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SIMULATION MODELS FOR AUTONOMOUS RENDEZVOUS AND CAPTURE

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Autonomous rendezvous and capture (AR&C) is a critical space technology with significant application to a variety of missions. Martin Marietta Astronautics Group (MMAG) has been developing AR&C technical capability in support of several recent NASA contracts. AR&C for the Mars Rover / Sample Return (MRSR) mission has been studied through a contract with Johnson Space Center. Incorporation of AR&C in the Space Transportation Vehicle (STV) lunar mission has been studied through a contract with Marshall Space Flight Center. MMAG has also been developing AR&C simulation capability under independent research and development studies. Simulation development has been driven by two goals - comprehensive software simulation of the autonomous rendezvous and capture mission from launch to final capture, and integration of an overall software and hardware simulation to support an AR&C flight demonstration. This presentation will highlight the AR&C software simulation tools, and analysis results from their application to the STV lunar mission. Plans for an integrated software and hardware simulation will also be summarized.

Comprehensive software simulation of autonomous rendezvous and capture must include ascent, orbital phasing, terminal rendezvous, station keeping, approach, and capture. Software tools have been developed to simulate each of these AR&C mission phases. POST, a program to optimize simulated trajectories, is a long-standing tool recognized industry wide for optimizing launch vehicle ascent trajectories. GENREN, an orbital phasing program, has been used on MRSR, Satellite Servicer System (SSS), Manned Mars Mission (MMM), and STV studies to generate parametric performance data. SEART, simulation and error analysis of rendezvous trajectories, has been used to perform sensor evaluations and sensitivity analyses for MRSR, SSS, MMM, and STV studies. PACS, a proximity operations and capture software simulation, has been derived from the high-fidelity, real-time, hardware-in-the-loop simulation in Martin Marietta's Space Operations Simulation (SOS) Laboratory.

These tools have been and are currently being used to provide parametric performance data for the STV lunar mission study. POST provided insight into the trade between launch window timing, ascent maneuvering, and on-orbit maneuvering to support autonomous rendezvous and capture for a dual launch STV configuration. GENREN was used to generate STV orbital phasing parametrics for evaluating alternative orbital phasing techniques. SEART examined STV terminal rendezvous options with a detailed Monte-Carlo analysis. Figure 1 shows the in-plane, target-relative trajectory dispersions from the Monte-Carlo study for terminal phase rendezvous between circular orbit altitudes of 260 and 295 km, using a Shuttle-type radar sensor. PACS is currently being used to perform trade studies of attitude control systems, guidance and navigation algorithms, on-board processors, and close-range sensors to support the STV lunar mission study. Figure 2 displays a typical propellant and ΔV time history for an approach from 300 m in front of the target vehicle.

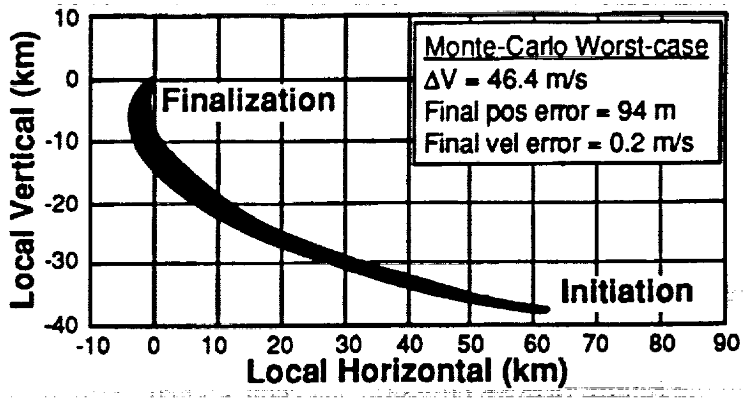

Figure 1 - LEO target-relative terminal rendezvous profiles (100 trajectories)

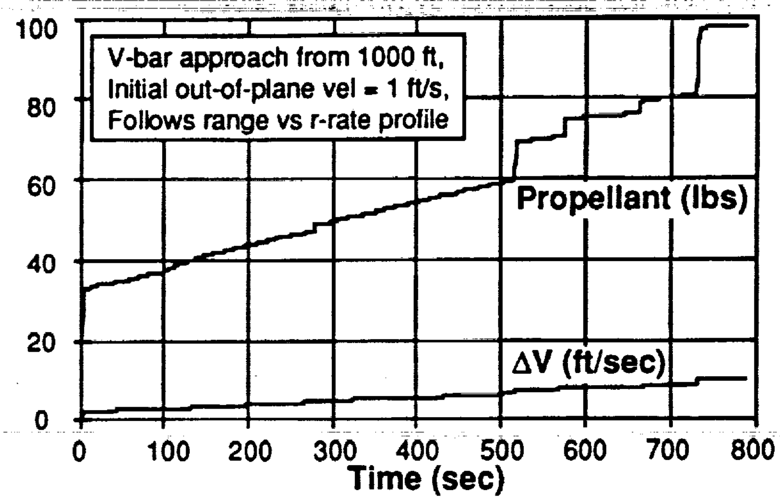

Figure 2 - Approach propellant and ΔV time history

In addition to maintaining a comprehensive set of software tools, Martin Marietta is committed to expanding our current hardware demonstration capability by integrating the critical AR&C technologies into a single, high-fidelity, real-time hardware/software simulation. This simulation will provide a test-bed not only for developing the key AR&C technologies, but for providing proof-of-concept for AR&C flight systems as well. Table 1 highlights the key technologies to be integrated in the AR&C demonstration at Martin Marietta. The SOS Lab will facilitate development of autonomous operations, including supervised autonomy to allow for operator intervention if required. The SOS Lab will also house range sensors and perform target image processing for the integrated simulation. Docking mechanism evaluation may also be performed in the SOS Lab. The Avionics Lab will provide IMU, star tracker, and CPU hardware and software simulation capability. The Robotics Lab will select appropriate computer vision algorithms for target recognition and pose estimation. Evaluation of capture techniques and hardware (berthing and docking) will be performed in the Robotics Lab. The Robotics Lab may also develop neural networks and model-based reasoning methods for sensor fusion, path planning, and optimization. The Photonics Lab will examine hardware and software for application of advanced image correlation and processing to support AR&C requirements. And finally, the Propulsion Lab will provide hardware and software simulation of ACS hot and cold gas thrusters. These labs will connected with a fiber optic network to support the real-time, high-fidelity simulation of key AR&C elements.

Table 1 - Integrated AR&C hardware and software simulation

Facility	Key Technology
SOS Lab	Autonomous operations, range sensor, image processor, docking mechanism
Avionics Lab	Inertial measurement unit, star tracker, central processor unit
Robotics Lab	Computer vision, berthing mechanism controls, docking mechanism dynamics, neural networks, model-based reasoning
Photonics Lab	Advanced image correlation and processing
Propulsion Lab	Attitude control system hot and cold gas thrusters

In summary, Martin Marietta has developed a comprehensive AR&C software and hardware simulation capability. The software capability provides for simulation of each AR&C mission phase, including launch, orbital phasing, terminal rendezvous, and capture. The hardware simulation capability provides for examination of autonomous operations, sensors, processors, and capture mechanisms. These tools will be integrated into a single, real-time, high-fidelity hardware/software simulation that will provide an environment for developing AR&C technologies and a test-bed for validating AR&C flight concepts.