SEMPA - A SCANNING ELECTRON MICROSCOPE AND PARTICLE ANALYZER FOR THE CRAF MISSION; Arden L. Albee and James G. Bradley, California Institute of Technology, Pasadena, Cal. 91125

INTRODUCTION. SEMPA is a newly developed spacecraft instrument, miniaturized from the scanning electron microscopes and energy-dispersive x ray analyzers now common in laboratories. The experiment, with J.T. Armstrong, D.E. Brownlee, A. El Goresy, and K. Keil as additional investigators, has been accepted for the Accommodation Phase of NASA's Comet Rendezvous/Asteroid Flyby mission, which is planned for launch in the '90s. SEMPA will (1) determine elemental composition, shape, morphology, and mineralogy of individual dust particles and (2) characterize the distribution in size and in the types of particles making up the dust flux. Such a basic characterization of the dust component of the comet will be utilized by numerous disciplines in achieving a better understanding of the comet nucleus. SEMPA's ground data system for the analysis of scanning images and of energy-dispersive x ray spectra will be a widely used commercial system. This approach will facilitate the detailed analysis of SEMPA data by the wider community of scientists interested in extraterrestrial materials.

CONCEPT. Spaceflight requirements demanded redesign of existing instrument concepts to adapt them to the space environment, minimize weight and power consumption, and increase the maintenance-free lifetime of certain components. This necessarily involved trade-offs against instrument performance. Nevertheless, the breadboard instrument developed at JPL [1,2] nearly equals the performance attained by the better SEM-EDS instruments of only a few years ago. SEMPA has the ability to survey all particles >0.1 μm, to quantitatively analyze particles as small as 0.25 μm for elements of atomic number >11 (Na), and to image particles with ~40 nm resolution.

Fig. 1 is an isometric view of the conceptual spaceflight instrument. Elemental analyses and high-resolution imaging will be achieved by means of an electrostatically focused, steppable electron beam of 15 keV energy. Long cathode life is provided by the development of a dual-LaB_6 cathode with magnetic deflection coils [3]. The x rays excited by the beam are analyzed by an energy-dispersive detector and counts accumulated in a 1024-channel PHA. The weight and power needed for detector cooling have been reduced by the development of a mercuric iodide detector that provides satisfactory performance at room temperature [4]. An image is created by digitally stepping the electron beam over the sample in a line-by-line raster. Backscattered electrons and secondary electrons are measured and digitized to 256 gray levels to form the image. A low-resolution map to detect particles or a high-resolution image of surface features may be produced by varying the beam size, step distance, and field of view. Alternatively, a compositional map may be produced by sensing the x rays as the beam is rastered.

SEMPA is preprogrammed in ROM to run automatic sequences, which are structured as subprograms, for sample acquisition, sample coating, x ray data acquisition, x ray mapping, and high-resolution imaging. Certain parameters are given default values that can be modified by uplink commands. Several standard operation programs that link subprograms will also be stored in ROM, but the stored subprograms can also be linked in different ways by uplink command. This approach allows SEMPA to perform its functions with minimal uplink, but can be adapted to provide for analysis of a wide variety of samples.

In the 1000-hour nominal operation of SEMPA it is expected that the comet environment will be sampled about 50 times, capturing about 200,000 individual dust particles for survey imaging, selective elemental analysis, and high-resolution imaging.

SAMPLING MODE	
Sampling sites	54 depressions ("dimples") on periphery of wheel
Site dimensions	800 x 800 μm area in each 1-mm dimple
Calibration sites	10 containing imaging and x ray standards
Sampling time	Programmable
Number of dust particles per sample	300 > 1 μm diameter, 3300 > 0.1 μm diameter, etc.
IMAGING MODE	
Electron beam current	10^{-10} A (minimum)
Resolution	Better than 40 nm beam diameter
Imaging detectors	Secondary electron detector, backscatter electron detector
X RAY ANALYSIS MODE	
Electron beam energy	15 keV
X ray energy range	1 to 10 keV
Elements analyzed	All with atomic number > 11 (Na)
Element concentration range	0.2 to 100% (by weight)
X ray energy resolution	<200 eV at 5.9 keV, <170 eV at 1.2 keV
Mass	11.9 kg
Power	22 watts

REFERENCES. [1] Hart, R.K. et al. (1981) SEM/1981 I, 96-104. [2] Conley, J.M. et al. (1983) Microbeam Analysis - 1983, 177-182. [3] Bradley, J.G. et al. (1986) Microbeam Analysis - 1985, 265-267. [4] Iwanczyk, J.S. et al. (1986) IEEE Trans. Nuclear Sci., NS-33, 355-358.