Progress on the Multi-Phase Flow Experiment for Suborbital Testing (MFEST)

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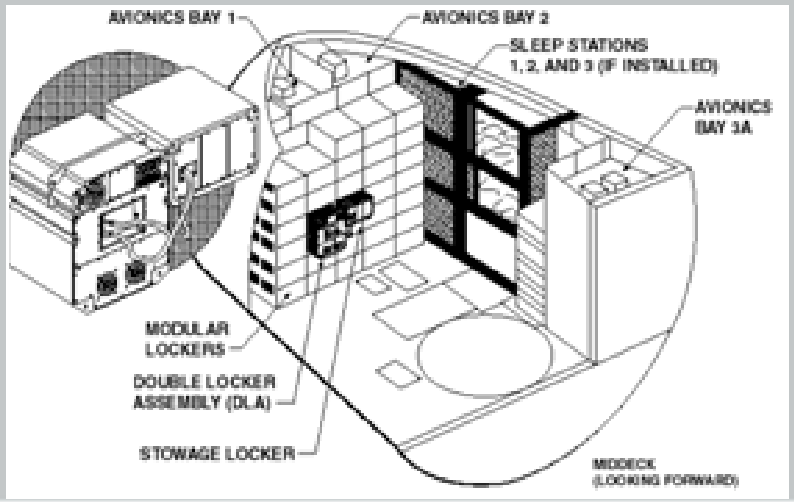
Overview

- Introduction
- Hardware Overview
- Flight Summary To Date
- Flight Environment Data
- MFEST Performance Data
- Modeling of Vortex Separator
- Summary

Introduction

- MFEST is an orbital flight experiment, originally designed for the Space Shuttle Mid-Deck to:
  1) test the feasibility of a water purifier for use in zero-gravity conditions, and
  2) demonstrate sustained operation of a two-phase flow system with a passive gas/liquid separator.
- MFEST was never flown due to mass, crew time, and other mission limitations.
- The primary objective of the current program is to **conduct a pathfinder, suborbital flight experiment for two-phase fluid flow and separator operations.**
  - suborbital flight would allow longer-duration, continuous operational testing with variable gravity over a wider range



Introduction

- MFEST variations from the original Immobilized Microbe Microgravity Water Processing System (IMMWPS) Flight Experiment include:
  - Orientation with respect to gravity (i.e., front panel originally in Shuttle nose-to-tail orientation, but for suborbital flight will be wing-to-wing)
    - Note: the flight profile and g-levels are also substantially different for suborbital flight
  - Experiment designed to be started in on-orbit, but for suborbital will be powered "ON" and running from pre-taxi to post-landing
  - IMMWPS was designed to operate for 10 day period, for assessment of biological water processing; for suborbital, will be operated for hours with up to 5 minutes of zero-g to assess system stability and separator performance
  - Avionics logic/software designed to monitor and record data at low frequency (order of minutes) to reduce data file size and facilitate downlink, etc.

