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Advanced Launch Vehicle Propulsion at the NASA Lewis Research Center

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ADVANCED LAUNCH VEHICLE PROPULSION AT THE NASA LEWIS RESEARCH CENTER

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ABSTRACT

At the NASA Lewis Research Center, several programs are investigating the benefits of advanced propellant and propulsion systems for future launch vehicles and upper stages. The two major research areas are the Metallized Propellants Program and the Advanced Concepts Program. Both of these programs have theoretical and experimental studies underway to determine the system-level performance effects of these propellants on future NASA vehicles.

METALLIZED PROPELLANTS

The Metallized Propellants Program is determining the performance and the system benefits of propellant combinations such as oxygen/kerosene/aluminum and oxygen/hydrogen/aluminum. In these combinations, the aluminum is gelled with the kerosene or the hydrogen. Adding the aluminum to the propellant increases its overall density and/or the specific impulse. The density increases reduce the volume of the vehicle, the tank mass and the total launch mass. All of these factors also contribute to reducing the drag of the launch vehicle during ascent. The specific impulse increases further reduce the vehicle size and mass. These mass reductions can significantly reduce the launch mass to orbit and potentially reduce the overall cost of space transportation.

Vehicle and System Performance Studies

A set of systems studies to determine the benefits for metallized propellant are underway. Using detailed upper stage and launch vehicle mission analysis and design codes, the payload performance for various propellant combinations can be determined. These studies include earth orbital, planetary and lunar missions. The initial mass in Low Earth Orbit (LEO) reductions over existing and planned propulsion systems are estimated. These LEO mass savings can also be translated into payload mass increases.

For launch vehicles, metallized propellants can provide increased propellant density. A higher density propellant can reduce the size of the launch vehicle stages and its dry mass. The reduced size reduces the drag losses on the vehicle. Also, the higher density propellant provides the ability to improve the Space Transportation Systems (STS). Liquid Rocket Boosters with the same physical dimensions as the current Solid Rocket Boosters have been studied by NASA and its contractors. Used in the Liquid Rocket Boosters, metallized propellants can deliver the same payload to LEO as the current Solid Rocket Boosters within their volume constraints. Other liquid propellant combinations cannot deliver the same payload within these volume restrictions. Metallized propellants can also be employed in improved versions of the current Atlas, Delta and Titan systems.

Experimental Program

In the experimental program, both in-house and contracted experimental work are continuing. Subscale test hardware using oxygen/hydrocarbon/aluminum propellants has been fired at NASA-Lewis (Ref. 1). This test apparatus has produced preliminary data on the aluminum combustion, specific impulse efficiency and the erosion of the injector elements and the nozzle. Additional experiments are being conducted using this and other subscale hardware. Higher thrust levels will be tested in future contracted work. Propellant rheology is also being studied both with computer models and test facilities. Propellant batches are being formulated to determine their flow properties and their long-term storage properties. Other contracted research into novel propellants and gellants is also funded under the NASA Research Announcement (NRA) Program.

University Research Program

Penn State University is conducting a series of experimental and theoretical investigations of the formation of aluminum oxide and its effect on metallized propellant performance. This work has led to additional understanding of the mechanisms for agglomeration and breakup of aluminum oxide particles in the rocket exhaust.

ADVANCED CONCEPTS FOR CHEMICAL PROPULSION

In the Advanced Concepts Program, very-high energy propellants, such as atomic hydrogen and other High Energy Density Matter (HEDM) propellant candidates, are being studied. This program has received much valuable information from the research underway at the Air Force Astronautics Laboratory and the Air Force Office of Scientific Research.

Many of the high energy propellants provide large increases in specific impulse. But along with the great potential of high-energy propellants are the attendant problems of free-radicals: production, storage and transportation. All of these factors are being investigated to determine the critical research directions for applying this material to propulsion. Only if these technical barriers are overcome will we gain the benefits of these propellants and propulsion systems.

Vehicle and System Performance Studies

Currently, atomic hydrogen is being analyzed for launch vehicles and upper stages. Using atomic hydrogen, the launch mass of future launch vehicles can be reduced by a factor of 3 to 10 over currently planned Space Transportation System-Cargo (STS-C) and

Advanced Launch System (ALS) vehicles (Ref. 2). The specific impulse range to deliver this reduced mass is 750 to 1500 lb_f-s/lb_m. Advanced upper stages using this propellant can also provide a benefit to the planetary program. Placing a spacecraft on a very high energy trajectory is possible if the specific impulse of atomic hydrogen can exceed 750 lb_f-s/lb_m.

In addition to the vehicle studies, the facilities for producing, transporting and storing atomic hydrogen are being analyzed. Large cryogenic storage facilities and magnetic field coils or generators are required for atomic hydrogen propellants. These facilities are being studied to determine the what size facility is best suited to each launch vehicle configuration.

University Research Program

A set of experimental and theoretical studies are underway at the University of Hawaii at Manoa and the University of Iowa (Iowa City). Atomic hydrogen research is being conducted at the University of Hawaii. The storage density and the methods which may enable increases in that density are under investigation. Experiments are being conducted to understand the energy release phenomena during recombination. The atomic hydrogen is stored in solid cryogenic hydrogen. Tritium decay is used to form the atomic hydrogen in the solid hydrogen.

At the University of Iowa, a survey of advanced propellants is being conducted. From this survey, the potential specific impulse of the very advanced propellants will be estimated. This study will allow a preliminary screening of the high energy density propellants and identify which propellant may be applicable to future NASA missions.

CONCLUSIONS

Advanced propulsion technology can provide several benefits to high-energy space missions. Some of these benefits are significantly reduced launch mass, increased payload delivery and potentially lower transportation system costs. Several current research programs in both metallized propellants and advanced concepts are identifying the research directions to gain significant benefits for future NASA missions. With a combination of in-house studies and experiments, contracted research and university grants, a wide range of propulsion system technologies with potentially significant benefits are under investigation.

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