Autonomy software architecture for LORAX
(Life On ice Robotic Antarctic eXplorer)

LORAX is a robotic astrobiological study of the ice field surrounding the Carapace Nunatak near the Allan Hills in Antarctica. The study culminates in a 100km traverse, sampling the ice at various depths (from surface to 10cm) at over 100 sites to survey microbial ecology and to record environmental parameters.

Numerous factors drive the need for autonomy in the LORAX mission. First, it will demonstrate robotic science technologies applicable to future Mars mission, and as such, must operate with limited human oversight and interaction. Secondly, the LORAX science goals require minimizing biological contamination risk from human presence. Finally, the mission takes place in a highly uncertain and dynamic environment with limited resources, making it essential that the rover adapt its plan of action to ensure successful completion of mission and maximize the number of samples analyzed.

The autonomy requirements from LORAX are shared by many robotic exploration tasks. Consequently, the LORAX autonomy architecture is a general architecture for on-board planning and execution in environments where science return is to be maximized against resource limitations and other constraints. Three key elements set it apart from other general planning-execution architectures currently used for rover operations.

1. Flexible plans describe families of plans having the same structure and outcomes. This flexibility increases the applicability of a plan in changing environments and reduces need for re-planning due to minor variations.
2. Continuous re-planning to do on-line plan optimization. This allows the autonomy system to seamlessly modify plans in response to outcomes that differ from what was expected.
3. Resource envelopes bound expected resource profiles. These envelopes provide better information on the feasibility of candidate plans in flexible and uncertain situations, and offer better search control information during planning.

The backbone of the LORAX autonomy architecture is EUROPA, a constraint-based planning framework. EUROPA supports the description of temporal actions and states, complex constraints and operations rules, and complex resources. The underlying representation and reasoning is based on dynamic constraint network reasoning. The advantages of the constraint-based approach include flexibility, generality, and improved efficiency.

The EUROPA system uses new methods to bound resource profiles, making it possible to reason effectively about resource use in partial and flexible plans. The LORAX autonomy architecture extends the baseline technology to handle certain types of non-linear and time-dependent resources, such as internal rover temperature and battery capacity.

Finally, the LORAX autonomy architecture defines a planning and execution system that supports parallel re-planning and execution. Execution results and real-world outcomes are used to generate alternative plans, which then, if appropriate, are spliced in to replace the current plan. This is made possible by the use of flexible plans, and the propagation of information through constraint reasoning.

The LORAX project is work-in-progress. The rover hardware is being finalized, and an initial prototype of the autonomy architecture is being evaluated. This will be extended to an initial version of the autonomy software operating individual instruments and sub-systems, leading to a full operations test in early 2006. These will in turn be followed by operations tests on glaciers, and then two missions to the Antarctic in 2007 and 2008.