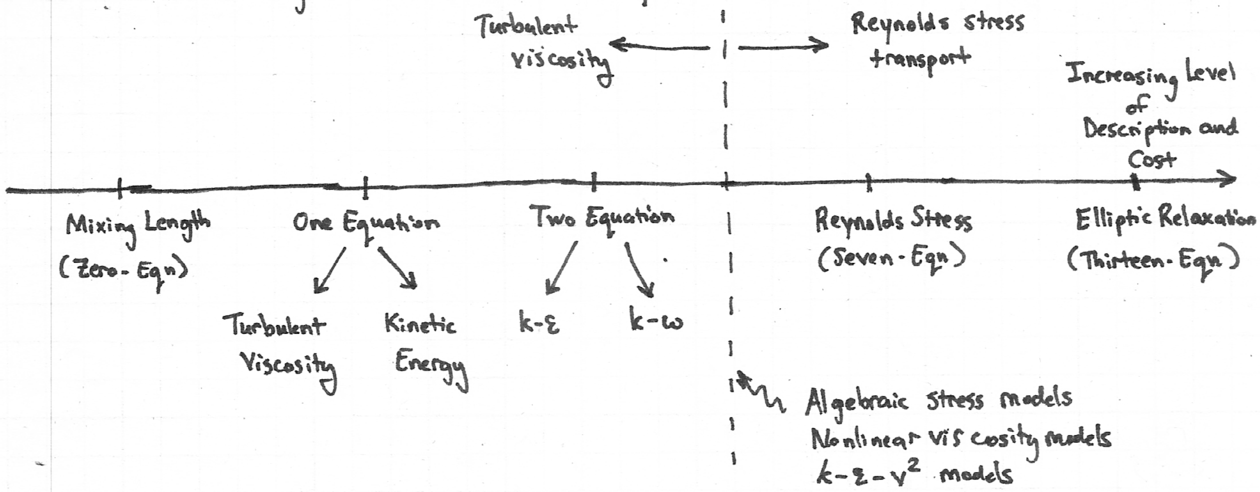
Discussion and Assessment of RANS Models:

The below diagram illustrates the hierarchy of RANS models introduced.



The various specifications, unknowns, and quantities modeled are also listed in the table below.

Model	Specified Fields	Unknowns	Primary Quantities Modeled
Mixing Length	l_m	–	$\langle u_i' u_j' \rangle$
Spalart-Allmaras	–	ν_T	$\langle u_i' u_j' \rangle, \frac{\bar{D}\nu_T}{\bar{D}t}$
Turbulent KE	l_m	k	$\langle u_i' u_j' \rangle, \varepsilon$
k-ε	–	k, ε	$\langle u_i' u_j' \rangle, \frac{\bar{D}\varepsilon}{\bar{D}t}$
k-ω	–	k, ω	$\langle u_i' u_j' \rangle, \frac{\bar{D}\omega}{\bar{D}t}$
Nonlinear Viscosity	–	k, ε	$b_{ij}, \frac{\bar{D}\varepsilon}{\bar{D}t}$
Algebraic Stress	–	k, ε	$b_{ij}, \frac{\bar{D}\varepsilon}{\bar{D}t}$
Reynolds Stress	–	$\langle u_i' u_j' \rangle, \varepsilon$	$R_{ij}, \frac{\bar{D}\varepsilon}{\bar{D}t}$
Elliptic Relaxation	–	$\langle u_i' u_j' \rangle, \varepsilon, f_{ij}$	$\bar{R}_{ij}, \frac{\bar{D}\varepsilon}{\bar{D}t}$
v^2-f with Elliptic Relaxation	–	k, ε, v^2, f	$\langle u_i' u_j' \rangle, \frac{\bar{D}\varepsilon}{\bar{D}t}$

As with any turbulence model, a RANS model should be evaluated and selected according to a particular set of criteria, including:

(i) Level of Description
(ii) Completeness
(iii) Cost and Ease of Use
(iv) Applicability
(v) Accuracy

The diagram and table included above address points (i) - (iv) above. In what follows, we discuss the accuracy of various RANS approaches.

- The k-ε model performs well for two-dimensional thin shear flows with small streamline curvature and mean pressure gradient.
- The k-ω model performs well for boundary layer flows with strong pressure gradients.
- For flows with characteristics far from simple shear (e.g., impingement), the k-ε model fails dramatically.
- Nonlinear viscosity models allow for the calculation of secondary flows and flows with strong rotation.
- Reynolds stress models can handle flows with strong swirl, significant streamline curvature, secondary features, and rapid variations.
- Reynolds stress models are very sensitive to the modeling of the pressure-strain.
- Elliptic relaxation models can handle impingement and separation.
- The Spalart-Allmaras model performs well for exterior aerodynamic flows.
- The model for $\bar{D}\varepsilon/\bar{D}t$ is frequently blamed for the poor performance of a model. Improvements may be made by tuning $C_{\varepsilon 1}$ and $C_{\varepsilon 2}$.

In Section 7.4.2 of "Statistical Theory and Modeling for Turbulent Flows" by Durbin and Reif, a comprehensive assessment of RANS models is conducted for a suite of examples: the plane diffuser, the backward facing step, vortex shedding, jet impingement, the square duct, and rotating shear flow. The plots for this section have been included on D2L for reference.