National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

SCHAN: Analysis of biomolecules from resilient microorganisms using supercritical CO_2 and subcritical H_2O

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Strategic Focus Area: In-Situ Extant Life Detection Technology **| Strategic Initiative Leader:** Victor S Abrahamsson

Objectives: The Supercritical CO_2 and Subcritical H_2O Analysis (SCHAN) instrument uses supercritical CO_2 for lysing microbes in order to analyze organic biosignatures at parts-per-trillion (ppt) concentration levels. The operational steps of the SCHAN instrument are as follows: 1) load sample and capture microbes or other particulates on a filter, 2) perform cell lysis with supercritical CO_2 (22 MPa, ≤250 °C), 3) extract, preconcentrate, separate, and detect organic biosignatures (**Fig. 1**).The overall goal in FY23 was to develop and validate a TRL 5 version of SCHAN. To achieve this, several parts of SCHAN needed to be modified or redesigned (**Fig. 2**).

Background: Life-detection missions to Enceladus and Mars have been identified as two of the top priorities for the upcoming decade by the Decadal Strategy for Planetary Science and Astrobiology 2023-2032. These documents have indicated that new technologies, and sensitive and versatile instruments such as SCHAN are needed to fulfill stringent mission concept measurement requirements. SCHAN offers several advantages over its competitors in terms of sensitivity, simplicity, and gentleness of approach (no harsh chemicals or very high temperatures that are commonly used by other instruments). SCHAN can detect down to $1{\times}10^4$ cells/mL of *B. atrophaeus*, which is over 1,000 times better than the traditional combination of pyrolysis/gas chromatography/mass spectrometry; that is, the techniques used in Sample Analysis at Mars (SAM; Curiosity rover) and the upcoming Mars Organic Molecule Analyzer (MOMA; Rosalind Franklin rover) [David, et al. *Analytical Chemistry* 2016; Meunier, et al. *Adv. Space Research* 2007].

