LESSONS LEARNED FROM THREE RECENT SAMPLE RETURN MISSIONS

Mike Zolensky and Scott Sandford

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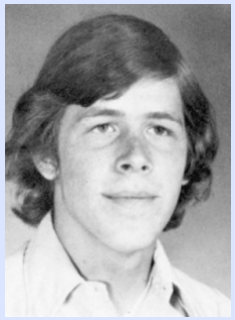


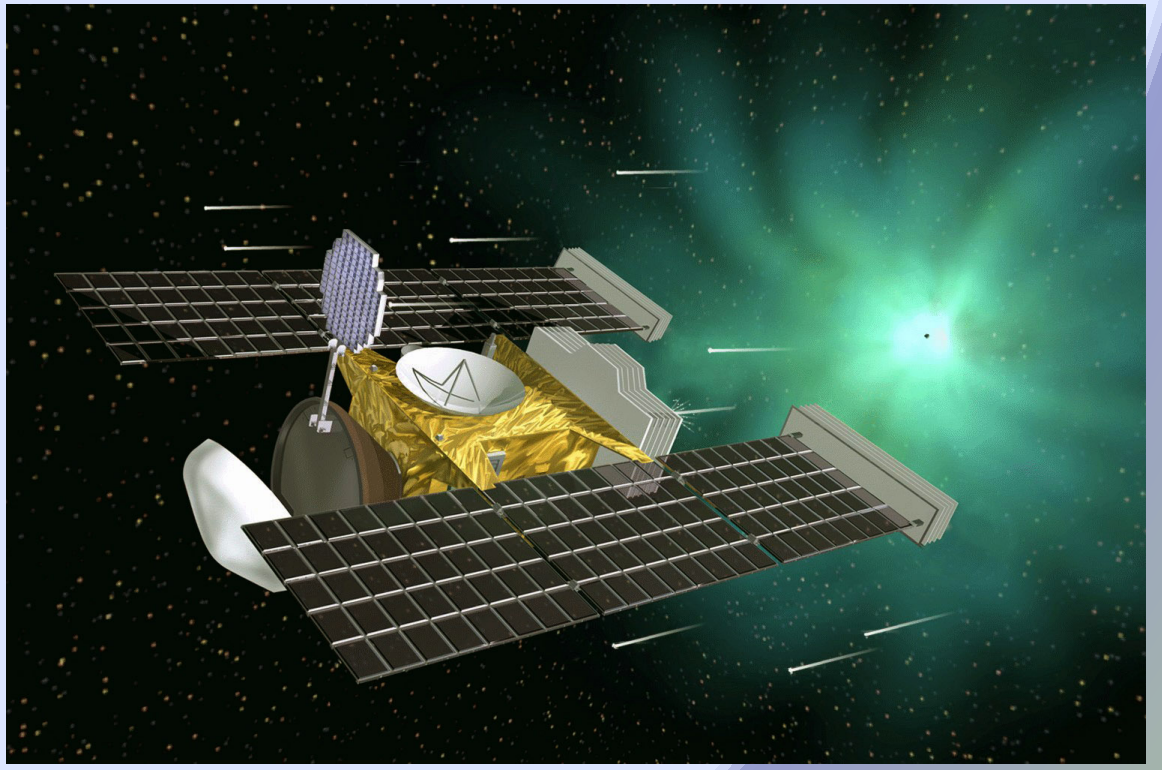
Introduction

We share lessons learned from participation on the Science Teams and Recovery/Preliminary Examination/Curation Teams for three *recent* sample return missions:

