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ABSTRACT

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TITLE: **RESULTS OF PROTOTYPE SOFTWARE DEVELOPMENT FOR AUTOMATION OF SHUTTLE PROXIMITY OPERATIONS**

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TECHNICAL DESCRIPTION:

A Rendezvous Expert System (REX) was implemented on a Symbolics 3650 processor and integrated with the 6 DOF, high fidelity Systems Engineering Simulator (SES) at the NASA Johnson Space Center in Houston, Texas. The project goals were to automate the terminal phase of a shuttle rendezvous, normally flown manually by the crew, and proceed automatically to docking with the Space Station Freedom (SSF). The project goals were successfully demonstrated to various flight crew members, managers, and engineers in the technical community at JSC. The project was funded by NASA's Office of Space Flight, Advanced Program Development Division.

Because of the complexity of the task, the REX development was divided into two distinct efforts. One to handle the guidance and control function using perfect navigation data, and another to provide the required visuals for the system management functions needed to give visibility to the crew members of the progress being made towards docking the shuttle with the LVLH stabilized SSF.

The Clohessy-Wiltshire targeting equations for relative motion were selected as the basic formulation for the guidance function. With minor modifications, the same CW algorithm was found to be sufficiently accurate not only to do standard Prox Ops targeting, but final approach, docking and even station keeping during the final approach.

Typical errors noted during the Vbar and Rbar approaches through docking with both shuttle Digital Autopilots will be reviewed. Results of off-line testing of the REX guidance algorithm with 100 worst case nav error IC vectors will be discussed, as well as modifications made to the CW guidance to allow straight line Line-of-Sight (LOS) final approaches like Vbar, Rbar, and TEA (torque equilibrium angle) to SSF.

To simplify the mode of operations with the shuttle GNC, REX was designed to operate in the minimum impulse mode with both the standard and latest alternate shuttle Digital Autopilot (DAP). REX was also capable of operation in Monitor and Automatic modes. In the Monitor mode, REX would only recommend pulses for manual crew execution via the translation hand controller (THC). In the Automatic mode, it would send the recommended pulses to the shuttle DAP for execution. The crew could take over control of the shuttle at any time by placing REX in the Monitor mode or turning off the guidance by pushbutton entries.

The rationale for breaking the proximity operations phase into the following four sub-phases will be discussed:

a. Insure Line-of-Approach (LOA) crossing, where LOA is Vbar (or Rbar)
b. LOA Capture
c. Vbar or Rbar final approach or stationkeeping
d. Docking

A discussion of how the shuttle systems were managed and the overall operations monitored will be conducted. The various trajectory and systems displays designed and implemented in REX will be discussed. These include real time plots of in-plane and out-of-plane relative motion; display of nav sensor data; display and selection of the guidance features; and plots of RCS propellant consumed and plume impingement loads on SSF as compared with previous simulation results by flight crews.

Other crew aids to be discussed include a pictorial display of the translation hand controller (THC) recommended pulses (backed up by a speech synthesizer), trajectory predictor icons that would indicate where the shuttle would be 5 and 10 minutes later (for collision avoidance and risk assessment), delta V pulse predictors to help crews in trajectory shaping, target icons drawn over a COAS representation for navigation error assessment, nav sensor health and status, and automated checker of crew procedures.

A feature added as the project matured was the RCS fuel saver. This feature checked the nav error, and if time to docking was sufficiently far in the future, would allow the errors to be corrected slowly and fuel used more efficiently. However, if time to docking was imminent, the fuel saver feature was automatically disabled and lateral errors reduced quickly in preparation for docking. A discussion of its operation and implementation will be conducted.

In regards to capture, the similarities and differences, from a guidance point of view, between docking and berthing after a final approach will be discussed.