



42-381 50 SHEETS 5 SQUARE  
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## HIERARCHY OF 3-D CONFIGURATION CFD METHODS

Linear "Singularity" Methods - use surface grids      Nonlinear "Field" Methods - use space grids

|                         | LIFTING-LINE METHOD   | VORTEX-LATTICE METHOD                          | PANEL METHOD  | FULL-POTENTIAL SOLVER  | EULER SOLVER  | NAVIER-STOKES SOLVER   |
|-------------------------|---|--|---|--|---|--|
| Fundamental Equations   | $\Gamma = \frac{Vc}{2} m \left[ \alpha - \left( \frac{d\Gamma}{dy} \frac{dy}{dy} \right) \right]$ | $w_z = \sum a_{ij} \Gamma_j = V \frac{dy}{dx}$ | $\phi_i = \mu_i = \sum a_{ij} \mu_j + \sum b_{ij} V_\infty$ | $\nabla \cdot (\rho \nabla \Phi) = 0$<br>$\nabla \times \vec{u} = 0 \quad \vec{u} = \nabla \Phi$ | $\nabla \cdot (\rho \vec{u}) = 0$<br>$\frac{D\vec{u}}{Dt} = -\frac{\nabla p}{\rho}$ | $\nabla \cdot (\rho \vec{u}) = 0$<br>$\frac{D\vec{u}}{Dt} = -\frac{\nabla p}{\rho} + (\nu + \nu_t) \nabla^2 \vec{u}$ |
| Properly models...      | Trailing vorticity, "high" R only   | + Sweep, low R effects                         | + Thickness effects, fuselages, nacelles...                 | + Shock waves (ignores vorticity)  | + Shock waves, vorticity, entropy   | + Viscous effects (turb. model approximate)  |
| Compressibility?        | Approx. via P-G   | Approx. via P-G                                | Approx. via P-G   | Yes, weak shocks only (ignores shock vorticity)  | "Exact"   | "Exact"  |
| Viscous Effects?        | Via 2-D airfoil data  | Difficult. Not done in practice.               | Via BL solvers and S* correction.                           | Via BL solvers and S* correction   | Via BL solvers and S* correction  | Already present  |
| C <sub>L</sub>          | Yes   | Yes  | Yes   | Yes  | Yes   | Yes  |
| dC <sub>L</sub> /dα     | Yes, needs 2-D data   | Yes (no thickness effects)                     | Yes   | Yes  | Yes   | Yes  |
| C <sub>D induced</sub>  | Yes   | Yes (Trefftz Plane)                            | Yes (Trefftz Plane)   | Yes (Trefftz Plane)  | Lousy (can't use Trefftz)   | Lousy (can't use Trefftz)  |
| C <sub>D wave</sub>     | Yes, needs 2-D data   | No   | No  | Yes, weak shocks only  | Yes   | Yes  |
| C <sub>M</sub>          | from 2-D data   | Yes  | Yes   | Yes  | Yes   | Yes  |
| Surface C <sub>p</sub>  | from 2-D data   | Maybe (Inaccurate at Leading Edge)             | Yes   | Yes  | Yes   | Yes  |
| CPU time on Workstation | < 1 sec.  | 5 sec. - 1 min.                                | 10 min. - 1 hr.   | 30 min. - 6 hrs.   | 10 hrs. - 5 days  | Weeks, months, ...   |