B. Burchett 5 min. update

Three active M.S. students

- Matt Winter – Hands on experiments for ME506; expects to defend this quarter.
- Austin Nash – Optimal control of indirect fire symmetric projectiles; to complete in May
- Peter Olejnik – Guidance and control of RHIT BeagleBone Quadcopter; just getting started.

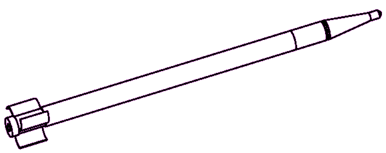
Sources of Inspiration

- Reviews for *Aerospace Science and Technology* (14 in past calendar year)
- Catapult projects

Most Recent publication

Burchett, B. T., and Nash, A. L., "Euler-Lagrange Optimal Control for Symmetric Projectiles", *Proceedings of the AIAA Science and Technology Forum and Exposition 2015,* Kissimee, FL, 5-9 January, 2015.

$$\left\{ \begin{array}{c} \dot{\xi} \\ \dot{\eta} \\ \ddot{w} \end{array} \right\} = \left[\begin{array}{ccc} \mathbf{\Phi} & \mathbf{\Gamma} & \mathbf{0} \\ \mathbf{0} & \mathbf{\Xi} & \mathbf{\Lambda} \\ \mathbf{0} & \mathbf{0} & 0 \end{array} \right] \left\{ \begin{array}{c} \xi \\ \eta \\ \dot{w} \end{array} \right\} + \left[\begin{array}{c} \mathbf{0} \\ \mathbf{b} \\ \mathbf{0} \end{array} \right] \left\{ \begin{array}{c} C_{Z0} \\ C_{Y0} \end{array} \right\}$$



$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$$

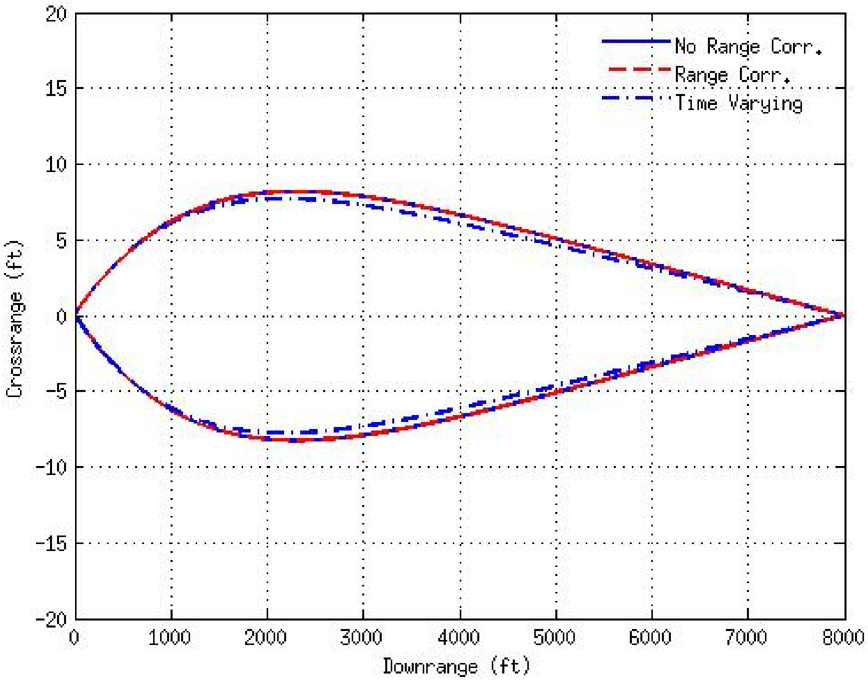
$$\xi = \left[\begin{array}{cccc} y & z & \theta & \psi \end{array} \right]^T, \ \eta = \left[\begin{array}{cccc} v & w & q & r \end{array} \right]^T, \ \mathbf{\Lambda} = \left[\begin{array}{cccc} 0 & 1 & 0 & 0 \end{array} \right]^T, \ \mathbf{\Gamma} = \frac{D}{V}\mathbf{I}$$

