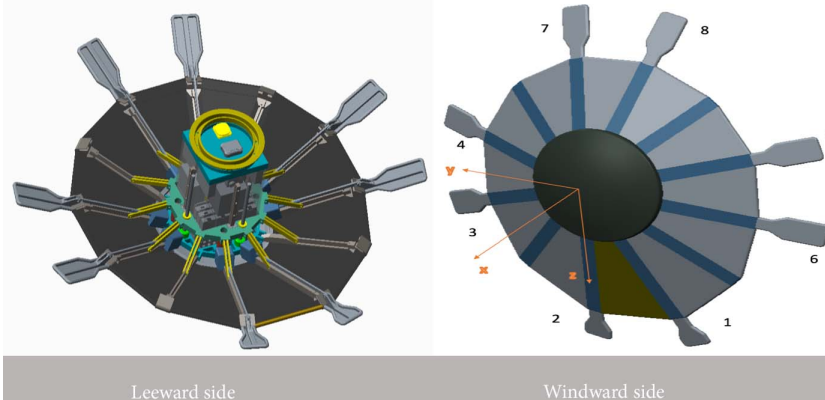


TECHNOLOGY SOLUTION

Aerospace



Leeward side

Windward side

Aerospace Vehicle Entry Flightpath Control

Control System that can be feasibly integrated with a Deployable Entry Vehicle (DEV)

The state-of-the-art in hypersonic entry Guidance and Control (G&C) is traditionally based on rigid entry vehicles, like the Orion capsule, Space Shuttle, etc., that use a Reaction Control System (RCS) to control the bank angle of the vehicle. However, for future high mass missions to Mars, advancements in hypersonic aerospace vehicle design, and evolving science goals, are stretching the performance capabilities of traditional entry systems.

NASA's Pterodactyl team at Ames Research Center has developed a novel yaw-to-bank control system for a non-traditional vehicle configurations, such as a Deployable Entry Vehicle (DEV) that can be folded and stowed. The approach provides vehicle stabilization, steering, and precise targeted landing. This control architecture is agnostic to control actuators and can be used with any aerospace vehicle with a strong dihedral effect and/or different guidance control variables.

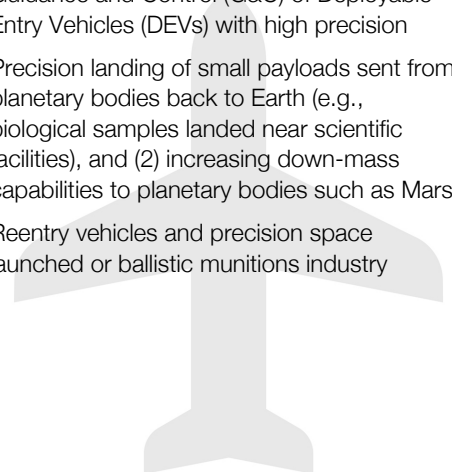
BENEFITS

- Enables the successful integration of non-propulsive control systems to realize vehicle configuration benefits that include: reductions in propellant mass requirements, net mass savings for the vehicle, and enhanced maneuverability from faster banking accelerations than possible with traditional systems.
- Provides a flexible control architecture applicable to:
 - aerospace vehicles flying subsonic, supersonic, and hypersonic flight speeds
 - different types of control actuators (e.g. MMCS, FCS, RCS, etc.)

APPLICATIONS

The technology has several potential applications:

- Aerodynamic bodies that require deployable control surfaces on articulating bodies
- Guidance and Control (G&C) of Deployable Entry Vehicles (DEVs) with high precision
- Precision landing of small payloads sent from planetary bodies back to Earth (e.g., biological samples landed near scientific facilities), and (2) increasing down-mass capabilities to planetary bodies such as Mars
- Reentry vehicles and precision space launched or ballistic munitions industry



THE TECHNOLOGY

This novel flightpath control system exploits the dihedral effect to control the bank angle of the vehicle by modulating sideslip (Figure 1). Exploiting the dihedral effect, in combination with significant aerodynamic forces, enables faster bank accelerations than could be practically achieved through typical control strategies, enhancing vehicle maneuverability. This approach enables vehicle designs with fewer control actuators since roll-specific actuators are not required to regulate bank angle. The proposed control method has been studied with three actuator systems (figure below), Flaps Control System (FCS); Mass Movement Control System (MMCS); and Reaction Control System (RCS).

- FCS consists of a flap configuration with longitudinal flaps for independent pitch control, and lateral flaps generating yaw moments. The flaps are mounted to the shoulder of the vehicle's deployable rib structure. Additionally, the flaps are commanded and controlled to rotate into or out of the flow. This creates changes in the vehicle's aerodynamics to maneuver the vehicle without the use of thrusters.
- MMCS consists of moveable masses that are mounted to several ribs of the DEV heatshield, steering the vehicle by shifting the vehicle's Center of Mass (CoM). Shifting the vehicle's CoM adjusts the moment arms of the forces on the vehicle and changes the pitch and yaw moments to control the vehicle's flightpath.
- RCS thrusters are mounted to four ribs of the open-back DEV heatshield structure to provide efficient bank angle control of the vehicle by changing the vehicle's roll. Combining rib-mounted RCS thrusters with a Deployable Entry Vehicle (DEV) is expected to provide greater downmass capability than a rigid capsule sized for the same launch



Multiple, independent control system configurations

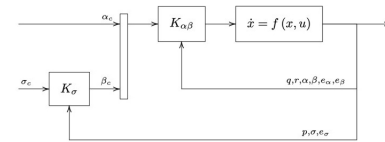


Figure 1: Yaw-to-bank control block diagram

PUBLICATIONS

Patent No: 11,772,828

D'Souza, et al., "Pterodactyl: System Analysis of an Asymmetric and Symmetric Deployable Entry Vehicle for Precision Targeting Using Flaps," <https://doi.org/10.2514/6.2021-0762>.

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