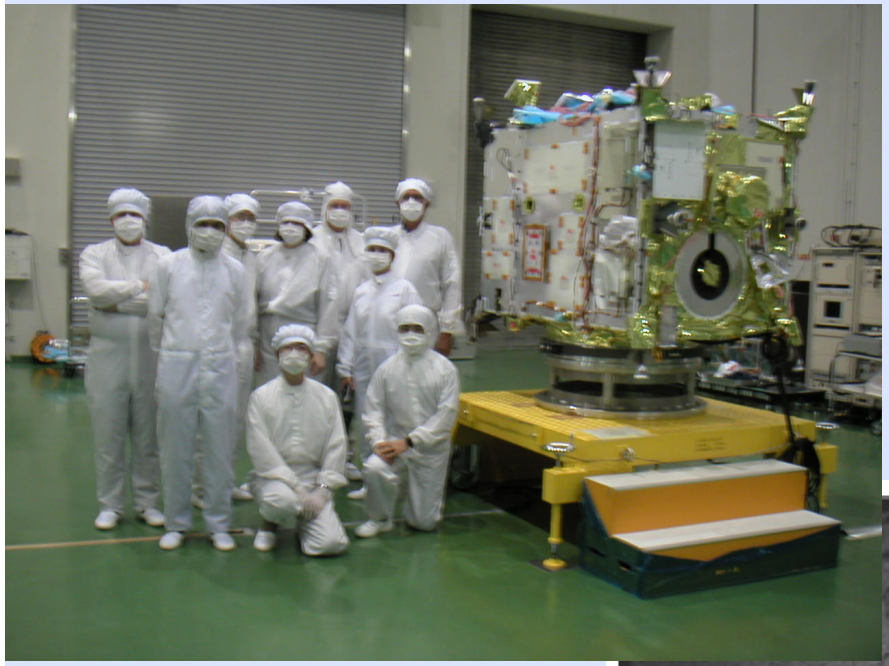
(1) the Long Duration Exposure Facility (LDEF), which returned IDPs and spacecraft debris particles in 1990, after 69 months in low-Earth orbit

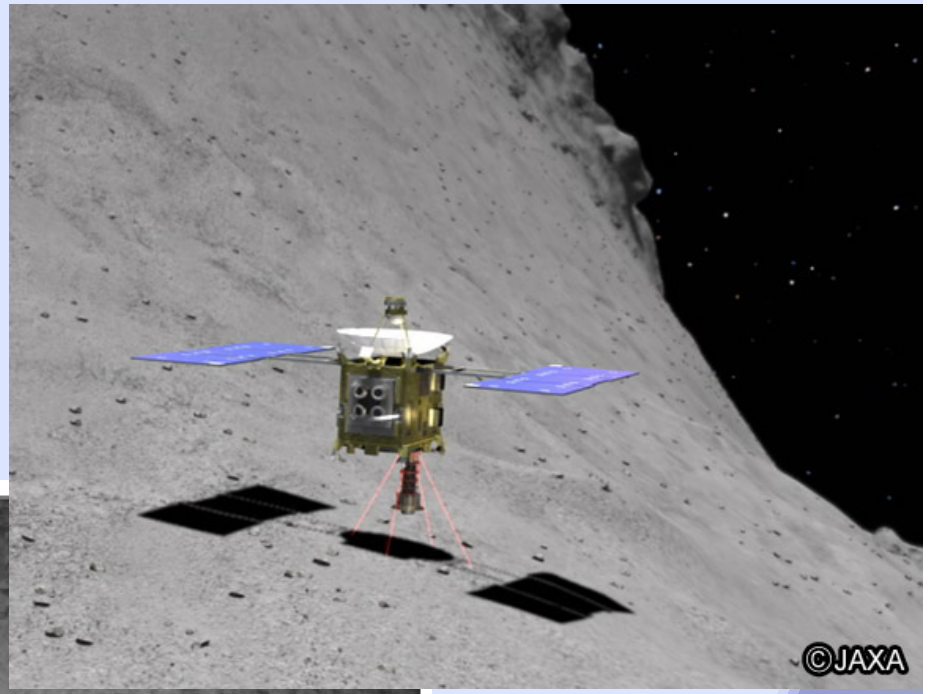
This was a test bed for dust collection ideas

