Engineering Faculty Document No.: 33-03
Date: March 9, 2004

TO: Faculty of Schools of Engineering
FROM: Faculty of the School of Aeronautics and Astronautics
SUBJECT: New Graduate Course

The Faculty of the School of Aeronautics and Astronautics has approved the new course listed below. This action is now submitted to the Engineering Faculty with a recommendation for approval.

AAE 624, Laminar-Turbulent Transition
Sem. 1, Class 1, cr. 3.
Prerequisite: AAE 511 or equivalent.

Course Description:
Instability mechanisms, such as: Kelvin-Helmholtz, Tollmien-Schlichting, Görtler, and crossflow. Secondary instabilities. Nonlinear and nonparallel effects; the Parabolized Stability Equations; receptivity; transition prediction. Effects of compressibility, heating, roughness, turbulence, noise, curvature, etc. Turbulent spots and the extent of transitional flow.

Reason:
This specialized course provides advanced education for an important topic. The class was taught in Fall 1995 and Fall 2001 as AAE690T, with enrollments of 6 and 7, respectively. The class is to be taught again in Fall 2004.

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Thomas N. Farris, Professor and Head
School of Aeronautics and Astronautics

AAE 624, Laminar-Turbulent Transition

- **Course Instructor:** Professor Steven P. Schneider

- **Course Description:**
  Basic instability mechanisms, such as: Kelvin-Helmholtz, Tollmien-Schlichting, Görtler, and crossflow. Secondary instabilities. Nonlinear and nonparallel effects; the Parabolized Stability Equations; receptivity; transition prediction. Effects of compressibility, heating, roughness, turbulence, noise, curvature, etc. Turbulent spots and the extent of transitional flow.

- **Course outline:**
  1. **Introduction:** Mechanisms of transition: linear and nonlinear instability, secondary instability, environmental noise, bypasses. Limitations of algebraic correlation schemes. Review of elementary wave theory. Review of the basic concepts of random processes and spectral analysis. [3 hours]
  2. **Linear Instabilities:** Kelvin-Helmholtz, Tollmien-Schlichting, Görtler, crossflow, attachment-line, and the higher or Mack modes in compressible flow. Spatial and temporal domains, nonparallel effects, etc. [9 hours]
  3. **General Parametric Effects:** Reynolds number, wall and freestream temperature, wall suction and blowing, geometry, etc. [3 hours]
  4. **Supersonic and Hypersonic Effects:** Mach number effects. Tunnel-wall radiated noise. Shock-layer instabilities. Flow chemistry. [6 hours]
  5. **Advanced Methods for Analysis and Prediction:** Transient Growth**:** The incompleteness of the linear-instability basis functions, which leads to transient growth phenomena. Nonlinear and Secondary Instabilities: Higher harmonics. Subharmonics. Secondary instabilities. Development of three-dimensionality. Importance of ambient disturbances. Variability of the routes to breakdown. Beyond Local Methods: The e^N method. The Parabolized Stability Equations. Direct numerical simulations, in either the spatial or temporal domains. [6 hours]
  6. **Intermittency and the Extent of Transition**: Turbulent spots, their form and growth. The linear-combination model of the intermittent region, and some alternatives. Effects of pressure gradient, turbulence level, three-dimensionality, curvature, etc. The importance of intermittency on gas-turbine blades. Methods of distinguishing turbulent and non-turbulent flow. [6 hours]
  7. **Roughness Effects:** The physical effects of roughness, the introduction of streamwise vorticity. Critical and effective heights, correlations. Effects of Mach number and geometry. Edge contamination. Roughness interacting with freestream disturbances to produce receptivity. [6 hours]
  8. **Case Studies**: Particular examples of instability and transition. Blunt cones at conditions simulating reentry. The Space Shuttle. Turbine blades on gas turbine engines. The slats of multielement airfoils. [3 hours]
  9. **Receptivity**: The origin of instability waves from ambient disturbances. Acoustical results, vortical results. High-speed effects, processing of disturbances by shocks. [3 hours]

- **Text:** The course is based on an extensive set of handouts, supplemented by reference lists and technical papers.