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$10,000 "Move It!" Lemelson-MIT Student Prize Undergraduate Team Winner

Modal Propellant Gauging (MPG): A system that provides real-time fuel gauging for aircraft and spacecraft

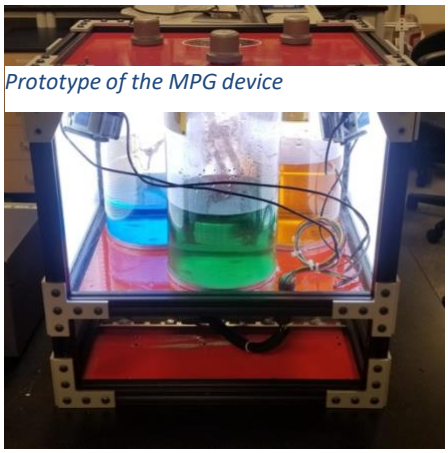
**The Challenge:** Fuel volume gauging during dynamic events like acceleration has been a long-standing challenge to aeronautical transportation. Fuel gauges on spacecraft and aircraft are notoriously ineffective against things like temperature change, fuel chemistry, or sloshing of fuel due to turbulence. As a result, reliable and robust fuel gauges do not exist.

Pilots are accustomed to the fact that cockpit fuel gauges are only able to correctly reflect fuel volume when the fuel tank is completely full or completely empty. There are an average of more than 1,200 plane crashes in the U.S. each year.[1] Fuel gauging errors are one of the leading causes behind these crashes.[2] To compensate for fuel gauging inaccuracies, pilots are forced to carry more fuel than necessary. In the spacecraft industry propellant gauging has been an issue for at least 50 years: a dropping fuel indicator and a persistent alarm caused moments of anxious uncertainty just before the Apollo 11 Lunar Module landed on the moon. Inaccurate fuel gauging results in over $1B in lost revenue annually in the commercial satellite industry.[3]

**The Solution:** The team's invention, Modal Propellant Gauging (MPG), is a technology that provides accurate, real-time fuel gauging for aircraft, spacecraft, tankers, and other vessels that carry sloshing liquid fuel. MPG uses the well-established technique of modal analysis, which incorporates acoustic vibration and sensors as a form of measurement. In this case, small, flexible patch sensors are applied to the outside of the fuel tank wall and are used to measure

1 https://www.ntsb.gov/investigations/data/Pages/aviation_stats.aspx.
2 https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=21274.
3 MIT. https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-851-satellite-engineering-fall-2003/lecture-notes/l15_costmodellec.pdf.

the contained liquid inside the tank. The MPG technology "listens" to the tank's vibrations excited by random impulses from the acoustic environments. In much the same way that running one's finger along the rim of a wine glass can excite tones that uniquely correspond to the level of liquid in the glass, the MPG can extract the fill level of contained liquids inside a tank, even under dynamic events that cause sloshing and rolling of the propellant or fuel.



*Prototype of the MPG device*

The MPG has electronic and software components that collect, interpret and store data from the sensors on the tank, and report the fuel level back to the pilot in the cockpit. MPG requires minimal calibration, works on both composite and metallic tanks, all types of fuel, and has a gauging resolution that increases with accuracy as the tank empties.

The MPG approach was conceived for zero-gravity space applications by the students' faculty advisor and his colleagues at NASA. The Carthage student team adapted this technology, developing smaller, lower-power versions of MPG that are suitable for aircrafts. The student team also wrote the software that adapts the MPG spacecraft approach to the more complex geometries of aircraft fuel tanks.

**Commercialization:** Due to its light weight and noninvasive application, the MPG can be incorporated into both future and existing aircraft and spacecraft without necessitating any major design changes to existing propellant management architecture. The team has tested the MPG and confirmed its efficiency and accuracy. MPG has been tested on manned parabolic flights and flown on Blue Origin's New Shepard vehicle, an unmanned suborbital rocket that allows for approximately three minutes in zero gravity.

The team has already been in talks with market leaders and companies, including an aircraft company and several space systems providers, which expressed interest in the MPG technology. The team has also conducted informal interviews with pilots and aircraft manufacturers and received widespread interest and desire to see the technology as a market option.

The students estimate the initial market size for MPG in the private aircraft industry will represent 25% of the after-market fuel systems market. The team is currently in the process of negotiating patent licensing, and has plans to modify the MPG to make the technology more robust, require less power, have lower equipment cost, and be easier for factories to recreate for commercial use.