The topic for Robotics, Tele-Robotics and Autonomous Systems, consists of seven technology subareas: Sensing and Perception; Mobility; Manipulation; Human-Systems Integration; Autonomy; Autonomous Rendezvous and Docking (AR&D); and Robotics, Tele-Robotics and Autonomous Systems Engineering. Robotics, Tele-Robotics and Autonomous Systems supports NASA space missions with the development of new capabilities, and can extend the reach of human and robotic exploration through a combination of dexterous robotics, better human/robotic interfaces, improved mobility systems, and greater sensing and perception. The Robotics, Tele-Robotics and Autonomous Systems topics focuses on several key issues for the future of robotics and autonomy: enhancing or exceeding human performance in sensing, piloting, driving, manipulating, and rendezvous and docking; development of cooperative and safe human interfaces to form human-robot teams; and improvements in autonomy to make human crews independent from Earth and make robotic missions more capable.

Subtopics

T4.01 Dynamic Servoelastic (DSE) Network Control, Modeling and Optimization

Lead Center: AFRC
Participating Center(s): JPL, LaRC

This subtopic addresses advanced control-oriented techniques for dynamic servoelastic (DSE) terrestrial, planetary, and space environment flight systems using distributed network sensor and control systems. Methods include modeling, simulation, optimization and stabilization of DSE systems to actively and/or adaptively control structural dynamic geometry/topology, vibration, atmospheric and intraspace disturbances, static/dynamic loads, and other structural dynamic objectives for enhanced dynamic servoelastic performance and stability characteristics.

- DSE control for performance enhancements while minimizing dynamic interaction.
- Flexible aircraft and spacecraft stabilization and performance optimization.
- Modeling and system identification of distributed DSE dynamics.
- Sensor/actuator developments and modeling for distributed DSE control.
- Uncertainty modeling of complex DSE system behavior and interactions.
- Distributed networked sensing and control for vehicle shape, vibration, and load control.

This subtopic also addresses capabilities enabling design solutions for performance and environmental challenges of future air and space vehicles. Research in revolutionary aerospace configurations include lighter and more flexible materials, improved propulsion systems, and advanced concepts for high lift/performance and drag/energy reduction. This subtopic targets efficiency and environmental compatibilities requiring performance challenges and
novel control-oriented techniques for aero-servoelastic considerations which are gaining prevalence in advanced aerospace flight vehicles, atmospheric and extra-terrestrial.

Technical elements for the Phase I proposals may also include:

- Mission/maneuver adaptivity with dissipative optimal energy-force distribution.
- Data-driven multi-objective DSE control with physics-based sensing.
- Robust sensing-control-communication networks for sensor-based distributed control.
- Compressive information-based sensing and information structures.
- Evolving systems as applied to self-assembling and robotic maneuvering.
- Scalable and evolvable information networks with layering architectures.
- Modular architectures for distributed autonomous aerospace systems.
- Multi-objective, multi-level control and estimation architectures.
- Distributed multi-vehicle dynamics analysis and visualization with complex simulations.
- Reduced order modeling capable of substructure coupling of nonlinear materials.

Development of distributed sensory-driven control-oriented DSE systems is solicited to enable future flight vehicle concepts and designs that manage structural dynamic uncertainty on a vehicle's overall performance. Proposals should assist in revolutionizing improvements in performance to empower a new generation of air and space vehicles to meet the challenges of terrestrial and commercial space concerns with novel concepts and technology developments in systems analysis, integration and evaluation. Higher performance measures include energy efficiency to reduce fuel burn and operability technologies that enable information network decompositions that have different characteristics in efficiency, robustness, and asymmetry of information and control with tradeoff between computation and communication.

Advanced mission applicability in Phase II should show the ability of aerospace GN&C systems to achieve mission objectives as a function of GN&C sensor performance, vehicle actuation/power/energy, and the ability to jointly design them as onboard-capable, real-time computing platforms with applicable environmental effects and robust guidance algorithms. Goals are to:

- Provide capabilities that would enable new projects/missions that are not currently feasible.
- Impact multiple missions in NASA space operations and science, earth science, and aeronautics.
- Be influential across aerospace and non-aerospace disciplines with dynamic interactions.

