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RRM3

RRM3 Fluid Management Device

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Introduction

The current development progress of the fluid management device (FMD) for the Robotic Refueling Mission-3 (RRM3) cryogen source Dewar is described. RRM3 is an on-orbit cryogenic transfer experiment payload for the International Space Station. The fluid management device is a key component of the source Dewar to ensure the ullage bubble is located away from the outlet during transfer. The FMD also facilitates demonstration of radio frequency mass gauging (RFMG) within the source Dewar. The preliminary design of the RRM3 FMD is a number of concentric cones of Mylar™ to maximize the volume of liquid in contact with the FMD in the source Dewar. This poster describes the design of the fluid management device and progress of hardware development.

System Configuration

The RRM3 Cryogenic Demonstration Subsystem (CDS) will transfer cryogen from a source Dewar to a receiver tank. An integral portion of the transfer process is the fluid management device (FMD) that functions in conjunction with the wick-heater autogenous pressurization system located in the source Dewar. The FMD is essential for several primary mission objectives and secondary technology demonstrations:

- Cryogen fluid management
- Fluid control for self-pressurization of source Dewar
- Primary mass gauging with Liquid/Vapor (L/V) detectors
- Maintaining stratified fluid conditions in the source Dewar
- Radio Frequency Mass Gauge (RFMG) technology demonstration

FMD Vane Analysis & Optimization

A figure of merit for predicting the performance of an FMD is the Bond number which is a ratio of body forces of a fluid to the surface tension force:

Relative liquid/vapor density ρ, gravitational acceleration g, and characteristic length L, describe the behavior of the bulk fluid in a form that is dimensionally compatible with the surface tension of the fluid σ. For Bond numbers less than 1.0, the surface tension dominates fluid behavior. For quiescent periods on-orbit the ISS, the bond number of a tank-sized characteristic length is around 0.2. The ultimate goal for FMD performance is to be capable of resisting accelerations of 50 µg. The number and spacing of the conical vanes is driven by the necessity to maintain short characteristic lengths and low Bond numbers.

