Advancing Technologies: The Morpheus Project

Morpheus Team, *Johnson Space Center*

Morpheus is a vertical test bed demonstrating new green propellant propulsion systems and autonomous landing and hazard detection technology (figure 1). Designed, developed, manufactured, and operated in-house by engineers at NASA's Johnson Space Center (JSC), the Morpheus Project represents not only a vehicle to advance technologies, but also an opportunity to try out "lean development" engineering practices.

Morpheus is a NASA-designed vehicle.

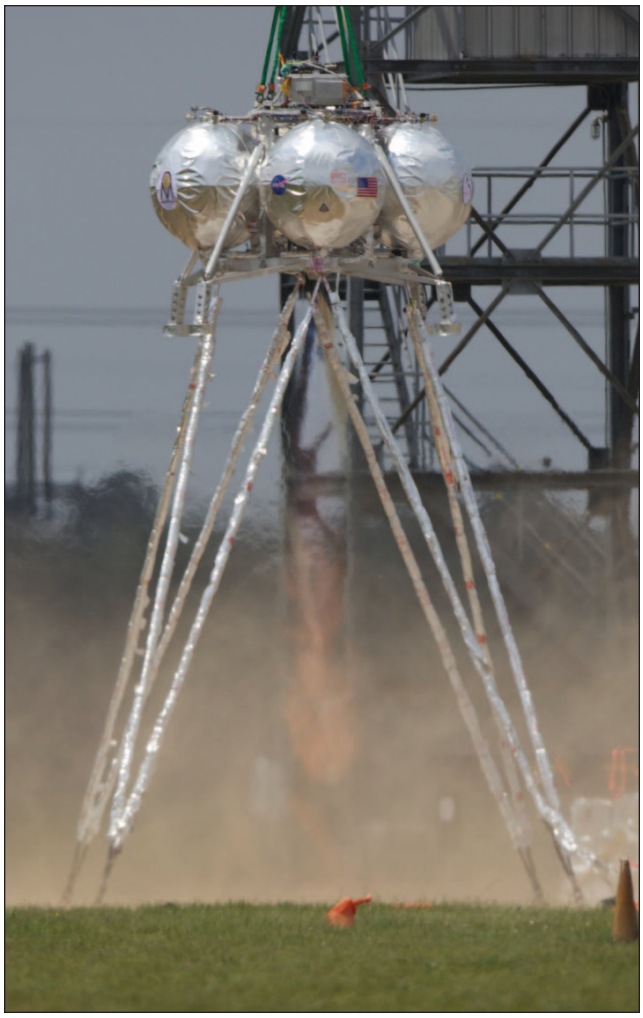

Fig. 1. *Morpheus test firing.*

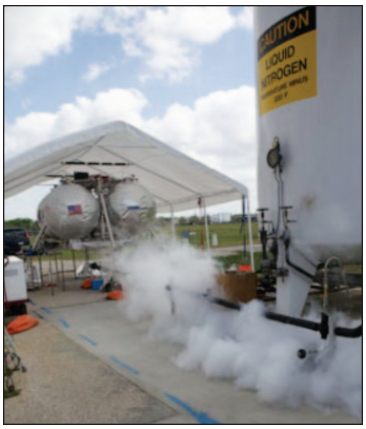

Fig. 2. *Cold flow test.*

Morpheus was manufactured and assembled at JSC and Armadillo Aerospace (Heath, Texas). Morpheus is large enough to carry 499 kg (1100 lbs) of cargo—e.g., a humanoid robot, a small rover, or a small laboratory to convert moon dust into oxygen—to the moon, performing all propellant burns after the translunar injection. The primary focus of the test bed is to demonstrate an integrated propulsion and guidance, navigation, and control system that can fly a lunar descent profile to exercise the Autonomous Landing and Hazard Avoidance Technology safe landing sensors and closed-loop flight control. Additional objectives include technology demonstrations—for instance, tank material and manufacture, reaction control thrusters, main engine performance improvements, helium pressurization systems, ground operations, flight operations, range safety, software, and avionics architecture.

