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NASA/ZeroG Microgravity Research

Pedro LLanos
PI, Embry-Riddle Aeronautical University

Sathya Gangadharan
CO-I, Embry-Riddle Aeronautical University

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Research Projects

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NASA/ZeroG Microgravity Research

Embry-Riddle Aeronautical University and Carthage College proposed a technology demonstration that has several advantages over passive slosh control. Relative to slosh baffles, the proposed MAPMD technology has a lower total mass, a much higher degree of surface wave suppression, and less volumetric intrusion into the tank. The MAPMD concept also is optimized for cylindrical tanks (unlike elastomeric diaphragms, which work only in spherical pressure vessels), and currently requires no structural design changes to existing cylindrical propellant tanks.

The objective of the current research project under PI Kevin Crosby (Carthage College and University of Texas Health Science Center in San Antonio) is to demonstrate the effectiveness of a low-gravity active-damping diaphragm in reducing the gauging uncertainty of the Modal Propellant Gauging (MPG) technology during propellant slosh. The active damping system relies on a cross-woven mesh of magnetic alloy film embedded in a polymer matrix and formed into a thin circular membrane that floats freely (in 1-g) on the surface of the propellant. The alloy has a large magnetic permeability and demonstrates strong magnetostriction (expansion) under a static applied magnetic field. When formed into a mesh, the alloy is a “smart material” that experiences dramatic changes in structural properties under an applied magnetic field, expanding and stiffening from a pliable mesh to a more rigid structure. A secondary effect of the interaction of the alloy with an applied magnetic field is that the mesh can be induced to accelerate along magnetic field gradients, generating forces on the liquid that can further damp slosh waves. It is the enhanced rigidity and the restorative damping force of the membrane that we exploit in this technology to suppress surface waves and to localize propellant during slosh. The active damping technology used in this technology demonstration has been under development for several years at Embry Riddle Aeronautical University. We refer to the mesh alloy embedded in the polymer matrix as a “Magnetoactive Propellant Management Device” (MAPMD). The MAPMD was developed by one of the authors of this proposal who, in partnership with Embry Riddle Aeronautical University, holds the patent for its application to slosh control (Sivasubramanian, et al., 2016). MAPMD has been demonstrated to suppress slosh in 1-g laboratory testing at the ERAU slosh facility with an effective reduction in slosh amplitudes of up to 50% for the low-mode rocking slosh commonly seen in low-gravity propellant slosh (Santhanam, et al., 2015).

Internal tank diaphragms have long been used in propellant management to control slosh. The diaphragm concept has evolved from elastomers with fixed boundaries on the inside walls of the tank to floating “micro-baffles” that move with the propellant to damp surface oscillations (Paul, 2016). While floating micro-baffles offer reliable slosh suppression in normal (1-g) gravity, the absence of a buoyant force in zero-g precludes their use in most space applications.

