

1. **Research Title:** Advanced Control Algorithms for Managing High Heat Flux Thermal Transients in Military Aircraft

2. **Individual Sponsor:**

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3. **Academic Area/Field and Education Level:**

Mechanical Engineering and Aerospace Engineering/Thermal Fluids, Heat Transfer, Controls Engineering, Thermal Modeling and Simulation (BS, MS or PhD level)

4. **Objectives:** Develop and evaluate advanced control algorithms for managing rapid, high heat flux thermal transients in military aircraft thermal management systems.

High power electronic systems, including active phased array radars, mission payloads, electronic warfare systems, and high discharge energy storage systems, can generate large heat loads over very short time periods. These rapid thermal disturbances can occur significantly faster than the thermal management system can respond.

The research will investigate the asymmetric dynamics between fast heat generation and the comparatively slower response of thermal transport systems. Modeling and simulation will be used to characterize these dynamic interactions and evaluate the limitations of conventional reactive feedback controllers, such as proportional integral derivative (PID) control.

Advanced control methodologies will be explored and compared for their ability to anticipate, mitigate, and manage fast thermal transients. Candidate approaches may include feed forward control, Model Predictive Control (MPC), optimal control, adaptive control, physics-informed control, or hybrid control strategies.

Controller performance will be evaluated using metrics such as peak temperature excursion, transient response, stability, thermal energy utilization, actuator response, auxiliary power consumption, and ability to maintain critical components within allowable operating temperatures.

5. **Description:** Future military aircraft are expected to incorporate increasingly capable and power dense mission systems. Advanced sensors, active phased array radars, high power electronics, and high discharge energy storage technologies can produce large and rapidly varying thermal loads.

Managing these loads presents a fundamental thermal controls challenge. Heat generation within high power electronic components can increase very rapidly, while the aircraft thermal

management system depends on slower physical processes such as heat conduction, fluid transport, thermal capacitance, heat rejection, and mechanical actuation of pumps, valves, compressors, and other components.

This difference in response times creates asymmetric thermal dynamics, where the thermal disturbance can develop substantially faster than the cooling system can react.

Conventional thermal control systems typically rely on reactive feedback. For example, a PID controller responds only after a measurable temperature or system state deviation occurs. Under sufficiently rapid thermal transients, this reactive response may occur too late to prevent excessive temperature excursions, potentially requiring increased cooling capacity, additional thermal energy storage, or oversized thermal management hardware.

This research will investigate advanced control algorithms specifically designed to address fast thermal transients and asymmetric thermal system dynamics. Dynamic thermal fluid models will be developed to represent transient heat generation, thermal capacitance, fluid transport delays, heat rejection, and actuator dynamics.

These models will be used to compare conventional feedback control against advanced control methodologies capable of anticipating or more effectively responding to rapid thermal disturbances. The research may investigate the use of predicted mission system loads, thermal system states, available thermal capacitance, or other system information to command thermal management components before critical temperature excursions occur.

Trade studies will quantify the relative benefits and limitations of candidate control algorithms and determine their impact on peak component temperature, system response time, auxiliary power demand, actuator utilization, thermal system efficiency, and required thermal management capacity.

The research will provide insight into the control strategies, sensing requirements, predictive information, and system characteristics required to effectively manage high heat flux thermal transients in future military aircraft.

6. **Research Classification/Restrictions:** Open to U.S. citizens only. Some aspects of this research may include ITAR restrictions.
7. **Eligible Research Institutions:** DAGSI (All DAGSI Universities).

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