Morpheus is a full spacecraft, with all the associated subsystems: avionics; software; guidance, navigation and control; power; power distribution; structures; propulsion; and instrumentation. Morpheus' propellant combination—liquid oxygen and methane—is of particular interest for a number of reasons (figure 2). It can be stored for longer times in space, compared to other common propellants such as liquid hydrogen.

It is extremely cheap and safe to operate and test, and performs better—much more so than hypergols, another type of fuel often used in space flight.

In addition, the methane can also be made from ice on the moon or Mars. In fact, about 454 kg (1000 lbs) of methane are produced on International Space Station and dumped overboard as waste gas every year—enough to entirely fill the Morpheus lander.

For in-space propellant transfer, Morpheus uses the propellant of choice for future missions that would use in-space refueling and/or depots. In addition, the lander has all the systems required for automated rendezvous and docking. With modification of the propellant and pressurization system for transfer plumbing and a docking mechanism that meets the international docking standard, two landers could rendezvous in low-Earth orbit and demonstrate all the key technologies required for in-space propellant transfer and storage of mid-temperature range cryogenic propellants. For an asteroid rendezvous, the lander would need more study, but conceptually the lander may have most of the systems needed to attempt an asteroid rendezvous. The precision landing system for Project Morpheus, with some modification to the software, could be used as is to rendezvous with an asteroid.

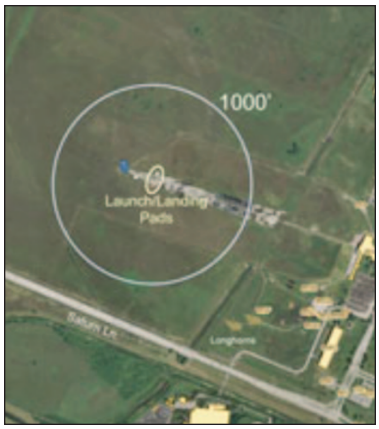

Fig. 3. *Distances from surroundings.*

The workforce behind Project Morpheus has gained valuable experience that will provide the cornerstone for design of future missions. In addition, the project is setting mid-range performance and design requirements that will drive down the production cost of future landers. Project Morpheus is taking the lessons learned from our industry partners to facilitate this alternative design approach.

Morpheus is actually the second vertical test bed built by the project team. The first, Pixel, was literally constructed from spare parts from Armadillo Aerospace through an Innovative Partnership Agreement. NASA converted the Pixel lander to use liquid oxygen and methane as its fuel, instrumented the vehicle and conducted early guidance, navigation, and control testing. Pixel was flown last year under tether 17 times and three free flights at Armadillo's facility near Dallas.

Vertical Test Bed Flight Complex

Morpheus is being tested at the Vertical Test Bed Flight Complex at JSC. Careful consideration has been given to the surroundings when planning thrust levels and future trajectories (figure 3). While we don't expect any complications, Morpheus has multiple safety controls including onboard soft abort systems and a wireless Flight Termination System. In addition, during a free flight, spotters are being placed in multiple locations to ensure that if the vehicle goes outside of the established flight path, the engine will be immediately shut down.

The Vertical Test Bed Flight Complex has three different pads that will be used for Morpheus testing (figure 4). The single pad on the west end of the complex is used for both hot fire and tethered tests.

A crane is used during both tethered and hot fire testing. During hot fire testing, the vehicle is also strapped to the ground. This allows the vehicle to remain virtually motionless during engine firings. The other two pads are used for free flights. During a free flight, Morpheus will fly up to a height of around 30 m (98 ft), then translate over to the western pad and descend for a soft landing.

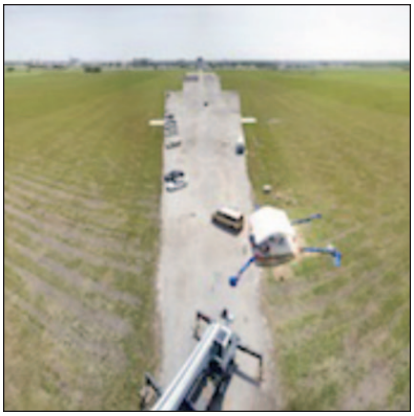
Fig. 4. *Tower view panorama.*