FUTURE PLANETARY PROBE DOPPLER WIND EXPERIMENT TECHNIQUES UTILIZING ADVANCED TRACKING & RANGING SUBSYSTEMS

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Introduction
Measurement of the composition, cloud structure, and dynamics of the upper atmosphere beneath the clouds requires in situ sampling from an entry probe. Dynamics of the atmosphere can be inferred utilizing Doppler techniques to track the motions of a probe during descent. Traditional Doppler wind methodologies demonstrated on the Galileo and Huygens probe missions to Jupiter and Titan [1], [2] depend strongly on the target, whether a large, rapidly rotating giant planet or a smaller more slowly rotating terrestrial planet. However, these techniques utilize a single probe and single Doppler line of sight, and therefore rely on the assumption of a priori knowledge of probe location, descent speed, and meridional winds and provide only a single component of the atmospheric dynamics at the probe location. new Doppler methodologies will utilize uplink and multiprobe techniques, and new radio science instrumentation.

Uplink One-Way Ranging
Uplink one-way ranging techniques from Earth to a descent probe can be used to improve the accuracy of planetary wind pro-files retrieved using traditional single probe, single line of sight Doppler wind techniques. Advances in Radio Science flight instrument technologies provide the opportunity to utilize one-way carrier and sequential ranging signals transmitted from Deep Space Network antennas. Signals from the Deep Space Network (DSN) can be recorded onboard a probe-mounted radio science open-loop receiver with onboard post-processing algorithms to produce precision measurements of probe range, position, and velocity with a significant improvement to atmospheric wind retrievals. The probe velocity relative to Earth is computed as the derivative of the ranging positional information and is therefore unaffected by any constant biases in the ranging data. Probe measurement of the DSN uplink signal can also provide a second projection of the horizontal winds that, when coupled with the probe-orbit wind projection, will provide the complete horizontal wind vector. [3], [4].

Doppler Tracking of Multiple Probes from Earth
Doppler tracking of multiple probes from the Deep Space Network or an orbiting spacecraft provides the opportunity to simultaneously characterize a single component of the atmosphere dynamics at multiple locations. Additionally, techniques that utilize multiple radio links comprising 1) uplink carrier and ranging from Earth to both an orbiter and probes (one signal), 2) carrier and ranging between an orbiter and probes, and 3) science telemetry from individual probes to an orbiter provide for the retrieval of multiple components of the wind dynamics at the location of each probe.

Doppler Tracking of Multiple Probes from a Single Planetary Lander Ground Station
The dynamics of planetary atmospheres can be better characterized if simultaneous wind measurements are made at multiple locations. One concept is for multiple balloon-borne transceivers to be released from and continuously transmit back to a lander ground station. With an ultrastable oscillator (USO) as a frequency reference, the position of the lander ground station can be very accurately established from Earth or an orbiting spacecraft, and will represent an anchor point for tracking the balloon transceivers.

Enhanced Radio Science Flight Instrument for Planetary Wind Measurements
To produce enough signal margin at the open-loop receiver on the probe, the 34 and 70-meter diameter Deep Space Network (DSN) antennas can be used to provide an uplink carrier with a frequency phase modulated with a Pseudo-Noise (PN) ranging signal. The one uplink signal from DSN will be detected and recorded by the open-loop receiver both on-board the Orbiter and the Probe. Orbiter attitude control for simultaneous pointing of antennae towards the Earth and the probe will be an issue. Radio science parameters of the DSN uplink carrier and ranging signal can be immediately recorded via a probe-mounted Radio Science Open-Loop Receiver comprising two modules: a radio frequency front end and a baseband processor.

An on-board Software Receiver will decode telemetry and extract the “Probe Solution” of the pseudo-range and time. These two parameters can then be transferred into the Probe Command and Data Handling System to be telemetered to the Orbiter. Simultaneously, the DSN uplink carrier and ranging signals are recorded and processed on-board the orbiter to compute an “Orbiter Solution” of the pseudo-range time.

Additionally, a carrier with ranging signal between the probe and orbiter is also recorded Open-Loop and processed to compute the “Orbiter-Probe Solution” of the pseudo-range & phase time tagged with probe-time reference. The three solutions are then used to determine and improve the probe position and velocity.

Each small balloon system can carry pressure and temperature sensors and a stable timing reference. By making precise frequency measurements at the Lander from each balloon capsule in flight, the signal can be used to accurately reconstruct the dynamics of each balloon thereby providing a three-dimensional measurements of the wind dynamics.