Completed Project (2011 - 2014)

Morpheus Vertical Test Bed (VTB)/Autonomous Landing and Hazard Avoidance Technology (ALHAT) Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

The AES Morpheus Vertical Test Bed (VTB)/Autonomous Landing and Hazard Avoidance Technology (ALHAT) project provided an advanced, reusable, integrated vertical test bed (VTB) platform for developing and maturing multiple human exploration subsystem technologies in a flight-like dynamic environment, including precision landing and hazard avoidance; Guidance, Navigation and Control (GN&C); advanced LOx-Methane propulsion; and other lander technologies.

ANTICIPATED BENEFITS

To NASA funded missions:

The technology has potential benefits and applications for use on the Resolve Prospector Mission and the Mars 2020 mission. The major benefits include development of reusable lander technologies including use of non-toxic propellants; assurance of safe landing sites for crewed or robotic vehicles on any solid planetary body on a wide variety of terrain and surface conditions; improved pin-point landing accuracy; and improved affordability of future spacecraft using these systems.

To NASA unfunded & planned missions:

The major benefits include development of reusable lander technologies including use of non-toxic propellants that could be used for multiple destinations; assurance of safe landing for crewed or robotic vehicles on any solid planetary body on a wide variety of terrain and surface conditions; and improved affordability of future HEO systems using these systems. Mission affordability is improved by reducing or eliminating the need to deploy/maintain orbital and ground navigation infrastructure.

To other government agencies:

Same as anticipated benefits to "NASA funded missions" and "NASA unfunded & planned missions" above.

Morpheus Free Flight 11 on April 24, 2014 with ALHAT in open loop

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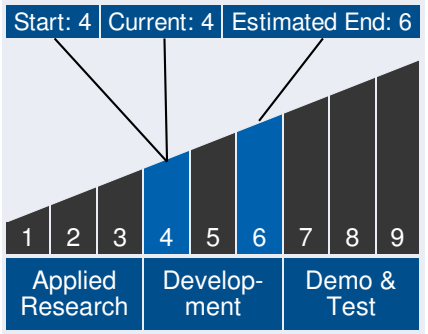
Technology Maturity



To the commercial space industry:

Same as anticipated benefits to "NASA funded missions" and "NASA unfunded & planned missions" above.

To the nation:

Same as anticipated benefits to "NASA funded missions" and "NASA unfunded & planned missions" above.

DETAILED DESCRIPTION

The Morpheus VTB/ALHAT project free flew a reusable Morpheus VTB with the integrated ALHAT system starting from a slant range of approximately 500 m to the landing target at the KSC Shuttle Landing Field (SLF), ascended to about 250 m and descended to a safe landing site, and demonstrated an autonomous closed-loop landing. This flight demonstrated real-time hazard detection and hazard avoidance, followed by a divert maneuver to the determined safe landing aim point, and a safe, controlled landing within a hazard field. This demonstration flight was a culmination of a series of earlier test flights, starting with improvements to the LOx-Methane propulsion system, GPS navigation, integrated reaction control system, and incrementally increasing in complexity by incorporating ALHAT sensor data. The project yielded not just technologies, but technologies integrated as capabilities that can then be easily adapted to human spaceflight mission architectures.

Management Team

Program Director:
- Jason Crusan

Program Executive:
- John Warren

Project Manager:
- Jon Olansen

Technology Areas

Primary Technology Area:
Entry, Descent, and Landing Systems (TA 9)
└ Descent and Targeting (TA 9.2)
  └ Autonomous Targeting (TA 9.2.8)
    └ Autonomous Hazard Detection and Avoidance (TA 9.2.8.4)

Secondary Technology Area:
Entry, Descent, and Landing Systems (TA 9)
└ Descent and Targeting (TA 9.2)
  └ Terrain-Relative Sensing and Characterization (TA 9.2.7)
    └ Advanced Sensors for Real-Time Three-Dimensional (3D) Terrain Mapping (TA 9.2.7.2)

Continued on following page.

