# Software

## QuakeSim 2.0

QuakeSim 2.0 improves understanding of earthquake processes by providing modeling tools and integrating model applications and various heterogeneous data sources within a Web services environment. QuakeSim is a multisource, synergistic, data-intensive environment for modeling the behavior of earthquake faults individually, and as part of complex interacting systems. Remotely sensed geodetic data products may be explored, compared with faults and landscape features, mined by pattern analysis applications, and integrated with models and pattern analysis applications in a rich Web-based and visualization environment. Integration of heterogeneous data products with pattern informatics tools enables efficient development of models.

Federated database components and visualization tools allow rapid exploration of large datasets, while pattern informatics enables identification of subtle, but important, features in large data sets. QuakeSim is valuable for earthquake investigations and modeling in its current state, and also serves as a prototype and nucleus for broader systems under development.

The framework provides access to physics-based simulation tools that model the earthquake cycle and related crustal deformation. Spaceborne GPS and Interferometric Synthetic Aperture (InSAR) data provide information on near-term crustal deformation, while paleoseismic geologic data provide longer-term information on earthquake fault processes. These data sources are integrated into QuakeSim's QuakeTables database system, and are accessible by users or various model applications. UAVSAR repeat pass interferometry data products are added to the QuakeTables database, and are available through a browseable map interface or Representational State Transfer (REST) interfaces. Model applications can retrieve data from QuakeTables, or from third-party GPS velocity data services; alternatively, users can manually input parameters into the models.

Pattern analysis of GPS and seismicity data has proved useful for mid-term forecasting of earthquakes, and for detecting subtle changes in crustal deformation. The GPS time series analysis has

also proved useful as a data-quality tool, enabling the discovery of station anomalies and data processing and distribution errors. Improved visualization tools enable more efficient data exploration and understanding. Tools provide flexibility to science users for exploring data in new ways through download links, but also facilitate standard, intuitive, and routine uses for science users and end users such as emergency responders.

*This work was done by Andrea Donnellan, Jay W. Parker, Gregory A. Lyzenga, Robert A. Granat, and Charles D. Norton of Caltech; John B. Rundle of University of California, Davis; Marlon E. Pierce and Geoffrey C. Fox of Indiana University; Dennis Mcleod of University of Southern California; and Lisa Grant Ludwig of University of California, Irvine for NASA's Jet Propulsion Laboratory. For more information, access http://quakesim.org.*

*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-48579.*

## HURON (HUman and Robotic Optimization Network) Multi-Agent Temporal Activity Planner/Scheduler

HURON solves the problem of how to optimize a plan and schedule for assigning multiple agents to a temporal sequence of actions (e.g., science tasks). Developed as a generic planning and scheduling tool, HURON has been used to optimize space mission surface operations. The tool has also been used to analyze lunar architectures for a variety of surface operational scenarios in order to maximize return on investment and productivity. These scenarios include numerous science activities performed by a diverse set of agents: humans, teleoperated rovers, and autonomous rovers. Once given a set of agents, activities, resources, resource constraints, temporal constraints, and dependencies, HURON computes an optimal schedule that meets a specified goal (e.g., maximum productivity or minimum time), subject to the constraints.

HURON performs planning and scheduling optimization as a graph search in state-space with forward progression. Each node in the graph con-

tains a state "instance." Starting with the initial node, a graph is automatically constructed with new successive nodes of each new state to explore. The optimization uses a set of pre-conditions and post-conditions to create the children states.

The Python language was adopted to not only enable more agile development, but to also allow the domain experts to easily define their optimization models. A graphical user interface was also developed to facilitate real-time search information feedback and interaction by the operator in the search optimization process.

The HURON package has many potential uses in the fields of Operations Research and Management Science where this technology applies to many commercial domains requiring optimization to reduce costs. For example, optimizing a fleet of transportation truck routes, aircraft flight scheduling, and other route-planning scenarios involving multiple agent task optimization would all benefit by using HURON.

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## MPST Software: MoonKommand

This software automatically processes Sally Ride Science (SRS) delivered MoonKAM camera control files (ccf) into uplink products for the GRAIL-A and GRAIL-B spacecraft as part of an education and public outreach (EPO) extension to the Grail Mission. Once properly validated and deemed safe for execution onboard the spacecraft, MoonKommand generates the command products via the Automated Sequence Processor (ASP) and generates uplink (.scmf) files for radiation to the Grail-A and/or Grail-B spacecraft. Any errors detected along the way are reported back to SRS via email. With MoonKommand, SRS can control their