



NASA STTR 2011 Phase I Solicitation

T8 Autonomous Systems

Autonomous and robotic systems are a critical capability in all of NASA's mission areas including Aeronautics, Earth and Planetary Sciences, and Human Spaceflight and will be more pervasive in the future. Current systems are primarily automated, able to respond to a predicted set of conditions and require human interaction and control. The goal of this topic area is to develop technologies and capabilities that will lead 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, particularly if communication delays are significant or unavailable. Specific capabilities include perception, cognition, and mobility/manipulation to enable Multi-robotic systems, Atmospheric Flight and Remote Sensing and Navigation in GNSS-Denied Environments.

Subtopics

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.

T8.02 Autonomous Systems for Atmospheric Flight and Remote Sensing

Lead Center: LaRC

Increasing levels of automation capabilities in the aviation arena, provides unique opportunities and challenges for civil aviation, and the aerial transport communities. Flight will be transformed as these capabilities mature and evolve in to integrated systems. In particular, autonomous and robotic, manned and unmanned civil aircraft systems will lead to a plethora of new markets, vehicle, and missions. These new systems with broad range of capabilities, and a huge diversity of shapes and sizes, must safely utilize the future National Airspace System. Both operational and machine autonomy will require tremendous breakthroughs through the new technology frontiers in machine intelligence, autonomy, robotics, and inter-connections of these technologies. Breakthroughs in these areas could lead to such societal capabilities as autonomous cargo carrying, surveillance, air taxis, small unmanned civil aircraft, Zip aircraft, on-demand VTOL aviation, airborne wind energy platforms and a host of other emerging distributed aviation systems. For purposes of this solicitation, autonomous vehicles have varying levels of autonomy that range from automated capability to fully autonomous flight where the system has the ability to learn, reason, and adapt. Military applications have demonstrated the ability to do automated flight but their use in civil aviation requires additional research and development. The primary interest of this sub-topic is to advance the technologies for robotic and autonomous vehicle perception, cognition, as well as system integration. Proposals should be written around one of the following themes described below:

- Autonomous and robotic air-vehicles can enable new markets reduce operational cost, and improve safety. Autonomous systems can be applied far beyond remotely piloted aircraft. Maximum machine effectiveness can only be realized through vehicle autonomous systems ability to learn, reason and adapt. Current practice is to have a reliance on stored information, which is complemented by GPS position information. If there is an on-board, real-time means to sense and react to the local environment (including air and ground features and traffic), then autonomous and robotic air-vehicle can be fully utilized. But addressing how adaptive systems can still be 'trusted' in critical flight environments and achieve FAA certification is a technical issue that must be resolved. Proposals are sought to develop innovate approaches and enabling technologies for autonomous, robotic, and embodied intelligent air-vehicles. Example scenarios could include but are not limited to carrying passengers and cargo through the NAS, search, rescue, and surveillance operations, and sentries to patrol coastal waters, and land borders. Proposal should consider perception, cognition, as well as GPS enabled, GPS-denied, and cooperating and non-cooperating traffic environments.
- There are a broad range of technical subjects relevant to these new aviation markets and highly diverse aircraft operations include Machine and Operational Autonomy, Off-Nominal Autonomy, Future Consensus and Statistically Based Regulatory Processes, Safety Assurance, Software Certification, Electric and Redundant Propulsion Systems, Airspace Separation Assurance and Detection, Peer-to-Peer Deconfliction, Wireless Sensor Networks for Smart Aircraft Sub-Systems, Fault Tolerant Systems, and Multi-Spectral Sensing and Data Fusion. Proposals are also sought in the integration of these technologies in combination to achieve new societal capabilities across specific aircraft configurations. Therefore, emergent vehicle autonomy platforms that can showcase capabilities that were previously unable to be performed (without autonomy). One example would be the ability to follow complex flight paths such as dynamic soaring, where autonomy enables an entirely new ability through both predictive and optimal trajectory planning and execution. Likewise extreme Short and Vertical Takeoff and Landing aircraft have key gust response sensitivities that could be greatly enhanced through degrees of autonomy within the control loop to achieve much faster response, and therefore new flight capabilities. Of particular interest is the ability to showcase how spiral development and rapid experimentation in aerial robotics can provide early lessons learned and guidance for future larger-scale technology investment. Such efforts could leverage the ability of dynamically-scaled sub-scaled vehicle testing to push very low high risk technology readiness levels to higher levels that more easily justify research investment.
- Autonomous Remote Sensing Measurement Technologies required to support Advanced Flight Testing, Earth Science, and Intelligence, Surveillance and Reconnaissance (ISR) Applications. NASA's HYTHIRM project (AIAA-2010-241) has demonstrated an emerging capability to obtain quantitative global thermal surface temperatures associated with a hypersonic vehicle in flight. The available technology adequately measured the acreage surface temperature of the Shuttle lower surface during reentry. Future hypersonic

