Since 2001, this application has been used for pre-mission failure mode training for many Range Safety Scenarios. It contains range asset link analysis, develops look-angle data, supports sky-screen site selection, drives GPS (Global Positioning System) and IMU (Inertial Measurement Unit) simulators, and can support conceptual design efforts for multiple flight programs with its capacity for rapid six-degrees-of-freedom model development. Due to the assembly of various object types into one application, the application is applicable across a wide variety of launch range problem domains.

This work was done by Raymond J Lanzi of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15571-1

Monitoring and Controlling an Underwater Robotic Arm

Lyndon B. Johnson Space Center, Houston, Texas

The SSRMS Module 1 software is part of a system for monitoring an adaptive, closed-loop control of the motions of a robotic arm in NASA's Neutral Buoyancy Laboratory, where buoyancy in a pool of water is used to simulate the weightlessness of outer space. This software is so named because the robot arm is a replica of the Space Shuttle Remote Manipulator System (SSRMS).

This software is distributed, running on remote joint processors (RJPs), each of which is mounted in a hydraulic actuator comprising the joint of the robotic arm and communicating with a poolside processor denoted the Direct Control Rack (DCR). Each RJP executes the feedback joint-motion control algorithm for its joint and communicates with the DCR. The DCR receives joint-angular-velocity commands either locally from an operator or remotely from computers that simulate the flight like SSRMS and perform coordinated motion calculations based on hand-controller inputs. The received commands are checked for validity before they are transmitted to the RJPs. The DCR software generates a display of the statuses of the RJPs for the DCR operator and can shut down the hydraulic pump when excessive joint-angle error or failure of a RJP is detected.

This work was done by John Haas and Brian Keith Todd of Johnson Space Center, Larry Woodcock and Fred M. Robinson of Oceaneering Space Systems, and Thomas (Jay) Costales of Raytheon Co. Further information is contained in a TSP (see page 1). MSC-24165-1

Digital Camera Control for Faster Inspection

Lyndon B. Johnson Space Center, Houston, Texas

Digital Camera Control Software (DCCS) is a computer program for controlling a boom and a boom-mounted camera used to inspect the external surface of a space shuttle in orbit around the Earth. Running in a laptop computer in the space-shuttle crew cabin, DCCS commands integrated displays and controls. By means of a simple one-button command, a crewmember can view low- resolution images to quickly spot problem areas and can then cause a rapid transition to high- resolution images. The crewmember can command that camera settings apply to a specific small area of interest within the field of view of the camera so as to maximize image quality within that area.

DCCS also provides critical high-resolution images to a ground screening team, which analyzes the images to assess damage (if any); in so doing, DCCS enables the team to clear initially suspect areas more quickly than would otherwise be possible and further saves time by minimizing the probability of re-imaging of areas already inspected. On the basis of experience with a previous version (2.0) of the software, the present version (3.0) incorporates a number of advanced imaging features that optimize crewmember capability and efficiency.

This program was written by Katharine Brown, James D. Siekierski, Mark L. Mangieri, Kent Dekome, John Cobarruvias, and Perry J. Piplani of Johnson Space Center and Joel Busa of the Draper Laboratory. Further information is contained in a TSP (see page 1). MSC-24319-1/168-1

Reaction Wheel Disturbance Model Extraction Software — RWDMES

Goddard Space Flight Center, Greenbelt, Maryland

The RMDMES is a tool for modeling the disturbances imparted on spacecraft by spinning reaction wheels. Reaction wheels are usually the largest disturbance source on a precision pointing spacecraft, and can be the dominating source of pointing error. Accurate knowledge of the disturbance environment is critical to accurate prediction of the pointing performance. In the past, it has been difficult to extract an accurate wheel disturbance model since the forcing mechanisms are difficult to model physically, and the forcing amplitudes are filtered by the dynamics of the reaction wheel. RDMES captures the wheel-induced disturbances using a hybrid physical/empirical model that is extracted directly from measured forcing data.

The empirical models capture the tonal forces that occur at harmonics of the spin rate, and the broadband forces that arise from random effects. The empirical forcing functions are filtered by a physical model of the wheel structure that includes spin-rate-dependent moments (gyroscopic terms). The resulting hybrid model creates a highly accurate prediction of wheel-induced forces. It accounts for variation in disturbance frequency, as well as the shifts in structural amplification by the whirl modes, as the spin rate changes. This software provides a point-and-click environment for producing accurate models with minimal user effort. Where conventional approaches may take weeks to produce a model of variable quality, RWDMES can create a demonstrably high accuracy model in two hours.

