STARDUST@HOME: VIRTUAL MICROSCOPE VALIDATION AND FIRST RESULTS. A. J. Westphal[1], J. Von Korff[1], D. Anderson[1], A. Alexander[2], B. Betts[2], D. Brownlee[3], A. Butterworth[1], N. Craig[1], Z. Gainsforth[1], B. Mendez[1] , T. See[4], C. J. Snead[1], R. Srama[5], S. Tsitrin[1], J. Warren[4], M. Zolensky[4], [1]Space Sciences Laboratory, University of California, Berkeley, CA, 94720, USA, [2]The Planetary Society, Pasadena, CA, [3]Astronomy Department, University of Washington, Seattle, WA, [4]Johnson Space Center, NASA, Houston, TX, [5]University of Heidelberg, Heidelberg, Germany

Introduction: The Stardust spacecraft carries the first sample of contemporary interstellar dust to be returned to terrestrial laboratories for analysis. Here we describe a project called Stardust@home, which has the goal of identifying these tiny particles in the Stardust Interstellar Collector using volunteers. We present measurements of the performance the web-based Stardust@home Virtual Microscope using inexperienced volunteers.

Identification of IS dust is a major challenge: At the time of this writing, the Stardust spacecraft is on its way home after seven years in interplanetary space. It carries a sample of cometary dust collected from the coma of a Jupiter-family comet – the first sample collected *in situ* from a planetary body and returned to Earth since the 1970's, and the first ever from beyond the Moon.

During two periods of the pre-encounter cruise phase, Stardust also collected, in an array of aerogel tiles dedicated to the purpose, the first sample of contemporary interstellar dust ever to be returned to terrestrial laboratories. Landgraf *et al*.[1] have estimated that a few dozen interstellar dust particles have impacted the Stardust Interstellar array. They estimate that these particles will be tiny – only ~1 micron to submicron in size.

Before analysis of these mostly submicron particles can begin, they must be located in the array of aerogel tiles. Fortunately, it is not necessary to image these tiny particles directly. Interstellar dust particles are captured at speeds, ~20 km sec^{-1}, that are much larger than the speed of sound in the aerogel. The nearly cylindrical shock wave produced by the particle in the aerogel cavities blows out a cavity in the aerogel with a diameter of a few microns[2]. This has two advantages: first, it facilitates the search since the tracks are an order of magnitude larger than the particles; second, the track is the signature of a hypervelocity impact, so the particle, if it survives, can be readily distinguished from other dust particles that may be present in or on the aerogel collector.

Nevertheless, locating these impacts is a formidable challenge. Imaging the particles requires high-magnification microscopy, and the area to be searched is large, ~1000 cm^2. We find that at the minimum magnification required, more than 1 million fields of view must be searched. We have considered automated identification of these impacts. In practice, aerogel contains flaws, inclusions, and surface defects that must be distinguished at very high efficiency from hypervelocity particle tracks. This makes automated identification very difficult, although this approach may be pursued in the future.

The human eye is exceptionally good at rapidly identifying tracks. However, the very large number of fields-of-view that must be searched exceeds the resources of any individual research group or even a realistically-sized consortium. Therefore, we have taken the approach of recruiting volunteers to participate in the idenfication of interstellar dust impacts. We have described this project, called Stardust@home, previously[3].

Data collection: Using an automated microscope that we developed several years ago for the analysis of high-energy astrophysics detectors, we automatically scanned an aerogel tile that had been shot with ~20 submicron carbonyl iron grains at ~20 km sec^{-1} using the van de Graaf dust accelerator at Heidelberg. These tracks are the best laboratory analog to interstellar dust impact tracks that are available. In each field-of-view, we collected a stack of ~40 images extending from ~20 microns above the surface to about ~160 microns below the surface. A total of ~1,300 images were collected over an area of ~1 cm^2. Only a small fraction of these images contained one or more tracks.

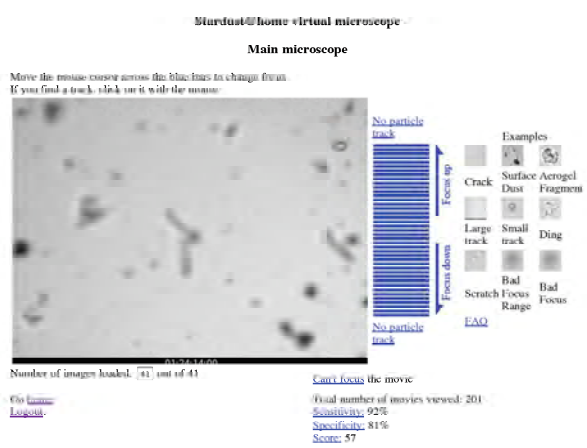

Figure 1. Screen shot of the VM. The VM is focused just below the surface of the aerogel. A IS analog is visible in the upper right of the view.

