PRISTINE PARTICLE COLLECTION WITH A CYCLONIC SEPARATOR ON LONG-DURATION STRATOSPHERIC FLIGHTS ABOVE AOTEAROA NEW ZEALAND

K. Hofmans[1], M. T. Bannister[2], J. P. Bradley[3], U. Yalcin[1], A. Aves[2], L. E. Revell[2], H. A. Ishii[3]. [1]School of Product Design, University of Canterbury, NZ; [2]School of Physical & Chemical Sciences, University of Canterbury, NZ; michele.bannister@canterbury.ac.nz, [3] Hawaiʻi Institute of Geophysics and Planetology, University of Hawaiʻi at Manoa, Honolulu, HI 96822, USA.

Introduction: Interplanetary dust particles (IDPs) are collected at an altitude of ~ 20 km in the stratosphere by impact onto silicone oil-coated 'sticky' collection surfaces mounted on WB57 and ER2 aircraft wing pylons; they have also been collected "dry" onto polymer substrates [1,2,3]. Recovery of IDPs from the collector surfaces involves both solvents and oils that may contaminate IDPs and compromise one of their most important constituents, extraterrestrial organic matter [4]. The high speed of the aircraft (~200 m sec^{-1}) can also cause larger IDPs to fracture on impact [2,3]. (Collection of IDPs at lower altitudes would be hindered by dilution in the higher terrestrial aerosol loading, as well as elevated levels of terrestrial contamination).

Here we describe a new approach to the collection of IDPs in the stratosphere, using a low-speed (~30 m sec^{-1}), long dwell-time solar-powered aircraft and a novel collector design. We propose to collect IDPs directly onto dry substrates (e.g., C, Si, Au. KBr, Nuclepore) compatible with multiple analytical instruments. Our novel cyclonic implementation aims to return IDPs and any other particles present (e.g., microplastics) intact from the stratosphere, minimizing sources of contamination, and in a manner that streamlines curation and subsequent laboratory investigations. For comparison and proof-of-concept, the passive collection surfaces currently in use on the ER2 and WB57 aircraft can also be mounted on the solar-powered aircraft.

Flight platform: Kea Aerospace's remotely piloted solar-powered Atmos aircraft [5] is under development in Christchurch, New Zealand, with flight testing of the prototype beginning in early 2023. Kea Atmos will fly in the stratosphere for up to 3 months at a time, primarily for ground imagery, at an expected average airspeed of 30 m sec^{-1}, shifting between altitudes of 65,000 ft and 55,000 ft during day/night cycles respectively.

Design requirements: A payload bay volume of 200 x 240 x 200 mm, mass up to 2 kg, and passive or minimal power draw provided our design envelope. The instrument can collect samples discretized during flight into sampling periods, each isolated from contamination. Collection duration and time for each sample is fully controllable, making it possible to avoid e.g., ascent, descent, or volcanic plumes; and deliberately collect, e.g., during meteor showers.

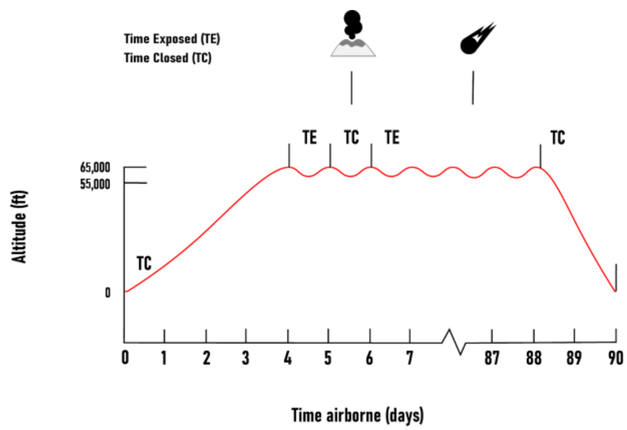

***Figure 1**: A schematic Kea Atmos collection flight plan.*

Instrument design: A *swift* model axial flow cyclonic separator (Fig. 2) uses a vortex of air to separate particles from the airstream [6,7]. Suspended particles move to the outermost part of the vortex, where they are free to settle in slow-moving air toward the base of the cyclone. The clean airstream exits through the top. Prototype dimensions computed based on [6] will capture 10–25 µm particles. All components avoid the use of plastic (excluding PTFE) to minimise sample contamination across IDPs and microplastics; the cyclone is designed to be 3D printed in $AlSi_{10}Mg$ alloy.

