LESSONS LEARNED FROM THREE RECENT SAMPLE RETURN MISSIONS.

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Introduction: We share lessons learned from participation on the Science Teams and Recovery/Preliminary Examination/Curation teams for three recent sample return missions: (1) the Long Duration Exposure Facility (LDEF), which returned to Earth with interplanetary dust and spacecraft debris particles in 1990 [1], (2) the Stardust Mission, which returned grains from comet Wild-2 and fresh interstellar dust to Earth in 2006 [2], and (3) the Hayabusa Mission, which returned regolith grains from asteroid Itokawa in 2010 [4].

Sample Contamination Issues: For Stardust and Hayabusa, especially, contamination control procedures were integral to flow of spacecraft manufacture, assembly, testing, flight and recovery. The science teams took a very active role in planning and implementing contamination control measures. We monitored contamination through numerous witness materials, which were all archived for later analysis. However, despite these precautions the Stardust spacecraft outgassing was sufficient to degrade camera operations, and the aerogel capture media was significantly contaminated during manufacture. We also never completely solved the problem of defining useful limits for organic contaminants of spacecraft hardware, which haunts us as we rather unexpectedly captured primitive cometary organics. It is critical to devise improved contamination control efforts. It is also critical to appoint contamination control leads from within the mission team for the lifetime of the mission. The mission team should also prepare for the mission to be more successful then is generally anticipated.

Spacecraft Recovery Operations: The mission Science and Curation teams must actively participate in planning, testing and implementing spacecraft recovery operations. The Genesis crash underscored the importance of thinking through multiple contingency scenarios and practicing field recovery for these potential circumstances. Having the contingency supplies on-hand was critical. A full year of planning for Stardust and Hayabusa recovery operations was insufficient, adding strain to the field teams. Care must be taken to coordinate recovery operations with local organizations and inform relevant government bodies well in advance .Recovery plans for both Stardust and Hayabusa had to be adjusted for unexpectedly wet landing site conditions. Documentation of every step of spacecraft recovery and deintegration is necessary, and collection and analysis of landing site soil was critical. The recovery of LDEF by the Space Shuttle was bungled, severely degrading the science return from the mission – concerns for human comfort outweighed important LDEF mission goals. We found the operation of the Woomera Text Range (South Australia) to be very robust in the case of Hayabusa, and in many respects we prefer this site to the domestic Utah Test and Training Range (used for Stardust). Recovery operations for all three spacecraft significantly suffered from the lack of a hermetic seal for the samples, probably in many additional ways which will only become apparent in the future. Mission engineers should be pushed to true seals for returned samples.

Sample Curation Issues: Many Curation issues are treated by Carl Allen's abstract for this meeting [3], but we can make additional suggestions. More than two full years were required to prepare curation facilities for Stardust and Hayabusa. Despite this seemingly adequate lead time, major changes to curation procedures were required once the actual state of the returned samples became apparent. Two years of Curation preparation are insufficient. The sample database must be fully implemented before sample return – for Stardust and LDEF we did not adequately think through *all* of the possible sub-sampling and analytical activities before settling on a database design. Also, analysis teams must not be permitted to devise their own sample naming schemes. Remote storage of a sample subset is critical.

Preliminary Examination (PE) of Samples: There must be some determination of the state and quantity of the returned samples, to provide a necessary guide to samples requesters and the inevitable oversight committee tasked with sample curation oversight. Sample PE must be designed so that late additions to the analysis protocols are possible, as new analytical techniques become available. We prefer an inclusive PE with in-depth investigation of a limited, but representative, subset of the returned samples (<10%). By being as inclusive as possible during PE information return was maximized and a broader community become acquainted with both the scientific value and problems associated with the samples in the shortest possible time

References: [1] Zolensky M.E. et al. (1991) The Journal of Spacecraft and Rockets, 28, 204-209; [2] Sandford S.A. et al. (2010) *Meteoritics and Planetary Science* **45**, 406-433; [3] Allen C. et al. (2011) This meeting; [4] Please see numerous LPSC 2011 abstracts.