11:48AM HD.00007 Roughness receptivity in swept-wing boundary layers - Computations1, HELENE REED, RICHARD RHODES, WILLIAM SARIC, Texas A&M University, College Station, TX — The laminarization of a swept-wing boundary layer by the introduction of passive spanwise-periodic roughness elements (DRES) near the leading edge is investigated at chord Reynolds numbers of approximately 7.5 million. The Texas A+M Flight Research Lab (FRL) is currently conducting flight tests of a 30-degree swept-wing model (SWIFT) mounted vertically below the port wing of a Cessna O-2A Skymaster. As a companion to the flight experiments, the current study is concerned with modeling the flowfield over the O-2 aircraft with the SWIFT model. The full-aircraft computational model was used to validate the flight-test configuration, as well as provide the basic state for the nonlinear parabolized stability equation (NPSE) formulation used to correlate shear-stress measurements, disturbance velocity amplitude, and roughness Reynolds number, and determine the efficacy of the DRES.

1This work was supported by: AFOSR and NASA Langley Research Center.

12:01PM HD.00008 DNS and theoretical study of perturbations in a hypersonic boundary layer over a flat plate, XIAOWEN WANG, UCLA, ANATOLI TUMIN, University of Arizona, XIAOLIN ZHONG, UCLA — Direct numerical simulation of receptivity in a boundary layer over a flat plate was carried out with perturbations introduced into the flow by periodic-in-time blowing-suction through a slot. The free stream Mach number is equal to 5.92. The perturbation flow field was decomposed into normal modes with the help of the multimode decomposition technique based on the spatial biorthogonal eigenfunction system. The decomposition allows filtering out the unstable mode hidden behind perturbations having another physical nature. The development of the filtered-out unstable mode is compared with a theoretical prediction based on the method of multiple scales that includes the nonparallel flow effects. The results illustrate how the multimode decomposition technique may serve as an efficient tool for gaining insight into the flow dynamics in the presence of perturbations belonging to different modes.

12:14PM HD.00009 Structure of Streaks Near the Leading Edge Singularity in a Blasius Boundary Layer, JOSE MANUEL VEGA, MARIA HIGUERA, ETSI Aeronáuticos. UPM — Streaky (S) perturbations (also called Klebanoff modes) in a Blasius boundary layer are examined in the vicinity of the leading edge singularity. Understanding the mathematical structure of S-perturbations in this limit requires to consider two eigenvalue problems, whose eigenfunctions exhibit two well separated scales in the normal direction: (i) \( \zeta = y/\sqrt{x} \sim 1 \) and (ii) \( y = \zeta \sqrt{x} \sim 1 \), where \( \zeta \) is the usual self similar variable in the boundary layer and \( x \) is the streamwise coordinate. These eigenvalue problems were considered by Luchini (JFM 1996), who calculated some of their solutions. The remaining solutions are calculated and used to obtain approximations of the relevant solutions of streamwise evolving parabolic problem that provides S-perturbations in this limit. Some of the results are also relevant in the restricted 2D problem.

12:27PM HD.00010 Low-Dimensional Modal Description of Optimal Streaks, MARIA HIGUERA, ETSI Aeronáuticos. UPM, JOSE MANUEL VEGA, ETSI, Aeronáuticos. UPM — Streaky perturbations play an essential role in the destabilization of boundary layers, especially in the presence of free-stream turbulence. These perturbations are calculated in terms of a streamwise evolving parabolic problem. Using the asymptotic behaviour of the solutions near the leading edge singularity, we obtain a low-dimensional modal description of the streaks in the case of a boundary layer attached to a flat plate. Comparison with optimal streaks obtained via the adjoint gradient (Luchini, JFM 2000), seems to indicate that the development of the instability may be understood on the basis of appropriate amplitude equations giving the streamwise evolution of the amplitudes of the relevant modes.

