in Understanding the Combustion Physics for Gelled Hypergolic Propellants

Stephen D. Heister & Timothee Pourpoint
Purdue University, West Lafayette, IN, 47907

1. Introduction/Background

In 2008, a team led by Purdue University was granted a contract from the U.S. Army Research Office under the Multidisciplinary University Research Initiative (MURI) program to study combustion of gelled hypergolic propellants. The Purdue-led MURI project involves 11 different principle investigators from four different institutions and has an annual budget of $1.25M. The membership of the team includes:

Purdue University: Stephen Heister , Overall Team Lead
Paul Sojka Team Lead, Gelled Fluid Physics
William Anderson Team Lead, Gelled Fluid Combustion
Osvaldo Campanella, Team Lead, Gelled Fluid Rheology
Carlos Corvalan, Primary atomization simulations
Robert Lucht, PLIF experiments on gelled drop combustion
Timothee Pourpoint, Reacting jet and droplet experiments
Steve Son, Droplet experiments
Univ. Massachusetts, Amherst: David Schmidt, Gelled droplet and jet simulations
Univ. of Chicago: Marcelo Carignano, Microscale modeling of rheology
N. C. State University: Phil Westmoreland, Chemical kinetics reduced order modeling
Iowa State University: Terry Meyer, Ballistic imaging of dense sprays

Figure 1 provides an overview of the technical organization and areas currently under study within this effort. Professor Campanella leads efforts in characterizing rheology and development of gelled propellant materials for consideration within the overall effort. Professor Sojka leads efforts relative to flow physics and atomization, while Prof. Anderson leads efforts concerning combustion. The team has been working for nearly 5 years and have made substantial progress in understanding the complex physical and chemical processes concerning hypergolic ignition of these substances. We have worked with nitric acid based oxidizers (IRFNA, WFNA) as well as hydrogen peroxide oxidizer. We have worked mainly with monomethyl hydrazine (MMH) as fuel, but more recent studies have focused on less toxic fuels including DMAZ and TMEDA. Current efforts have found some exciting new

chemical additives that greatly enhance hypergolicity of nitric-acid based propellant combinations.

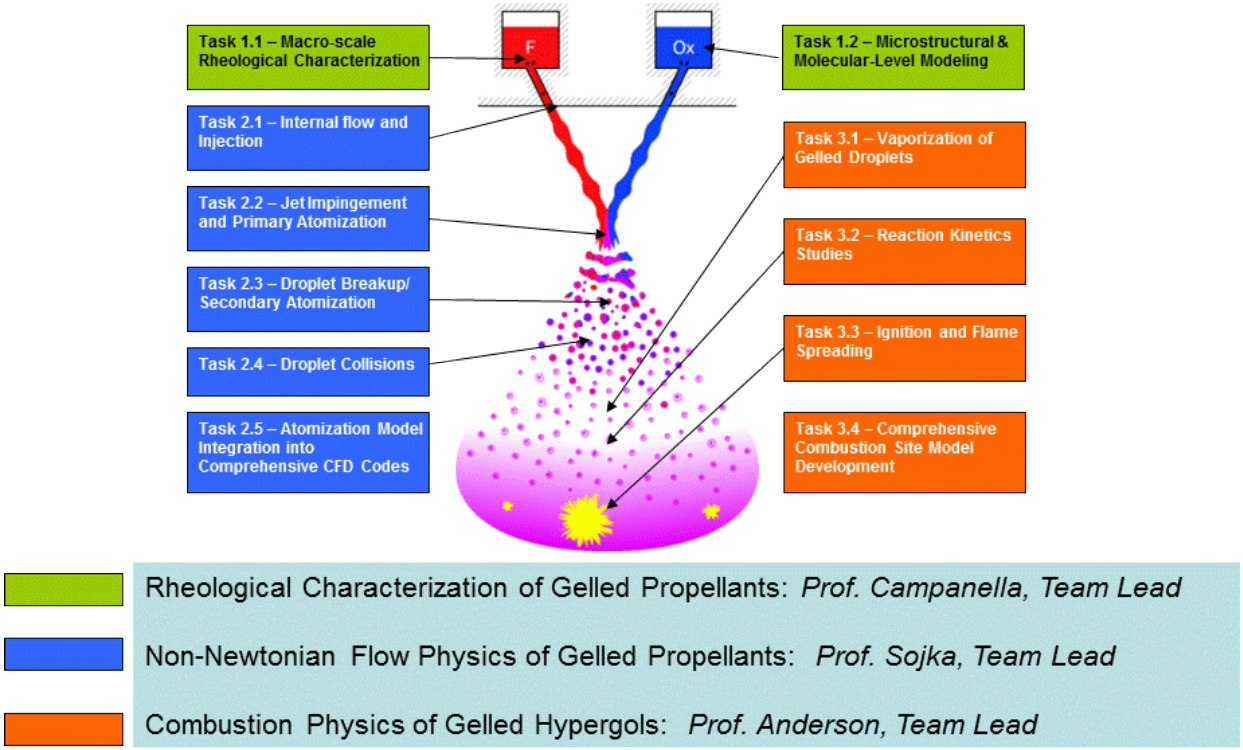

Figure 1: Overall technical organization of the Purdue MURI team outlining 11 different technical tasks under the 5-year effort.