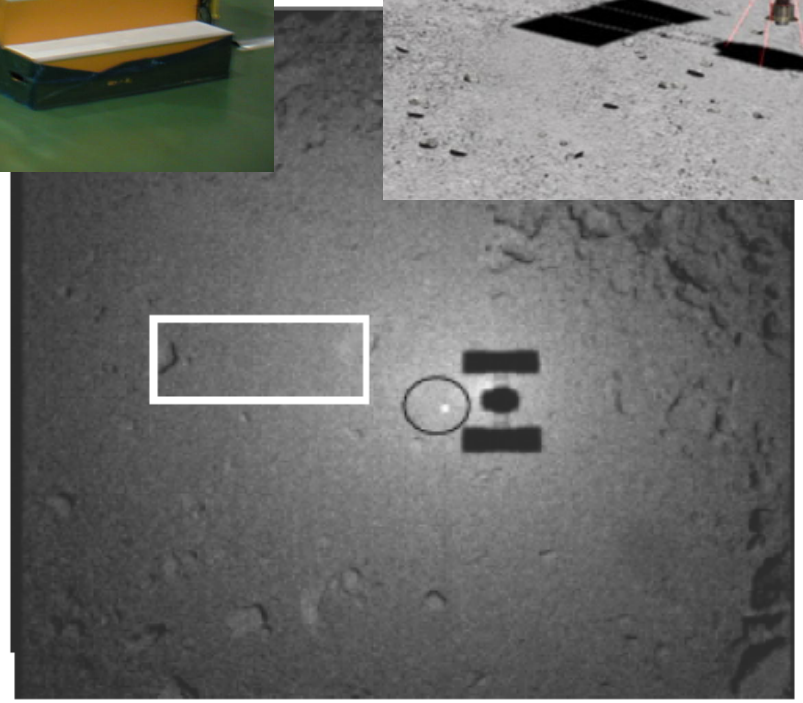
(2) the Stardust Mission, which returned coma grains from comet Wild-2 and fresh interstellar dust to Earth in 2006,
and



(3) the Hayabusa Mission, which returned regolith grains from asteroid Itokawa in 2010







