Aircraft Energy Management: A Best Practice for Integrating Safety and Efficiency

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NTAS 2022

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Overview

- My background
- Airplanes and energy
- Mitigating the risks of energy mismanagement
- Managing two sides of the same energy coin
- Energy management safety and efficiency goals

- Energy management training plan
- Training building blocks
- Integrating energy safety and efficiency

- Benefits from an integrative approach
- Energy management in the new era of aviation

My Background

Available online at http://docs.lib.purdue.edu/jate

JATE

Journal of Aviation Technology and Engineering 3:1 (2013) 24–36

Flight Energy Management Training: Promoting Safety and Efficiency

Juan R. Merkt

Davis Aviation Center, Jacksonville University

AS 316

SAFETY PRINCIPLES OF AIRCRAFT ENERGY MANAGEMENT

- *Mishandling the airplane's energy state is a significant factor in loss of control, controlled flight into terrain, and approach-and-landing accidents.*

- *Recognizing the dangers of energy mismanagement, the FAA Airman Certification Standards (ACS) now require that pilot candidates demonstrate understanding of energy management concepts.*
- *This hands-on course will take you above and beyond the new FAA requirements.*
- *Through lectures and simulated flight testing you will learn to view, monitor and control the airplane as an energy system, enhancing your knowledge and skills to fly safely.*

Questions? Contact Dr. Juan Merkt (merktj@erau.edu)

Aircraft Energy Management:

Preventing Accidents & Conserving Fuel

April 5th | 2:30-3:00 pm

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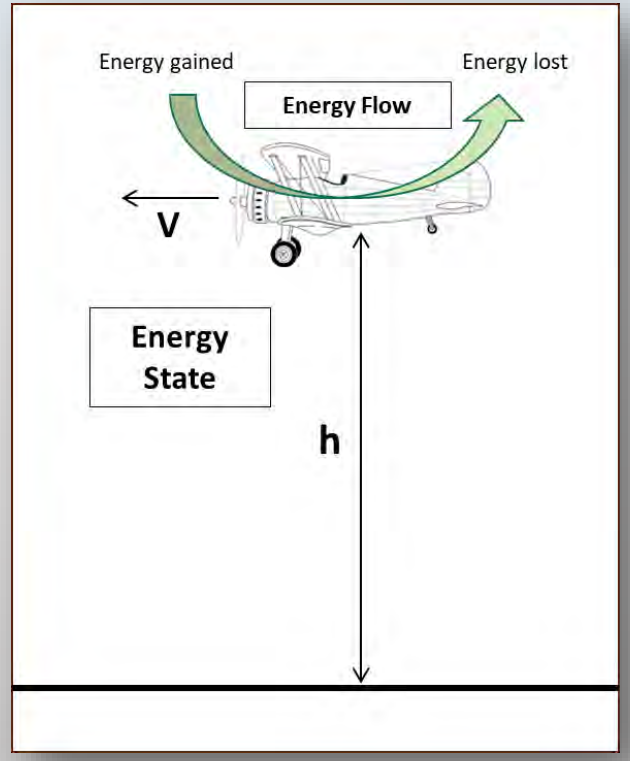
Juan Merkt, PhD

Associate Professor of Aeronautical Science

Airplane: Quintessential Energy System



Mitigating the Risks of Energy Mismanagement

- **Accidents**

SAVING LIVES

Unsafe altitude and speed
CONTROL

- **Wasted fuel**

PROTECTING ENVIRONMENT

Inefficient fuel
PERFORMANCE

Managing Two Sides of The Same Energy Coin

Flight control

Controlling ***altitude*** and ***airspeed***

Flight performance

Managing ***fuel***

Energy Management Safety Goal

Manage mechanical energy to achieve and maintain vertical flightpath-speed targets, while mitigating hazards caused by unstable deviations or rapidly degrading energy states

FLIGHT CONTROL

Energy Management Efficiency Goal

Manage the energy source using principles of energy conservation aimed at reducing the amount of fuel consumed per unit distance or time