2. Proposed Content

Obviously, the MURI effort has been large and literally dozens of publications have stemmed from the work. However, as the field of hypergolic ignition is over 50 years old, there are a relatively small number of important discoveries that have stemmed from recent efforts. It is the author's intent to summarize these most salient points in the EUCASS forum. A second objective of the proposed paper is to provide a detailed account of current efforts within Task 3.4 in Fig. 1. As a part of our effort, we reserved the final year of the project to conduct a capstone experiment, with companion computation. The experiment that was selected was an atmospheric test of a single impingement site in a region near a wall. This configuration is motivated by a vortex injector concept[1] that was recently studied by U.S. Army wherein

[1] M. Nusca and S. Michaels, "Modeling of Impinging-Stream/Swirl Injectors in a Hypergolic Fuel Engine," in *39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit* Huntsville, Alabama, 2003.

propellants are injected at the chamber periphery rather than the more common approach of injection at the chamber head-end. Figure 2 summarizes the configuration to be studied. Testing is to be conducted with a variety of injection velocities for the like doublet configuration shown. The included angle between fuel and oxidizer injectors is 60 degrees and a flat plate is used to mimic the round combustor wall. We anticipate sharing both experimental and modeling results from this study in the EUCASS forum.

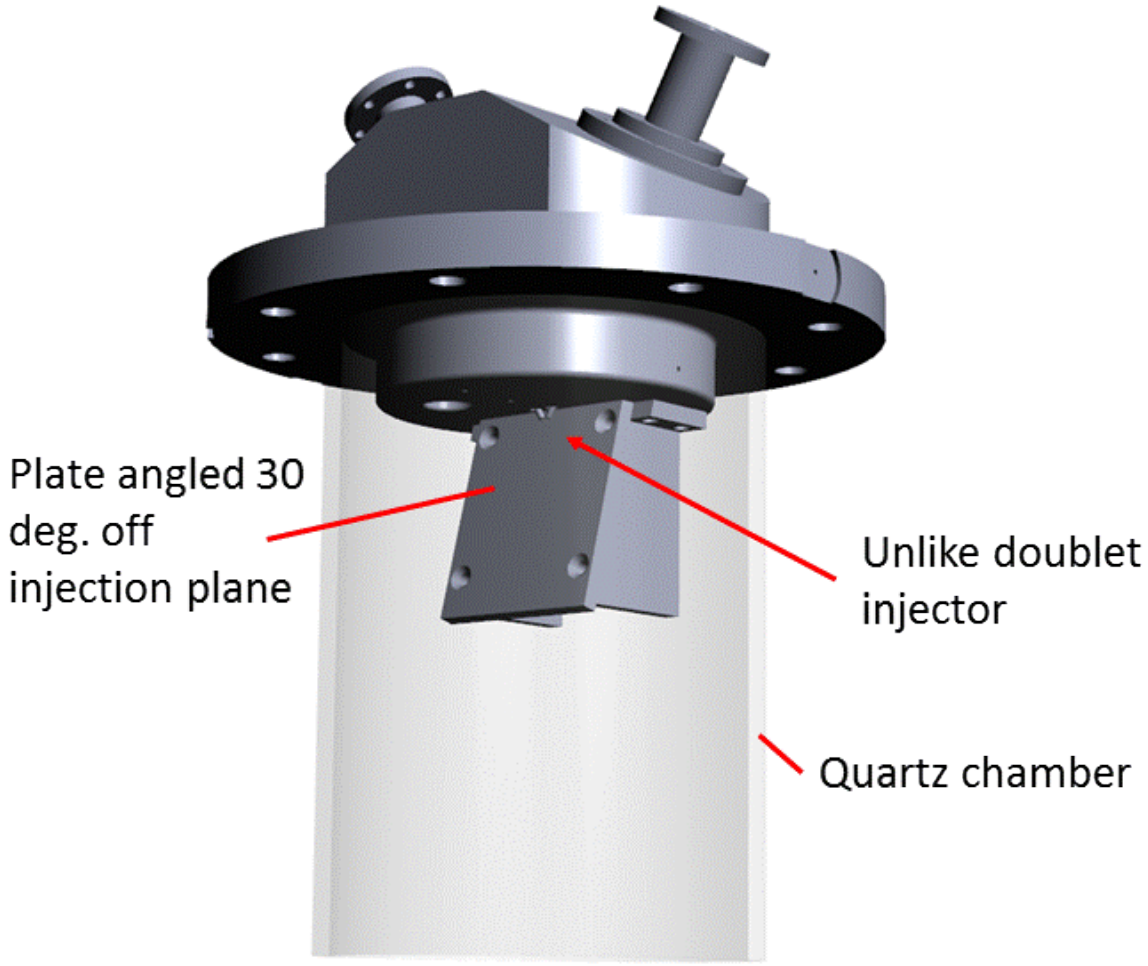

Figure 2: Configuration of MURI Capstone experiment. Experiments are to begin in early 2013 and companion calculation is currently under development.