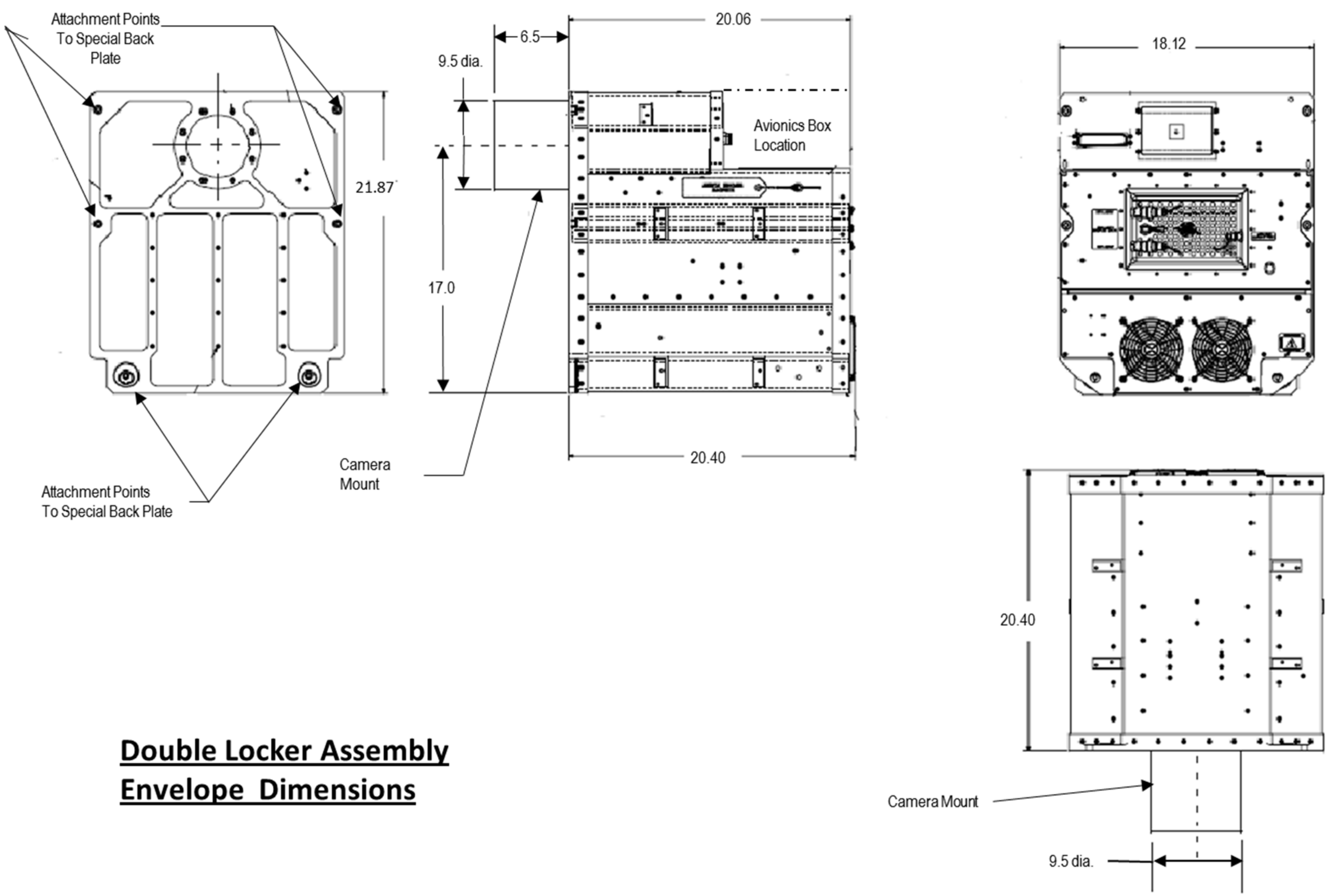
Hardware Overview

- MFEST Hardware consists of two components
  - Double Locker Assembly (DLA)
    - Contains Pumps, Passive gas/liquid separator and Microbial Processor Assembly
  - Avionics Box
    - Contains Power Distribution System and Single Board Computer for control and data collection
- Back plate of passive gas/liquid separator changed to a clear Lexan® plate to allow visual observation of the two-phase flow
  - Added a camera fixture containing two LED lights and a digital camera to record flow configuration in passive gas/liquid separator during zero-g
    - Note: this and the Lexan® plate were the only significant modifications made to the original payload design

