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Course Outline
A&AE 624 Laminar-Turbulent Transition

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Spring 2018 - Asynchronous via Audio Recordings Only

Catalog-type Description:
A&AE 624 Laminar-Turbulent Transition. Sem. 1. 3 credits. Prerequisite: A&AE511 or equivalent. 3 lecture hours per week. Instability mechanisms, such as: Kelvin-Helmholtz, Tollmien-Schlichting, Görtler, and crossflow. Secondary instabilities. Nonlinear and non-parallel 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.

Note: This specialized course was last offered in the Fall of 1995, 2001, 2004, 2008, 2012 and 2016. Most of the class is based on extensive handouts in the form of Acrobat PDF files, which are available on the website (contact the instructor to get the password). In Spring 2018 the class is being offered to a few select on-site and off-site students via recorded audio.

Text: No good text is available. A reference list will be handed out, along with selected review articles.

Grading: Two two-week problem sets and a 12-week project.

(over)

Course Outline

Topics 8 and 9 are more advanced; coverage will vary depending on available time and student interest. See also the detailed outline of the handouts. The content is to be updated as the semester progresses.

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.

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.

3. **General Parametric Effects:** Reynolds number, wall and freestream temperature, wall suction and blowing, geometry, and so on.

4. **Supersonic and Hypersonic Effects:** Mach number effects. Tunnel-wall radiated noise. Shock-layer instabilities. Flow chemistry.

5. **Advanced Methods for Analysis and 'Prediction':**

   (a) **Transient Growth:** The incompleteness of the linear-instability basis functions, which leads to transient growth phenomena.

   (b) **Nonlinear and Secondary Instabilities:** Higher harmonics. Subharmonics. Secondary instabilities. Development of three-dimensionality. Importance of ambient disturbances. Variability of the routes to breakdown.

   (c) **Beyond Local Methods:** The e^N method. The Parabolized Stability Equations. Direct numerical simulations, in either the spatial or temporal domains.

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, turbulent level, three-dimensionality, curvature, and so on. The importance of intermittency on gas-turbine blades. Methods of distinguishing turbulent and non-turbulent flow.

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.

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.

9. **Receptivity:** The origin of instability waves from ambient disturbances. Acoustical results, vortical results. High-speed effects, processing of disturbances by shocks.