needs. What is the range accuracy? Two (2) percent of the range. Can tilt and roll could be determined? Yes, it can, using the Synthetic Estimation Filter.

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Office of Spaceflight Standard Spaceborne Global Positioning System (GPS) User Equipment Project

by Penny E. Saunders, NASA, JSC

The Global Positioning System (GPS) provides: 1) position and velocity determination to support vehicle GN&C, precise orbit determination and payload pointing; 2) time reference to support onboard timing systems and data time tagging; 3) relative position and velocity determination to support cooperative vehicle tracking; and 4) attitude determination to support vehicle attitude control and payload pointing.

The expected GPS performance depends on system implementation, hardware design, software design, and GPS service. The standard spaceborne GPS user equipment project was begun by JSC to identify the benefits of a standard GPS receiver development for the STS, SSF, and ACRV and the potential benefits to other NASA programs. The Office of Space Flight then recommended the collection of NASA-wide GPS requirements and preparation of a project plan including cost and schedule estimates. A common GPS system can reduce development, maintenance, and logistics costs.

There are two services provided by GPS, standard and precise. Some commercial applications have achieved centimeter level accuracy using GPS. However, commercial off-the-shelf systems cannot handle the high velocities and Doppler shift. Nevertheless, ACRV, CTV, SSF, and STS can use militarized systems that use Coarse Acquisition, the standard service.

A task team of representatives from JSC, MSFC, GSFC, and JPL was formed to develop a Standard Spaceborne GPS Receiver. The design approach is to maximize the use of available hardware and software, minimize user program integration cost, and provide upgrade options for unique requirements and anticipated future requirements. The design also should reflect: a modularized approach in receiver architecture for incorporation of user-unique requirements, addition of NASA unique command, control and data interfaces, and modified software to accommodate vehicle dynamics; addition of NASA's safety, reliability, and quality standards; and addition of radiation protection.

The project consists of three phases: the definition phase, development phase, and production phase. The definition phase should be completed in September of 1993, the development phase completed in December of 1995, and the production phase starting in January of 1996 and continuing until completion of the last flight unit that is needed.

The GPS application to AR&C consists of placement on both the chaser vehicle and the target vehicle. It includes a communication link between the vehicles so that relative position data can be determined. The expected performance depends on: (1) number of common satellites; (2) receiver measurement accuracy and measurement types; (3) relative state processing algorithms, (4) receiver/processor commonality; and (5) type of GPS service used.

In summary, standard GPS User Equipment development ensures commonality and coordination between user programs, thus providing overall NASA cost reduction and improvement in relative tracking capability. The cost reduction is due to the one-time versus multiple nonrecurring engineering efforts, quantity purchases of flight units, and consolidated engineering supporting development, logistics, operations, and maintenance. The use of a common hardware and software design results in the improvement in relative tracking capability and also improves accuracy and simplifies interfaces.

Concerns discussed following the presentation: When the author mentioned that there is an agreement for scarring SSF for a GPS receiver the audience responded enthusiastically. A question from the floor came up regarding the issue of putting GPS receivers in a vacuum environment and whether the issue was addressed in the standard GPS requirements. It was answered that this issue had not been addressed but the present requirements assume an atmospheric environment. A comment from the floor was that the Explorer platform will fly next year and it will have a GPS receiver onboard operating in a vacuum. A final question was: Are the different accelerations of SSF and the chase vehicle a problem? The answer was that acceleration is generally not a problem. Velocity is the driver because of the Doppler shift.

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Autonomous Pre-alignment of a Docking Mechanism

by Monty B. Carroll and John A. Thompson
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The subject project can be described as the development and testing of a digitally controlled docking mechanism. The mechanism consists of a 6 DOF parallel manipulator for docking interface pre-alignment, and a machine vision sensor for real-time target tracking. The parallel manipulator also can be used for capture/latching, energy attenuation, and structural rigidization of docking, but the scope of this paper is the proof-of-concept demonstration of autonomous pre-alignment of a docking mechanism using machine vision.

The docking mechanism incorporates 8 linear actuators in tandem attached to a lower and an upper ring. The lower ring is stationary while the upper ring maneuvers the mechanical docking interface in three-dimensional space. Each linear actuator of the manipulator is position controlled by a dedicated digital servo controller and receives actuator length commands from a central IBM PC based master controller. The master controller oversees operation of the linear actuators and receives real-time position and orientation data from either a machine vision processor or a manual 6 DOF input device. The machine vision system, a gray-scale and binary vision system, senses an optical target on the passive docking interface via a CCD camera on the docking mechanism's stationary base. It then provides real-time position and orientation commands to the master controller. The master controller kinematically resolves position lengths of each actuator and moves the docking interface to align with the approaching target. A host or user interface to the master controller provides the start, stop, reset, or mode commands, and displays current manipulator position.

The demonstration of the autonomous prealignment of a docking mechanism was a success, showing a full scale working prototype utilizing machine vision. System response was estimated at 5 hertz. Docking interface alignment was accurate to approximately 20 mm (0.75 inches). It is believed that these system parameters could be considerably enhanced by several minor hardware and software upgrades. The machine vision accuracy was dependent upon the distance of the target from the CCD camera. The positional accuracy obtained for each of target sphere was about one percent of the actual distance. Additionally, it was noted that lighting condition variations greatly influenced vision tracking accuracy. This did not affect the demonstration greatly, since constant lighting could be maintained. However, a more robust tracking algorithm, less sensitive to lighting, was determined possible.

The technology demonstrated in this project has the potential to improve the efficiency and configuration of a docking system. A sensor controlled docking mechanism could have smaller capture guides and shorter attenuator strokes, thereby reducing weight. The capture and attenuation loads would be reduced because of the precise method of alignment. Future work is to include the study of the remaining phases of docking; i.e., capture/latching, attenuation, and structural rigidization. In addition, upgrades to hardware and software are being considered.