CUBESAT CONSTELLATION FOR COMMUNICATIONS AND MARS RADIO MONITORING.

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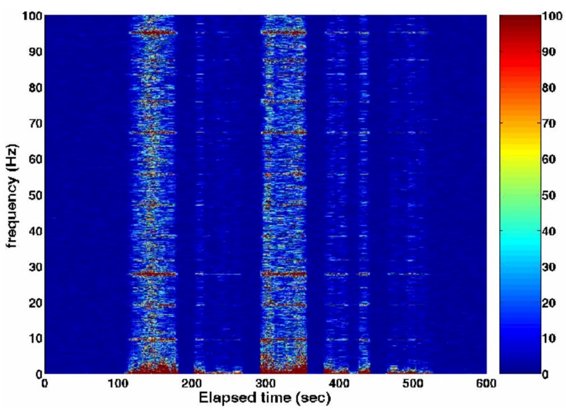
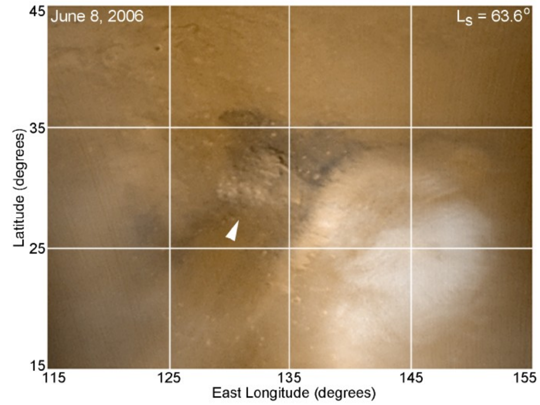
Introduction: Determining the frequency, geographical distribution and severity of electrical activity, (which converts water vapor to hydrogen peroxide) has important implications for the compatibility of the Martian atmosphere and surface with organics. Severe electrical discharges can also be a hazard for humans and robots. Electrical activity, created by charge separation in convective dust storms, has been detected through Earth-based observations [1], but little is known about the causes and consequences of this phenomenon. The emissions were seen intermittently during a 3½ hour period out of a total of about 60 hrs of observation over three weeks. More detailed exploration of these discharges can be obtained by Mars orbital measurements augmented by ground-based observations with the NASA Deep Space Network (DSN) during mission tracking passes.



Ground-based Observations: The Deep Space Network (DSN) has on-site signal processing equipment capable of automatically detecting Mars electrical activity. DSN antennas are pointed almost continuously at Mars. The equipment could detect such emission as effectively as the equipment used by Ruff et al. [1] to make the original detection. New signal processing equipment, for which a prototype is currently being



developed, could better characterize such activity. Procedures and software would need to be developed to automate radio monitoring of Mars for such activity.

Array of Orbiting Sensors: A detection system orbiting Mars would be many orders of magnitude more sensitive, even with less capable receivers and hemispherical antennas. This is because the electrically active region fills a far greater fraction of the beam of an orbiting antenna than any Earth-based antenna.

Satellite-based Networking: A constellation of small communication relay satellites, providing surface and orbiting sensors and roving humans with a time-delay-tolerant packet-switched network could operate as such sensor system for electrical activity, and provide discharge location information. Such a constel-

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lation could be flown as an augmentation of a larger mission, not requiring a separate launch. Delay Tolerant Networking (DTN) technology can autonomously manage disconnections and disruption of the communications network. The relative motion between the CubeSats and the main relay orbiter (which could be a science mission itself) allows for a data mule style of relay networking, which is slow but works even when the inter–CubeSat distances are very long, causing the network to become sparsely connected.

For complete coverage of the planet, there would need to be about 60 CubeSats at the altitude like that of of MRO. They could be delivered in stages as parts of a series of missions. Altitude and degree of coverage are parameters to be balanced against satellite complexity and cost. With patch antennas, 1 W transmitters and 1000 km separation, the baud rate would be about 600. Similar CubeSat-based networks have been studied for use on Earth [2,3].

Science Data Recording: With a small amount of additional electronics, a network node subjected to nearby electrical activity (interference) could switch to science recording for later data transmission. With suitable on-board clocks, the satellites could locate electrical activity by time delays, a cruder version of GPS. The planet's Schumann resonances impose a unique time signature which could be used to correlate the signals received at different nodes.

Interaction with other Missions: When electrical activity is detected, either by triangulation with orbital sensors or detection from earth coupled with optical images of dust storm activity, other orbiting sensors such as optical and UV cameras and gas radio spectrometers could be re-targeted automatically to examine the region of interest for changes in atmospheric or surface composition. Examples of such missions would be the MRO HiRise (though that one can probably not be reprogrammed for automatic response) or the instrument suite proposed in response to this call under the title “Searching for evidence of extant subsurface biological and geological processes from Mars orbit”.

Surface Radiometry: With careful calibration, the radio receivers could also characterize sub-surface thermal conductivity and temperature. This might help find reservoirs of subsurface ice, a consideration for long-duration human activity.

Concept Summary: Monitoring of Mars natural electrical activity is important for both understanding Mars processes as well safe operation of human or robotic missions. These observations can be implemented with varying levels of possible complexity and cost:
1. ground-based, round-the-clock monitoring of Mars for natural, non-thermal radio emission using the DSN;
2. a constellation of CubeSat-like communications antennas also programmed to record and analyze radio interference;
3. satellites with more sensitive and calibrated receivers, and possibly several frequencies, to measure subsurface properties of Mars.

Response to Challenge Areas:

Challenge Area 1: Instrumentation and Investigation Approaches. Monitoring for non-thermal emission from electrostatic discharges is analogous to radio monitoring for lightning on Earth, although the physical parameters are very different. It indicates the location of strong convection and localized ionization. Calibrated to radiometric accuracy, orbiting receivers can map sub-surface thermal and composition properties.

Challenge Area 3: Mars Surface System Capabilities. Knowledge of electrical activity near the surface can be important to the operation of landed assets. An orbiting packet-switched communications system would allow near real-time coordination of activities on the surface and in orbit, even by different missions.

References:

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[2] J. M. Nelson, “Persistent Military Satellite Communications Coverage Using a CubeSat Constellation in Low Earth Orbit,” Master's thesis, U. of Central Florida, 2010.

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Additional Information: For additional information regarding this concept, call the lead author at 818-354-5623, or send an e-mail message to one of the addresses given in affiliation footnotes.