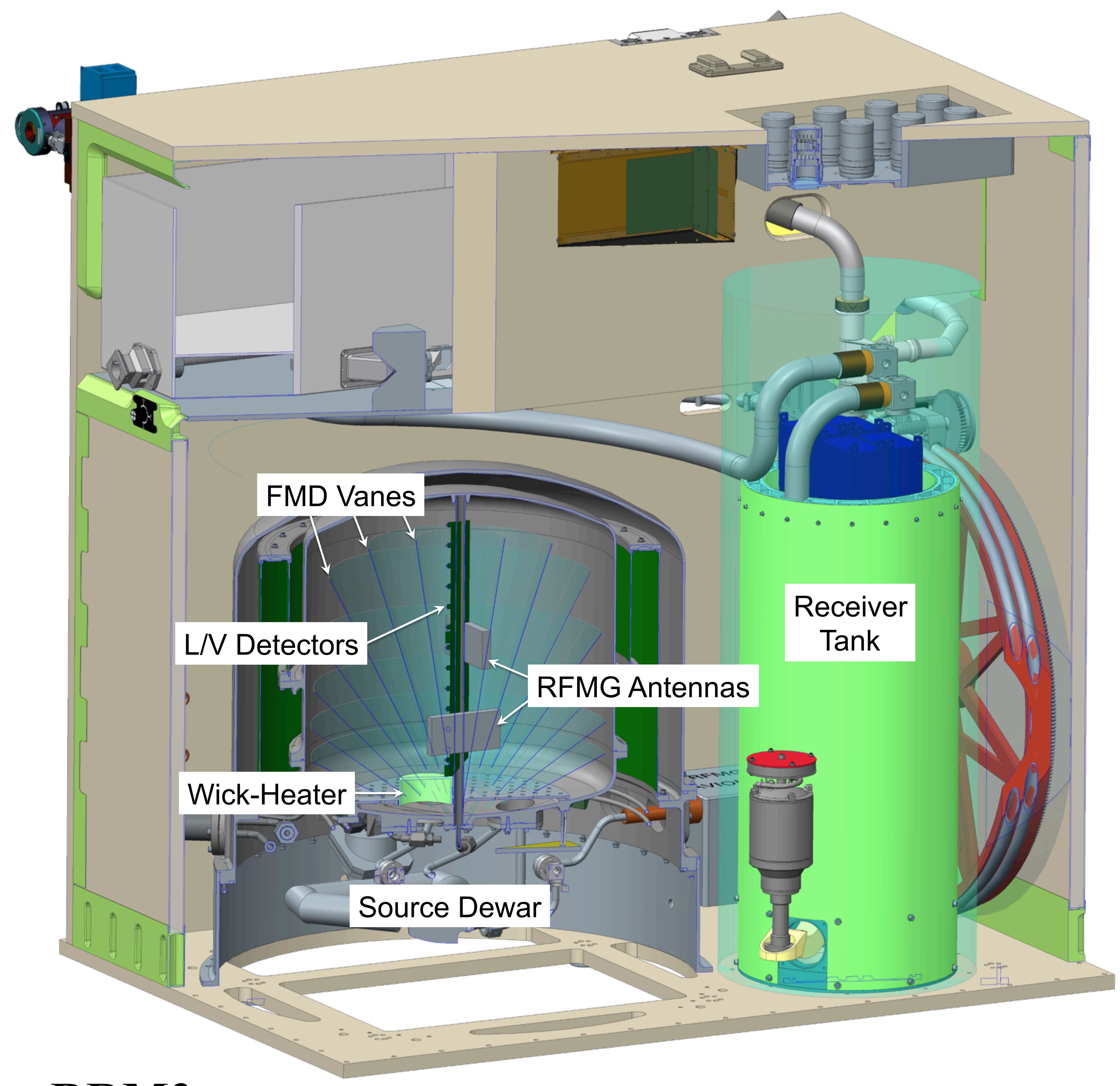
Ullage Shape Prediction

Surface Evolver (Ver. 2.7) was used to predict ullage bubble shapes and locations. Important analysis products for optimization of the FMD to meet flight requirements :

1. Relative surface energy of each state, giving a measure of stability to perturbations, or likelihood of achieving that condition.
2. Equilibrium states should ideally converge to one solution at a relatively small ullage for an optimized system, enabling L/V mass gauging.

Analysis is limited to systems with low Bond numbers or highly dominated by surface tension. Additional 3-D fluid analysis is required to capture transients.

RRM3 Cryogen Demonstration Subsystem



RRM3

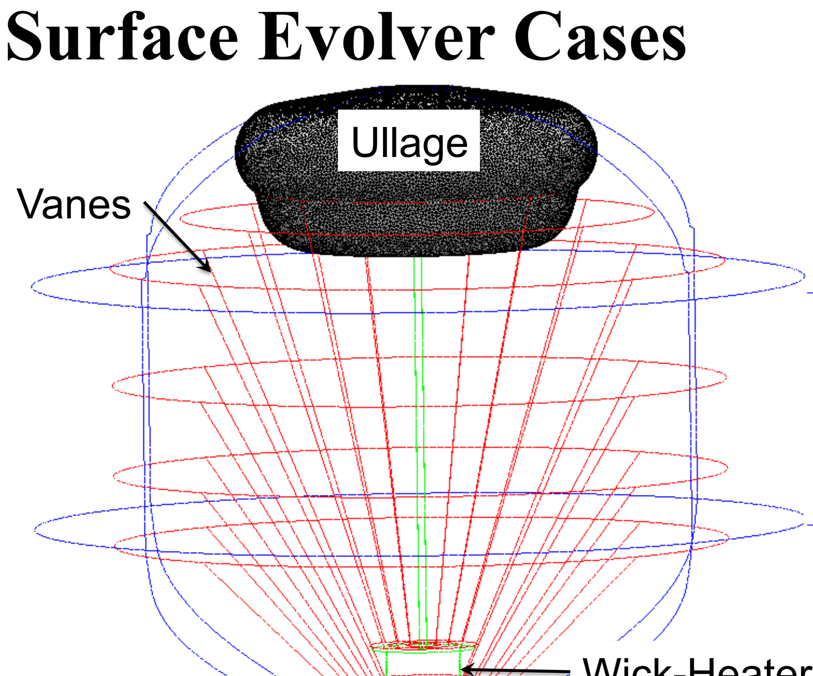
- Demonstrate robotic and cryogenic technologies for satellite resupply
- Planned for delivery to ISS in 2017

