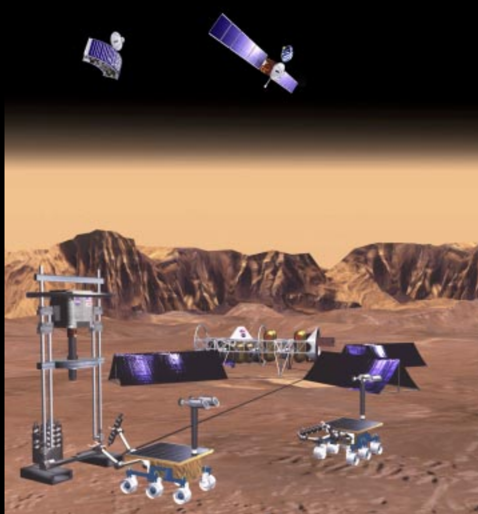
2001 Research Update



Exploration Systems Autonomy

Jet Propulsion Laboratory

Earth and space science datasets are becoming larger, year after year. The scientific communities, and the larger public, are requesting greater access to these datasets. Previously hard to access, these datasets either exist within network-accessible archives or they are generated upon demand using high-performance computers. At JPL, we have developed ways in which these parties can interact with existing data through simple (often web-based) user interfaces, which hide the complexity of the computing required to analyze and visualize the datasets.

CURRENT RESEARCH

National Virtual Observatory

Using the yourSky custom sky image mosaic server (http://yourSky.jpl.nasa.gov/), a user can rapidly access arbitrary regions of the sky from member archives as a single FITS (a standard format for astronomical images) image, regardless of the native partitioning scheme of the archive. The Digitized Palomar Observatory Sky Survey (DPOSS) and the Two Micron All-Sky Survey (2MASS) are currently accessible with yourSky.

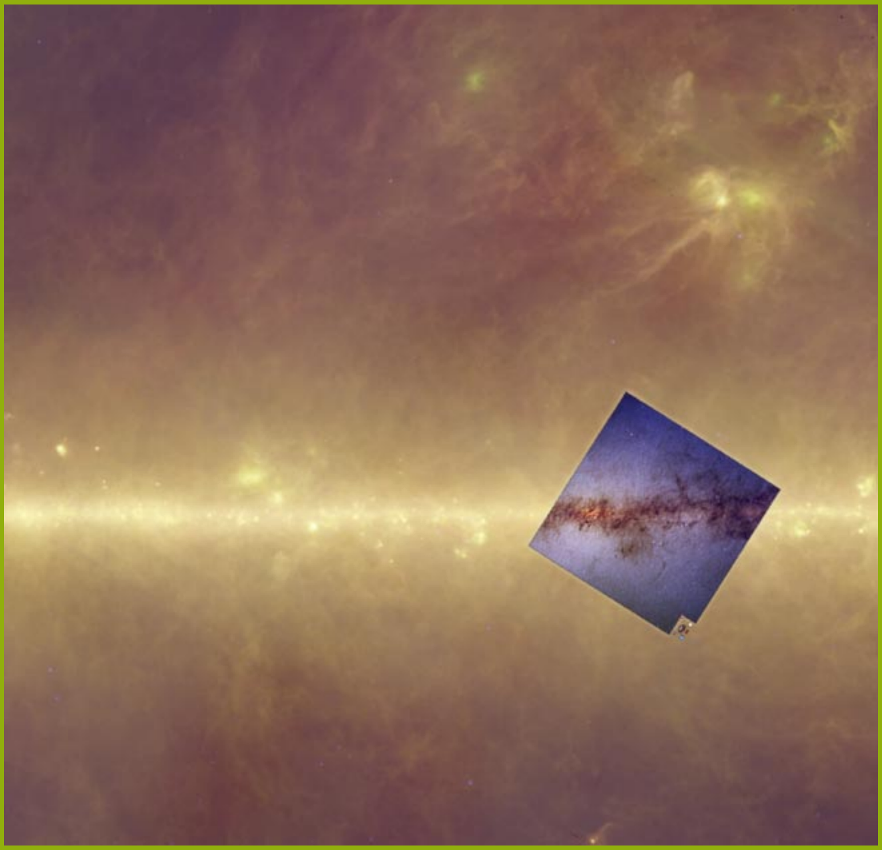
Creation, Analysis, & Visualization of Large Science Datasets