cruise vehicles or advanced launcher configurations will challenge affordable human-in-the-loop remote imaging capability in terms of high speed tracking, spatial/spectral resolution and temperature sensitivity. A next generation system would entail a "smart payload" with a UAS optimally designed around it. The payload would ultimately permit autonomous long range target acquisition, tracking, image stabilization and enhancement, real-time sensor re-configuration and aircraft attitude/orientation to optimize the data collect thus significantly increasing mission flexibility while reducing operational costs. Phase I proposal should include an assessment of current imaging technology capabilities for spatially resolved thermal imagery along with requirements for a next generation autonomously controlled sensor/platform system. Proposals should consider Identification of technology gaps and lay out of a technology development roadmap. Software and hardware demonstrations are encouraged. Integration and autonomous control of the following technologies include: system simulation software; advanced high resolution focal plane array development including multi-color focal plane arrays; large apertures; miniaturization of high frame rate multi-waveband (i.e., visible, NIR, SWIR, MWIR, LWIR) including spectral/hyperspectral sensors; advanced radiometric simulation software; real time imaging processing and post processing deconvolution algorithms; adaptive optics; target recognition and low latency tracking algorithms; active feedback for platform command and control functions and local navigation and communication. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable of integrating with a UAS.

T8.03 Autonomous Navigation in GNSS-Denied Environments

Lead Center: LaRC

Current NASA research/development and mission capabilities for exploration of remote planetary surfaces are primarily focused on automated telerobotic systems dependent on human control. More fully autonomous systems will be required for future missions, particularly where communications with Earth may be limited, unavailable for extended periods of time and have significant delays.

This subtopic is to investigate the autonomous navigation capabilities required for land and possibly aerial vehicle operation in areas lacking GNSS and/or magnetic compass to expanded exploration roles within planetary environments. A specific area of interest is to investigate biologically inspired algorithms and capabilities, such as techniques used by insects, such as Honey Bees, to accomplish this goal. Optical flow, image motion across the field of vision, offers unique capabilities for hazard detection and avoidance, landmark navigation, distance judgment, cave navigation, speed regulation, and visual odometry. Current technology is very computationally intensive. It is desired that with hardware support, high speed optic flow measurements can be obtained to speed up and simplify the extraction of motion information from the visual scene, which would both enhance obstacle and hazard detection and avoidance, as well as speed up the navigation process. This will be very critical if VTOL flight can be achieved, as a fuel-limited, in-motion VTOL vehicle is ill positioned to wait for a complicated and time consuming image analysis to be accomplished. Additionally, current laser scanner/imaging technology used for generating terrestrial 3D maps have mass and power requirements that are excessive for smaller planetary robotic exploration systems. Low mass, low power 3D mapping systems accommodated on planetary missions could be employed to support autonomous vehicle navigation and maneuvering operations. One example would be a parent vehicle that could launch multiple smaller vehicles that would autonomously explore larger regions and then navigate back to the parent vehicle to transmit data and refuel. In addition to navigation, these vehicles could gather detailed, photorealistic 3D maps that can be fused with associated science data and used by scientists, students, and the general public for "participatory exploration" activities.

Initial activities would include an assessment of current technology capabilities that could be compared to requirements to identify technology gaps, lay out a technology development roadmap, and develop a software simulation of proposed system and operation. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable autonomous navigation in environments that do not allow GNSS or magnetic compass navigation and have limited or no communication between vehicles.