Parameter	Capability
Gravity	Capable of operating with a gravity vector of ≤50 µg in any direction.
Upset Recovery	FMD will be capable of upset recovery within 60 minutes.
Ullage Control	Capable of rejecting ullage vapor from the tank outlet for fill levels greater than 5%.
Key interfaces	Mounts to the bottom head of Source Dewar tank, interfaces with the wick-heater system, provides space for the RF Mass gauge and a liquid vapor detector array.
Transfer	Capable of completing 5 transfers of 10-15 L, at a rate of 200 L/hr. Outlet feed quality 90-99% liquid.
Electrical Properties	FMD's Electrical conductivity will be low enough to not interfere with the operation of the RF Mass gauge.
Material Compatibility	Liquid methane, LN_2, LAr, and IPA.

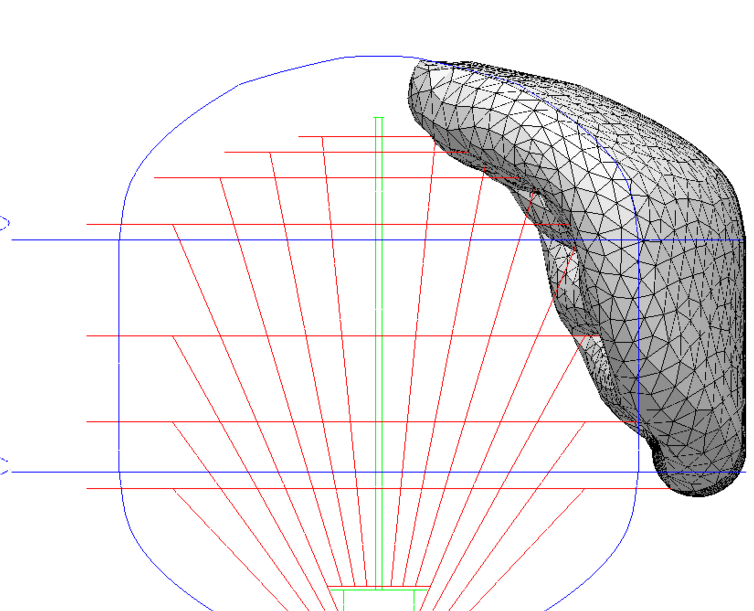
Vane Construction

To avoid contamination due to the flexibility of the vanes and cryogenic temperatures of the source Dewar, ultrasonic welding was chosen over adhesive. Vanes are cut from 0.010 in. thick clear Mylar™ and welded together. Tabs in the vanes are inserted into brackets and bolted to a baseplate.

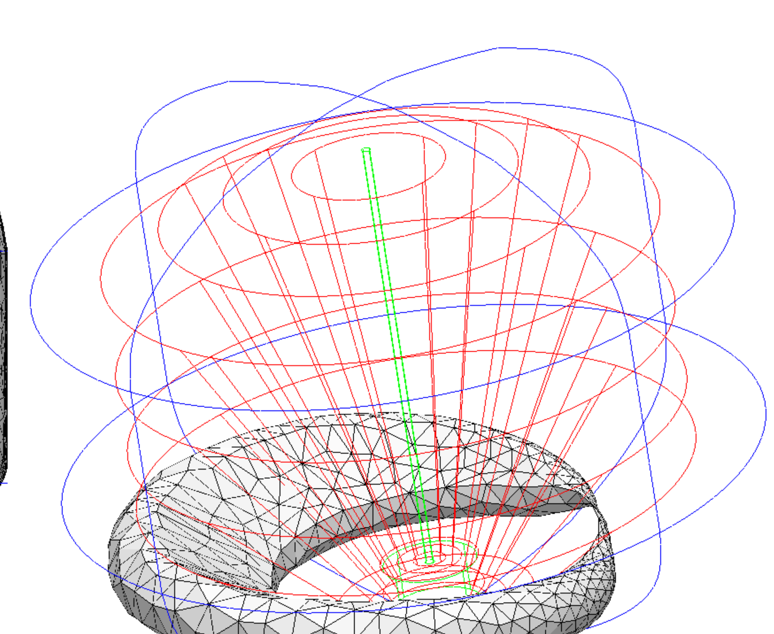
Surface Evolver Cases



95% Fill & Ideal Ullage Location



88% Fill & Side-Bubble



95% Fill & Bottom Ullage

RFMG Simulator Tank Bottom with Vanes