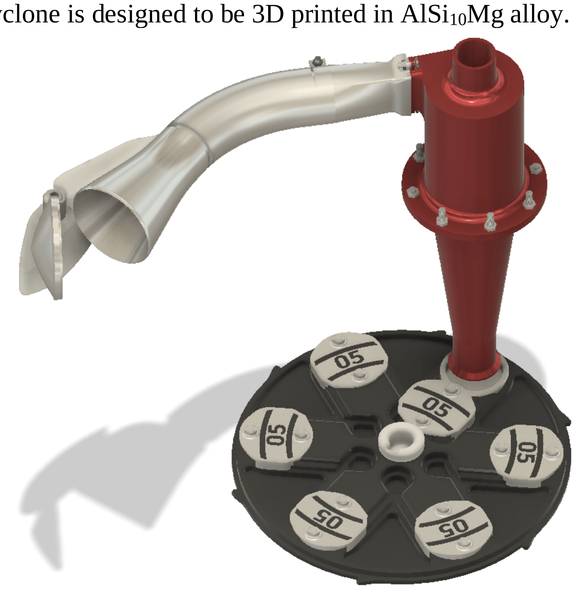

***Figure 2**: Rendering of intake (silver), cyclonic separator (red) and cartridge (black) with six sample containers (silver circles) for the collector design.*

The closable duct (Fig. 2) feeds into individual 8081 Aluminum sample containers with base and slide/clip-on lids (Fig. 3a). These are internally 25mm diameter, to permit the insertion of commonly available analytical substrates. This allows for a direct transition from the aircraft post-flight to analytical optical (IR, Raman), electron-beam, ion-beam and synchrotron methods, without requiring the complications of sample transfer.

Figure 3: *Renderings of (a) single sample container; (b) the tracked underside of the container cartridge lid.*

The six individual containers sit within an 8081 Al cartridge; a lid forms a press-seal onto its base. Two tracks on the underside of the cartridge lid (Fig. 3b) interface with the two small knobs on the top of each container lid. When a sampling period ends, the motor (Fig. 4, behind red handle) rotates the cartridge base and all containers within. The container lids follow the tracks in the cartridge lid (Fig. 3b), closing the full container and opening the lid of the next empty container. This enables a fully-sealed transition between collection containers using a single motor.

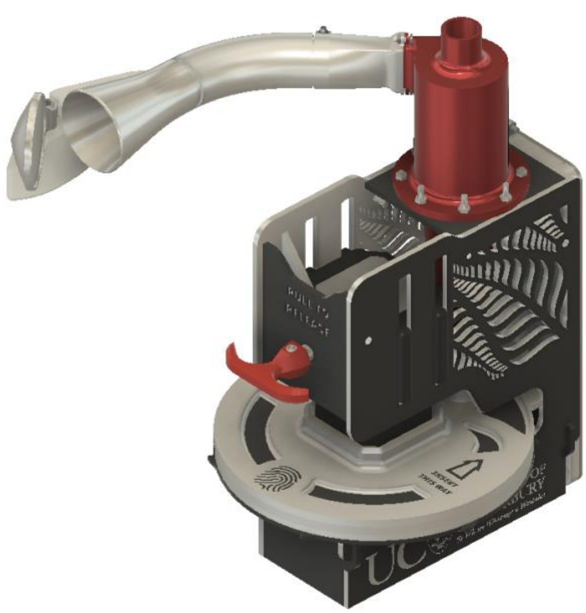

Figure 4: *Rendering of the assembled collector with its collector cartridge rotator motor, control electronics and watercut aluminium housing.*

Figure 5: *Rendering of the collector integrated in the Kea Atmos payload bay.*

The collector is designed to mount inside the Atmos payload bay (Fig. 5). A quick-release system (Fig. 4., red handle) allows for rapid and safe insertion and removal of the container cartridge following each flight.

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