Sample Contamination Issues

Spacecraft Recovery Operations

Scientists versus Engineers

Flight Heritage

Curation Issues

Preliminary Examination (PE) of Samples

Sample Contamination Issues

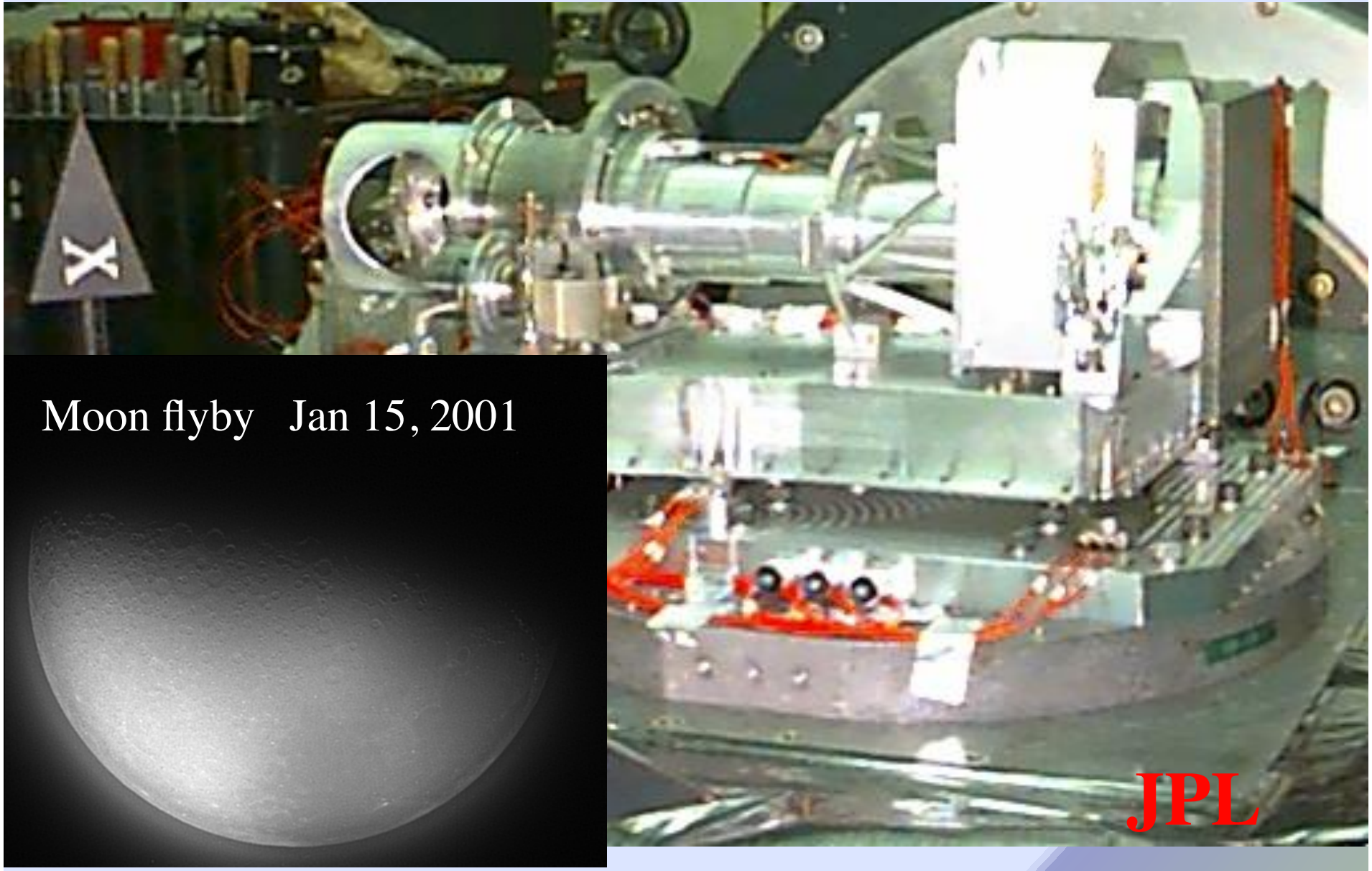
For Stardust and Hayabusa, especially, contamination control procedures were integral to flow of spacecraft manufacture, assembly, testing, flight and recovery.

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.

Optical Navigation Camera (Voyager optics/ Cassini CCD)



Aerogel

Schedule versus Cleanliness

Sample Contamination Issues

We never 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 for future missions.

The mission team should also prepare for the mission to be more successful than they anticipate!

LDEF

Stardust

Hayabusa

Spacecraft Recovery Operations

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 contingency supplies on-hand for all recovery operations is critical.

Spacecraft Recovery Operations

A full year of planning for LDEF, Stardust and Hayabusa recovery operations was insufficient, adding unneccesary strain to the field teams.

Care must be taken to coordinate recovery operations with local organizations and inform relevant government bodies well in advance.

