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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
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Title:	ROBUST ADAPTIVE NONLINEAR CONTROL STRATEGIES FOR ADVANCED AERIAL VEHICLES: THEORY AND APPLICATIONS
Chairperson:	Dr. Sven Esche, Dept. of Mechanical Engineering, School of Engineering and Science
Committee Members:	Dr. Brendan Englot, Dept. of Mechanical Engineering Dr. Serban Sabau, Dept. of Electrical and Computer Engineering Dr. Mishah U. Salman, Dept. of Mechanical Engineering Dr. Hamid Jafarnejad Sani, Dept. of Mechanical Engineering

ABSTRACT

The ongoing evolution of the aerospace industry has seen significant developments of advanced aerial vehicles, such as reusable launch vehicles (RLVs) and hypersonic flight vehicles (HFVs). Despite the potential benefits of these vehicles, their design presents substantial challenges, including complicated aerodynamics, strong nonlinearities, large flight envelopes, and demanding flight environments. This dissertation aims to enhance robust adaptive control methodologies to render them more suitable for practical implementation in advanced aerial vehicles.

The research comprises the development of two advanced adaptive higher-order sliding mode control (SMC) methodologies for reentry RLV attitude control and an adaptive robust backstepping control strategy for HFV control. The methodologies address various challenges, including modeling uncertainties, disturbances, actuator faults, control input saturation, and state constraints.

First, a novel adaptive second-order nonsingular fast terminal sliding mode fault-tolerant control scheme for RLVs during reentry is proposed. This control law eliminates initial phase oscillations, does not require prior knowledge of disturbance upper bounds, and offers increased robustness compared to existing methods. Furthermore, it addresses modeling uncertainties, disturbances, and actuator faults.

Then, a two-loop control scheme for RLV attitude control is introduced as an alternative to the terminal SMC-based approach. The proposed outer-loop and inner-loop controllers are extended to be multivariable and input-constrained methods, further enhancing their suitability for real-world applications. This control scheme adeptly addresses prevalent challenges in RLV attitude control systems, including input constraints, state-dependent disturbances, and multivariable control.

A comprehensive state-constrained control strategy for HFVs is formulated, which, for the first time, simultaneously addresses multiple challenges, including actuator faults, control input saturation, aerodynamic uncertainties, and both nominal and stochastic external disturbances. An adaptive backstepping control strategy is adopted, and neural networks are implemented to guarantee its sufficient robustness. This control strategy ensures proper operation of the vehicle by restricting specific states to predefined ranges, making it highly practical for real-world HFV control systems.

In conclusion, this dissertation contributes to the advancement of robust adaptive control methodologies for advanced aerial vehicles, addressing an extensive array of challenges and demonstrating their potential suitability in real-world contexts. Comparative simulation tests are also included to validate these findings.