



NASA STTR 2011 Phase I Solicitation

T8.01 Autonomous Multi-Robotic Systems

Lead Center: LaRC

Current NASA research/development and mission capabilities are primarily focused on single, automated robotic systems. For example, exploration of remote planetary surfaces has used single automated Telerobotic vehicles, dependent on human control, which limits the area covered, scope of mission and risk of a single point mission failure.

The goal of this topic area is to develop technologies and capabilities that will lead to fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required. Of specific interest in this topic area is techniques for cooperation among multiple robotic vehicles to achieve complete mission objectives autonomously that cannot be accomplished by current robotic architectures. This would permit the exploration of larger spatial areas/volumes, increase system redundancy and enable distributed capability deployment, where vehicles can have varying sensor/manipulator capabilities to better achieve a broad range of objectives. The system would autonomously distribute required tasks amongst themselves based upon each vehicle's capabilities/equipment package and adapt to changes in the environment, learned knowledge and failures on individual vehicles.

Three possible examples of multiple cooperating vehicles systems are described below, but other concepts will be considered:

- A "Parent" vehicle would provide transportation, control and logistical support for multiple "Child" vehicles, extending data gathering and mapping operations. For example, a Walker/Gecko could provide access to subterranean areas, the Walker navigating large rock fields, while the Gecko would be employed for exploring lava tubes and caves. The system requirements include: docking, deployment, recovery, and storage of the Child vehicles; re-fueling the Child vehicles; local navigation and communication, and adapting to potential failures, including the loss of communication.
- A flying swarm of a large number of smaller vehicles, operating autonomously yet cooperatively, could extend the exploration range while maintaining direct surface contact as the swarm "hops" from point to point. Such a design has the added benefit that individual failure would not condemn the mission to fail (e.g., 80% of individuals could fail with 100% mission success). A swarm design presents new problems

such as how the swarm will effectively fly in formation and how the swarm will determine course of action. Because much of the environment is unknown, the swarm must adapt to unforeseen situations. Centralized control and predetermined script execution is likely not practical. Without directions from a central controller, individual members of the swarm are limited to local observations and communication with neighboring members. From these observations, individuals must make autonomous decisions and take individual action. From these actions, a behavior emerges. Thus, the challenge is to design the swarm for desired emergent behavior beyond just formation flying, the swarm must demonstrate decisions on actions to complete an exploratory mission without a central controller, but rather the combined action of autonomous individuals.

- A sensor network, a distribution of a large number of connected, capable devices distributed over a region, could extend the range of exploration without the requirement for mobility. Conventional sensor network design is limited to a sense and send scenario where individual devices periodically sense the environment and send information through a multi-hop network of others to the central controller. However, a much more complex mission could be accomplished by a "virtual swarm" over the distribution. While the individual devices remain fixed after initial deployment, the application could move around the network as required to complete the mission. To take full advantage of the architecture and achieve maximum success, the application must adapt to unforeseen circumstances presented by the environment. A successful demonstration will exhibit communication among a fixed set of devices that directs where and when observations are taken and what actions will be taken to complete a mission (i.e., virtual mobility). Devices must not be directed by a central controller or a predetermined script but must exhibit adaptive behavior to a non-deterministic scenario.

Phase I activities should include an assessment of current technology capabilities relative to future requirements, identify technology gaps and lay out a technology development roadmap for an integrated system. An integrated software simulation of the proposed concepts is desirable. Potential subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of an integrated prototype system of multiple cooperating autonomous vehicles.