A Mach 0.8, 40,000 ft. Challenge

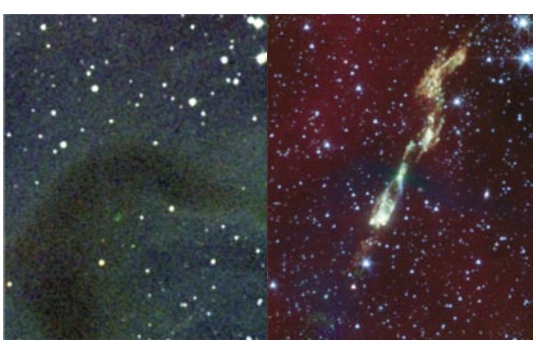
MPC Products Corp., based in Skokie, Illinois, USA, has developed an actuator control system that will be used by NASA to control a drive system for the Cavity Door System that covers a large cavity in the rear fuselage of a modified Boeing 747 housing a large infrared telescope. The telescope is the largest to ever be placed in an aircraft and will aid in the study of infrared light emitted from astronomical objects, including complex molecules, new forming solar systems and black holes. MPC is using several dSPACE tools to design the control software for this very unique project.

- **NASA project: Stratospheric Observatory for Infrared Astronomy (SOFIA)**
- **Challenge to open and close a cavity door during flight**
- **Safety-critical control strategies developed with tools from dSPACE**

MPC Products Corp. is completing the final testing phase on a more than four-year NASA project to develop an actuator control system that will mechanically operate a cavity door drive system (CDDS) for the largest telescope ever to be placed in an aircraft. The reflecting telescope will allow scientists to study distant astronomical objects such as stars, comets, asteroids, forming solar systems and black holes. It is being permanently installed inside of an airborne astronomical observatory – a modified Boeing 747SP referred to by NASA as SOFIA (Stratospheric Observatory for Infrared Astronomy).

Necessity for Stratospheric Observation

With its 2.5-meter aperture, the SOFIA telescope will be capable of making observations that are impossible for even the largest and highest of ground-based telescopes. The telescope, provided to NASA by the DLR (German Aerospace Center), is designed to detect the infrared light or energy that is emitted from many different kinds of astronomical objects. Most forms of infrared light/energy are blocked by water vapor in the Earth's atmosphere, making it almost impossible to view from ground-based telescopes. But flying at about 40,000 feet above ground, the SOFIA telescope will have the capability to detect infrared light 100 to 1,000 times greater than ground-based telescopes.



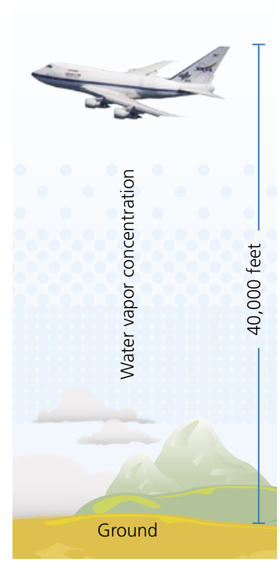
▲ *The young star L1157 in visible light (left) and an infrared image of the same star (right). In visible light, this star appears black. Credit: NASA, JPL Cal Tech, L. Looney (University of Illinois).*

Door to the Sky

One of the key engineering aspects necessary to achieve this remarkable observation capability is through the design of the CDDS. The challenge, according to MPC Program Manager Chris Wall, was to design an actuator control system capable of opening and closing the large telescope cavity door on an airplane flying at Mach 0.8 – about 500 mph – at 40,000 feet altitude. In addition to speed and altitude, MPC had to take other load factors into consideration, including ice formation, inertial loads and gravitational forces.

"This has certainly been the most comprehensive software project we've undertaken," Wall said. "Within the next six months, we will be delivering (to NASA) the hardware that will be going on the aircraft to open and close the door system."

MPC Systems Lead Engineer Matt Polley explained that the telescope is run by a computerized control system, which drives electromagnetic motors to move the telescope into position. The doors are required to follow close to the telescope as it moves, relative to the aircraft maintaining position on the observed object. "The control system we designed for the doors con-



▲ *At 40,000 feet (approx. 12 km), the water vapor has gone down by a factor of about one thousand.*

sists of two redundantly driven actuators commanded by an electronic control unit," Polley said. "Accurate position and speed control are a critical part of the door design. If the door doesn't move correctly, if it moves too fast, or if it goes beyond the set limits, it could damage the aircraft and cause a catastrophe."

