FROM TITAN TO THE GIANT PLANETS: ADAPTING DRAGONFLY'S CRYOGENIC INSTRUMENTATION TO URANUS AND SATURN PROBES. R. D. Lorenz[1], [1]Johns Hopkins Applied Physics Lab, Laurel, MD 20723, USA. Ralph.lorenz@jhuapl.edu.

Introduction: In-situ exploration of the giant planets poses a number of significant challenges, even for notionally simple measurements of basic atmospheric properties. Among these challenges are cryogenic (and high temperature) operation, large entry decelerations, and long cruise duration. Several of these challenges are common to Titan exploration, and are being addressed by the Dragonfly Geophysics and Meteorology package (DraGMet) presently in development.

Atmospheric Structure Measurements: Ample historical precedents (Galileo, Pioneer Venus) exist for atmospheric structure (pressure and temperature) measurements with what are essentially Commercial Off-The-Shelf (COTS) sensors. However, some attention needs to be paid to accommodation to minimize the sensor response time, errors due to dynamic or radiative effects, etc.. Beyond Mars missions and Dragonfly, the development of atmospheric structure instrumentation is also underway (led by this author) for the DAVINCI probe to Venus.

It is conventional also to measure the upper atmospheric density profile via the drag during hypersonic entry, as measured with accelerometers. On US Mars missions of the last 2 decades this has been performed with accelerometers packaged in Inertial Measurement Units (IMUs). Since planetary probes without e.g. landing propulsion do not require IMUs (which are relatively heavy and power-hungry) only the accelerometer sensors themselves need to be installed (as for Huygens and DAVINCI). Possible rotational motions contribute a small error term to accelerometer measurements, so data can be improved by also measuring angular rates with compact solid state sensors (again, as planned for DAVINCI). Note that beyond their scientific interest, acceleration and angular rate measurements are important to understand the engineering performance of entry, descent and landing (EDL) systems, and NASA has mandated such measurements as an Engineering Science Investigation on competed missions.

Optical Measurements: The absorption and scattering of sunlight is of interest in constraining radiative-convective models of atmospheric structure, and the distribution of clouds in particular. Arbitrarily elaborate instrumentation is possible, but simply collimated and filtered photodiode detectors provide the key information, especially when spin of a probe provides azimuth sweeps. DraGMet uses a photodiode detector qualified for 94K operation to detect blowing dust on Titan.

Methane Abundance: Humidity, or the abundance of the dominant condensable constituent is of interest in understanding cloud physics. While elaborate instruments such as mass spectrometers can measure such gases, there may be utility in simple measurements to yield high vertical resolution. DraGMet uses a cryogenic mirrored absorption cell, coupled by optical fibers to sources and detectors in the warm vehicle body to measure methane abundance on Titan.

Acoustic Measurements: the speed of sound profile in giant planets is determined predominantly by temperature. An additional factor [1] that is prominent at Uranus is the mix of ortho:para hydrogen, which serves as a tracer of vertical mixing. While an active time-of-flight pulse system, such as that used on Huygens [2] could be used, in fact a speed of sound measurement on a probe could be as simple as a whistle, with a resonant cavity excited by the airflow of probe descent. DraGMet has qualified microphones for cryogenic operation that could measure the frequency of such a whistle with minimal resource impact.

Electric Fields and Conductivity: Electric fields and particle charging are important to understand aerosol coagulation physics, cloud convection etc. AC electric fields may also (as on Earth) result from a Schumann resonance. DraGMet's EFIELD sensors could be readily adapted to a giant planet mission, especially if probe rotation modulated the electric fields.

Data Processing: The atmospheric structure investigations on Galileo and Pioneer Venus were limited by the very austere downlink bandwidth, coupled with the need to process data in real time, with very limited computation. The latter constraint is somewhat relaxed in the Uranus/Saturn epoch, in that modern instruments like DraGMet can apply relatively sophisticated and flexible data selection and compression to maximize the science value per bit of data that is transmitted.

References: [1] R. D. Lorenz, Speed of Sound in Outer Planet Atmospheres, *Planetary and Space Science*, **47**, 67-77, 1999 [2] Hagermann, A., …, R.D. Lorenz, et al., In-situ Speed-of-Sound Measurements of the Atmosphere of Titan, *Icarus*, **189**, 538-543, 2007