Hardware Overview

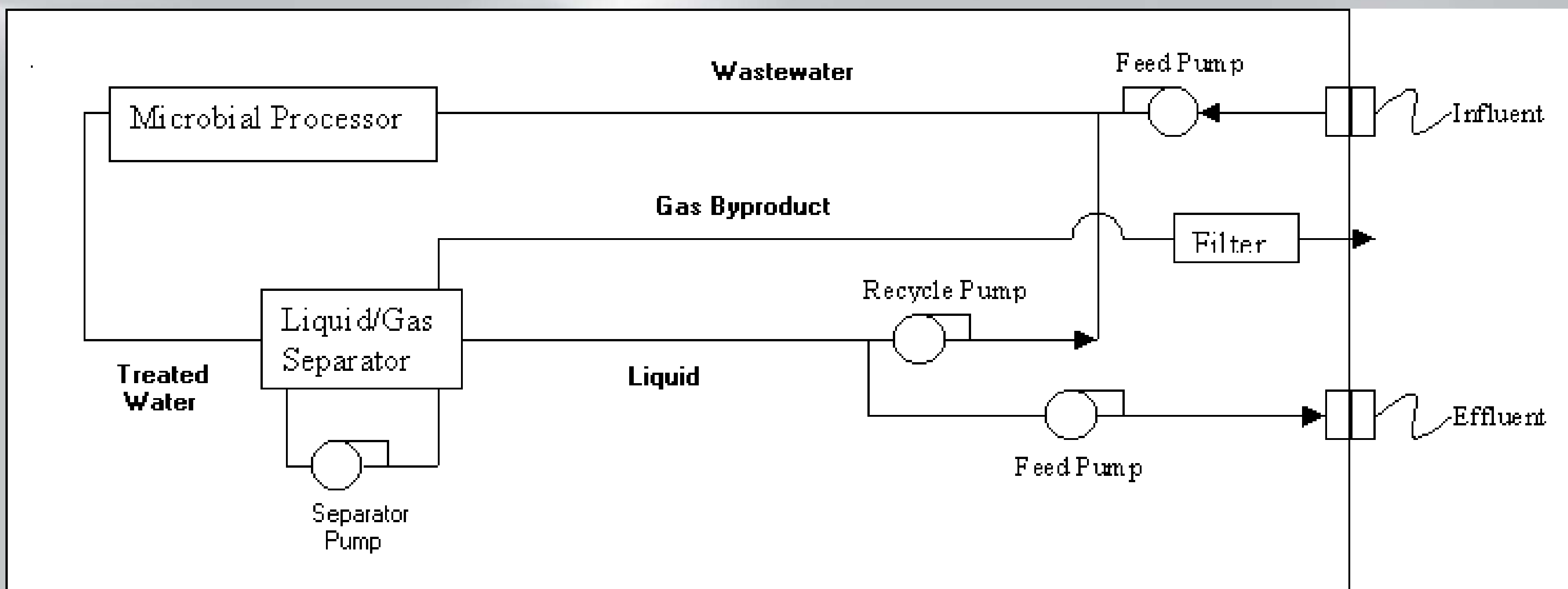
- Passive gas/liquid separator uses acoustic gauge (Panametrics® Model 25DL) to monitor fluid inventory
- A HP® ThinkPad is used to input parameters via a coaxial cable to the MFEST
- Information is recorded and displayed on LED monitor mounted in Avionics Box
- Payload Weight
  - 54.8 Kg (120.8 lbs.) without water