Algorithm Design

To develop the actuator control system, MPC's team designed a test set up to simulate the system's opera-

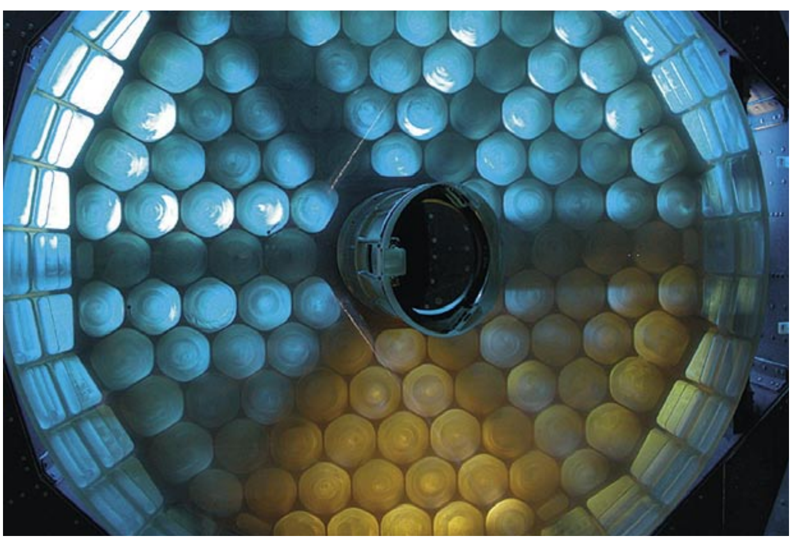
> *"This has certainly been the most comprehensive software project we've undertaken."*
> ***Chris Wall, MPC Products Corporation***

tional environment utilizing dSPACE tools. A modular system was established with a dSPACE DS1005 processor board to achieve real-time and high sampling rates, a dSPACE resolver card, a dSPACE encoder card, and a dSPACE DS2201 analog-to-digital multi-I/O board designed for applications requiring a lot of varying I/O types. Polley said the dSPACE tools were used to fine-tune the control design and generate a control methodology for simulating the aerodynamic and gravitational loads that the CDDS will encounter during actual operation. More than 400 system-level requirements had to be taken into consideration as part of the design process. "A crucial element of this project was to simulate the roll and gravitational loads that the actuators will experience during aircraft operation," Polley said. "Because this behavior could

not be defined as a linear function, we had to custom-build a computer system to do closed-loop controls. The system is quite large in terms of the loading, and is more complex than our normal dynamometers, which have lower torque output."
"It was a major challenge to wrap our hands around

> *"The dSPACE tools were used to fine-tune the control design and generate a control methodology for simulating the aerodynamic and gravitational loads that the cavity door drive system of NASA's SOFIA program will encounter during actual operation at 40,000 feet."*
> ***Matt Polley, MPC Products Corporation***

the software development aspect," Polley continued. "We used dSPACE tools to aid in our development process. The tools are very adaptable and are being used on multiple projects here at MPC."



◀ Sky light seen through the 2.5-meter SOFIA primary mirror. Picture taken before the mirror received its opaque aluminum coating. Foto: Stratospheric Observatory for Infrared Astronomy (SOFIA) Education and Public Outreach (E/PO) Universities Space Research Association (USRA).

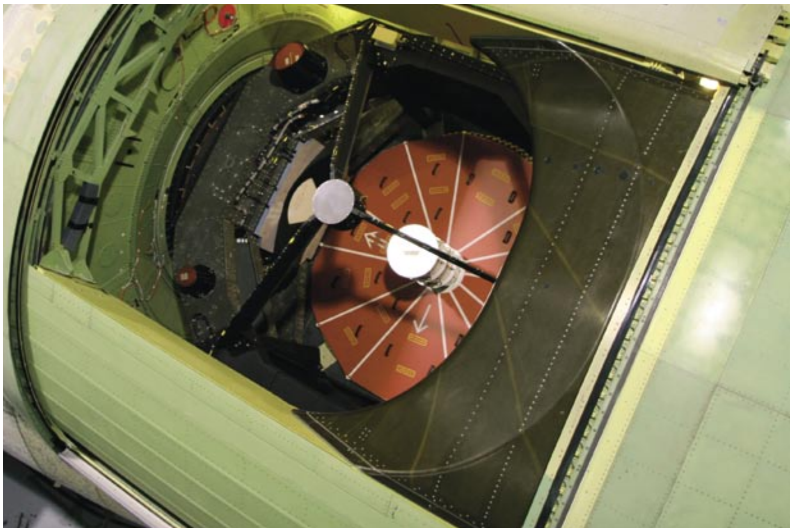
▲ *Boeing 747SP during a test flight. The SOFIA infrared telescope is installed in the rear fuselage.*

Testing Phase

MPC is wrapping up the final production phase of its first development units. The company is preparing to start a "testing only" phase to prove that its actuator control design works by simulating all conceivable conditions that may be encountered while the telescope and CDDS are in operation and airborne. NASA will obtain the equipment and start testing the CDDS independently in August of 2008.

"We have an excellent team in place," Wall said. "We've been working directly with NASA to streamline the software to their expectations. There has been a lot of collaborative effort." MPC will be on site to support NASA with the integration of the Cavity Door System and actuator control system onboard the SOFIA aircraft. MPC will also assist NASA as it prepares to engage open door flight testing, which will result in the first infrared pictures of constellations.

For more information on the SOFIA program, visit www.sofia.usra.edu
For more information on MPC Products Corporation, visit www.mpcproducts.com



◀ *The telescope that is the heart of NASA's Stratospheric Observatory for Infrared Astronomy is nestled in the SOFIA 747's rear fuselage. The door opens and closes like an eyelid.*
Photo provided by NASA, USRA (Universities Space Research Association), and L-3 Communications Integrated Systems.