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December 2010

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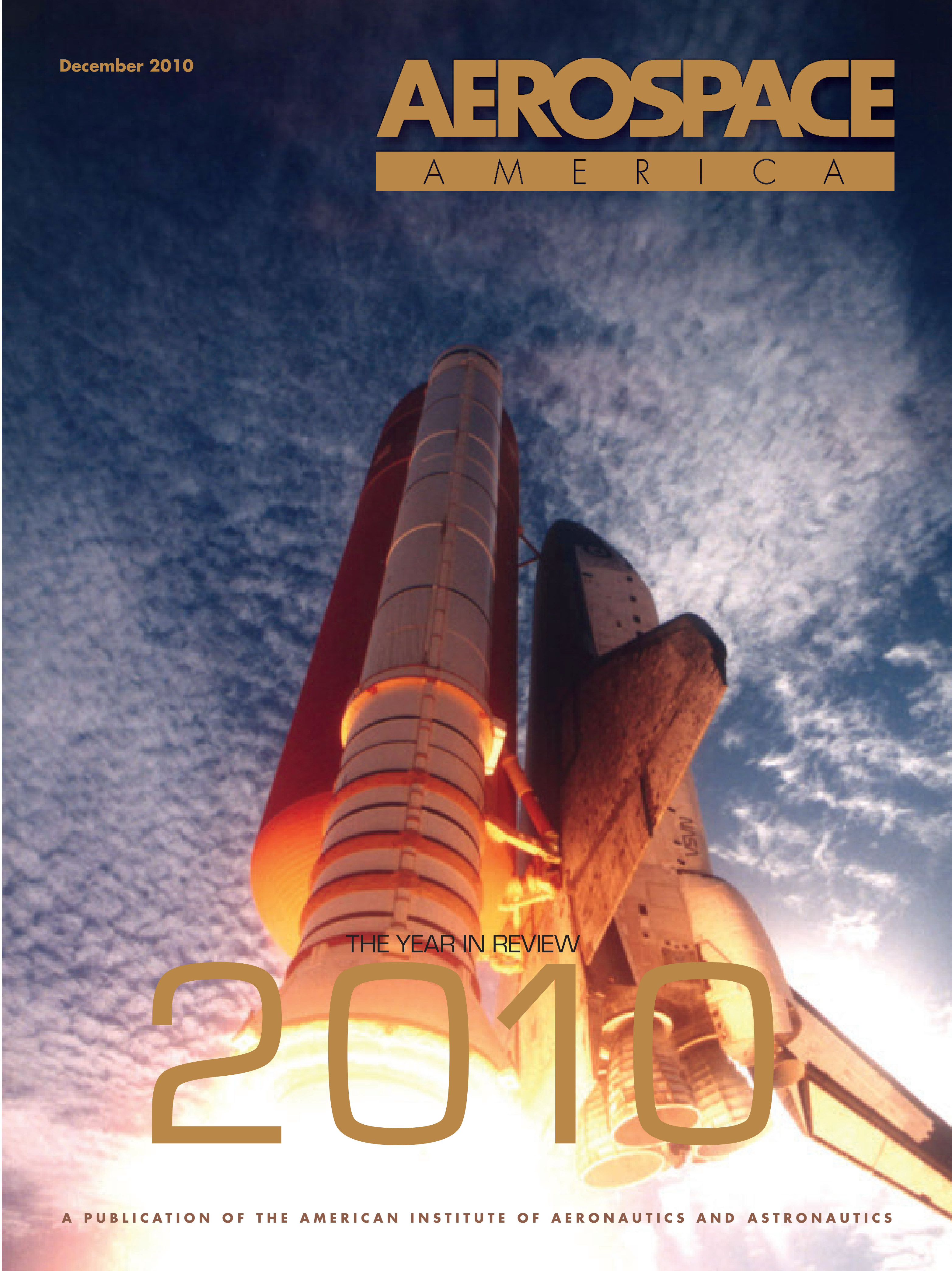


