

The following questions should begin the process of defining the specific PMD requirements. Additional questions may result from the answers provided.

General

Propellants. What are the propellants?

Temperature. What is the operating propellant temperature range?

Pressure Loss. What is the maximum allowable tank assy flow loss? At what flow rate, and in what liquid?

Tank Pressure. What is the fill pressure range? the handling pressure range? the launch pressure range? the operational pressure range? When does pressurization occur? Is the system blow down or regulated?

CG & Attitude Control. Are there any propellant CG and/or propellant motion issues and or requirements. Please note that PMDs can be used to control propellant Cg and motion but they are generally much heavier than required for gas free propellant delivery. PMD Technology can provide fluid dynamic and/or simplified equivalent spring mass models to analyze propellant/spacecraft interaction (instead of imposing requirements on the PMD which will add mass).

Gauging. Are there any gauging systems issues that the PMD can help or hinder by positioning propellant?

Tank & Spacecraft Definition

Tank Shell. Please define the tank internal geometry.

Spacecraft Layout. Please define the coordinate system used in answering subsequent questions about acceleration environments. In addition, please define tank, thrusters (& thrust vector), and CG locations in this coordinate system. A visual layout aids in limiting PMD design and analysis to “real” possibilities instead of generalized requirements.

If more than one tank is present, define propellant & describe manifolding. With manifolded tanks describe any issues (e.g. propellant transfer, etc.).

Ground Operations:

Filling. Please describe the filling process. Attitude, max flow rate, tank pressure.

Handling. After propellant loading, is the tank always handled upright outlet up or can it be in other attitudes? Please describe (Proton and/or Sea Launch compatible is sufficient, if required). Acceleration levels between 0.1 and 10 Hz are required. Also define vertical direction relative to tank throughout handling.

Draining. How is the tank drained (if need be)? Attitude, max flow rate, tank pressure.

Boost:

Launch. What is the tank attitude? What is the fill fraction range? Are all phases of ascent tree axis stabilized (if not describe)? Is any propellant required during launch?

Separation. What is the separation event acceleration environment. At what rate and about which axis is the vehicle spinning? How much propellant is required for recovery?

System Priming. Are the lines wet to the thrusters or is there a low (or zero) pressure line(s) between a valve and the thrusters. If such a line exists, when is it filled or primed? Describe acceleration environment at the time of line priming? How much propellant is required maximum? What is the tank pressure at priming?

First Propellant Demand. Describe the conditions of the first propellant demand. What is the acceleration environment preceding the use and during the propellant use (linear accelerations, angular accelerations, and angular rates)? What is the flow rate during this demand. How much propellant is required maximum?

Operations:

Propellant Use & Acceleration Events. Please describe each event during operations that either a) uses propellant and/or b) accelerates the propellant tank (be sure to include all rotations of the spacecraft). It is often useful to break the mission into phases if applicable (e.g. for geos, insertion & on orbit operations). Necessary specifics for each event include:

Duration of coast period preceding maneuver/event (if no coast, define acceleration environment immediately preceding maneuver)

Acceleration Environment (magnitude, direction, spin rate, etc.) during event (Please specify min & max and whether the magnitude is tied to fill fraction)

Propellant flow rate (steady state and/or duty cycle & pulse width) (Please specify min & max and whether the magnitude is tied to fill fraction)

Event duration and/or propellant quantity required maximum

Fill fraction range (give EOL conditions and BOL conditions is different)

Once in a lifetime event or repeatable

Contingency. If any, what are the contingency requirements? What is the acceleration worst case environment preceding the propellant use and during the propellant use (linear accelerations, angular accelerations, and angular rates)? What is the flow rate and the maximum quantity of propellant required? What is the fill fraction and pressure range during contingency? How many events per lifetime are required (if unlimited, say so)?

Depletion. During what maneuver is depletion expected? Please describe the acceleration environment and the flow rate.