Hardware Overview



Double Locker Assembly Envelope Dimensions

Simplified IMMWPS Flow Schematic



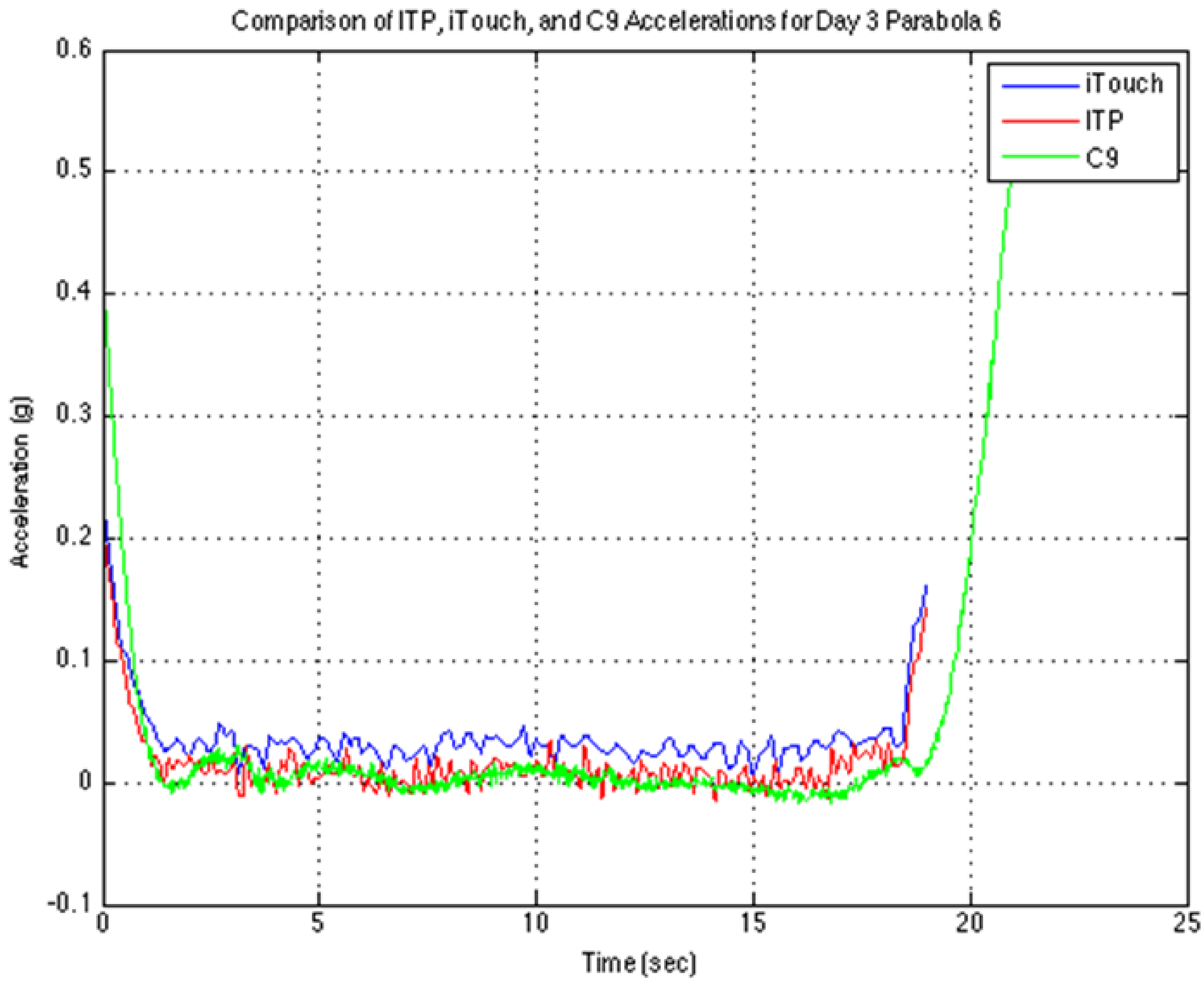
Flight Summary To Date

- Parabolic Flight Campaign #1
  - Sponsored by Office of Chief Technologist, Flight Opportunities Program
  - Week of September 10, 2012
  - Completed only 1 partial-day of flight testing due to bad weather (only 33 zero-g parabolas completed, some parabolas abbreviated and poor quality due to turbulence (< 25 sec, up to +/- 0.1-g above target gravity)
  - MFEST overall performed well
  - Sufficient data was obtained to complete testing in the horizontal orientation, which most closely simulates the gravity orientation for its original planned Shuttle Mid-Deck testing

Flight Summary To Date

- Parabolic Flight Campaign #2
  - Sponsored by Office of Chief Technologist, Flight Opportunities Program
  - Week of February 25, 2013
  - Completed 2 full flights (i.e., 40 parabolas each) and 2 partial flights (i.e., 35 and 10 parabolas respectively; last flight cut short due to aircraft accelerometer anomalies)
    - Lunar- and Mars-g parabolas were also included in flight days 1 and 2; completed 6 lunar-g and 4 Mars-g parabolas overall
  - MFEST overall performed well
  - Sufficient data was obtained to complete testing in the vertical orientation, which most closely simulates the gravity orientation expected for flight on SpaceShip 2

