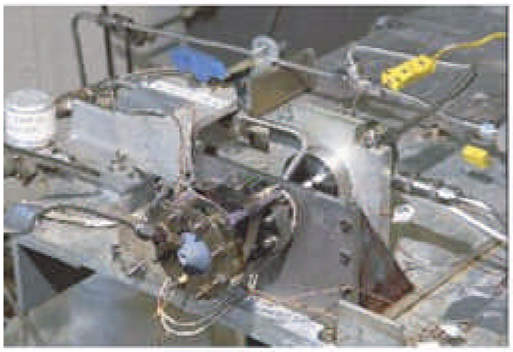
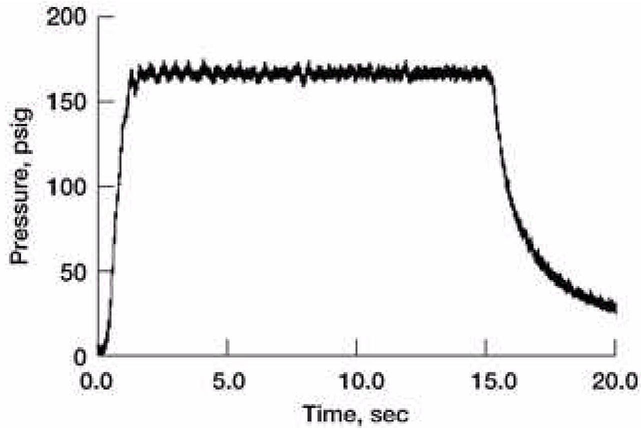
High-Performance Monopropellants and Catalysts Evaluated

The NASA Glenn Research Center is sponsoring efforts to develop advanced monopropellant technology. The focus has been on monopropellant formulations composed of an aqueous solution of hydroxylammonium nitrate (HAN) and a fuel component. HAN-based monopropellants do not have a toxic vapor and do not need the extraordinary procedures for storage, handling, and disposal required of hydrazine (N_2H_4). Generically, HAN-based monopropellants are denser and have lower freezing points than N_2H_4. The performance of HAN-based monopropellants depends on the selection of fuel, the HAN-to-fuel ratio, and the amount of water in the formulation. HAN-based monopropellants are not seen as a replacement for N_2H_4 per se, but rather as a propulsion option in their own right. For example, HAN-based monopropellants would prove beneficial to the orbit insertion of small, power-limited satellites because of this propellant's high performance (reduced system mass), high density (reduced system volume), and low freezing point (elimination of tank and line heaters).

Early technology efforts centered on a HAN-glycine formulation that had a relatively low performance but was compatible with state-of-art catalysts. More recent work has been oriented toward HAN formulations that perform better than N_2H_4, with a specific impulse I_{sp} goal of 250 sec. The combustion environment of high-performance HAN formulations is both high-temperature (>1700 °C) and corrosive (nitric acid, steam). State-of-art catalysts have not lasted more than a few seconds in this aggressive combustion environment. The developmental challenge is to develop catalysts (carrier and active coating) that can survive longer in the HAN combustion environment.

Under a Glenn-contracted effort, Aerojet Redmond Rocket Center conducted testing to provide the foundation for the development of monopropellant thrusters with an I_{sp} • 250 sec. A modular, workhorse reactor (representative of a 1-lbf thruster) was used to evaluate HAN formulations with catalyst materials. Stoichiometric, oxygen-rich, and fuel-rich formulations of HAN-methanol and HAN-tris(aminoethyl)amine trinitrate were tested to investigate the effects of stoichiometry on combustion behavior. Aerojet found that fuel-rich formulations degrade the catalyst and reactor faster than oxygen-rich and stoichiometric formulations do. A HAN-methanol formulation with a theoretical I_{sp} of 269 sec (designated HAN269MEO) was selected as the baseline. With a combustion efficiency of at least 93 percent demonstrated for HAN-based monopropellants, HAN269MEO will meet the I_{sp} • 250 sec goal.





Left: Workhorse reactor used for HAN-based monopropellant testing, Right: typical chamber pressure trace for baseline propellant formulation and catalyst.

Various ceramic carrier materials were evaluated in laboratory testing and the workhorse reactor. These high-temperature ceramics generally have lower surface areas than state-of-art catalysts but are more thermally stable at high temperatures. One catalyst material, using a relatively low-cost carrier, demonstrated the longest lifetime (over 5 min) and throughput (900 g) ever accomplished with high-performance monopropellants.

The Aerojet test program identified a baseline formulation and catalyst material for a monopropellant with an I_{sp} > 250 sec, and it provided fundamental insights to HAN combustion and catalyst behavior. These efforts have established a firm foundation for the development of high-performance monopropellant thrusters.

Glenn contact: Brian D. Reed, 216-977-7489, Brian.D.Reed@nasa.gov
Author: Brian D. Reed
Headquarters program office: OAT
Programs/Projects: Earth Science, Space Science