IN SITU TITAN INSTRUMENTS AND THE CASE FOR MICROFLUIDICS-BASED SAMPLE PROCESSING AND ANALYSIS. M. L. Cable[1], A. M Stockton[1], M. F. Mora[1] and P. A. Willis[1], [1]NASA Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., M/S 302-231, Pasadena, CA 91109, Peter.A.Willis@jpl.nasa.gov.

Introduction: Titan is an enigmatic moon, shrouded in haze and coated with a veneer of organic material. These organics are heterogeneous, resembling kerogen, and include constituents that may exceed an *m/z* of 10,000 [1]. Analysis of such complex samples has become a major focus in the effort to understand Titan as a prebiotic chemical system.

Alhough pyrolysis data acquired from pure samples and simple mixtures is readily interpreted, this technique has severe limitations when applied to complex organic mixtures such as the material present on Titan. Unpredictable side reactions and decomposition products can severely impair determination of the initial composition. A recent study [2] therefore suggested that liquid-based assays would be significantly less destructive and allow for retention of more information of the original sample.

To that end, we explore the potential of microfluidic-based techniques for both sample handling and processing on an in situ Titan mission. In these analyses, samples are either dissolved in liquid or maintained in their original form, and do not experience chemical alteration brought on by extreme heating.

Microfluidics, also termed 'lab on a chip', has been under development for nearly two decades with the goal of facilitating chemical analysis on a small scale both inside and outside the laboratory. Benefits to such technology include low mass and power requirements, small sample size (nL to µL) and, when coupled to higly sensitive detection techniques such as laser-induced fluorescence, enables high resolution separations of various species of interest including amino acids and carboxylic acids with sub parts-per-trillion detection limits [3-4].

We investigate the potential for sample handling and interrogation using microfluidics as an enabling technology on Titan. New challenges to such an environment include cold-tolerant materials and electronics, as well as exploration of nonaqueous chemical analysis techniques for in situ analysis at low temperature.

Microfluidic Sample Handling: Recently, advancements in automated microfluidic sample manipulation and analysis using monolithic membrane microvalve systems [5] have established this technique as a strong candidate for in situ science. These microfluidic devices will be able to serve both as a sample bus and a miniaturized chemical laboratory. The technology is modular, reprogrammable and capable of manipulating small fluid volumes using very low power and mass, making this device ideal for sample processing where many factors may be unknown prior to launch and/or landing. Further, the valving architecture has the added flexibility of handing both gas and liquid samples, permitting aerosol analysis in addition to liquid phase interrogation (Fig. 1). These microfluidic devices are able to perform manipulations required for liquid chemical analysis, such as extrac-

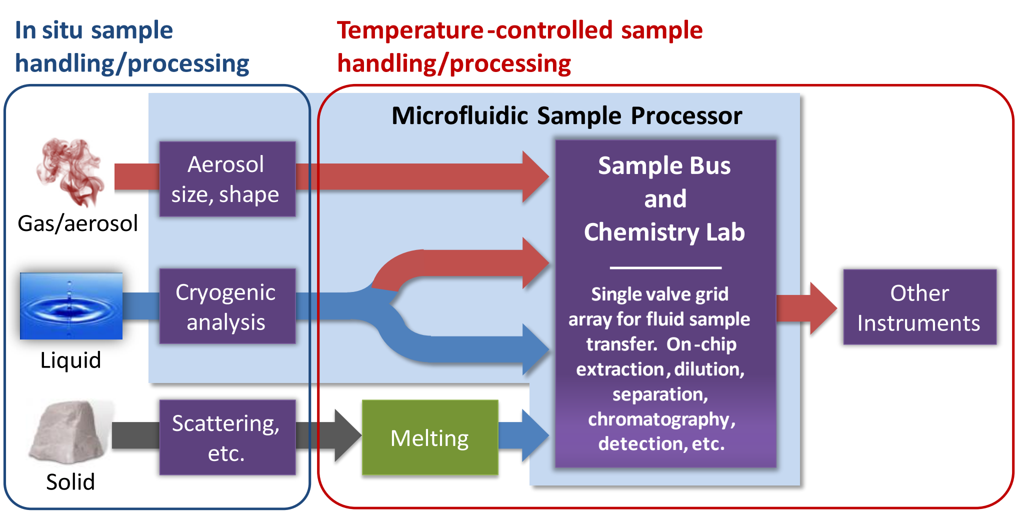

Figure 1. Flow chart of sample handling for an in situ Titan mission, with some proposed instrument and analysis techniques. Microfluidics enables both sample handling via a 'Sample Bus' and sample analysis using a microfluidic 'Chemistry Lab' capable of performing a variety of experiments.

tion, dilution and addition of reagents, as well as various separation protocols. Further, as most on-chip analyses are nondestructive, one sample can be passed through the microfluidic device and then to other instruments for concomitant analysis. Such a system is particularly effective where the microfluidic device performs some type of electrophoretic or chromatographic separation, greatly simplifying downstream assays such as mass spectrometry or absorbance spectroscopy.

Roadmap for Technical Development: In order to effectively understand the efficacy of microfluidic sample handling for an in situ Titan mission, further testing is required. For example, devices based on glass and Teflon should be tested down to Titan surface temperatures (90 K) using methane and ethane as the liquid phase. The same device must also exhibit satisfactory performance at higher temperatures where other solvents with varying dielectric constants can be employed to improve sample solubility. Appropriate chemical protocols should also be developed to best separate and detect target species in these samples, such as amines, amino acids and nitriles. These experiments should also involve stability studies to ensure that the method and reagents will survive the 7 year journey to Titan. Coupling of a nondestructive technique such as laser induced fluorescence to a comprehensive downstream mass spectrometer or similar instrument should also be explored.

References: [1] Coates A. H. et al. (2007) *Geophys. Res. Lett., 34,* L22103. [2] Greer J. R. et al. (2011) Keck Inst. Space Studies, Calif. Inst. Tech. [3] Chiesl T. N. et al. (2009) *Anal. Chem., 81*, 2537–2544. [4] Stockton A. M. et al. (2011) *Astrobiology*, *11*, 519-528. [5] Mora M. F. et al. (2011) *Anal. Chem.*, *83*, 8636-8641.

Additional Information: The recent Titan study cited here was part of a collaborative effort of various institutions and industry and funded through the Keck Institute for Space Studies at the California Institute of Technology. A copy of the report is available for download:

www.kiss.caltech.edu/study/titan/report.pdf.