Low-Gravity MAss GAuging System (MAGA)

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Description --
The MAGA fluid mass gauging system is a non-invasive method based on excitation and measurement of acoustical resonant frequency modes that vary approximately with the inverse square root of the residual fluid/tank mass. Exact frequency variation depends on the nature of the structural support / tank system, its supports, etc., and the number of degrees of freedom in such a system. Longitudinal and transverse modes, as well as coupled modes and combination frequencies, may be observed. Resonance amplitudes also vary with mass, and those data provide independent confirmation of the fluid/tank mass determined using resonance frequencies alone.

The physical basis for the method is derived from the theory of small oscillations excited by forced resonance. Unlike some gauging methods, the mass sensitivity (dm/m) is best when the fluid mass is lowest. MAGA is a direct mass measurement method that is independent of the fluid type and requires no secondary fluid properties or numerical or thermodynamic algorithms. Regardless of fluid density, any equivalent fluid mass will produce the identical resonant frequency. Provided that the fluid is in contact with the tank wall, as is typical in a quiescent condition, the method works equally well in any gravitational environment, including zero g. It is independent of the fluid distribution, because frequency is independent of initial mass positioning. The method is also applicable to a subliming solid.

TRL --
The MAGA TRL is 4. Using an integrated MAGA system comprising a tank containing a variable fluid mass, its supports and vibration sensors, and a structural mounting frame, non-hysteretic data were obtained using miniature electronics components and a conventional DAS using Labview and mathematical analysis software. The test apparatus scale was equivalent to some non-cryogenic spacecraft fuel tanks.

Risk--
The risk level for this technology is very low. MAGA is an accurate yet inexpensive fluid mass gauging method, but implementation requires a good understanding of the physics of multi-mass spring systems and how to instrument them. The prototype cost for hardware and recent testing was < $5k. However, certain objectives as detailed in e) must be demonstrated to further reduce the risk for space-flight applications.

Development Work--

MAGA was originally proposed in response to NASA solicitation NNCO6ZPT001R in October 2005 in a Letter of Intent by N-Science Corp. A MAGA prototype was subsequently fabricated in late 2005 to early 2006, when initial data were obtained by adding non-fluid mass elements to the tank. The initial test setup used discrete component electronics, and crude resonance detection measurements using an oscilloscope, verified the expected frequency dependence on mass. From 2007 to 2010 SBIR proposals to NASA and DoD were not funded and MAGA was inactive. The most recent configuration of MAGA, funded by N-Science IRAD and a collaboration with the Colorado School of Mines Center for Space Resources, uses mostly the original hardware, but now water is the working fluid for adding or reducing the tank internal mass. The DAS also uses modern digital methods for best signal-to-noise ratio and detection of resonance. Results of testing during July and August 2011 have provided excellent monotonic data over the entire fill range for several tank orientations and methods of structure support in 1 g.

Planned Activities for Achieving TRL 5--

This readiness level requires a "representative environment" and "realistic supporting elements". As applied to MAGA, this would mean both ground testing in 1 g and a low-g demonstration in a NASA flight demo aircraft, and using a more space-like tank or dewar, e.g., an insulated cryogenic tank (perhaps containing LN2) with low heat leak supports (G10). The existing DAS electronics and PC would also need to be further miniaturized, and alternate frequency sensing technologies would need to be investigated and compared to the existing one.