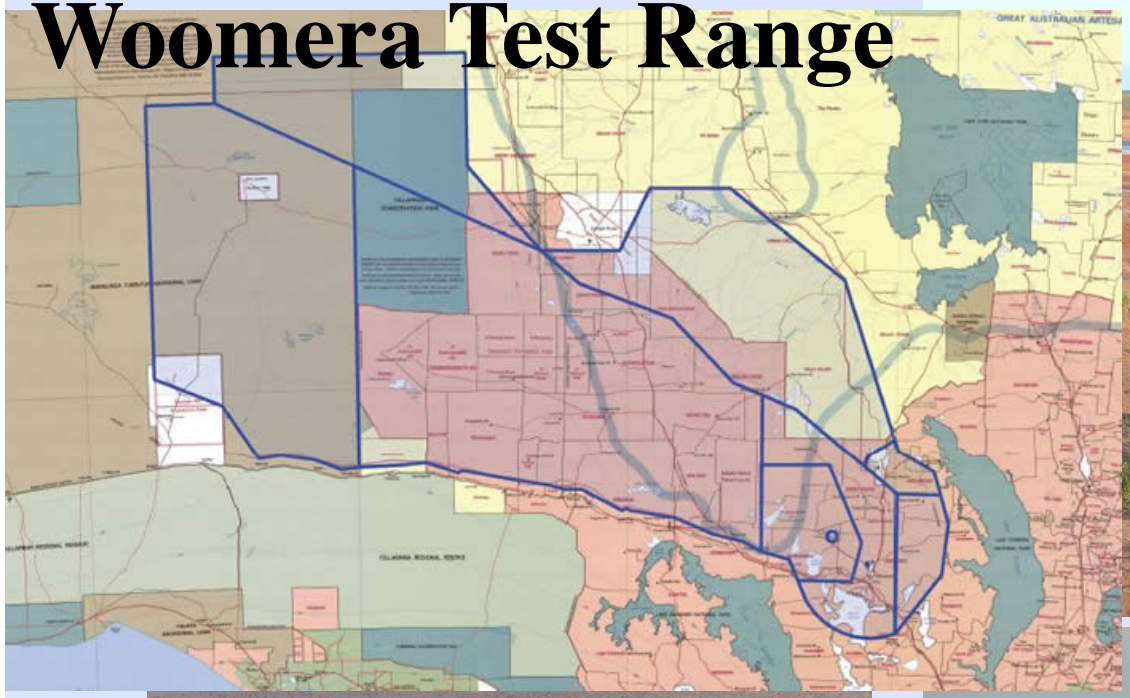
Recovery plans for both Stardust and Hayabusa had to be adjusted for unexpectedly wet landing site conditions.

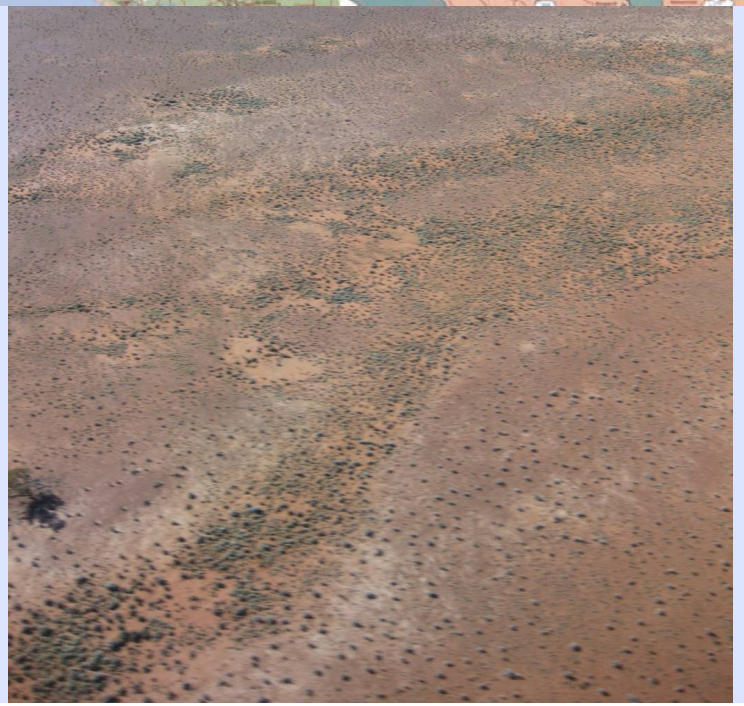

UTTR


2004/12/01


2004/12/01

Woomera Test Range





Problem

- No sample return missions in the past 40 years have had hermetically sealed sample containers

- Never assume!
  - When you are told that the sample return capsule does not have to be hermetically sealed because the landing site is always dry, don't assume this will be true

Mission engineers should be pushed to provide "true" seals for returned samples.

Spacecraft Recovery Operations

Documentation of every step of spacecraft recovery and deintegration is necessary, and collection and analysis of landing site rock/soil is critical

The recovery of LDEF by the Space Shuttle was bungled, severely degrading the science return from the mission – concerns for human comfort out-weighed important LDEF mission goals

Always think carefully about using an astronaut crewed platform for sample recovery operations

We found the operation of the Woomera Text Range 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

Spacecraft Recovery Operations

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.