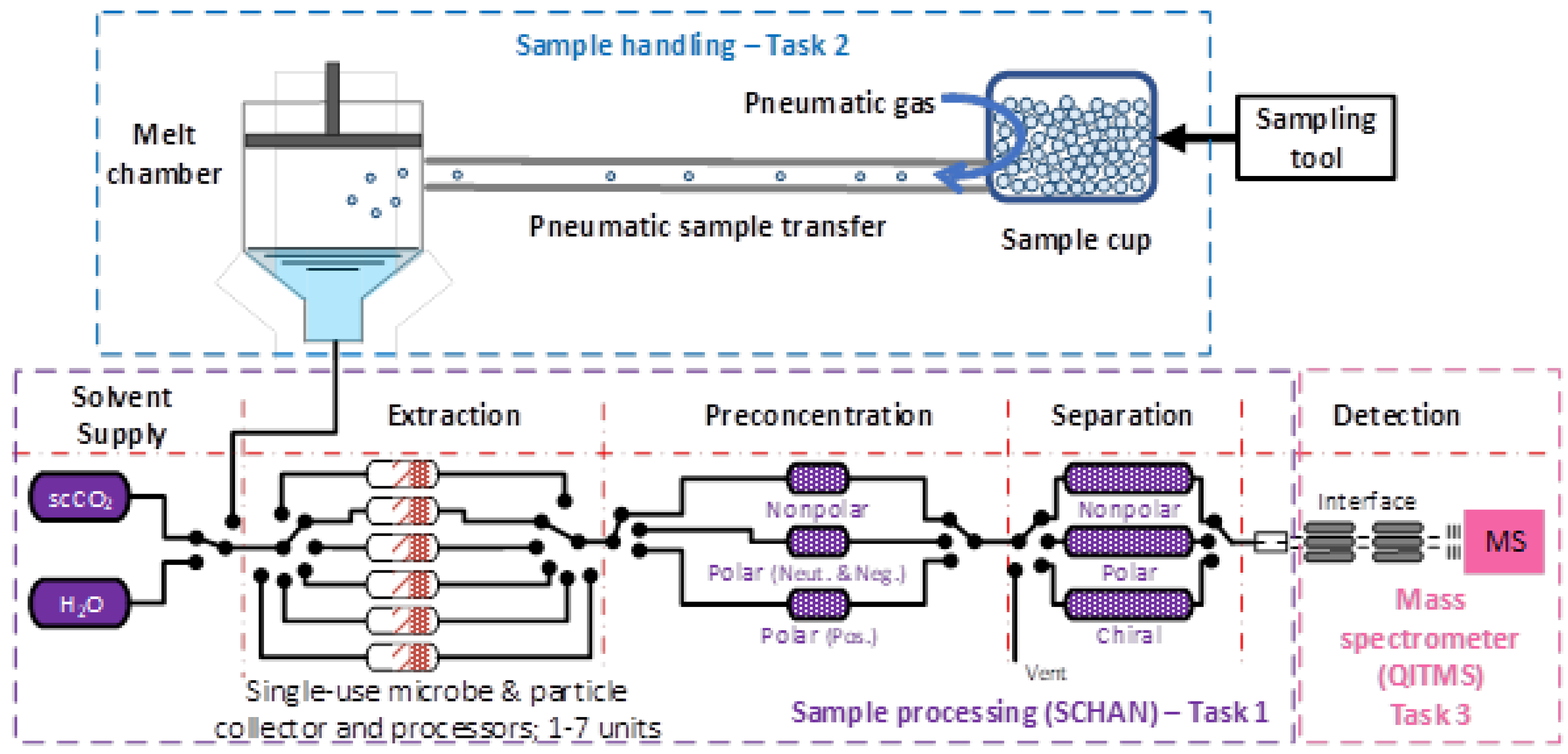

Figure 1. Schematic overview of the Initiative, with SCHAN outlined as Task 1. In FY23 SHaD and SCHAN were tested in series with a seawater sample (see Figure 4). Extracted organic biosignatures were subsequently preconcentrated, separated (chromatography), and detected, with extremely low LODs.

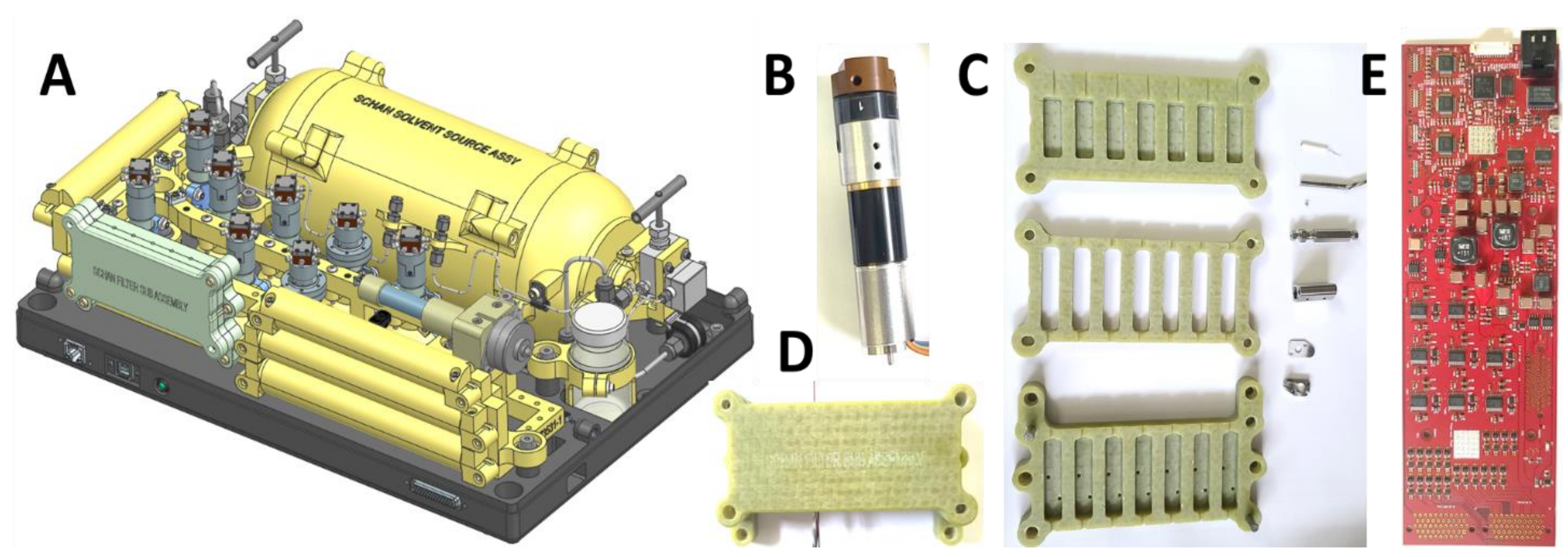

Figure 2. The SCHAN brassboard instrument was redesigned to be TVAC compatible and to include an integrated microbe filtering and lysing unit using methods developed in FY22. **A** The subsystem design has been finalized. **B** The microfluidic valves were redesigned for higher reliability and assembled. **C** The new filter assembly holds individual temperature-controlled filters for 7 samples, which are mounted into an insulating composite structure **D**. **E** The new control electronics have been designed, fabricated, assembled, and verified.