Flight Environment Data

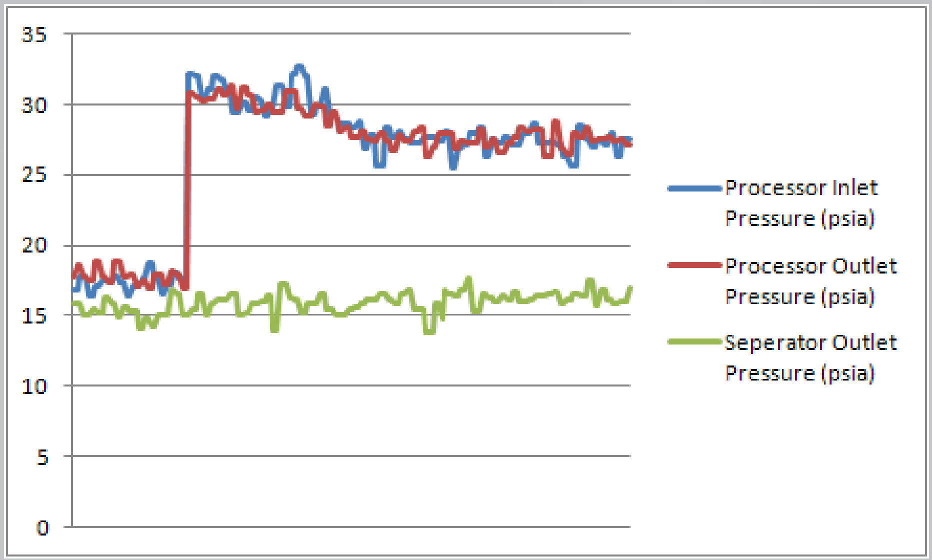


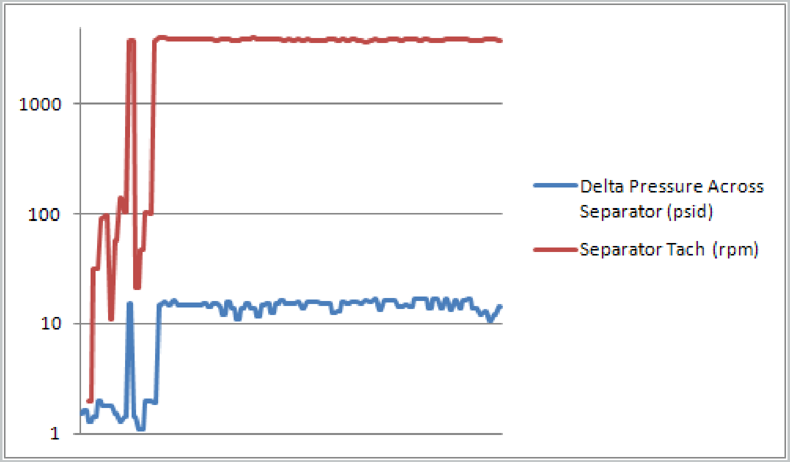
Flight Environment Data

- SERC and iTouch Acceleration Instrumentation
  - ITP - Summit Accelerometer 35203B-R006
    - +/- 6g max. scale, range adjustable
    - Temperature compensated
  - Apple iTouch – STMicroelectronics LIS302DL
    - ± 2g/± 8g dynamically selectable full-scale
    - Temperature compensated
- Comparison ITP and iTouch Vertical Acceleration profiles for Day 3 Parabola 6 during Reduced Gravity
  - Cross-Correlation – 0.8885
  - RMSD – 0.0068
- Cabin Pressure and Temperature remained nominally constant throughout the flights

MFEST Performance Data

- With a nominal liquid inventory, overall MFEST system parameters appear to reach steady-state within the first hour of operation (e.g., system temperatures, pressures), regardless of variation in gravity



