Reconfigurable Martian Data Cloud. D. J. Sheldon[1], R. C. Moeller, P. Pingree, N. Lay, G. Reeves, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Blvd., Pasadena, California, 91109.

Introduction: The objective is to develop a constellation of small satellites in orbit around Mars that would provide a highly scalable and dynamically allocatable high performance computing resource. This type of computing resource would be required to help minimize the risk associated with potential human based safe Martian landing and ascent. Managing the safe landing and ascent of humans on Mars would require orders of magnitude more data processing and analysis than is currently available through a single spacecraft. The envisioned small satellite constellation would be organized to function as a cloud of servers, data storage and networked based communication platforms.

Discussion: Cloud computing environments have revolutionized terrestrial IT tasks by providing significant data aggregation, computing power and variable resource accessibility. Cloud computing provides a shared resource pool in terms of data processing and storage that can scale to meet the needs of a particular application. Many smaller nodes can outperform a large, dedicated hardware platform.

Having a cloud based computational resource for potential Maritian landing and ascent operations means high performance computation and analysis capability could be provided with a much smaller cost than a large dedicated satellite. Smaller individual resources require proportionally smaller power sources. This promotes reliability and enhances long-term operation.

The Martian computing cloud would be used to manage communications between the earth and landing vehicles and ground transmitters and other orbiting assets, all at the same time. The system could be reconfigured to handle changing mission requirements. This is different than using a high performance system that is designed for a given series of tasks but remains idle for other tasks because of the lack of reconfiguration.

The software architecture for a data cloud is significantly different from that of a dedicated processor. The traditional role of an operating system partioned on physical hardware is different when compared to a virtualized operation environment implemented in a cloud computing environment. Software kernels that run on virtual machines require only a few device drivers for support. This flexible architecture enhances power optimization as well providing the scalability of resource utilization and optimization that is not available through a general processor based solution.

A key innovation for this proposal is the use of Field Programmable Gate Arrays (FPGAs) as the basis for the cloud. FPGAs are now beginning to be embraced as significant performance enhancing technology in terrestrial cloud computing because of the ability to provide hardware acceleration of data analysis [1]. The highly parallel fine-grained architecture of modern FPGAs helps them reduce power consumption while increasing data throughput. Performance is a key milestone for the cloud based environment and FPGAs have been shown to outperform dedicated CPUs by a factor of over 100X for specific applications [2].

The Xilinx V5QV FPGA [3] is chosen this application. The V5QV is specifically designed for use in space applications with a total dose hardness to > 1MRad and Single Event Upset (SEU) immune radiation hard by design implementation. Virtex-5QV FPGA provides an integrated high-speed SERDES solution for space, with 18 channels of >3GHz multi-gigabit serial transceivers. Data transfer rates in excess of 1GB/sec are possible.

A single node in the constellation could have a V5QV FPGA, 1GB of DDR2 memory, 128MB of embedded flash memory, and 64GB of solid state disk memory with both NAND flash and radiation hardened 16Mb MRAM memory. Coupled with an existing low power RF transceiver design [4], the system is capable of 400km data transmission for data rates of 256kbps. This single system would consume 2-4 Watts of power.

All of this technology is ready to use today. The mission concept and design could begin now and be ready to support a near term 2018 launch. A technology demonstration could be accomplished in 1 or 2 years by implementing a scaled down version in a 3-5-node configuration implemented on a cube sat based earth-orbiting mission.

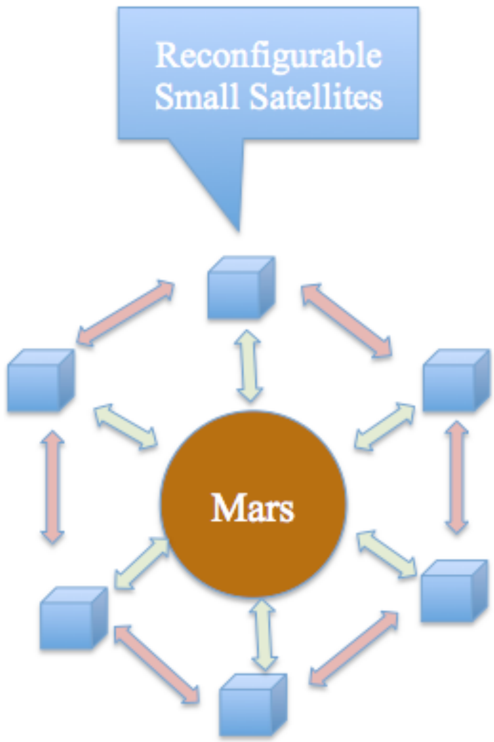
References:

[1] Madhavapeddy A. and Singh S. (2011) http://research.microsoft.com/pubs/146343.

[2] http://wallstreetfpga.com

[3] http://www.xilinx.com

[4] Kuhn W., et.al. (2007), vol. 95, No.10 Proceedings of the IEEE.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