The server performs on-the-fly mosaicking of images while meeting user-specified criteria, including the dataset to be used, wavelength, position on the sky, coordinate system, projection, data type, and resolution. A web browser interface was built as part

The center portion of a 20-GB image mosaic of Andromeda constructed by yourSky from 18 DPOSS plates in two visible wavelengths.

of yourSky to allow access from the desktop for custom mosaic requests and mosaic retrieval on a common desktop machine with only the ubiquitous web browser as a client. The yourSky server maintains a database that is used to determine which images are required to construct a requested mosaic. The images are then automatically retrieved from their respective archive(s), and the mosaic is constructed rapidly using a high-performance parallel code. As this process is not currently fast enough to allow true interactive response, one of the items that the user supplies is an e-mail address. When the mosaic is completed, an e-mail is sent to that address to notify the user that the mosaic is complete and may be picked up. As such, yourSky represents an early module of the emerging National Virtual Observatory. NVO will be a collection of interoperable codes and data all living on high-performance computational "grids."

Demonstration of visualization of multiresolution, multispectral, geographically distributed astronomical datasets. Image server software delivers image tiles from each data site and the visualization client combines the data streams while providing smooth pan and zoom on massive images and astronomical catalog viewing capabilities.

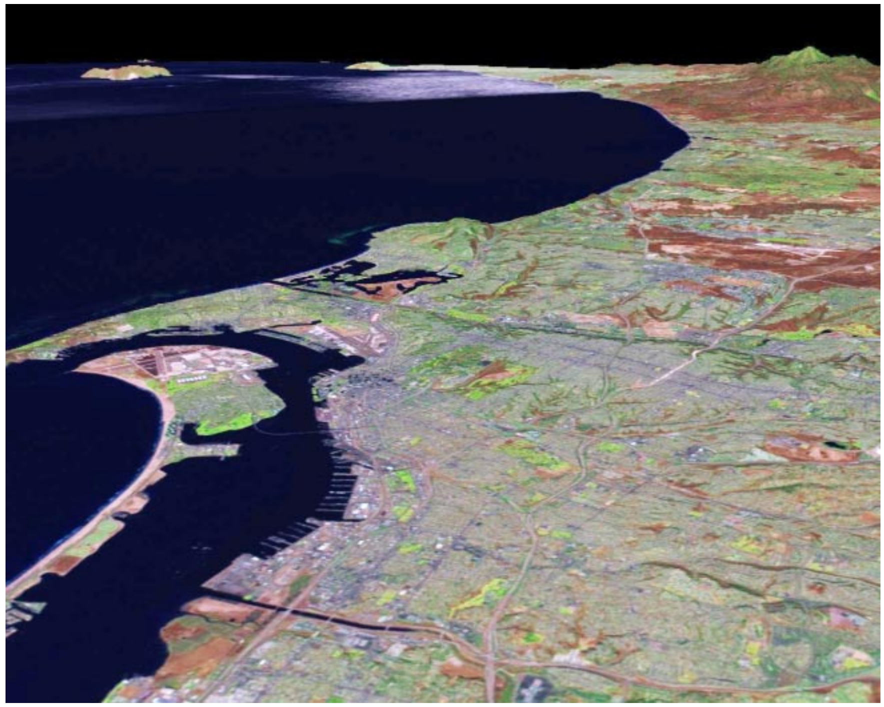


Visualization and Animation of Terrain Data

RIVA (Remote Interactive Visualization and Analysis) is a parallel terrain-rendering system for interactive visualization and exploration of large terrain datasets. It renders 3-D perspective views by overlaying Earth or planetary imagery on a digital elevation model. RIVA uses an efficient ray-identification algorithm, and is scalable to large machines, large datasets and large images, including the ability to render out-of-core. Multiple viewport rendering allows it to render an image as large as 3,000 × 4,000 pixels or more. RIVA includes a 2-D image and flight path viewing program and a keyframe preview feature to assist the user in designing and previewing a flight path.