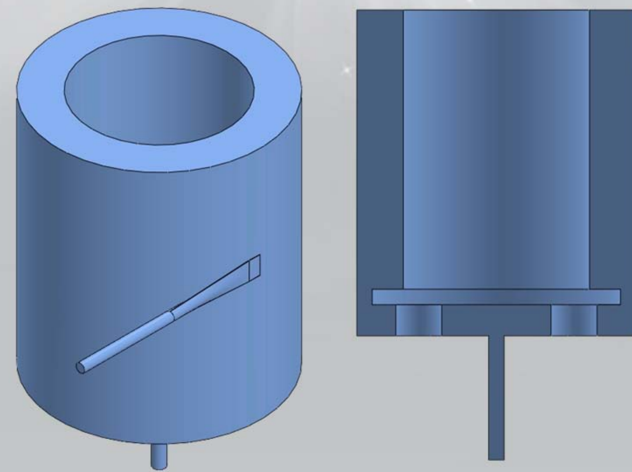


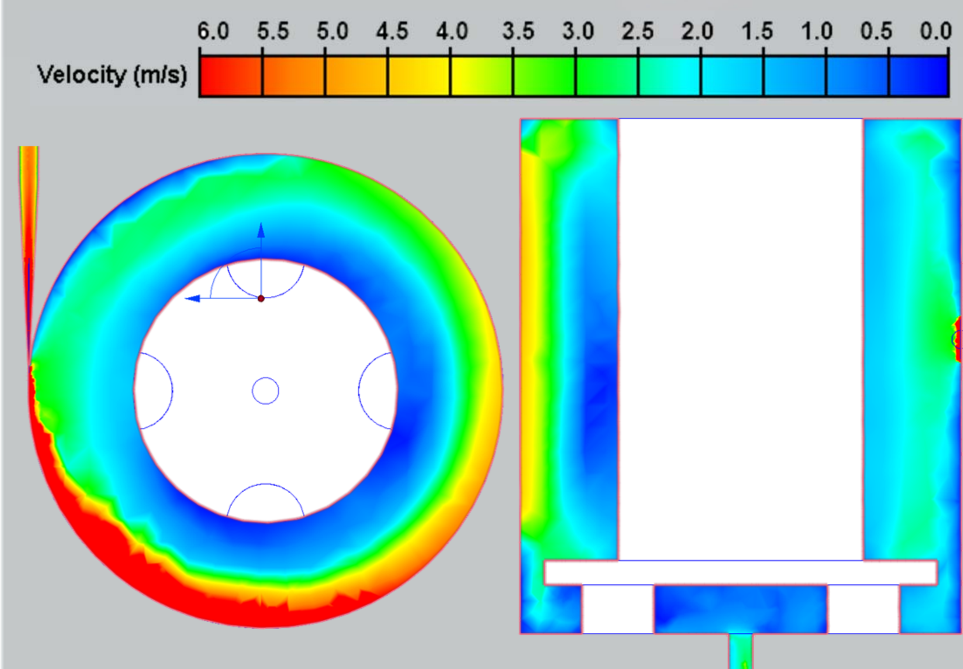
MFEST Performance Data

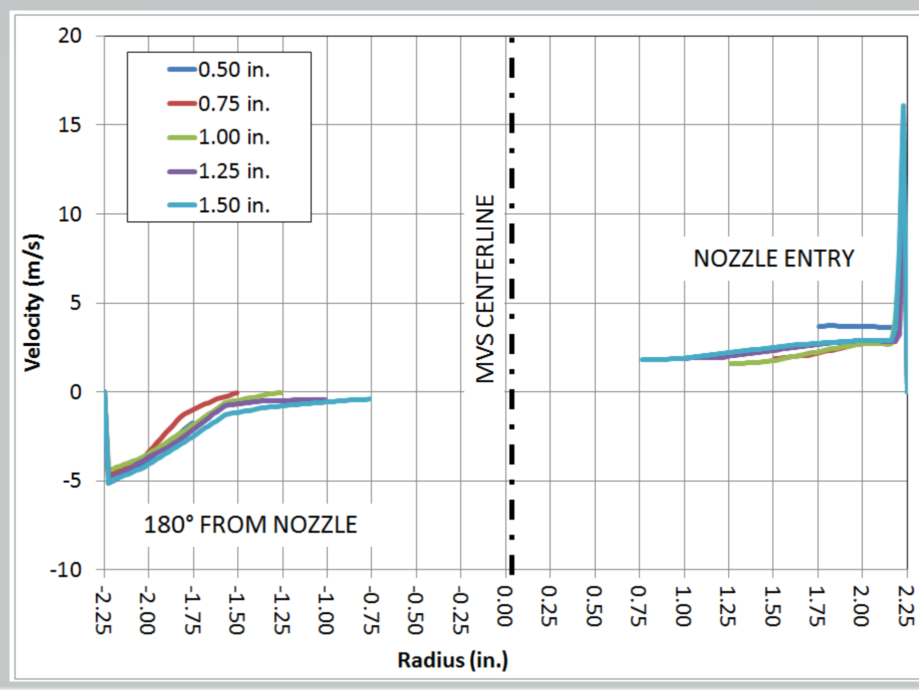
- Visual data shows the separator also performed sufficiently during both the gravity and zero-g conditions
  - MFEST and the separator were originally designed to operate with the primary access oriented ceiling to floor
  - For the suborbital orientation, the separator performs similar to a front-load washing machine, with chaotic flow during the gravity periods and some vapor exiting through the liquid outlet and passing through the pump(s)
  - For the zero-g periods, the separator performed as designed with a stable vortex initiated at the centerline

Modeling of Vortex Separator

- Velocity profile modeled using CFD (Autodesk)
- Used to predict separation performance
  - Bubble transit time
  - Developed acceleration







SUMMARY

- MFEST has been shown to successfully operate in parabolic flight testing, including its environment data collection (i.e., the iTouch) and camera systems
- The MFEST team would like to state their readiness for suborbital flight and request manifesting to a suborbital carrier/flight manifest at the earliest opportunity