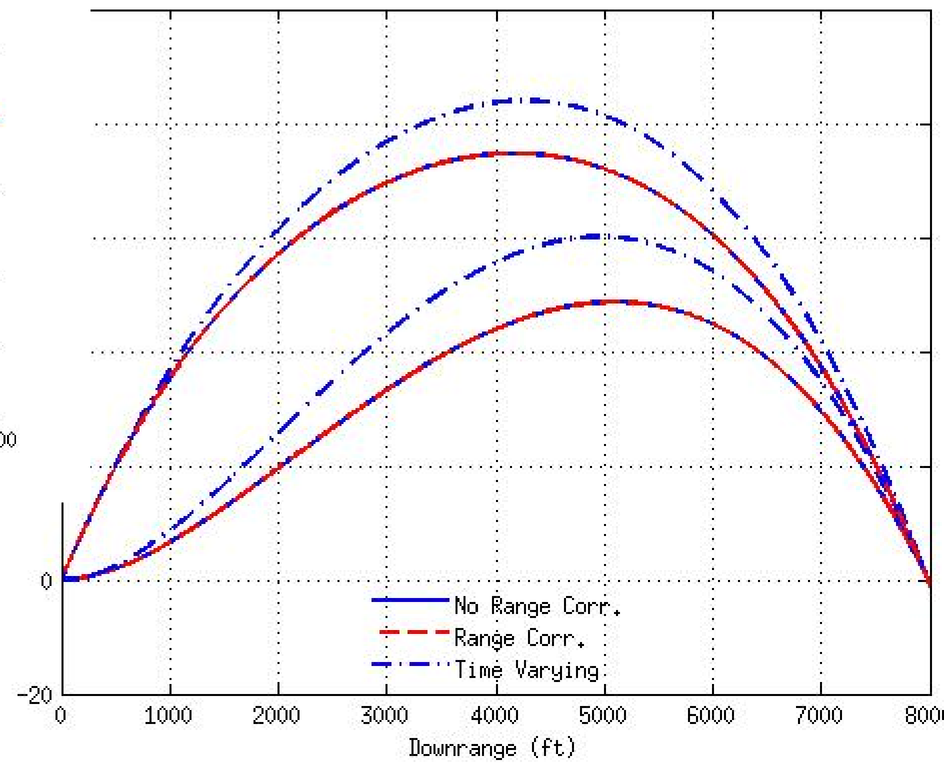
$$\mathbf{\Phi} = \left[\begin{array}{cccc} 0 & 0 & 0 & D \\ 0 & 0 & -D & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{array} \right], \ \mathbf{\Xi} = \left[\begin{array}{cccc} -\mathbf{\Xi}_1 & 0 & 0 & -D \\ 0 & -\mathbf{\Xi}_1 & D & 0 \\ \mathbf{\Xi}_2 & \mathbf{\Xi}_3 & \mathbf{\Xi}_4 & -\mathbf{\Xi}_5 \\ -\mathbf{\Xi}_3 & \mathbf{\Xi}_2 & \mathbf{\Xi}_5 & \mathbf{\Xi}_4 \end{array} \right]$$

LTI Finite Horizon Optimal Control, Cont'd

- System matrices are time varying such that $\mathbf{A}(s) = \mathbf{A}(p(s), V(s))$, etc.:
- We present three solutions
  - System matrices treated as constant in the Hamiltonian solution.
    - State / co-state, control found by numerical matrix exponential of Hamiltonian times range to go.
  - Same as previous with 'vacuum trajectory' range correction.
  - System matrices vary with time, and Riccati solution solved recursively backward in time.

- Comparison, typical Controlled trajectories from the three control strategies:





Work in Progress (with A. Nash)

- Allow for high launch angles ($\theta(s)$ assumed small in previous work).
- System matrices become time varying such that **A**(s) = **A**($\theta(s)$,p(s),V(s)), etc.:
- **N**(s) is the solution to the time varying Riccati eqn:

$$\dot{\mathbf{N}}(s) = -\mathbf{N}(s)\mathbf{A}(s) - \mathbf{A}^T(s)\mathbf{N}(s) + \mathbf{N}(s)\mathbf{B}(s)\mathbf{R}^{-1}\mathbf{B}^T(s)\mathbf{N}(s) - \mathbf{Q}$$

- Riccati eqn. Is solved recursively backward in time
- Control is based on the Riccati solution at the current time

$$\mathbf{u}(s) = -\mathbf{R}^{-1}\mathbf{B}^T(s)\mathbf{N}(s)\mathbf{x}(s)$$