ENGINE & AERODYNAMIC PERFORMANCE

Energy Management Training Plan

- Use an "**outside-the-box**" instructional approach so that **safety** and **efficiency** principles can be:

- Taught to **any pilot**

- Applied to **everyday flying**

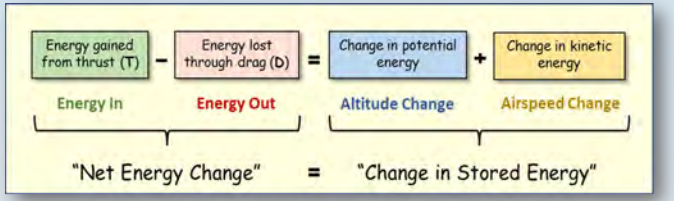
Training Building Blocks

- Energy principles across disciplines

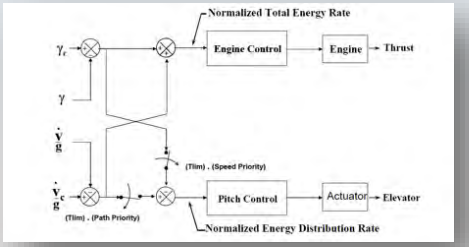
- Pilot-oriented approach

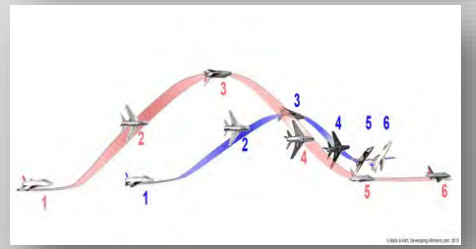
Combining Principles from Four Disciplines

- **Physics**: Laws of Motion & Conservation of Energy
- **Engineering**: Total Energy Control System (**TECS**)
- **Military Science**: Energy Maneuverability (**E-M**)
- **Biology**: Bioenergetics of Locomotion (**BEL**)



Energy Balance Equation





PROBLEM…

$$\frac{\theta}{\delta_{vci}} = \frac{K_{vci}}{S}\frac{g}{V_G}\frac{(\tau_{\theta_2}S+1)\omega_{SP}}{S^2+2\zeta_{SP}\omega_{SP}S+\omega_{SP}^2} \quad (10)$$

Here δ_{vci} is the vertical control inceptor deflection, K_{vci} is the vertical control inceptor gain. Since

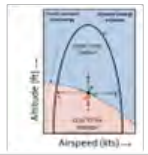
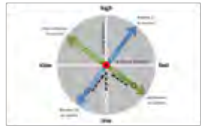
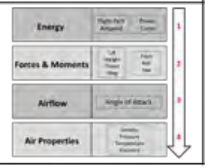
$$\frac{\gamma}{\delta_{vci}} = \frac{\theta}{\delta_{vci}}\frac{\gamma}{\theta} = \frac{\theta}{\delta_{vci}}\frac{1}{(\tau_{\theta_2}S+1)} \quad (11)$$

it follows in order to achieve (10) , the final $[\gamma/\delta_{vci}]$ TF must be

$$\frac{\gamma}{\delta_{vci}} = \frac{K_{vci}}{S}\frac{g}{V_G}\frac{\omega^2}{S^2+2\zeta\omega S+\omega^2} \quad (12)$$

Here V_G is the groundspeed. This $[\gamma/\delta_{vci}]$ TF can be realized by using feed the forward gains K_{FFP} and K_{FFI} to create two zeros designed to cancel two poles of the $[\gamma/\gamma_c]_{auto}$ TF, equation (3). One of these numerator zeros is used to cancel the τ_{θ_2} associated pole and the second zero is used to cancel the first order pole that is part of the third order part of the denominator of the $[\gamma/\gamma_c]_{auto}$ TF. Thus the "ideal" SP frequency and damping coefficient in (10) can be specified. For example: selecting $\omega = \omega_{SP} = 2$ rad/sec and $\zeta = \zeta_{SP} = 1$ results in:

$$\frac{\gamma}{\delta_{vci}} = \frac{K_{vci}}{S}\frac{g}{V_G}\frac{(K_{FFP}S^2+K_{FFI}S+1)}{(.25S^2+1S+1)(\tau_D S+1)(\tau_{\theta_2}S+1)} \quad (13)$$

