AE 6450 - Rocket Propulsion

Catalog Data: AE 6450: Rocket Propulsion. Credit 3 (3-0-3). (taught in alternate years).
Analysis and design of a broad range of space vehicle propulsion options including liquid, solid, hybrid, combined-cycle, and advanced propulsion systems.

Textbook: Brown, Charles. *Spacecraft Propulsion*. AIAA. 1995.

References: Huzel and Huang. *Modern Engineering for Design of Liquid-Propellant Rocket Engines*. AIAA. 1992.

Hill and Peterson. *Mechanics and Thermodynmaics of Propulsion*. Addison-Wesley. 1992.

Heiser and Pratt. *Hypersonic Airbreathing Propulsion*. AIAA. 1994.

Escher, W. J. D. *The Synerjet Engine: Airbreathing/Rocket Combined-Cycle Propulsion for Tomorrow's Space Transports*. SAE International. 1997.

Course notes and handouts.

Coordinator: Dr. John R. Olds, assistant professor of A.E.

Goals: The objectives of this course are to introduce the student to the basics of propulsion system analysis and performance prediction for a wide range of space vehicle propulsion options. Emphasis will be placed on propulsion system selection and application of propulsion analysis to vehicle-level design. Specifically the goals are to,

a) Teach the student basic performance prediction methods for liquid and solid rocket engines.

b) Familiarize the student with a variety of space vehicle propulsion options and components and the advantages and utility of each.

c) Expose the student to the terms and methods used in the rocket propulsion field.

Prerequisites by Topic:

1. AE 3450 Thermodynamics & Compressible Flow or equivalent.

2. AE 4451 Jet & Rocket Propulsion or equivalent.

3. Simple computer coding skills (any language including Matlab).

Topics:

1. Introduction (1 hr.)

- course overview, syllabus, grading, etc.

2. Rocket Engine Basics (6 hrs.)

- calculation of rocket thrust via momentum equation
- definition of I_{sp}, thrust coefficient (C_f), c*, expansion ratio
- ideal expansion, over/under expansion (**computer project 1**)
- typical nozzle designs (cone, bell, plug)
- sources of losses (frozen vs. equilibrium flow, divergence, etc.)

3. Monopropellant Thrusters (4 hrs.)

- overview of small pressure-fed thrusters
- cold gas (N_2) thrusters (**computer project 2**)
- hydrazine/catalyst thrusters
- resisto-jet thrusters
- historical examples and state-of-the-art

4. Bipropellant Liquid Rocket Engines (10 hrs.)

- thermodynamics of liquid rocket engines
- common propellant combinations (storable, cryogenic c*ís, handling -- trades)
- engine cycles (gas generator, staged combustion, expander, etc. -- trades)
- turbomachinery design (pumps, turbines, impellers, etc.) (**computer project 3**)
- other engine components (ignitors, GG, cooling loops, etc.)
- historical examples and state-of-the-art

5. Solid Rocket Motors (8 hrs.)

- propellant/fuel options (characteristics -- trades)
- effect of grain cross section shape (thrust shaping)
- propellant burning law (regression rate vs. pressure) (**computer project 4**)
- historical examples and state-of-the-art

6. Hybrid Rocket Propulsion (4 hrs.)

- common propellant combinations and configuration
- system performance characteristics (advantages -- trades)
- historical examples and state-of-the-art

7. Combined-Cycle Propulsion (6 hrs.)

- thermodynamics of high speed airbreathing propulsion
- conventional ramjet and scramjet propulsion
- turbine-based combined-cycle propulsion (TBCC, turboramjet)
- rocket-based combined-cycle propusion (RBCC) **(computer project 5)**

8. Advanced Propulsion (4 hrs.)

- electric/ion propulsion (electric or nuclear)
- nuclear thermal rockets (NTR)
- pulsed detonation engines (PDE)
- Daedalus, solar sails, etc.

Tests (2 hrs.)

Total = 45 hours

Computer Usage:

Students will be required to access a personal computer or workstation to complete computing project assignments. Suitable computers can be found in the school and Instituteís computing laboratories and in research laboratories. In addition, in-class instruction will rely on classroom computers and projection equipment.

Programming Projects:

There will be five assigned computer projects. No more than a beginner level of programming skill will be required to complete any project. In some cases, the assignments can be completed on a simple spreadsheet.

1. Use isentropic flow equations to determine the internal pressure along the inside of a given nozzle vs. nozzle length. Create plots to show that thrust is maximized for an ideally expanded nozzle.

2. Using simple rocket engine performance equations, determine the effect of chamber (inlet) pressure on the thrust and I_{sp} of a nitrogen cold gas thruster. Create a graph of I_{sp}, thrust, and C_f vs. pressure.

3. Given pump and turbine efficiencies, create a simple cycle balance model for a given liquid engine. Create plots of thrust, I_{sp}, turbine work, NPSH, and pump rpm vs. throttle setting.

4. For a given tubular solid rocket motor configuration, write a program to calculate internal pressure and regression rate vs. time. Create plots of overall motor thrust and I_{sp} vs. time.

5. For a given ascent flight path of an RBCC-powered launch vehicle, calculate the thrust coefficient and the I_{sp} produced by the combined-cyle engine. Plot the results vs. flight Mach number.