The software consists of a graphical user interface (GUI) that enables the user to specify all analysis parameters, to evaluate analysis results and to iteratively refine the model. Underlying algorithms automatically extract disturbance harmonics, initialize and tune harmonic models, and initialize and tune broadband noise models. The component steps are described in the RWDMES user's guide and include: converting time domain data to waterfall PSDs (power spectral densities); converting PSDs to order analysis data; extracting harmonics; initializing and simultaneously tuning a harmonic model and a wheel structural model; initializing and tuning a broadband model; and verifying the harmonic/broadband/structural model against the measurement data.

Functional operation is through a MATLAB GUI that loads test data, performs the various analyses, plots evaluation data for assessment and refinement of analysis parameters, and exports the data to documentation or downstream analysis code. The harmonic models are defined as specified functions of frequency, typically speed-squared. The reaction wheel structural model is realized as mass, damping, and stiffness matrices (typically from a finite element analysis package) with the addition of a gyroscopic forcing matrix. The broadband noise model is realized as a set of speed-dependent filters. The tuning of the combined model is performed using nonlinear least squares techniques.

RWDMES is implemented as a MATLAB toolbox comprising the Fit Manager for performing the model extraction, Data Manager for managing input data and output models, the Gyro Manager for modifying wheel structural models, and the Harmonic Editor for evaluating and tuning harmonic models. This software was validated using data from Goodrich E wheels, and from GSFC Lunar Reconnaissance Orbiter (LRO) wheels. The validation testing proved that RWDMES has the capability to extract accurate disturbance models from flight reaction wheels with minimal user effort.

This work was done by Carl Blaurock of Nightsky Systems, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC15401-1

Conical-Domain Model for Estimating GPS Ionospheric Delays

Sources of error in a standard ionospheric delay model are eliminated.

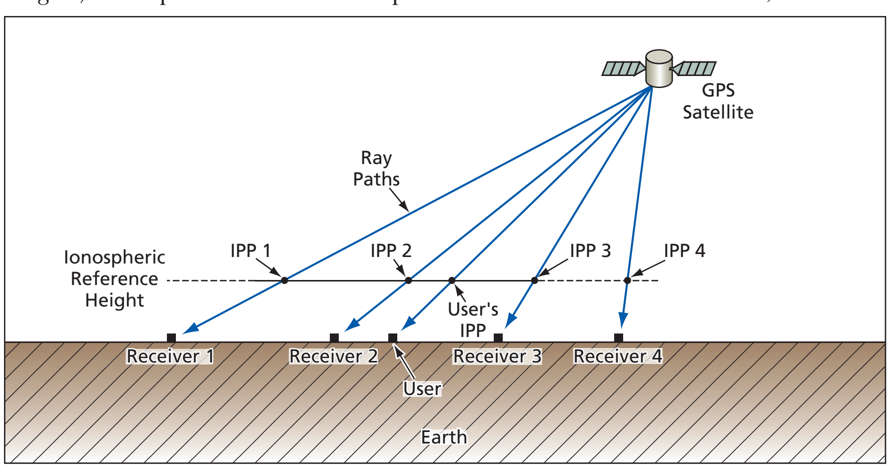
NASA's Jet Propulsion Laboratory, Pasadena, California

The conical-domain model is a computational model, now undergoing development, for estimating ionospheric delays of Global Positioning System (GPS) signals. Relative to the standard ionospheric delay model described below, the conical-domain model offers improved accuracy.

In the absence of selective availability, the ionosphere is the largest source of error for single-frequency users of GPS. Because ionospheric signal delays contribute to errors in GPS position and time measurements, satellite-based augmentation systems (SBASs) have been designed to estimate these delays and broadcast corrections. Several national and international SBASs are currently in various stages of development to enhance the integrity and accuracy of GPS measurements for airline navigation.

In the Wide Area Augmentation System (WAAS) of the United States, slant ionospheric delay errors and confidence bounds are derived from estimates of vertical ionospheric delay modeled on a grid at regularly spaced intervals of latitude and longitude. The estimate of vertical delay at each ionospheric grid point (IGP) is calculated from a planar fit of neighboring slant delay measurements, projected to vertical using a standard, thin-shell model of the ionosphere. Interpolation on the WAAS grid enables estimation of the vertical delay at the ionospheric pierce point (IPP) corresponding to any arbitrary measurement of a user. (The IPP of a given user's measurement is the point where the GPS signal ray path intersects a reference ionospheric height.) The product of the interpolated value and the user's thin-shell obliquity factor provides an estimate of the user's ionospheric slant delay.

Two types of error that restrict the accuracy of the thin-shell model are absent in the conical domain model: (1) error due to the implicit assumption that the electron density is independent of the azimuthal angle at the IPP and (2) error arising from the slant-to-vertical conversion. At low latitudes or at mid-latitudes under disturbed conditions, the accu-



Multiple GPS Receivers and a GPS Satellite define a conical domain. At locations between receivers, inospheric slant delays are interpolated by a planar fit model at the inospheric reference height.