National Aeronautics and Space Administration

Mid-Air Helicopter Delivery for Mars (MAHD): Experimental Risk Reduction Campaign

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Program: FY22 R&TD Strategic Initiative

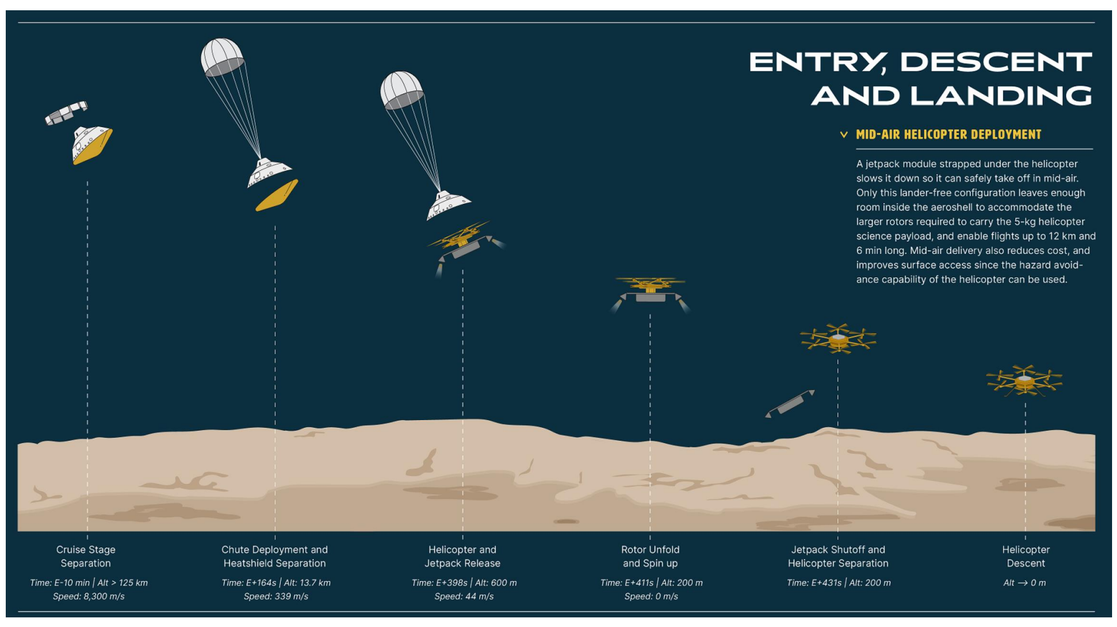
Strategic Focus Area: Mid-Air Deployment for Mars Helicopter - Strategic Initiative Leader: J. (Bob) Balaram

Objectives:

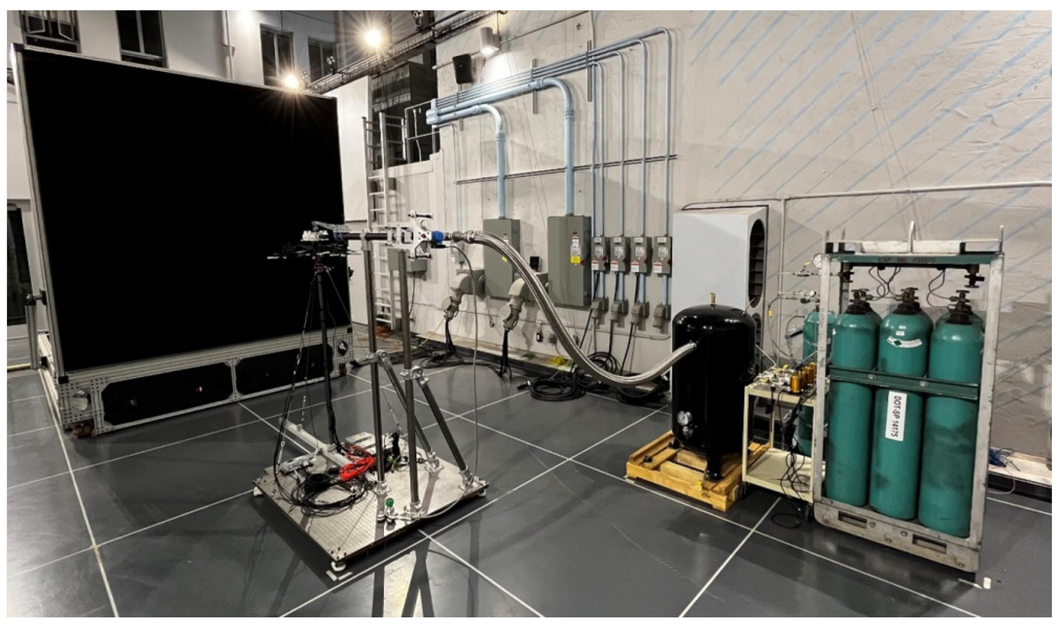
Experimental risk reduction effort to use a jetpack for Mid-Air Helicopter Delivery (MAHD) on Mars.

1. Measure flow properties and force-torque in a scaled 1-atm / 1-g helicopter-jetpack experiment in Caltech's CAST wind tunnel facility.
2. Model the flow using Computational Fluid Dynamics (CFD) simulations of both the Mars case and the experimental case.
3. Model the flexible modes of both the Mars case and experimental case.
4. Demonstrate force-torque sensing in high-fidelity DARTS simulations of the Mars case, using experiment-validated models.

Background:



MAHD concept of operations



Full testbench in front of wind tunnel at Caltech-CAST

Approach and Results:

1. Designed and built 20%-scale experimental static test-bench including MSH model and a cold-gas jetpack analogue, in Caltech- CAST wind tunnel facility. 4-day test campaign to collect in-situ flow measurements and force/moment data.
2. Successfully built fully-integrated jet-rotor-wind Mars CFD simulations of the Mars case. Confirmed FY21 preliminary results. Mesh, boundary conditions, and simulation is underway to match the experimental 1-atm / 1-g setup.
3. Built a Finite Element Model (FEM) of the jetpack in NASTRAN, using a set of rigit pointmasses to model the trusters, tanks and MSH. Led to modified jetpack structure to meet flex mode requirements for force-torque sensing and trimming the rotors before take-off.
4. New MAHDCAT high-fidelity GNC simulation. Includes HeliCAT3, jetpack dynamics, aerodynamics of the structures, closed-loop pulsed thruster controls, and flex modes. Preliminary results confirms force-torque sensing disturbances are well separated from the wind signal (0.1-1 Hz).

Significance/Benefits to JPL and NASA:

- MAHD jetpack concept to TRL 4 through experimental test campaign in laboratory environment and simulations.
- Raising the TRL of MAHD is critical to enable in-situ mobility science missions at Mars at a lower cost than previous missions.

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Clearance Number: CL#
Poster Number: RPC#

Publications:

Delaune et al., “Mid-Air Helicopter Delivery at Mars Using a Jetpack”. IEEE Aerospace Conference, Big Sky, Montana, March 2022.

Delaune et al., “Jetpack Concept for Mid-Air Helicopter Delivery at Mars” presentation, IPPW, September 2022

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