pospheric and orbit correction) spanned from 15 to 68 percent. With this tropospheric correction, low-frequency errors can be removed from InSAR images. Additionally, results show that for days with high-quality ECMWF data, the SBLM ZTD correction performs as well as the GPS ZTD correction. Finally, the tropospheric correction enabled

orbit correction, and by correcting for both errors, the quality of the InSAR images increased significantly.

By correcting for the troposphere, other errors become visible. The main contributor to the remaining errors is uncertainties with determining the satellite orbit. Because the orbit error is now separated from the tropospheric error, the

orbit can be corrected for more accurately.

⏩ Technique for Calculating Solution Derivatives With Respect to Geometry Parameters in a CFD Code

John H. Glenn Research Center, Cleveland, Ohio

A solution has been developed to the challenges of computation of derivatives with respect to geometry, which is not straightforward because these are not typically direct inputs to the computational fluid dynamics (CFD) solver. To overcome these issues, a procedure has been devised that can be used without having access to the mesh generator, while still being applicable to all types of meshes. The basic approach is inspired by the mesh motion algorithms used to deform the interior mesh nodes in a smooth manner when the surface nodes, for example, are in a fluid structure interaction problem. The general idea is to model the mesh edges and nodes as constituting a spring-mass system. Changes to boundary node locations are propa-

gated to interior nodes by allowing them to assume their new equilibrium positions, for instance, one where the forces on each node are in balance.

The main advantage of the technique is that it is independent of the volumetric mesh generator, and can be applied to structured, unstructured, single- and multi-block meshes. It essentially reduces the problem down to defining the surface mesh node derivatives with respect to the geometry parameters of interest. For analytical geometries, this is quite straightforward. In the more general case, one would need to be able to interrogate the underlying parametric CAD (computer aided design) model and to evaluate the derivatives either analytically, or by a finite difference tech-

nique. Because the technique is based on a partial differential equation (PDE), it is applicable not only to forward mode problems (where derivatives of all the output quantities are computed with respect to a single input), but it could also be extended to the adjoint problem, either by using an analytical adjoint of the PDE or a discrete analog.

⏩ Acute Radiation Risk and BRYNTRN Organ Dose Projection Graphical User Interface

This program estimates the whole-body effective dose, organ doses, and acute radiation sickness symptoms.

Lyndon B. Johnson Space Center, Houston, Texas

The integration of human space applications risk projection models of organ dose and acute radiation risk has been a key problem. NASA has developed an organ dose projection model using the BRYNTRN with SUM DOSE computer codes, and a probabilistic model of Acute Radiation Risk (ARR). The codes BRYNTRN and SUM DOSE are a Baryon transport code and an output data processing code, respectively. The risk projection models of organ doses and ARR take the output from BRYNTRN as an input to their calculations. With a graphical user interface

(GUI) to handle input and output for BRYNTRN, the response models can be connected easily and correctly to BRYNTRN. A GUI for the ARR and BRYNTRN Organ Dose (ARRBOD) projection code provides seamless integration of input and output manipulations, which are required for operations of the ARRBOD modules.

The ARRBOD GUI is intended for mission planners, radiation shield designers, space operations in the mission operations directorate (MOD), and space biophysics researchers. BRYNTRN code operation requires extensive

input preparation. Only a graphical user interface (GUI) can handle input and output for BRYNTRN to the response models easily and correctly. The purpose of the GUI development for ARRBOD is to provide seamless integration of input and output manipulations for the operations of projection modules (BRYNTRN, SLMDOSE, and the ARR probabilistic response model) in assessing the acute risk and the organ doses of significant Solar Particle Events (SPEs).

The assessment of astronauts' radiation risk from SPE is in support of mis-

sion design and operational planning to manage radiation risks in future space missions. The ARRBOD GUI can identify the proper shielding solutions using the gender-specific organ dose assessments in order to avoid ARR symptoms, and to stay within the current NASA short-term dose limits. The quantified evaluation of ARR severities based on any given shielding configuration and a specified EVA or other mission scenario can be made to guide alternative solutions for attaining determined objectives set by mission planners.

The ARRBOD GUI estimates the whole-body effective dose, organ doses, and acute radiation sickness symptoms for astronauts, by which operational strategies and capabilities can be made for the protection of astronauts from SPEs in the planning of future lunar surface scenarios, exploration of near-Earth objects, and missions to Mars.

Probabilistic Path Planning of Montgolfier Balloons in Strong, Uncertain Wind Fields

This algorithm can be used for underwater unmanned vehicles for automated scientific data collection and for military uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

Lighter-than-air vehicles such as hot-air balloons have been proposed for exploring Saturn's moon Titan, as well as other bodies with significant atmospheres. For these vehicles to navigate effectively, it is critical to incorporate the effects of surrounding wind fields, especially as these winds will likely be strong relative to the control authority of the vehicle. Predictive models of these wind fields are available, and previous research has considered problems of planning paths subject to these predicted forces. However, such previous work has considered the wind fields as known *a priori*, whereas in practical applications, the actual wind vector field is not known exactly and may deviate significantly from the wind velocities estimated by the model.

A probabilistic 3D path-planning algorithm was developed for balloons to use uncertain wind models to generate time-efficient paths. The nominal goal of the algorithm is to determine what altitude and what horizontal actuation, if any is available on the vehicle, to use to reach a particular goal location in the least expected time, utilizing advantageous winds. The solution also enables one to quickly evaluate the expected time-to-goal from any other location and to avoid regions of large uncertainty. This method is designed for balloons in wind fields but may be generalized for any buoyant vehicle operating in a vector field.

To prepare the planning problem, the uncertainty in the wind field is modeled. Then, the problem of reaching a particular goal location is formulated as a Markov decision process (MDP) using a discretized space approach. Solving the MDP provides a policy of what actuation option (how much buoyancy change and, if applicable, horizontal actuation) should be selected at any given location to minimize the expected time-to-goal. The results provide expected time-to-goal values from any given location on the globe in addition to the action policy.

This stochastic approach can also provide insights not accessible by deterministic methods; for example, one can evaluate variability and risk associated with different scenarios, rather than only viewing the expected outcome.

The resulting path-planning tool is a general-purpose guidance algorithm that can be applied to exploration balloons on any moon/planet with atmosphere, including Titan, Mars, Venus, and gas giants, provided the wind field models are available. The algorithm is particularly useful for mission planning and trade studies because it not only delivers the optimal expected path, but also provides insights into the variability and risk associated with different mission scenarios (e.g., under different wind variability or vehicle capabilities). Finally, these techniques may be useful for other variably buoyant vehicles operating in strong vector fields, such as underwater vehicles in ocean currents, which may have additional scientific or military significance.