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Rendezvous Radar for the Orbital Maneuvering Vehicle

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The Rendezvous Radar Set (RRS) was designed at Motorola's Strategic Electronics Division in Chandler, Arizona, to be a key subsystem aboard NASA's Orbital Maneuvering Vehicle (OMV). The unmanned OMV, which was under development at TRW's Federal Systems Division in Redondo Beach, California, was designed to supplement the Shuttle's satellite delivery, retrieval, and maneuvering activities. The RRS was to be used to locate and then provide the OMV with vectoring information to the target satellite (or Shuttle or Space Station) to aid the OMV in making a minimum fuel consumption approach and rendezvous. The OMV development program was halted by NASA in 1990 just as parts were being ordered for the RRS engineering model. The paper presented describes the RRS design and then discusses new technologies, either under development or planned for development at Motorola, that can be applied to radar or alternative sensor solutions for the Automated Rendezvous and Capture problem.

The RRS is an X-Band all solid-state, monopulse tracking, frequency-hopping, pulse-Doppler radar system. One square meter targets are detected at ranges greater than 4.5 nautical miles and larger targets are detected at up to 10 nautical miles. The target is then tracked in angle, range, and range rate to a range of 35 feet from the OMV. Three-sigma measurement performance of <0.1 fps velocity error and <10 ft range error during target track are features of the design. Efficient Gallium Arsenide FET devices for the RF stages and low-power CMOS technology for the digital signal and data processing functions are used extensively to minimize power consumption. To assure mission reliability high-reliability parts are used throughout and the RRS is electrically redundant. Single event upset (SEU) effects have been addressed at both system and circuit levels in the design.

The weight of the electrically redundant system was estimated at 90 pounds, of which 40 pounds was contributed by the antenna, gimbals, motors, etc., leaving 50 pounds for the electronics. Recent progress at Motorola in the infusion of commercial technologies and modern packaging into space systems, promises substantial reductions in size, weight, and cost compared to traditional space hardware designs. Small satellite programs such as Motorola's IRIDIUM space-based personal communications system are developing new packaging approaches for both microwave and digital space-based hardware that could be applied to benefit programs like the RRS. Examples include the use of digital multi-chip modules that would reduce the RRS processor weight by over 70% and MMIC microwave modules that could nearly eliminate critical alignment and tuning procedures (and thus reduce cost and risk) during production.

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A Berthing and Fastening Strategy for Orbital Replacement Units

by John Vranish and Edward Cheung
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A summary of the GSFC applied research effort in robotic berthing is provided. The summary includes several demonstrations and experimental highlights illustrated on video. Two GSFC developments are central to the research, the "Capaciflector" sensor and the "Spline-Locking" Screw fastener.

The Capaciflector is an outstanding close-in complement to vision sensing and is central to collision avoidance, alignment, and precontact and contact control. Its suitability for use in space

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is described in detail in the presentation showing that this sensor is outstanding for space use. It has, indeed, already gone through most of the space qualification criterion.

The Spine-Locking Screw is central to robotic (and astronaut hand tool) fastening. A fundamental change to the basic machine screw, it permits robots to fasten objects (and themselves in a walking mode) to other objects with high preload forces from small input torques and without any possibility of cross-threading. In addition, this fastener can be slightly modified to provide an outstanding electrical connection along with the mechanical. Like the "Capaciflector," this fastener already has been recognized as an outstanding system for use in space.

Taken together, the "Capaciflector" and the "Spine-Locking" Screw extend the state-of-the-art in automated berthing technology. It is now possible to have smart instrumented payloads with a sensing capability that can easily be fastened by robots with unprecedented control and safety throughout.

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A Binocular Stereo Approach to AR&C at the Johnson Space Center

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Automated Rendezvous and Capture requires the determination of the 6 DOF relating two free bodies. Sensor systems that can provide such information have varying sizes, weights, power requirements, complexities, and accuracies. One type of sensor system that can provide several key advantages is a binocular stereo vision system.

Binocular stereo uses two video cameras on the rendezvous vehicle viewing the target vehicle. The target vehicle is equipped with a passive target that allows for easy and robust identification of the target. Range to the target is inferred from the different bearings in the left and right camera views of the target points. When the target has three or more identifiable points in a known geometry, the attitude of the target can be inferred from the bearings and ranges to the three points.

One of the main advantages of such a binocular stereo vision sensor is the simplicity of the hardware. The system uses standard video cameras and digital processing hardware. These items are likely to be present already on the rendezvous vehicle. The other major hardware components required include image digitizing electronics and possibly camera lens and pointing controls. Another advantage of this system is that it uses only passive sensors, limiting the amount of power required. Also, the system requires only a passive target so that rendezvous is possible with non-powered or dysfunctional satellites and systems.

Another advantage of the stereo vision approach is that the system designer has many design trade-offs that can be used to "scale" the system to a particular application (specific baseline, range accuracy, etc.). For example, the field of view of the cameras can be narrowed to increase the operational range of the sensor at the expense of limiting the minimum range at which the system can operate. Other variables that can be altered include camera resolution, baseline distance between the cameras, and vergence angle of the camera pair. Also, the system processor can be replaced with a more powerful one if faster update rates are necessary.

Binocular stereo has some limitations that need to be addressed when considering the sensor requirements. One of the key limitations of this system is the limited operational range of the sensor and the limited range accuracy at longer distances. Range is calculated using a triangle whose vertices are the two cameras and the target point. As the target point moves far away from the cameras, the triangle is elongated, and the errors in measuring the bearing angles dominates the measurement and accuracy suffers. Another reason for the limited operating range of the sensor is