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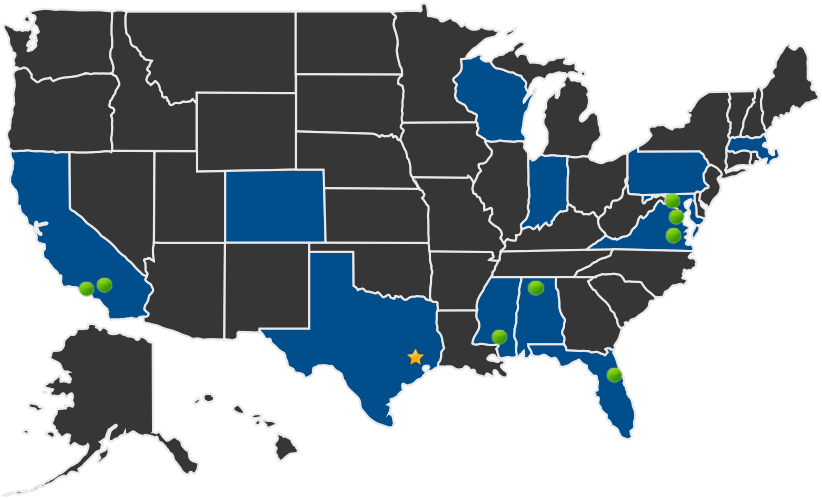
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Johnson Space Center

Supporting Centers:

- Dryden Flight Research Center
- Goddard Space Flight Center
- Jet Propulsion Laboratory
- Kennedy Space Center
- Langley Research Center
- Marshall Space Flight Center
- NASA Headquarters
- Stennis Space Center

Technology Areas *(cont.)*

Additional Technology Areas:

Entry, Descent, and Landing Systems (TA 9)
- Aeroassist and Atmospheric Entry (TA 9.1)
  - Deployable Hypersonic Decelerators (TA 9.1.4)
    - Advanced Guidance and Navigation Systems (TA 9.1.4.6)
- Descent and Targeting (TA 9.2)
  - Terrain-Relative Sensing and Characterization (TA 9.2.7)
    - Advanced Sensors for Spacecraft Velocimetry and Altimetry (TA 9.2.7.1)
- Landing (TA 9.3)

Other Organizations Performing Work:

- Applied Physics Laboratory
- L-3 Communications
- Marquette University
- Microcosm, Inc. (Hawthorne, CA)
- Oceaneering Space Systems
- Purdue University
- University of Texas
- UT El Paso-CSETR

Contributing Partners:

- Armadillo Aerospace
- Astrobotic Technology, Inc.
- Boston Power
- Jacobs Engineering
- Masten Space Systems, Inc.
- Space Center Houston
- United Launch Alliance
- European Space Agency

IMAGE GALLERY

Morpheus Vertical Test Bed (VTB)/Autonomous Landing and Hazard Avoidance Technology (ALHAT)

DETAILS FOR TECHNOLOGY 1

Technology Title

Morpheus Vertical Test Bed (VTB)/Autonomous Landing and Hazard Avoidance Technology (ALHAT)

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The Morpheus VTB/ALHAT project free flew a reusable Morpheus VTB with the integrated ALHAT system starting from a slant range of approximately 500 m to the landing target at the KSC Shuttle Landing Field (SLF), ascended to about 250 m and descended to a safe landing site, and demonstrated an autonomous closed-loop landing. This flight demonstrated real-time hazard detection and hazard avoidance, followed by a divert maneuver to the determined safe landing aim point, and a safe, controlled landing within a hazard field. This demonstration flight was a culmination of a series of earlier test flights, starting with improvements to the LOx-Methane propulsion system, GPS navigation, integrated reaction control system, and incrementally increasing in complexity by incorporating ALHAT sensor data. The project yielded not just technologies, but technologies integrated as capabilities that can then be easily adapted to human spaceflight mission architectures.

Capabilities Provided

The Morpheus VTB/ALHAT project will provide advanced, reusable, integrated lander/payload technologies, including the capability to achieve an autonomous, safe, pin-point landing on any solid planetary body on a wide variety of terrain and under any lighting conditions. These lander technologies, including non-toxic propellant propulsion, would be applicable to a variety of potential HEO surface destination missions, including those involving robotic and/or crewed exploration.

Potential Applications

Potential applications for this technology is pin-point landing accuracy for locating and landing on safe landing sites, autonomous controls, and potential for reusablity for surface landers for crewed and robotic missions to the Moon and Mars.

Performance Metrics

Metric	Unit	Quantity
Landing Precision (prioximity to target site)	m	3
Velocimeter measurement improvements	factor	ten