Phase I Project Summary

Firm: Orbital Technologies Corporation

Contract Number: NNX10CD20P

Project Title: Non-Toxic Ionic Liquid Fuels for Exploration Applications

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Purpose of the Research:

This Phase I project assessed the feasibility of developing new, non-toxic ionic liquid fuels for exploration applications. Traditional rocket fuels such as MMH are highly toxic and consequently increase risk and cost of NASA missions. New fuels that are non-toxic but provide equal performance would decrease cost and increase safety. Ionic liquids, which are salts that are liquid under 100°C, offer several advantages such as low volatility, high density, and high energetic content. This work set out to synthesize a set of ionic liquid rocket fuels and characterize them to assess their suitability.

Description of the Research Carried Out:

The Phase I program included synthesis, materials testing, ignition testing, and performance and system analysis. The goal of the synthesis work was to create two sets of ionic liquids, one hypergolic with NTO and one hypergolic with LOX. The strategy was to design the anions to produce the hypergolity and then tailor the cations to achieve high performance. Drop ignition tests assessed the reactivity of the formulations with nitric acid and measured their ignition delays. Thermal tests assessed the stability of these fuels at high temperature. Thermochemical calculations predicted the rocket engine performance of these fuels, and subsequent systems analysis assessed their integration to a typical propulsions system. The results enabled an evaluation of the feasibility of the approach and defined direction for Phase II work.

Phase I Results:

The Phase I work was very successful, producing 13 ionic liquids with potential as rocket engine fuels. The synthesis work created a group of 11 ionic liquids with organo-borate anions designed for use with NTO and 2 ionic liquids with organo-aluminate anions designed for use with LOX. Subsequent screening tests showed that these 13 ionic liquid formulations were indeed viable fuel candidates. Ignition tests showed that all of the formulations were hypergolic with nitric acid. The videos acquired during these tests displayed the steps to reaction of these hypergol pairs and allowed determination of the ignition delay time. Some of the ionic liquid candidates showed exceptionally fast reaction times. Thermal tests demonstrated that all of these compounds were stable at increasing temperatures to at least 150°C. Performance calculations showed that these fuels should deliver about the same I_{sp} as MMH or slightly less and that the density I_{sp} with be on the order of 10% greater. Collectively, these results demonstrated that ORBITEC is able to design new, non-toxic fuels suitable for replacing MMH in rocket engine systems.

Justification for Phase II Continuation:

The Phase I work demonstrated the feasibility of developing ionic liquids with organo-metallic content as rocket engine fuels. The samples developed in Phase I were quite promising, showing high performance estimates, fast ignitions, and favorable and stable material properties. Subsequent Phase II work is highly likely to produce excellent non-toxic fuels that will have broad application in NASA, the military, and the commercial sector.