Virtual microscope performance: Two of us (JVK and DPA) have developed a web-based Virtual Microscope (VM) that simulates the performance of a real microscope. Specifically, it allows a user to focus up and down in a field of view using a scrollbar. Sliding the computer mouse over the scrollbar switches images in the stack of images sufficiently rapidly that focusing is smooth. The VM is written in a combination of html and javascript. Users first are shown a series of example training fields of view, showing examples of analog IS tracks and of various features that can be confused with tracks. After this, the user must pass a test, consisting of 10 views with and without tracks. If the user passes the test (8 out of 10 is the passing score) the user can then register and can proceed to scan images. The VM feeds calibrated images into the datastream in order to measure the efficiency of each user. The user does not know which views are real and which are calibration views. Because of the very small number of tracks in the aerogel, some calibration views were artificially generated by splicing the image of an analog track into a blank view. Efficiency consists of two statistics: the *sensitivity* is the user's efficiency at correctly identifying tracks, and the *specificity* is the user's efficiency at correctly identifying views with no tracks. Both statistics are shown to the user on the VM. A productivity *score* (the number of calibration images correctly identified minus the number incorrectly identified) is also shown on the VM.

Between 1 December 2005 and 4 January 2006, we invited colleagues, friends, and family to test the alpha (non-public test) version of the VM. We deliberately did not coach these volunteers. With only a few exceptions, none of the volunteers had worked with aerogel before. On around 30 December 2005, an unknown person leaked the web address of the VM to a public website – this resulted in a total of >100 users who registered and used the VM. In Figures 2 and 3 we show the measured sensitivity and specificity of the 75 users among both populations who examined at least 10 calibration images with tracks and at least 8 calibration images with no tracks. The mean (median) sensitivity and specificity were 0.98 (1.00) and 0.96 (1.00), respectively.

Discussion: We have carried out a measurement of the performance of our search strategy using a VM and volunteers. This measurement is necessarily artificial. However, we tried to make a realistic and conservative simulation using deliberately dusty and cracked aerogel and the best available analogs for IS dust impacts in aerogel. Although we are encouraged by these results, the success of this approach has yet to be demonstrated using data from the real Stardust IS tray.

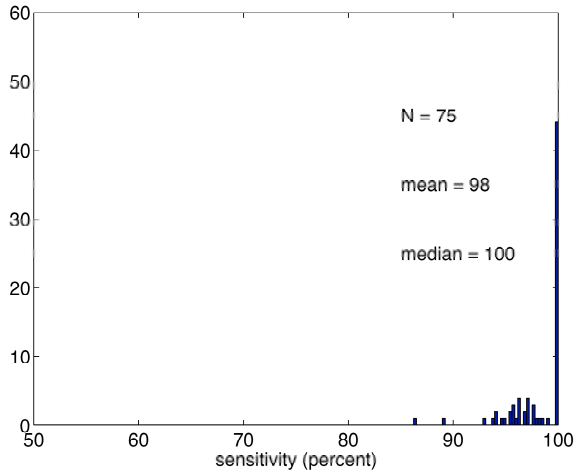

Figure 2. Measured sensitivity for 75 users who measured at least 10 calibration views with tracks and 8 calibration views with no tracks. Random guesses would give 50% sensitivity.

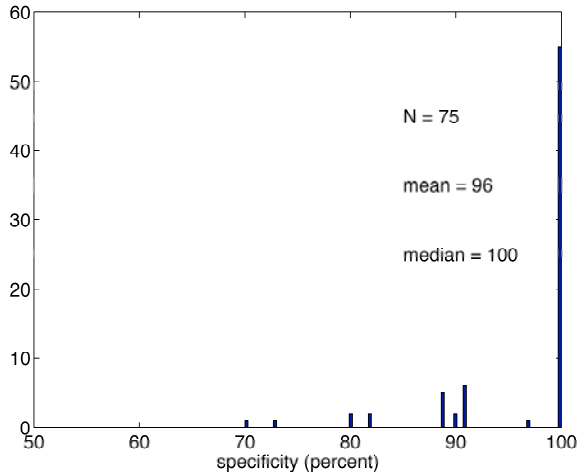

Figure 3. Measured specificity for 75 users who measured at least 10 calibration views with tracks and 8 calibration views with no tracks. Random guesses would give 50% specificity.

References: [1] Landgraf M. et al. (1999) *PSS, 47,* 1029–1050. [2] Dominguez, G. (2005) PhD thesis, Univ. of California, Berkeley [3] Westphal A. J. et al (2005) *Proc. of the 36th Lunar Planet. Sci. Conf.*, 36, 108 -212