JPL uses RIVA to build fly-over animated movies for scientific exploration and outreach purposes. During fiscal year 2001, we created two high-definition fly-over movies: a movie showing the principal natural hazards of San Diego and a Lewis and Clark trail movie following their 1804–1805 journey from St. Louis to the Pacific Ocean.

We also assembled a seminal HDTV production facility consisting of a SGI Onyx2 with HDTV capabilities, an HDTV VCR and an HDTV monitor. We then developed software for real-time playback of HDTV computer-generated frames, including technologies for lowering the required data bandwidth. We have created custom software for the New York–based American Museum of Natural History's (AMNH) HDTV production facility to simplify integration of Earth science data. AMNH is engaged in producing a series of HDTV "Science Bulletins" to be distributed to a number of museums and media outlets. This JPL–AMNH co-developed technology is an important component of this Science Bulletin work.



A sample frame from the movie "Principal Natural Hazards of San Diego," created with RIVA.

MAPUS (http://mapus.jpl.nasa.gov)

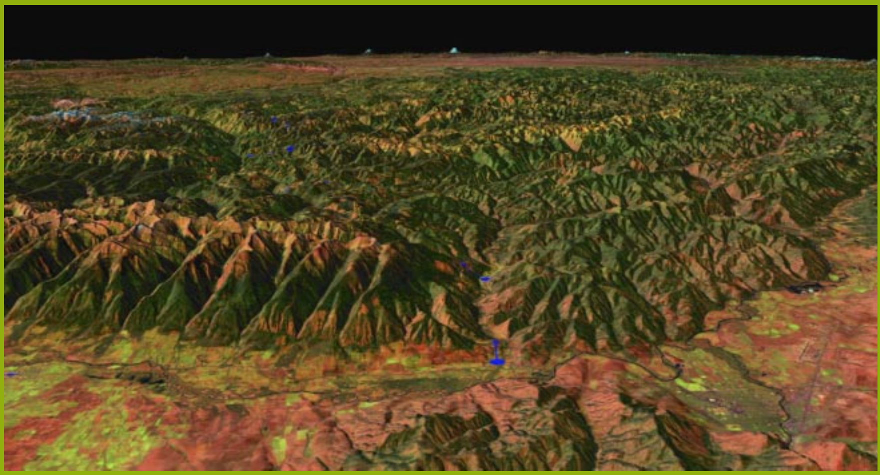
Map United States (MAPUS) is a JPL web site that is an example of a graphic, map-driven web-based interface that permits a user to interact with a very large dataset. The NVO project will use both the technology developed for MAPUS and that developed in yourSky (discussed above). MAPUS allows a user to view, pan, and zoom a mosaic image of the complete United States, using Landsat and elevation data. Additionally, a user can turn on and turn off overlays, which include state and county boundaries and rivers. The site usage is rapidly increasing, and many public users have provided positive comments about this new tool.