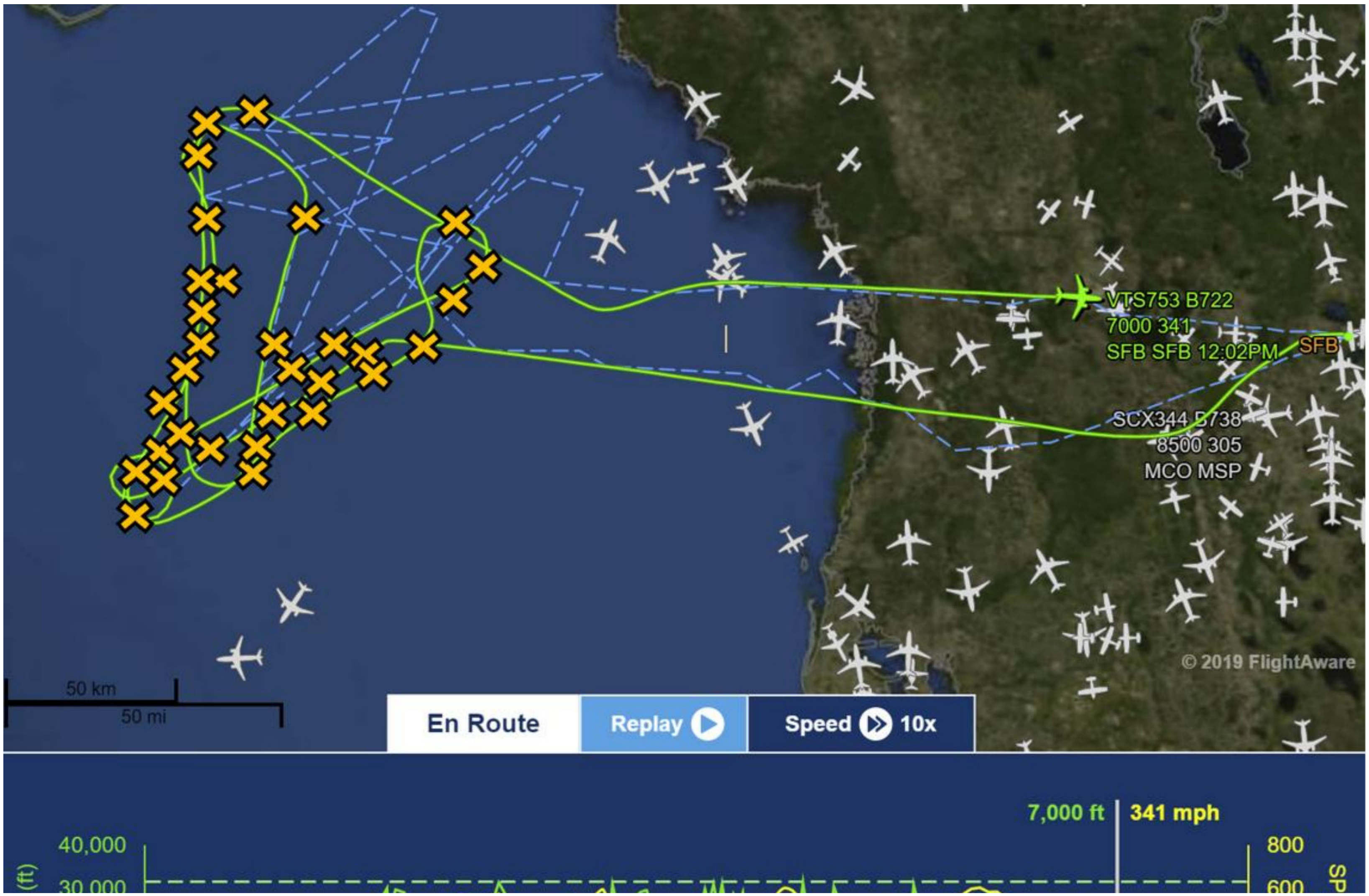
We proposed to test a hybrid of the existing MAPMD diaphragm in which an external magnetic field is used to position the free diaphragm near the top surface of the liquid in low gravity (where buoyant forces are not active). By adjusting the gradient of the magnetic field, the position of the diaphragm can be manipulated with high resolution, while the strength of the magnetic field determines the restorative forces applied to the sloshing liquid. The “Field Gradient Control” method of positioning a free-floating diaphragm is a new approach to propellant slosh mitigation that is both minimally invasive to the propellant tank (requiring only the free-float diaphragm inside the tank) and is scalable to large tank systems. The proposed test had three key objectives:

Objective 1: Demonstrate the ability to position the MAPMD diaphragm at the free surface of the liquid using field gradient positioning

Objective 2: Measure the reduction in slosh amplitude of low-gravity propellant simulant slosh when the MAPMD is activated (relative to passive diaphragm slosh suppression), and

Objective 3: Correlate the reduction in slosh amplitude with enhanced low-gravity gauging resolution of the MPG technology. The reduction in slosh amplitude will be measured relative to a free-floating but unactuated MAPMD.

