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Techniques for Simplifying Operations Using VML (Virtual Machine Language) on Mars Odyssey and SIRTf

VML (Virtual Machine Language) is an advanced procedural sequencing language which simplifies spacecraft operations, minimizes uplink product size, and allows autonomous operations aboard a mission without the development of autonomous flight software. The language is mission-independent, high level, human readable script. It features a rich set of data types (including integers, doubles, and strings), named functions, parameters to functions, IF and WHILE control structures, polymorphism, and on-the-fly creation of spacecraft commands from calculated values.

The ground component of VML consists of a mission-independent compiler, a data-driven command generator, and an execution tool, all of which run on one or more Unix workstations. The VML compiler translates human readable source files to an uplinkable binary format. The data-driven VML command generator translates mission-specific spacecraft commands for the compiler from human-readable text to binary. The offline sequence execution tool runs sequences at speeds several thousand times real-time, and provides debugging features, integrated reports, and interactive execution options. These tools allow iterative development of blocks and sequences with a turnaround time measured in seconds rather than the hours or days typical with a full-up software test lab.

Parameterization and use of reusable functions called blocks onboard the spacecraft has several advantages over ground expanded sequences. Mission safety is enhanced, since blocks receive more scrutiny up front during development. Development of sequences is simplified, since blocks provide a rich set of behaviors that can be invoked. The review and test process for the invoking sequences is simplified, since the behavior of the reusable blocks is well understood. Mission costs for autonomy can be reduced, since responses to conditions can be coded into blocks and upgraded without changing flight software. Uplink load is reduced, since the blocks physically reside onboard the spacecraft.

VML use on Mars Odyssey and the Space Infrared Telescope Facility (SIRTf) has allowed spacecraft operations teams to place autonomy aboard deep space missions. For instance, the Mars Odyssey team has developed VML blocks and sequences which autonomously detect unexpected blooming of the Martian atmosphere during aerobraking end-game and raise the orbit of the spacecraft to a safe altitude, without ground intervention. SIRTf is using VML functionality to gather more data during the mission by detecting when the facility has settled after a slew, rather than using worst-case settling times. SIRTf also uses VML to dynamically build spacecraft commands, dramatically reducing the size of uplink products and allowing the mission to live within its Deep Space Network communications allocation.

This paper discusses techniques for parameterizing routine operations using onboard blocks. The relationship between one-use sequences and reusable blocks is discussed. Reduced development effort due to iterative block development is outlined. The ability to migrate to the spacecraft functionality which is more traditionally implemented on the ground is examined. The implications for implementing spacecraft autonomy without the need for expensive flight software agent development is also discussed.