Mars Terrain Generation and Rover Simulation

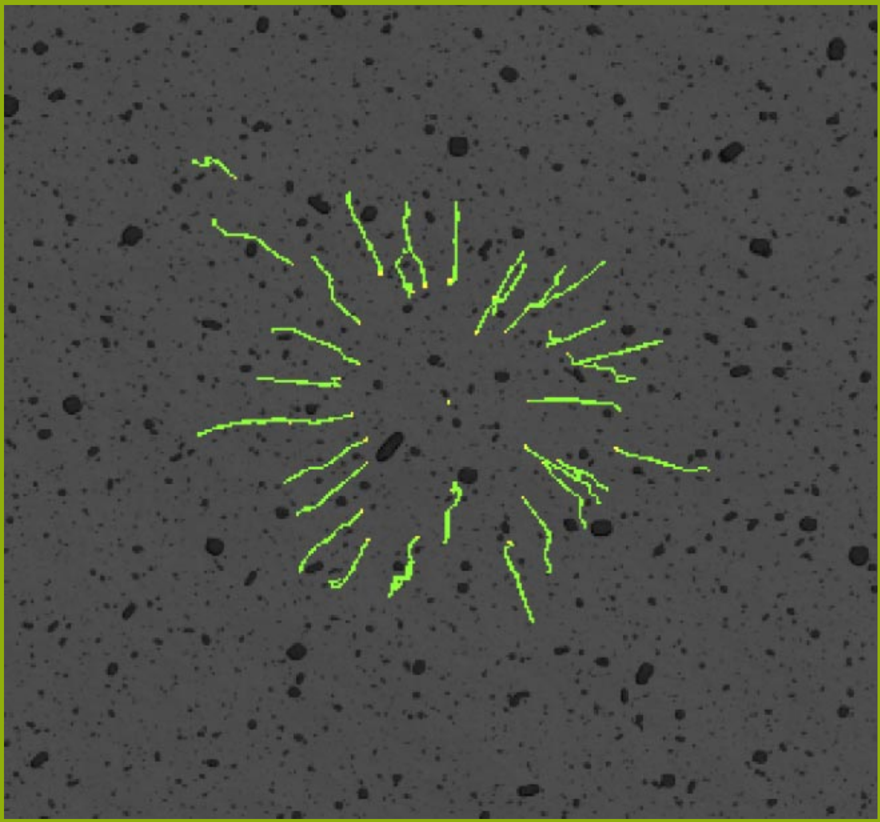
The Mars simulation work involves two main areas: synthetic terrain generation and rover simulation and visualization. These areas are clearly interrelated, and are part of a much larger JPL effort in simulation of the robotic Martian exploration, which in turn is part of the larger NASA effort of *in situ* exploration of the Solar System.

We demonstrated this past year the ability to build a terrain server to supply synthetic Martian terrain. This server can generate terrain with user-specified, large-scale slope distributions, craters, and rock densities to resolution as fine as 1 centimeter and for areas up to about 40 square kilometers. (We expect to eclipse the 40-square-kilometer limit shortly.) These capabilities have been certified by the Mars 2003 Project Scientist as reflective of the best statistical knowledge of the Martian terrain. The capability to ingest the best knowledge of the site-specific terrain as gathered by satellite observations will soon be productized as well. All of this runs efficiently and (relatively) quickly on JPL's institutional supercomputers, and can be served locally back to those same computers running simulations, delivered as bulk data files, or served as patches on demand over the networks to a client.

Our simulation efforts have focused on Martian rovers operating on simulated terrain. By employing parallel machines, many simulation trials can be executed at once. This provides an ideal environment in which to explore performance over a range of terrains, rover designs, and autonomous navigation algorithms. The results are fed into JPL risk analysis tools and are simulta-



A sample frame from the movie "Lewis and Clark: Search for the Northwest Passage," created with RIVA.



A still image from a multi-rover simulation. Multiple rovers are placed an equal distance from an objective and start toward the objective. The current position of each rover is a yellow dot, and a green trail marks the last 30 positions. Depending on the terrain, some rovers can advance faster than others.

neously visualized to increase human understanding of the simulations. Three separate rover navigation algorithms have been ported into the high-performance simulation framework.

TECHNICAL CONTACT

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NEW TECHNOLOGY/SOFTWARE

Parallel Image Mosaicking Program — NTR #21121

Four Navigation Software Libraries: CCSDSTIME, TIMETRANS, NAVSYS-HP, and NAVSYS-SUN — NTR #20956

PUBLISHING OUR PROGRESS

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Andrew Johnson, Allan Klumpp, James Collier, and Aron Wolf, "Lidar-based Hazard Avoidance for Safe Landing on Mars," *Proceedings of the 11th AAS/AIAA Space Flight Mechanics Meeting*, Santa Barbara, CA, February 2001.

J. C. Jacob and L. Plesea, "Fusion, Visualization, and Analysis Framework for Large, Distributed Data Sets," *2001 IEEE Aerospace Conference Proceedings*, Big Sky, MT, March 10–17, 2001. (Catalog Number 00TH8442C, ISBN 0-7803-6600-X)

R. W. Gaskell, J. B. Collier, L. E. Husman, and R. L. Chen, "Synthetic Environments for Simulated Missions," *Proceedings of the IEEE Aerospace Conference*, Big Sky, MT, March 10–17, 2001.

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JPL 400-1044 07/02