Genesis Mission: Overview and Status. D. S. Burnett[1] and the Genesis Science Team, [1] MC 100-23, Calif. Inst. of Technology, Pasadena, CA 91125, burnett@gps.caltech.edu.

Overview: The Genesis Mission hit bottom (literally) in Sept. 2004 when a failed parachute deployment caused the crash of our Sample Return Capsule (SRC) upon Earth return. However, we have been picking up the pieces (literally) and have begun a slow comeback towards meeting our science objectives. Our biggest problem has been dealing with surface contamination, both crash-derived and otherwise. Progress is being made and preliminary analytical results will be reported at this meeting.

Background. Placed at the L1 point for 27 months from Dec 2001 through April 2004, the Genesis spacecraft collected solar wind, one ion at a time, by exposing pure materials. At 1 keV/amu, the solar wind ions implant and stick in the collector materials. The returned materials are being analyzed in terrestrial laboratories. The top-level science objectives of Genesis are: A) Measure the isotopic compositions of solar matter to a precision sufficient for planetary science application; B) Improve knowledge of solar elemental abundances by at least a factor of 3; C) Provide independent compositional data for the three different solar wind regimes; and D) Provide a reservoir of solar matter to meet the needs of 21st century planetary science.

Working in a specially-designed clean room at JSC, collector materials were placed inside a "canister" (JPL designed and built) which in turn was mounted inside the SRC. Most collector materials were 10 cm point-to-point hexagons mounted in 5 circular (roughly 80 cm) arrays with typically 54 hexagons/array. One array (C) was mounted in the cover of the canister and collected 27 months of solar wind. The other 4 arrays were mounted in a stack. The top array in the stack (B) collected the same bulk solar wind sample as C. The lower three arrays in the stack provide the regime samples with one of the 3 deployed depending on the prevailing solar wind. Solar wind monitors (ion and electron electrostatic analyzers; LANL) mounted on the spacecraft deck determined the prevalent solar wind regime and commanded deployment of the appropriate array. The array switching mechanisms (JPL) worked perfectly during the mission. In addition to the collector array materials, a special ion focusing mirror (the Concentrator) was designed and built by LANL to provide a sample of enhanced O and N fluence. The solar wind incident over 40 cm was concentrated onto a 6 cm diameter target with an average concentration factor of 22. Finally, Al and Au "kidney" foils were placed in available locations, and a bulk metallic glass collector mounted on top of the array deployment mechanism.

Status. Recovering science after the crash involves 3 general steps: 1) Recover sufficient intact material, 2) Assess and mitigate surface contamination, 3) Learn to allocate and analyze smaller than expected areas. Step 1 is complete. Step 2) is the hardest, but the transition to step 3) is under way.

1) The crash produced major fragmentation and loss of collector materials. If we regard the smallest usable fragment as 3 mm in size, we now have greater than 15,000 small pieces as opposed to the expected 275 hexagons. There are relatively few pieces greater than 1 cm in size, but in principle, we have enough material to complete our science objectives. Three of four concentrator targets were recovered intact with most of the pieces of the fourth recovered. The Au kidney foil was recovered essentially intact, but badly crinkled. The Al kidney was in one piece but badly deformed. The bulk metallic glass collector was recovered intact and essentially undeformed.

2-3). In reality, steps 2) and 3) are being worked simultaneously, because cleaning requirements and permissible methods vary with the analytical method. Cleaning tests are a way of life but they are being custom-tailored. In the case of some noble gas analyses, cleaning is not necessary, but these appear to be the only exception. There are four classes of surface contamination: A) Particles, mud, water drop residues from the crash. The particles are from Utah, the SRC, and powdered collector materials (Si and Ge). Essentially all Ge collectors were reduced to powder by the crash. B) A highly refractory organic/silicon film, affectionately known as the brown stain, not crash-derived. C) A ubiquitous submicron particulate ("aerosol") source of inorganic contamination. D) Pre launch surface contamination. Based on analysis of control samples, this is significant in some cases.

Removing particles has focused primarily on wet cleaning methods. These are applicable to all collectors except for the Au and Al coatings on sapphire where delamination is an issue. The following approaches have been used: a) simple ultrasonic water rinse, b) commercial ammonia soap (Micro90) + organic solvents (semiconductor industry recipe), c) 30% KOH, d) HF followed by Micro90 and e) HF vapor etch.