Engineers versus Scientists

Define roles and responsibilities at the earliest stage, to minimize infighting – especially between engineers and scientists whose brains are wired differently

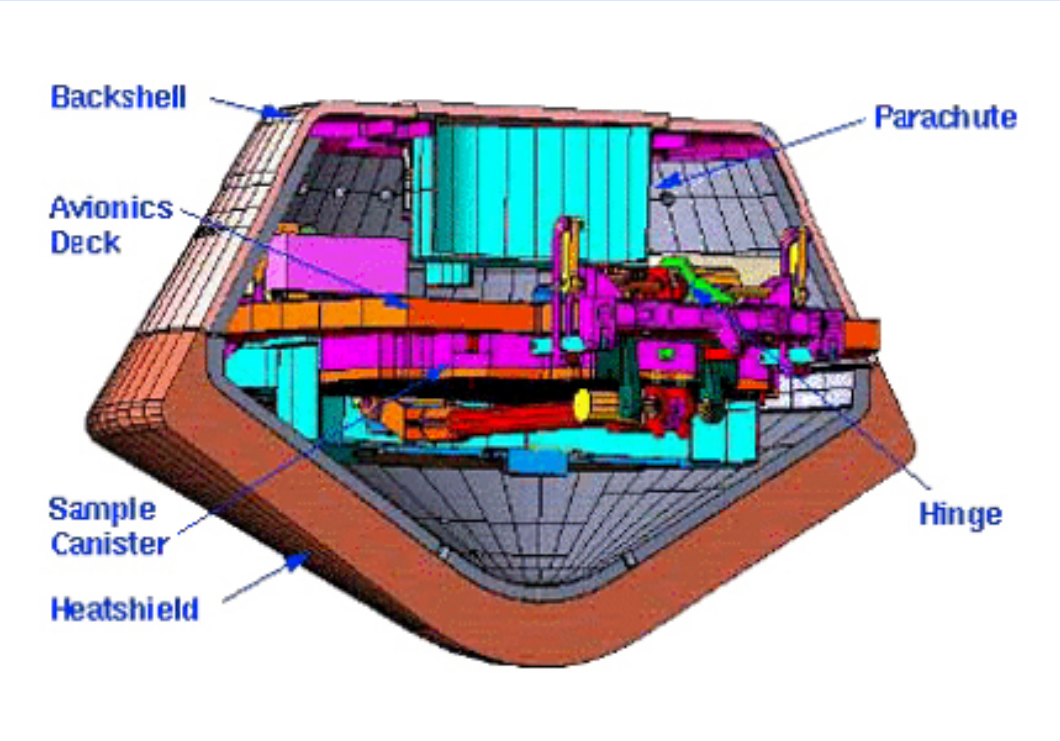
Engineers are very reluctant to think like Scientists

So:

It is necessary for Mission Scientists to think like Engineers

Flight Heritage

Genesis SRC based on Stardust's SRC



- “Flight Heritage” can be a trap
  - The advantage of flight heritage is that you can avoid testing everything
  - The disadvantage of flight heritage is that you have not tested everything

Curation Issues

Many Curation issues are treated by Carl Allen's talk 2 hours ago, 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