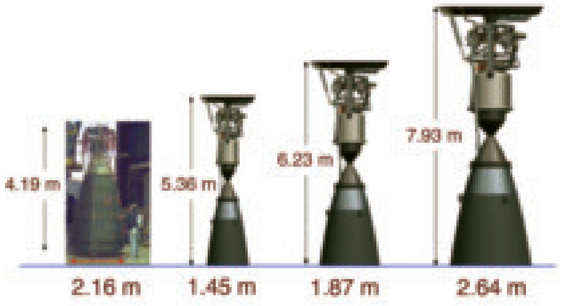
THE YEAR IN REVIEW

2010

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Nuclear and future flight propulsion

by **Bryan Palaszewski** and the **AIAA Nuclear and Future Flight Propulsion Technical Committee**



The performance and size of the RL10B-2 chemical engine can be compared with different thrust NTR engines.

Atmospheric mining in the outer solar system was investigated as a means of fuel production for high-energy propulsion and power. Fusion fuels such as helium 3 (3He) and hydrogen can be wrested from the atmospheres of Uranus and Neptune.

In 2009 Case Western Reserve, assisted by NASA Glenn, undertook six aerospace design studies of such mining. Both 3He and hydrogen were the primary gases of interest, hydrogen being the main propellant for nuclear thermal or nuclear fusion rocket-based atmospheric flight. Four teams addressed issues associated with atmospheric cruiser-based and balloon-based mining vehicles. Two teams focused on outer planet moon mining for the gases. Many of the cruiser designs were effective in gathering 3He in less than one year.

Using nuclear thermal propulsion, or NTP (with primarily closed-cycle gas core rocket technology), effective flights into and out of the atmospheres of Uranus and Neptune were possible. Outer planet moon mining vehicles were also designed and parametric analyses of 3He concentration conducted. A central power system supported multiple miners, making the mobile miners lighter than those with onboard power. Some teams concluded that NTP must focus on very high specific impulse closed-cycle gas core powered vehicles. Uranus' and Neptune's vast reservoirs of fuels are more readily accessible than those of Jupiter and Saturn and, with the advent of nuclear fusion propulsion, may offer the best option for the first practical interstellar flight.

Laser-driven inertial confinement fusion (ICF) is extremely attractive for deep-space propulsion and has been the subject of several conceptual design studies. However, these were based on older ICF technology using either "direct or indirect X-ray-driven" type target irradiation. This leads to rather low energy gains. Moreover, traditional deuterium tritium fusion was selected, requiring tritium breeding and delivering 80% of the fusion energy in neutrons that cannot be directed through an exhaust nozzle.

However, important new directions have developed for laser ICF in recent years following the development of "chirped" lasers capable of ultrashort pulses with powers of terawatts up to a few petawatts. This has led to the exciting concept of "fast ignition," where the petawatt laser beam strikes a precompressed target, creating a hot spot in the interior of the target burn that propagates outward into the surrounding fuel. This then greatly increases energy gain, because part of the required input energy is replaced by the propagating burn. Fast ignition is very efficient in giving very high gains while maintaining a low electron temperature, allowing ignition of more demanding fusion fuels such as p-11B. The University of Illinois and the Los Alamos National Laboratory conducted this work.

NASA's recent Mars DRA (design reference architecture) 5.0 study examined mission, payload, and transportation system options and requirements for a human Mars mission in the 2031-2033 timeframe. A proven technology, NTP could potentially enable future human Mars missions with reasonable initial mass in LEO and a reasonable number of Ares V launches. However, to recapture, mature, and flight qualify NTP systems in time to support future cargo and crewed Mars missions in the post-2030 timeframe will require meaningful, sustained investments beginning in the next several years.

These investments will attempt to establish firm NTP engine system requirements using updated Mars mission analysis and payload estimates; recapture composite Rover/NERVA fuel element technology, and mature uranium dioxide in tungsten metal "cermet" fuel technology; perform high-fidelity modeling, design, and engineering of candidate engine systems; prepare test facilities; and conduct the required nuclear/nonnuclear demonstration tests of NTP fuels, components, and subsystems in preparation for "contained" full-scale ground testing of both demonstration and flight-type engines.

Assuming five years of technology preparation and then a 10-year development phase, NTP flight testing can begin in the late 2020s, in time to support initial human Mars flights in the 2031-2033 timeframe.