We are able to quantify that we have clean surfaces. A. Westphal has developed an automated optical microscope scanning system which provides quantitative size distributions down to at least 1 micron with particle detection down to 0.3 microns. This system is now installed and operational in a clean room environment at JSC.

Depending on sample and particle size, all of these techniques reduce the particle densities by factors of 10-100. This may be sufficient for some applications. Most of the larger particles are only superficially bound and can be easily removed with the ultrasonic high purity water rinse. Barring problems arising in additional testing, this will be a standard Curtorial Facility cleaning procedure (see Allton/Calaway abstract). The KOH treatment has proven difficult to control. On Si, it appears to etch through the brown stain and any underlying SiO_2, then rapidly attack the Si containing the solar wind. The HF treatments may partially remove the brown stain, but more tests of this are needed.

Extensive characterization of brown stain has been made by ellipsometry and photoelectron spectroscopy with some studies by SIMS and by FIB/TEM (Graham, LLNL). The brown stain is highly variable in thickness, but 50 A is a typical value, and at this thickness, solar wind attenuation is not important. The ellipsometry will be used for routine characterization by the Genesis Curatorial Facility, which will permit us to monitor fluctuations. The ellipsometry will work on most collector materials, but not on the kidney or bulk metallic glass samples. Of great interest is the fact that some samples appear to have essentially no brown stain. It may be that cherry-picking is a major means of dealing with contamination.

The brown stain is very resistant to solvents and acids, and even to vacuum heating in air up to 400C. The most promising removal techniques are the “dry etching” approaches of wide use in materials science. An O plasma has been successfully used on the Au kidney foil and on Si. UV ozone cleaning for Si is being actively studied. One variation using UV exposure in HCl solution reduced the C/Si (XPS) ratio by a factor of 4 on a flight sample. An O plasma treatment in a commercial RIE (reactive ion etching) instrument reduced the C/Si, as measured by XPS, to background levels. A SF_6 plasma etch removes the brown stain on bulk metallic glass without loss of noble gases (see Grimberg et al. abstract).

A major series of tests of RIE etching of Mg contamination on Si using SIMS analyses showed mixed results, but the least ambiguous tests indicate significant contamination reduction. For an O plasma etch we assume that the silicone component of the brown stain is converted to SiO_2, and a subsequent HF etch is required to remove the SiO_2 along with other inorganic contaminants. In these tests, treatments with HF and $HF+H_2O_2$ were compared, with the clear contamination reductions being observed with the HF alone. These tests also showed that a superficial Mg contamination layer was added by the Micro90 particle treatment used. For SIMS analysis this layer sputters away very rapidly, and has no effect on solar wind analysis, but it would be more important for other analytical approaches with poorer depth resolution.

Surface Damage. With the possible exception of the Concentrator targets, all collector material surfaces are pitted and scratched to some degree. The loss in area from these is not significant, but contaminants imbedded in these may be an issue for analytical approaches that involve measurement of large areas. This is an issue that requires additional study.

Analysis Overview. About 75 allocations of at least 100 small subcentimeter samples of Genesis materials have been made, most with the goal of studying how to clean surfaces but with the hope that rapid progress will be made leading to actual measurements as well. Analysis to date is focused on validation that we are measuring things correctly, emphasizing the more abundant elements (He, Ne, Mg, Fe). Mg and Ne will serve as major reference elements and need to be measured precisely.

Summary. In Genesis pre-launch planning we set up 18 prioritized measurement objectives. The crash has raised the bar considerably in terms of the difficulty of making these measurements; however, at present we are not giving up on any of these, although an enormous amount of work remains to be done. Contamination is our biggest challenge, but our overall optimism is justified by the fact that the contamination is *on* the surface and the solar wind is *below* the surface. The signal and the dirt are physically separated (see, e.g., Jurewicz et al. abstract). A challenge is that the amount of separation between solar wind and contamination is small, circa 100 Angstroms. But, Genesis is a sample return mission and we have our samples back on Earth. All of contemporary science and technology are available to clean the surfaces without disturbing the implanted solar wind. With a little luck the major effect of the crash will be a delay.