Image below: Parabolic flight November 2019



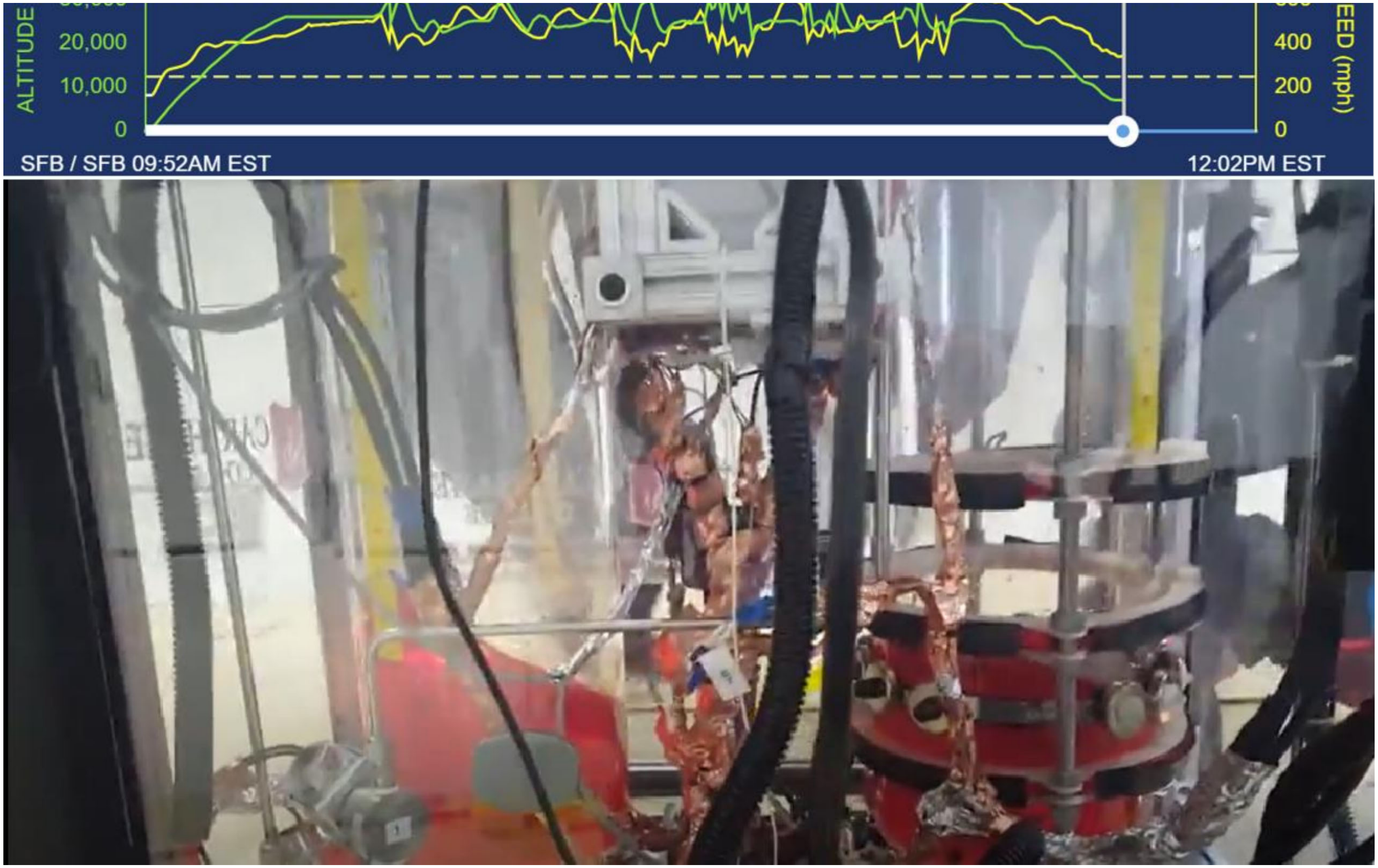
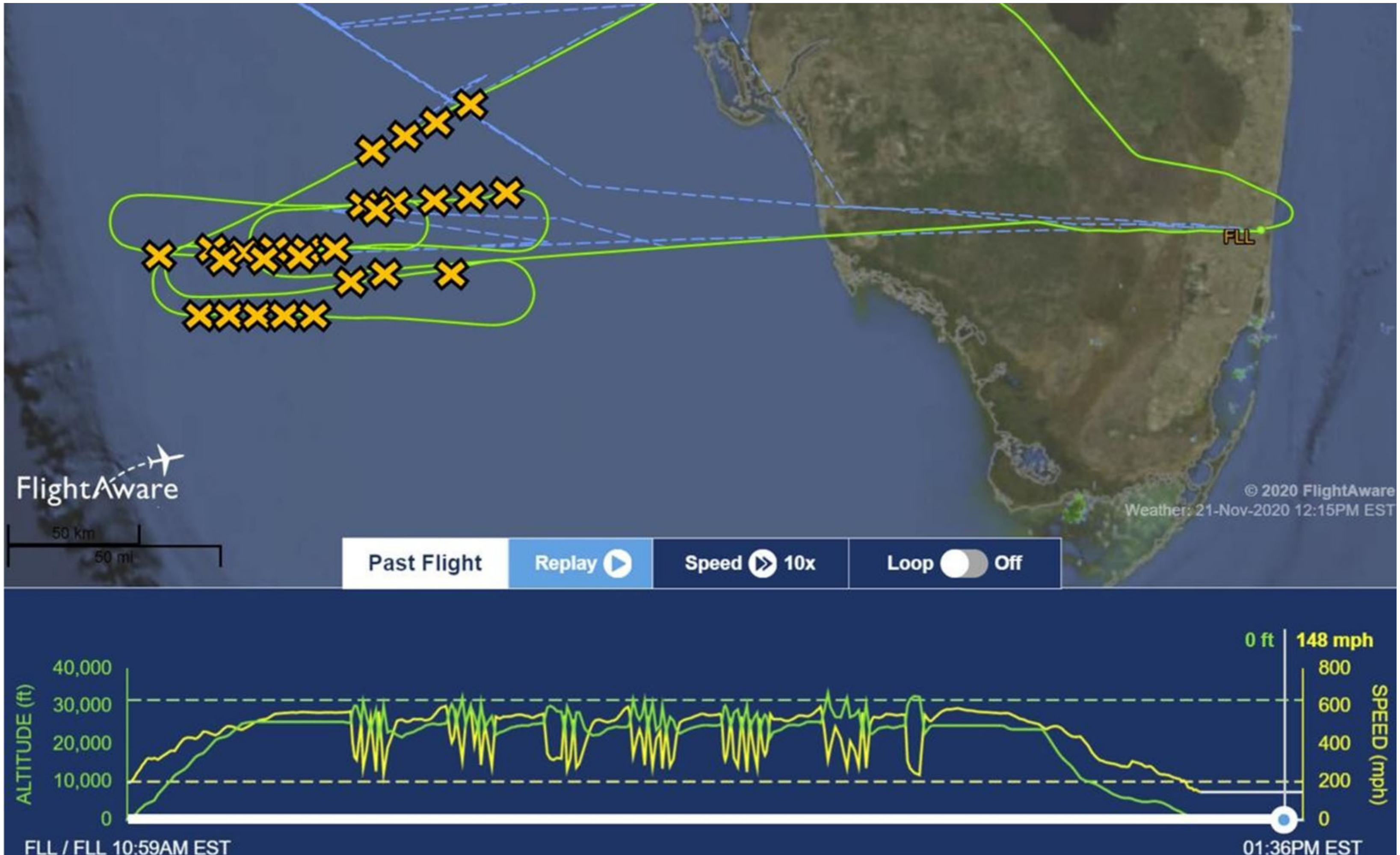


Image below: Parabolic flight November 2020


FlightAware
50 km
50 mi
FLL
© 2020 FlightAware
Weather: 21-Nov-2020 12:15PM EST
Past Flight
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Loop Off
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ALTITUDE (ft)
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30,000
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01:36PM EST


CARTHAGE COLLEGE
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Image below: Accompanied with Carthage College and ERAU students

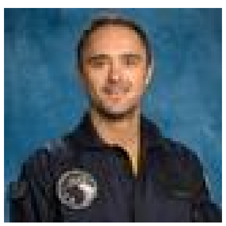
Research Dates

01/01/2018 to 12/31/2021

Researchers

Sathya Gangadharan

Mechanical Engineering Department
Ph.D., Virginia Polytechnic Institute and State University
M.S., Memorial University of Newfoundland



Pedro LLanos

Applied Aviation Sciences Department
Ph.D., M.S., University of Southern California
M.S., University of Oklahoma Norman Campus

Tags: **NASA Flight Opportunities Program , Modal Propellant Gauging Technology , Magnetoactive Propellant Management Device (MAPMD)**
Categories: **Faculty-Staff**