The Evolution of Utilizing Manual Throttling to Avoid Excessively Low LH_2 NPSP at the SSME Inlet

Rick Henfling

NASA/Johnson Space Center

December 2010

In the late 1970s, years before the Space Shuttle flew its maiden voyage, it was understood low liquid hydrogen (LH_2) Net Positive Suction Pressure (NPSP) at the inlet to the Space Shuttle Main Engine (SSME) could have adverse effects on engine operation. A number of failures within both the External Tank (ET) and the Orbiter Main Propulsion System (MPS) could result in a low LH_2 NPSP condition, which at extremely low levels can result in cavitation of SSME turbomachinery. Operational workarounds were developed to take advantage of the onboard crew's ability to manually throttle down the SSMEs (via the Pilot's Speedbrake/Throttle Controller), which alleviated the low LH_2 NPSP condition. Manually throttling the SSME to a lower power level resulted in an increase in NPSP, mainly due to the reduction in frictional flow losses while at the lower throttle setting.

Early in the Space Shuttle Program's history, the relevant Flight Rule for the Booster flight controller in Mission Control did not distinguish between ET and Orbiter MPS failures and the same crew action was taken for both. However, after a review of all Booster operational techniques following the Challenger disaster in the late 1980s, it was determined manually throttling the SSME to a lower power was only effective for Orbiter MPS failures and the Flight Rule was updated to reflect this change.

The Flight Rule and associated crew actions initially called for a single throttle step to minimum power level when a low threshold for NPSP was met. As engineers refined their understanding of the NPSP requirements for the SSME (through a robust testing program), the operational techniques evolved to take advantage of the additional capabilities. This paper will examine the evolution of the Flight rule and associated procedure and how increases in knowledge about the SSME and the Space Shuttle vehicle as a whole have helped shape their development. What once was a single throttle step when NPSP decreased to a certain low threshold has now become three throttle steps, each occuring at a lower NPSP threshold. Additionally the procedure, which for early Space Shuttle missions required a Return-to-Launch-Site abort, now results in a nominal Main Engine Cut Off and no loss of mission objectives.