$E((\theta - E(\theta))\cdot(\theta - E(\theta))^T)$

$= E(\theta\theta^T - \theta\theta^{*T} - \theta^*\theta^T + \theta^*\theta^{*T})$

$\cancel{= E(\quad X^{-1} X^{-T}}$

$= E(\cancel{(X^TX)^{-1}X^Ty \cdot y^TX \cdot (X^TX)^{-1}}^T)$

$\theta = \theta^* + X^{-1}\epsilon$

$\theta^T = \theta^{*T} + \epsilon^T(X^{-1})^T$

$Var(X) = E[(X - \mu(X))^2]$

$\cancel{\theta^*\theta^{*T}} + \cancel{\theta^*\epsilon^T(X^{-1})^T} + \cancel{X^{-1}\epsilon\theta^{*T}} + X^{-1}\epsilon\epsilon^T(X^{-1})^T$

$- \cancel{\theta^*\theta^{*T}} - \cancel{X^{-1}\epsilon\theta^{*T}}$

$- \cancel{\theta^*\theta^{*T}} - \cancel{\theta^*\epsilon^T(X^{-1})^T}$

$+ \cancel{\theta^*\theta^{*T}}$

$E(\epsilon) = 0$

$E(\epsilon^2)$

$E(\epsilon\epsilon^T)$

$\Rightarrow E(X^{-1}\epsilon\epsilon^T(X^{-1})^T)$

$= (X^TX)^{-1} E(\epsilon\epsilon^T) = (X^TX)^{-1}\sigma^2$ #