6th International Workshop on
Verification and Testing of Space Systems

Session 9
Special Tests

Testing the Mars Helicopter

Author:
G.L. Seal, Jet Propulsion Laboratory, California Institute of Technology

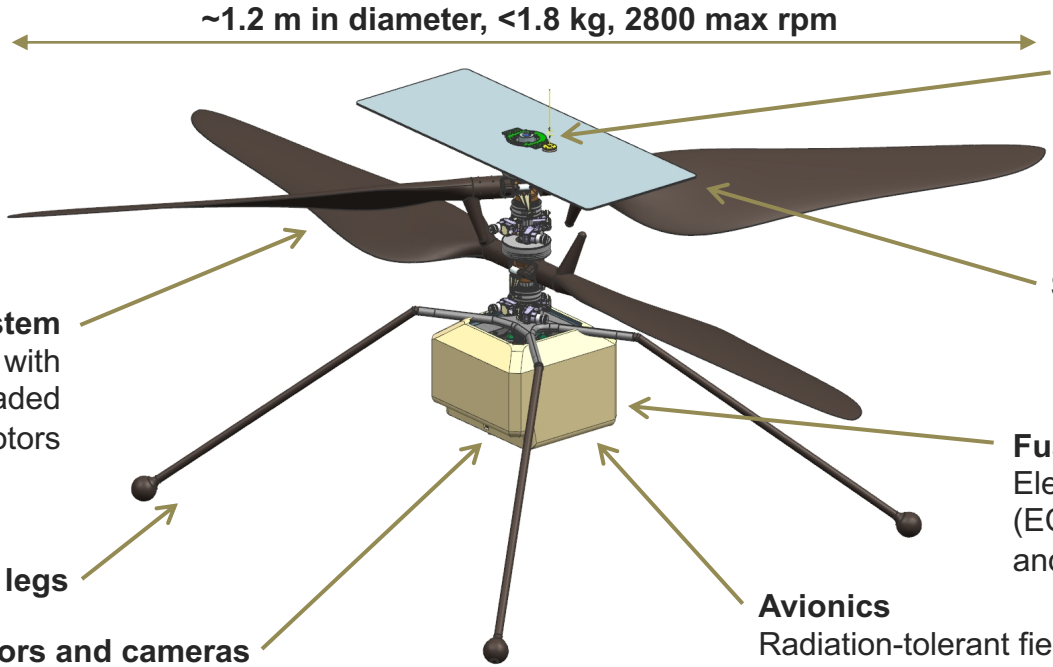
SPEAKER: Gabriella L. Seal
e-mail: Gabriella.L.Seal@jpl.nasa.gov

Torino, 21 – 22 – 23 May 2019

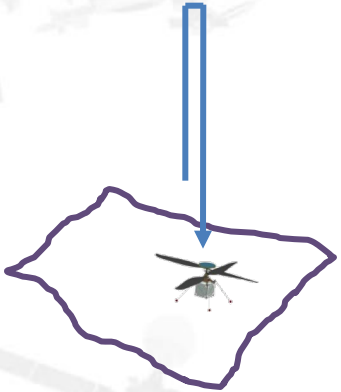
Agenda

- Overview of the Mars helicopter technology demonstration
- Testing the Mars helicopter
  - Key challenges
  - Our approach
  - Results and discussion
- Conclusions and acknowledgements

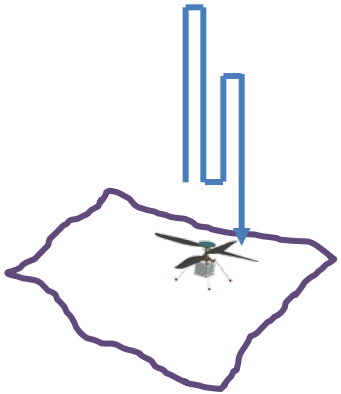
Overview of the Mars Helicopter



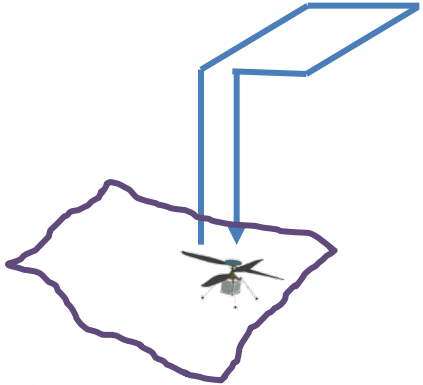
Helicopter Technology Demonstration (Notional)



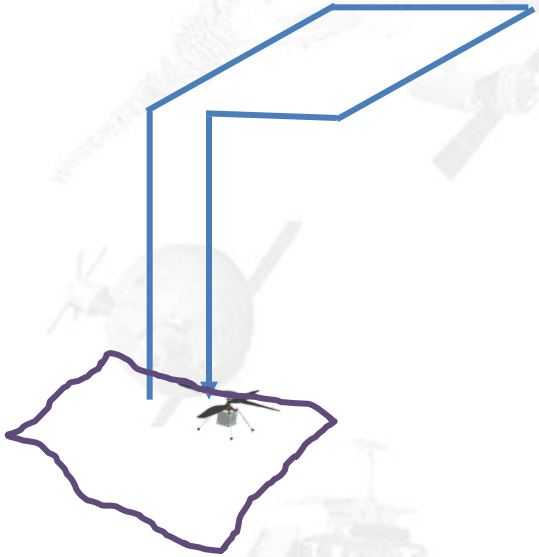
Flight 1
Ascend, hover, land



Flight 2
Vertical ascent and descent profiles at different thrust settings



Flight 3
Lateral flight path that returns to starting point



Flights 4–5
More challenging flight paths (e.g., larger lateral flights that return to safe experiment area, increased altitude)

Key Challenges

- Cost and schedule constraints
  - Limited budget, no room for error
- Unknown delivery system
  - Uncertain vibration and shock environment, boundary conditions
- Helicopter unable to lift its own weight on Earth
  - Need sophisticated support equipment
- No joystick
  - Helicopter must fly autonomously in a range of environmental conditions (ground terrain, wind speed and direction, etc.)