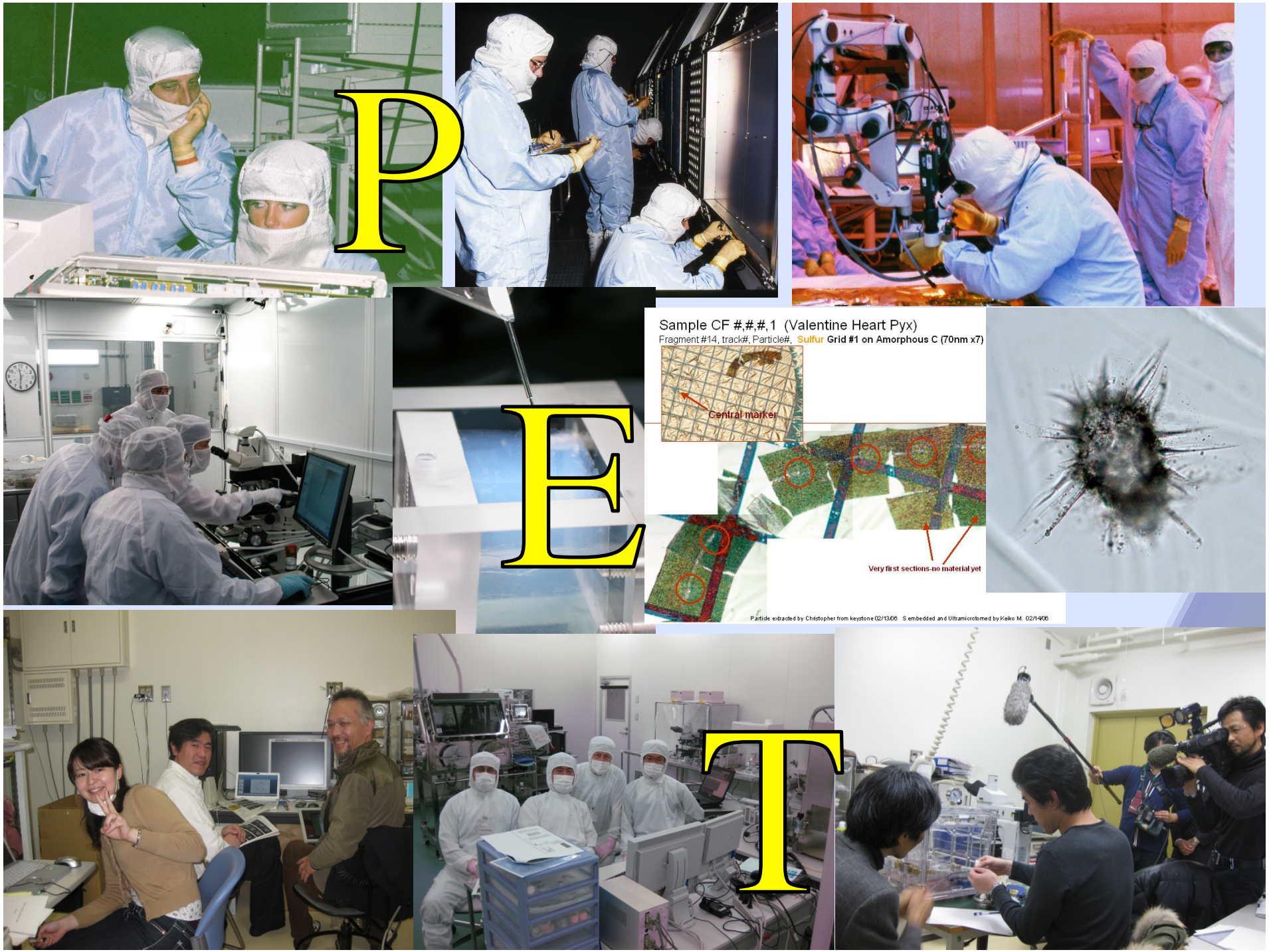
Curation Issues

The sample data-base 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 final database design.

Analysis teams **must not** be permitted to devise their own sample naming schemes

Remote storage of a sample subset is critical


P
E
T
Sample CF #,#,#,1 (Valentine Heart Pyx)
Fragment #14, track#, Particle#, Sulfur Grid #1 on Amorphous C (70nm x7)
Central marker
Very first sections-no material yet
Particle extracted by Christopher from keystone 02/13/06 S embedded and Ultramicrotomed by Keiko M. 02/14/06

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 workers and the inevitable oversight committees

Sample PE should 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 is maximized and a broader community becomes acquainted with both the scientific value and problems associated with the samples in the shortest possible time.

For more insight into how Sample Return PET should be done, please attend the Hayabusa session on Thursday