**State of the Art**

This subtopic will:

- Provide capabilities that would enable new projects and missions that are not currently feasible, using distributed sensing and controls for network processing.
- Impact multiple missions in NASA space operations and science, earth science, and aeronautics.
- Be influential across aerospace and non-aerospace disciplines with dynamic interactions.

Potential technical impacts are:

- Vehicle energy efficiency with passive/active dissipativity for control and dynamic stability with extreme power constraints.
- Weight minimization through dynamic servoelastic control.
- Mission adaptivity and robustness with real-time, consensus-coordinated control dealing with computation, communication, and dynamics.

New technologies proposed should have the potential to impact the following NASA missions:

- Data availability for science missions.
• Mission planning.
• Autonomous rendezvous/docking technology.
• Environmental monitoring for human habitation.

Apart from NASA missions, the aeronautics technology could be adapted for development and use in autonomous operation of wind/ocean energy and smart space power grid systems in dynamic environments. There are number of advantages to exploring this subtopic technology:

• Increase in autonomy and fuel efficiency of coordinated robotic vehicles and sub-components.
• Improved science, atmospheric, and reconnaissance data.
• Cost, risk and reliability of flight vehicles for a terrestrial, planetary, or space mission.
• Inter-networks with improved dynamic behavior.

Potential technical impacts are:

• Vehicle energy efficiency with passive/active dissipativity for control and dynamic stability with extreme power constraints.
• Weight minimization through dynamic servoelastic control.
• Mission adaptivity and robustness with real-time, consensus-coordinated control dealing with computation, communication, and dynamics.

T4.02 Regolith Resources Robotics - R3
Lead Center: KSC
Participating Center(s): ARC, LaRC

The use of robotics for In-Situ Resource Utilization (ISRU) in outer space on various planetary bodies is essential since it uses large quantities of regolith that must be acquired and processed. In some cases this will happen while the crew is not there yet, or it will take place at a remote destination where the crew cannot spend much time due to radiation exposure limits (Asteroids, Marâs Moons & NEOâs). Communications latencies of greater than 40 minutes at Asteroids mandate autonomous robotics applications. Proposals are sought which provide solutions for the following space resource related technology area:

Asteroid Resource Prospecting and Characterization

The first step towards using resources derived from small bodies in space, such as water, volatiles, metals and organic compounds is to visit the Near Earth Object (NEO) target body and prospect it with sample acquisition devices and subsequently do characterization of these samples. Proposals are sought for innovative resource prospecting mission concepts and associated technology demonstrations such as autonomous small marsupial free flier prospector spacecraft that can sample an asteroid, comet or Mars moon and transport the sample back to a locally orbiting spacecraft with an associated suite of characterization instruments for analysis.

Proposals are sought for innovative resource prospecting mission concepts, technology development, and demonstrations.

Technologies include sample acquisition methods and devices, regolith anchoring methods, autonomous conops, sub-surface access, excavation, specialized sensors, dust lofting mitigation, perception in dusty environments, mobility methods, surveying, remote sample characterization, geodetic mapping, replenishing and transferring robotic commodities such as propellants, electric power, data transfer, pneumatics and robust interfaces for commodity transfer.

Future prospecting missions include:

• Water/Ice on Mars, Mars moons or Earthâs Moon.
• Micro-gravity Near Earth Object (NEO) operations to prospect/sample surface resources.
Lava tubes/shadowed crater cold traps on planetary surfaces to characterize volatiles accumulation.

**T4.03 Coordination and Control of Swarms of Space Vehicles**

**Lead Center: JPL**

This subtopic is focused on developing and demonstrating technologies for coordination and autonomous control of teams and swarms of space systems including but not limited to spacecraft and planetary rover teams in a dynamic environment.

Possible areas of interest include but are not limited to:

- Coordinated task planning, operation, and execution.
- Relative localization in space and on planet surface.
- Close proximity operations of spacecraft swarms including sensors required for collision detection and avoidance.
- Fast, real-time, coordinated motion planning in areas densely crowded by other agents.
- Human-Swarm interaction interfaces for controlling the multi-agent system as an ensemble.
- Distributed fault detection and mitigation due to hardware failures or compromised systems.
- Communication-less coordination by observing and estimating the actions of other agents in the multi-agent system.

Phase I awards will be expected to develop theoretical frameworks, algorithms, software simulation and demonstrate feasibility (TRL 2-3). Phase II awards will be expected to demonstrate capability on a hardware testbed (TRL 4-6).