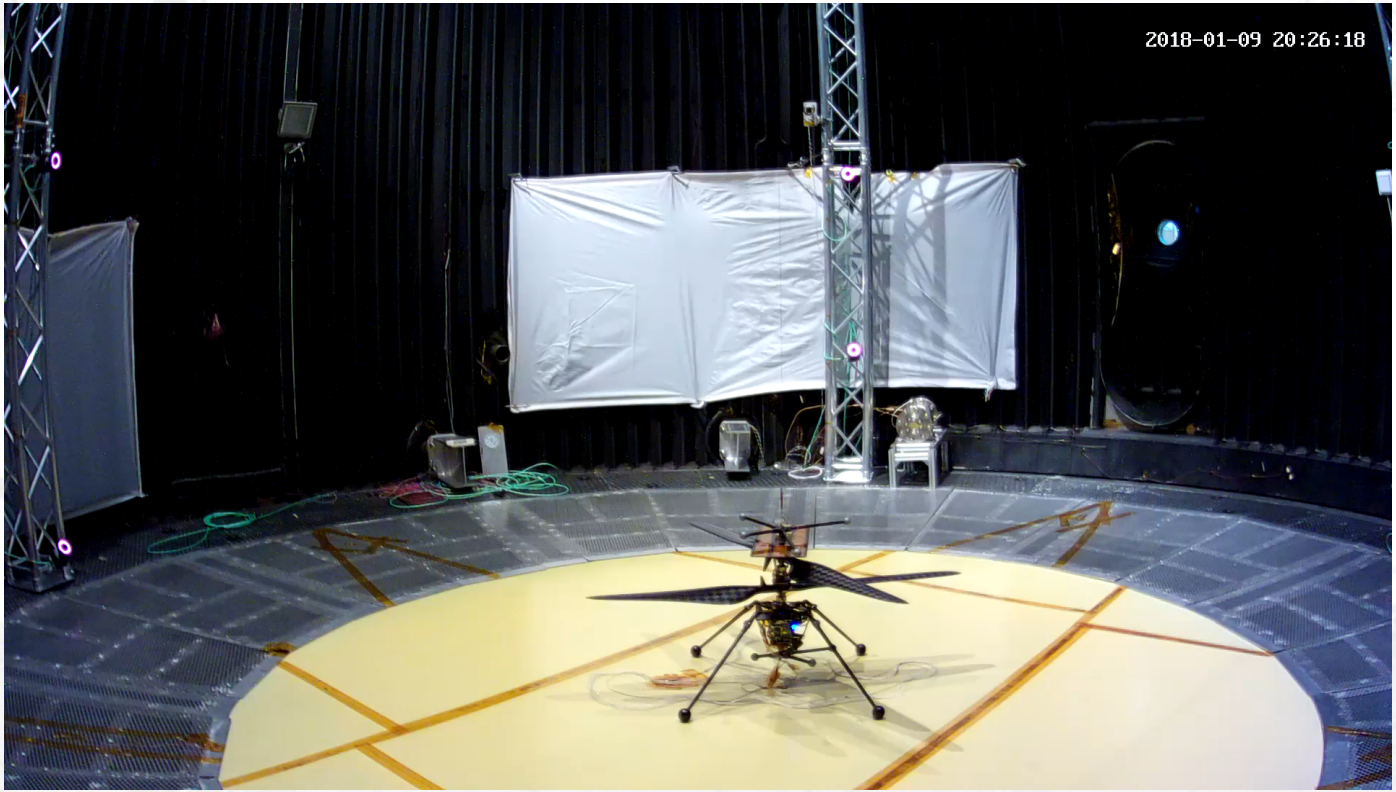
Our Approach

- **Modeling and analysis** of flight dynamics to inform design of both the vehicle and the control algorithms
- Limited **system identification testing** to characterize the flight dynamics of the as-built vehicle in partially replicated Mars conditions
- **Engineering development model** (EDM) helicopter as a learning platform for vehicle and test fixture characterization

(Partially) Replicating Mars Conditions

- Mars gravity
  - Gravity offload system
  - Tether affects the fidelity of the system dynamic response
- Steady-state wind
  - Low-speed swing-arm motions, high-speed wind wall with fixed helicopter
- Terrain
  - Mock surfaces, visual targets with appropriate lighting for navigation

Hover Test, Engineering Development Model



Flight Helicopter Test Campaign

- Environmental testing
  - Thermal vacuum/Mars pressure to validate survival energy predictions and demonstrate start-up and functionality at cold
  - Random vibration with delivery system
  - Shock (via deployment device firings)

- Abbreviated system identification testing
  - Full spin in Mars atmosphere
  - Motor characterization at hot and cold

Conclusions

- Many exceptions to the “test as you fly” principle
  - Have not tested helicopter with base station
  - Have not demonstrated flight at colder than room temperature
  - Have not fully simulated Mars wind conditions, particularly transient gusts
  - Have not tested navigation sensors (camera, lidar) with realistic Mars terrain
  - Have not tested helicopter take-off or landing with realistic Mars terrain, particularly slope

- However, the piecemeal approach used in the EDM and FM helicopter test campaigns gives us confidence that the helicopter will operate as intended during the mission

Thank you: Michael Kokorowski, MiMi Aung, Bob Balaram,
Havard Grip, and the rest of the helicopter team