Monday, November 24, 2008 10:30AM - 12:40PM – Session HE Rayleigh-Taylor Instabilities 003A

10:30AM HE.00001 3-D Simulations to Investigate Initial Condition Effects on the Growth of Rayleigh-Taylor Mixing, ARINDAM BANERJEE, Missouri S&T (formerly University of Missouri-Rolla), MALCOLM J. ANDREWS, Los Alamos National Laboratory — The effect of initial conditions on the growth rate of turbulent Rayleigh–Taylor (RT) mixing has been studied using carefully formulated numerical simulations. An integrated large-eddy simulation (ILES) using a finite-volume technique was employed to solve the three-dimensional incompressible Euler equations with numerical dissipation. The initial conditions were chosen to test the dependence of the RT growth parameters \( (\alpha_s, \alpha_u) \) on variations in \( \alpha_u \) the spectral bandwidth, \( \alpha_s \) the spectral shape, and \( \alpha_u \) discrete banded spectra. Our findings support the notion that the overall growth of the RT mixing is strongly dependent on initial conditions. Variation in spectral shapes and bandwidths are found to have a complex effect of the late time development of the RT mixing layer and raises the question of whether we can design RT transition and turbulence based on our choice of initial conditions. In addition, our results provide a useful database for the initialization and development of closures describing RT transition and turbulence.

10:43AM HE.00002 Exploring Rayleigh-Taylor Initial Conditions Using a New LES Moment Closure, DANIEL ISRAEL, Los Alamos National Laboratory — The effects of initial conditions on the initial transient and long-time development of self-similarity in a Rayleigh-Taylor mixing layer are explored using a new, moment-closure based, large-eddy simulation (LES). The model is derived using moment closure techniques analogous to those developed for Reynolds-averaged Navier Stokes (RANS) of variable density turbulence. Instead of using a scaling equation to obtain a RANS length scale, an LES filter width is chosen just small enough to resolve the large turbulence structures. This model can reproduce the evolution of the large turbulent structures, with good results in both two and three-dimensional simulations. In this presentation, results using the new LES model are compared to DNS predictions as well as theoretical scaling laws. Two regimes are examined: first, the initial transient and approach to self-similarity, or square plexiglass tank, which encloses the liquids, is affixed to a test sled on the rail system. The test sled is then pulled downward, using a system of weights and pulleys, at a rate greater than that of gravity. This produces the upward body force that drives the instability. The resulting fluid flows are visualized with backlit imaging using an LED backlight in conjunction with a monochrome high-speed video camera, both of which are affixed to the test sled. Initial perturbations are either unforced and allowed to progress from thermal background noise or forced by vertically oscillating the liquid combination to produce Faraday internal waves. The results from both of these experimental setups are compared to numerical simulations performed using the CFD code Miranda. Good agreement between the experiment and the simulation is obtained.

10:56AM HE.00003 Large Atwood number, miscible-liquid experiments and simulations on the Rayleigh-Taylor instability, MICHAEL ROBERTS, JEFFREY JACOBS, University of Arizona, WILLIAM CABOT, Lawrence Livermore National Laboratory — Experiments and numerical simulations are presented in which an incompressible system of two miscible liquids is accelerated to produce the Rayleigh-Taylor instability. In the experiment, the initially stable, stratified liquid combination is accelerated on a vertical rail system. Either a rectangular or square plexiglass tank, which encloses the liquids, is affixed to a test sled on the rail system. The test sled is then pulled downward, using a system of weights and pulleys, at a rate greater than that of gravity. This produces the upward body force that drives the instability. The resulting fluid flows are visualized with backlit imaging using an LED backlight in conjunction with a monochrome high-speed video camera, both of which are affixed to the test sled. Initial perturbations are either unforced and allowed to progress from thermal background noise or forced by vertically oscillating the liquid combination to produce Faraday internal waves. The results from both of these experimental setups are compared to numerical simulations performed using the CFD code Miranda. Good agreement between the experiment and the simulation is obtained.