Approach and Results: To mature SCHAN toward TRL 5, TRL 5-compatible microfluidic valves were redesigned with new actuators (brushless with Hall sensors instead of brushed DC motors) to improve reliability by adding additional position control and torque margin. The SCHAN filter assembly and all its subcomponents have been designed and fabricated, and includes seven individually temperature-controlled (up to 250 °C) filter holders located in a thermally-insulating composite structure. This design allows each unit to be individually heated for precise control and power savings. The electronics were redesigned for vacuum compatibility as required for TRL 5. The new control board has additional channels and features required by the new valves, the filter assembly, and drivers for the Sample Handling and Distribution (SHaD, Task 2) subsystem. The SHaD-SCHAN combination was demonstrated using Ocean World analogs (seawater and frozen seawater from the Pacific Ocean). The analysis of ~2 g of liquid or solid sample was completely automated once the sample was added into the SHaD chamber. Multiple fatty acids were detected at parts-per-billion level or lower (**Fig. 3**). The SCHAN TRL 5 subsystem will be complete by Dec. 31 and TVAC testing with both SCHAN and SHaD is scheduled to be completed by Feb. 28.

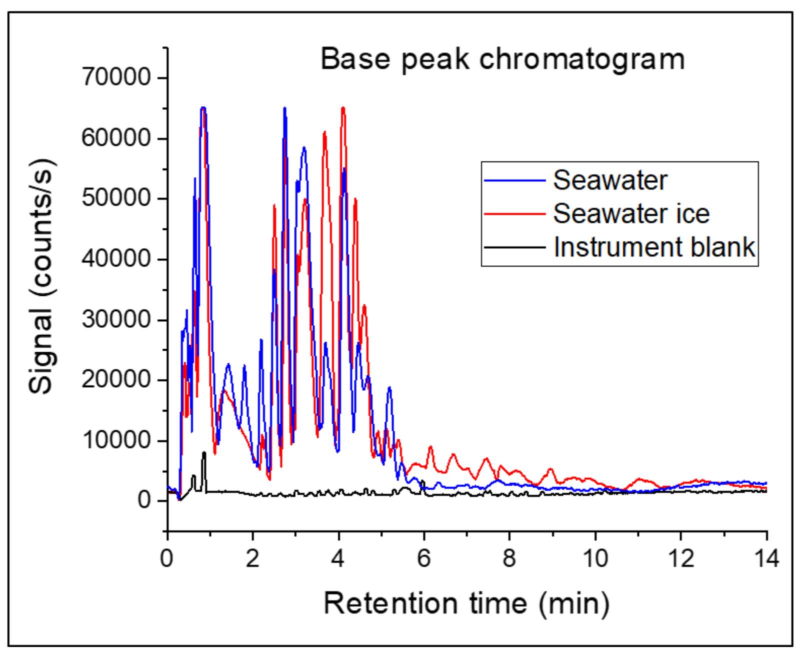

Figure 3. Coupling of SHaD (sample handling, Task 2) and SCHAN (analysis, Task 1) subsystems was successfully demonstrated with a seawater (blue trace) and sea ice (red trace) Ocean World analog sample from the Pacific Ocean. Analysis revealed several fatty acids, in addition to many other organics. No other instrument is capable of detecting fatty acids at the parts-per-trillion level, showing that SCHAN is uniquely capable of detecting extant life at these low concentrations.

Significance/Benefits to JPL and NASA: The SCHAN instrument is applicable to life-detection missions to Mars and Ocean Worlds. SCHAN is now the most sensitive instrument in the world for in-situ lipid analysis (high priority organic biosignatures with high longevity). SCHAN is also unique in its capability of completely integrated sample processing for microbe lysis coupled with chemical analysis without organic solvents, and is capable of detecting $1{\times}10^4$ cells/mL – this is the lowest so far reported for a separation instrument (e.g. gas chromatography or capillary electrophoresis).

Publications:

[A] Henderson, B. L., J. Prothmann, V. Abrahamsson, W. W. Schubert, F. Chen, F. Zhong, Y. Lin, A. J. Williams and M. L. Tuite. "Enabling Analysis of Resilient Biomaterials with Supercritical Carbon Dioxide and Subcritical Water". *2022 Astrobiology Science Conference*, AGU, Atlanta, GA, 2022.

[B] Abrahamsson, V., B. L. Henderson, F. Zhong, J. Prothmann, Y. Lin and I. Kanik, "SCHAN: Supercritical CO_2 and subcritical H_2O analysis instrument for in-situ detection of organics and life". *2022 Astrobiology Science Conference*, AGU, Atlanta, GA, 2022.

[C] Henderson, B. L., et al. "A New Approach to Sensitive Analysis of Resilient Biomaterials." LPI Contributions 2806 (2023): 1734.

[D] Abrahamsson, Victor, et al. "A Novel Integrated In-Situ Instrument for Analysis of Organic Biosignatures." AGU Fall Meeting Abstracts. Vol. 2022. 2022.

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