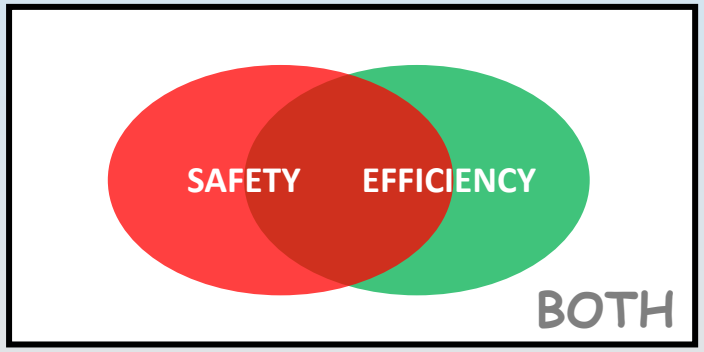
Money analogy	
Map analogy	
Mountain analogy	
Reservoir analogy	
Energy-control rule map	
Energy error diagram	
Top-down approach	

Pilot-Oriented Approach

- Analogies
- Top-down
- Hands-on

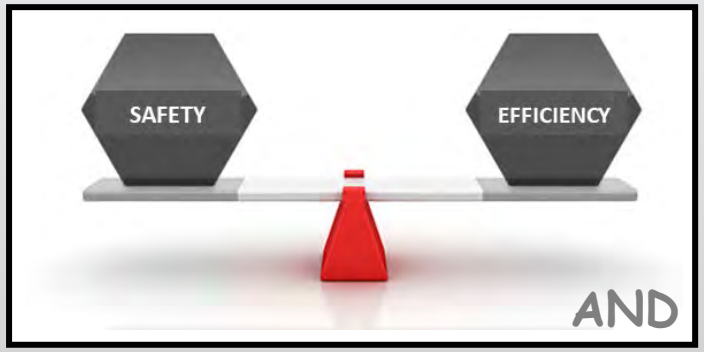
Integrating Energy Safety and Efficiency

Intersection



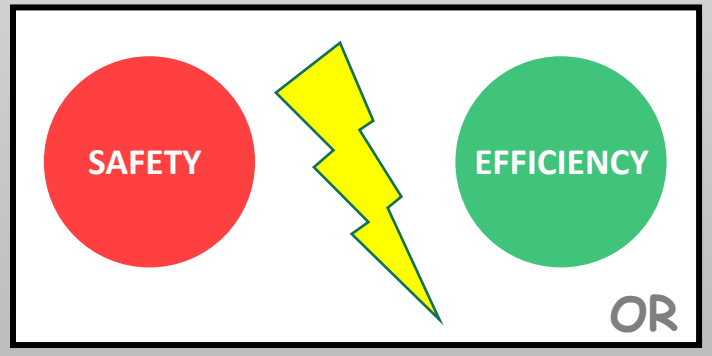
- Dealing with low inflight fuel
- Correcting and preventing path-speed deviations

Balance



- Selecting path-speed targets
- Minimizing turns

Conflict



- Clearing obstacles
- Dealing with unsafe weather

Benefits from an Integrative Approach

- **Energy management training** can assist pilots develop energy safety and conservation skills to mitigate inflight “energy crises”, thus preventing accidents and unnecessary waste of fuel

- Efficient pilots understand the importance of **conserving resources** and **protecting the environment**

- Obviously, pilots **must never compromise safety for efficiency**

- An **integrated** approach enhances the ability to assess **intersections**, **balances**, and **conflicts** between **safety** and **efficiency** in any phase of flight, thus helping pilots make the appropriate decision in critical situations

Energy Management in the New Era of Aviation

- Energy and power source limitations will make integrating **safety** *and* **efficiency** even more critical in the operation of electric vertical-takeoff-and-landing (**eVTOL**) aircraft



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