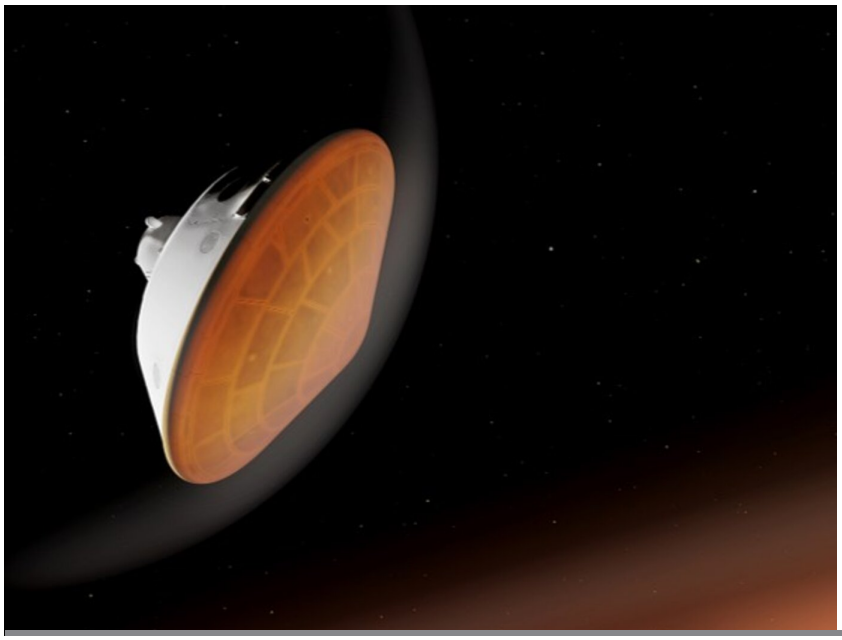


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Aerospace

System for Flight Control of Extremely Fast (Hypersonic) Aircraft

Lift-augmenting, power-harvesting magnetohydrodynamic patch

Researchers at NASA's Langley Research Center have designed an electrode-based system for guidance, navigation and control of aircraft or spacecraft moving at hypersonic speeds in ionizing atmospheres. The system is composed of two electrodes that sit on the surface of a craft's thermal protection system (TPS) and an electromagnet positioned beneath the craft's TPS. The system operates based on the principles of magnetohydrodynamics (MHD) and uses energy harvested from the ionized flow occurring during flight at hypersonic speeds to power the electromagnet and generate extremely large Lorentz forces capable of augmenting lift and drag forces to steer and control the craft. The energy harvested can alternatively be stored for later use. NASA's system is simpler than conventional methods for control of hypersonic craft (e.g., chemical propulsion, shifting flight center of gravity, or trim tabs) and enables new entry, descent, and landing mission architectures.

BENEFITS

- Is a simple design: The MHD patch is composed of two electrodes and an electromagnet.
- Generates large lift and drag forces: Simulations show the MHD patch generates forces up to 200 kN under Neptune atmosphere reentry conditions which are projected to be similar to Earth.
- Harvests power: The MHD patch harvests power via skimming of ionizing atmospheres.
- Is radar-silent: The MHD patch is non-protruding and is projected to have minimal radar signature.
- Enables larger payloads to be delivered faster: The MHD patch facilitates entry of larger, heavier craft into planetary atmospheres (including earth) at higher speeds.

APPLICATIONS

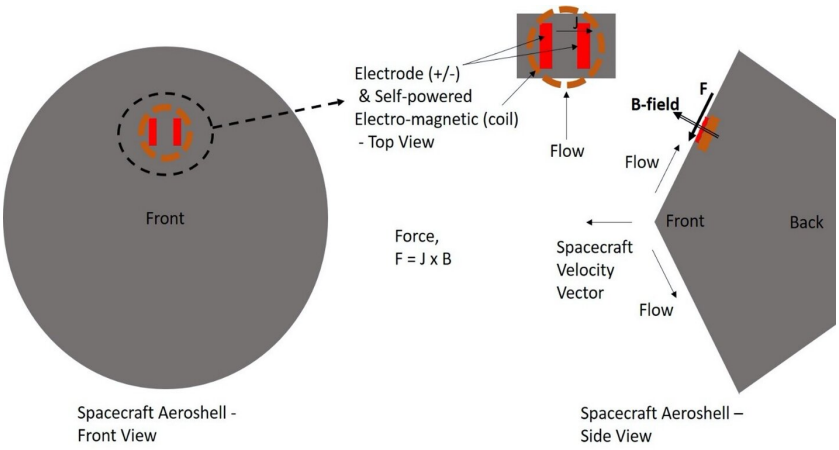
The technology has several potential applications:

- Aerospace and defense: Guidance, navigation, and control of hypersonic aircraft and spacecraft; power harvesting; aerocapture

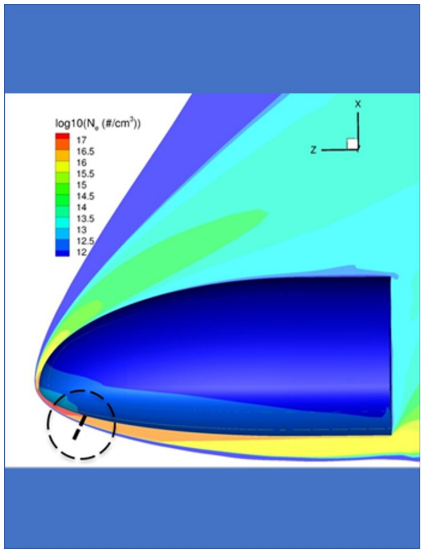
THE TECHNOLOGY

NASA's MHD patch technology consists of two electrodes positioned a prescribed distance apart on the surface of the TPS of an aircraft or spacecraft and an electromagnetic coil placed directly below the electrodes with the magnetic field protruding out of the surface. During hypersonic flight, the conductive ionizing atmospheric flow over the surface enables current to flow between the two electrodes. This current is harnessed to power the electromagnet which in turn generates strong Lorentz forces that augment lift and drag forces for guidance, navigation, and control of the craft. Alternatively, the current can be used to charge a battery. Changing the size of the MHD patch (e.g., the length or distance between the electrodes), the strength of the electromagnet, or the direction of the magnetic field enables tuning of generated forces for a given craft design. Multiple MHD patches can be leveraged on a single craft.

In-silico evaluation of the MHD patch technology on select aeroshell designs for mock entry into planetary atmospheres has been performed. A $1m^2$ MHD patch exerts forces up to 200 kN under simulated Neptune atmosphere entry, significantly increasing the lift/drag (L/D) ratio for the aeroshell investigated. This value is the same order of magnitude as the "whole body" drag and lift forces computed for the aeroshell suggesting the generated forces can be used to control a craft.



Elements of a MHD patch integrated with a blunt body aeroshell of a spacecraft



Location of MHD patch on aeroshell for Neptune atmosphere entry calculations. Electron number density (Ne) is illustrated by the color gradient.

PUBLICATIONS

Patent Pending

New Magnetohydrodynamic (MHD) Lift Concept for More Efficient Missions to Mars and Neptune. Conference Paper. December 29, 2021. https://arc.aiaa.org/doi/abs/10.2514/6.2022-0934. New Magnetohydrodynamic (MHD) Lift Concept for More Efficient Missions to Mars and Neptune. Presentation. January, 2022. https://ntrs.nasa.gov/citations/20210025128. Effect of Plasma Sheaths on Earth Re-entry MHD Processes. December 29, 2021. https://arc.aiaa.org/doi/10.2514/6.2022-0980

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LAR-20033-1, LAR-TOPS-363

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