LESSONS LEARNED FROM THE STARDUST SAMPLE RETURN MISSION.

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Introduction: These are science and mission design and operations lessons learned from the Stardust Mission, which returned grains from comet Wild-2 to Earth in 2006 [1].

Science Lessons: Major discoveries of the Stardust Wild-2 samples include the presence of numerous chondrules and CAI in a comet, which requires a much more dynamic early solar system than many had envisaged, and verified predictions made by models requiring outward flow of early solar system solids before the early nebular gas had dissipated [1-3]. No evidence has been found for the presence of live ^{26}Al in the comet, suggesting late accretion [4]. Carbonates and unusual sulfides were found which potentially require activity of liquid water within the comet, but to only a minor degree at best [5-6]. The presence of abundant thermally-metamorphosed silicates in Wild-2 appears to require assembly from an earlier generation of bodies [7]. The abundance of presolar grains in the Wild-2 samples appears to be below what has been found in most chondritic IDPs and primitive chondrites [1]. The bulk mineralogy of Wild-2 grains does not match the mineralogy from any single other known astromaterial [7], and is also strikingly unlike that inferred from Spitzer Telescope spectra of Comet Temple 1 dust [8]. Amino acids and other fragile organics have been detected among the Wild-2 samples [9], which highlights the critical importance of further developing techniques for organic analysis in small samples, and cleaning outbound spacecraft.

Sample Contamination Issues: Stardust contamination control procedures were integral to the flow of spacecraft manufacture, assembly, testing, flight and recovery. We monitored contamination through numerous witness materials, which were all archived for later analysis, but never completely solved the problem of defining useful limits for organic contaminants of spacecraft hardware.

Spacecraft Recovery Operations: A full year of planning for Stardust recovery operations was insufficient, adding strain to the field teams. Engineers should be pushed to provide true seals for returned samples, especially those from organic-rich bodies.

Sample Curation Issues: Two years of Curation preparation are insufficient. Remote storage of a sample subset is critical, for Stardust the remote samples are in a vault in New Mexico.

Preliminary Examination (PE) of Samples: The Stardust PE was designed so that late additions to the analysis plans were encouraged, as new analytical techniques become available.

References: [1] Brownlee et al. (2006) *Science* **314**, 1724-1726; [2] Zolensky et al. (2006) *Science* **314**, 1735-1740; [3] Nakamura et al. (2008) *Science* **321**, 1664-1667; [4] Ogliore et al. (2012) *Ap. J*. **745**, 19-24; [5] Mikouchi et al. (2007) *Lunar And Planetary Science XXXVIII*; [6] Berger et al. (2011) *GCA* **75**, 3501-3513; [7] Frank et al. Submitted to *GCA*; [8] Lisse et al. (2006) *Science* **313**, 635; [9] Sandford S.A. et al. (2010) *Meteoritics and Planetary Science* **45**, 406-433.