Israel Association for Automatic Control
5 Day Course 10-14 March 2013
Hotel Daniel, Herzliya

Tactical and Strategic Missile Guidance

Fee:
5000 NIS/participant for participants 1-20 from the same company or organization.
4000 NIS/participant for participant 21 and up from the same company or organization.
Course material, full lunches, and coffee breaks are included.
Registrations received after 28 February 2013 will be charged 10% more.

Registration form:
See separate doc and pdf files on the IAAC Web Site.

Summary:
This course will help you understand and appreciate the unique challenges of both tactical and strategic missile guidance. So everyone can clearly understand the principles of missile guidance, concepts are derived mathematically, explained from a heuristic perspective, and illustrated with numerical examples and computer animations. Course mathematics and examples are nonintimidating. Computer source code is included in MATLAB so interested participants and duplicate the examples presented and explore issues beyond the scope of the course.

Instructor:
Paul Zarchan has more than 40 years of experience designing, analyzing, and evaluating missile guidance systems. He has worked as Principal Engineer for Raytheon Missile Systems Division, has served as Senior Research Engineer with the Israel Ministry of Defense, was a Principal Member of the Technical Staff for C.S. Draper Laboratory and was also a Member of the Technical Staff at MIT Lincoln Laboratory where he worked on problems related to missile defense. He is the author of *Tactical and Strategic Missile Guidance, Sixth Edition* and the co-author of *Fundamentals of Kalman Filtering: A Practical Approach, Third Edition*.

Who Should Attend:
This course will benefit managers, engineers, and programmers at all levels who work with or need to learn about interceptor guidance system technology. The heuristic arguments and numerous examples will give managers an appreciation for guidance so that they can interact effectively with specialists. Engineers and programmers will find the detailed course material and many MATLAB source code listings invaluable for both learning and reference. Attendees will receive a complete electronic set of course notes.

Key Topics:

- Interceptor guidance system technology.
- How subsystems influence total system performance.
- Useful design relationships for rapid guidance system sizing.
- Using adjoints to analyze missile guidance systems.
- Innovative methods for improving system performance.
- Common design pitfalls and their engineering fixes.
- Why ballistic missiles and boosters are challenging targets.
- Optimal guidance laws for improving performance against weaving targets.

C o u r s e O u t l i n e:

Sunday March 10 (Morning)

1. **Numerical Techniques**. Review of all numerical techniques used in the course so that all material will be easy to understand. Simulation examples, with source code.
2. **Fundamentals of Tactical Missile Guidance**. How proportional navigation works and why it is an effective guidance law. Illustration of important closed-form solutions and their utility. Development of simplified engagement simulation and computer animation illustrating effectiveness of proportional navigation.
3. **Method of Adjoints and the Homing Loop**. Show how to construct an adjoint and how method of adjoints are used to analyze missile guidance systems and develop system error budgets
4. **Noise Analysis**. Illustrating computerized numerical techniques for simulating noise. Using the Monte Carlo technique for getting statistical performance projections by making many computer runs. How to use stochastic adjoints to get statistical performance projections in one computer run

Sunday March 10 (Afternoon)

5. **Proportional Navigation and Miss Distance**. Developing useful design relationships for rapid guidance system sizing. Showing how system dynamics, acceleration saturation and radome effects limit system performance.
6. **Covariance Analysis.** An alternative method for analyzing the missile homing loop and how it compares to the adjoint method of analysis.
7. **Digital Noise Filters in the Homing Loop**. Properties of simple digital noise filters (i.e., alpha-beta and alpha-beta gamma filters) and how they can work in a missile guidance system. How target maneuver can be estimated with range and line-of-sight information.

8. **Advanced Guidance Laws**. Deriving optimal guidance laws without optimal control theory. How missile acceleration requirements can be relaxed with augmented proportional navigation. How to compensate for system dynamics with optimal guidance.
9. **Kalman Filters and the Homing Loop**. Introducing the Kalman filter and showing how it is related to alpha-beta and alpha-beta gamma filters. Combining Kalman filters with optimal guidance. Showing how radome effects and time to go errors limit system performance.

Monday March 11 (Morning)

10. **Endoatmospheric Ballistic Targets**. The importance of speed, re-entry angle, and ballistic coefficient in determining the deceleration of a ballistic target. Why decelerating targets are difficult to hit and guidance laws for dealing with them.
11. **Extended Kalman Filtering.** Performance comparisons of linear, linearized, and extended Kalman filters for estimating the ballistic coefficient of a decelerating ballistic target.
12. **Other Forms of Tactical Guidance.** How beam rider and command to line-of-sight guidance work without a seeker.
13. **Tactical Zones.** Introduction to the rocket equation and how drag limits system performance.

Monday March 11 (Afternoon)

14. **Strategic Considerations.** Why the flat earth, constant gravity approximation is not appropriate for long range missiles. How Newton's law of universal gravitation can be used and it's impact on performance. Useful closed-form solutions for the required velocity and time of flight for strategic missiles.
15. **Boosters**. Using the rocket equation for booster sizing and an introduction to gravity turn steering for boosters
16. **Lambert Guidance**. Why the solution to Lambert's problem is fundamental to steering a booster so that it will arrive at a desired location at a certain time. How to guide liquid fueled boosters with Lambert guidance and solid fueled boosters with GEM guidance.
17. **Strategic Intercepts.** How classical guidance concepts can be used to explain stragteic interceptor perofmance against balliastic and boosting targets.
18. **Miscellaneous Topics.** Pulsed and burnout guidance for intercepting targets.

Tuesday March 12 (Morning)

19. **Radome Slope Estimation**. What happens if a guidance and control engineer has lunch with a signal processing engineer. Using dither signals and bandpass filtering to extract radome slope estimates within a missile guidance system

20. **Multiple Target Problem.** How two targets falling within seeker field of view can lead to enormous miss distances. Rules of thumb will be developed relating the necessary ratio of time left after seeker resolution to the guidance system time constant, the missile acceleration limit and the apparent shift in target location.
21. **Intercept Point Prediction Error.** How tracking sensor properties influence prediction error and interceptor divert requirements.
22. **Filtering Options For Boost Phase Intercept.** A comparison of two filtering approaches for the interception of a target during its boost phase

Tuesday March 12 (Afternoon)

23. **Weaving Targets and Proportional Navigation.** How proportional navigation system performance is related to guidance system time constant and target weave frequency. How very large miss distances due to weaving targets can be induced unless special actions are taken.
24. **Optimal Guidance Against Weaving Targets.** Improving performance of missile guidance system to weaving targets using optimal guidance techniques
25. **Filtering and Guidance For Weaving Targets.** Comparison of linear and nonlinear Kalman filtering techniques for improving performance
26. **Filter Bank Approach to Weaving Target Problem.** How a bank of linear Kalman filters (fixed MMAE technique) can be used to estimate target weave frequency and improve missile performance.

Wednesday March 13 (Morning)

27. **Airframe Linearization**. Deriving force and moment equations based on geometry of missile airframe. Linearizing to find aerodynamic transfer functions.
28. **Introduction to Flight Control System Design.** Designing simple flight control systems to improve damping of bare airframe.
29. **The Three-Loop Autopilot.** Designing a flight control system to satisfy both time domain and frequency domain constraints.
30. **Feedback Linearization.** A simple technique for dramatically improving flight control system performance.

Wednesday March 13 (Afternoon)

31. **Potential Problems With Modern Control and Autopilot Design.** Showing how disaster can result if the frequency domain method of analysis is neglected during preliminary autopilot design.
32. **Line-of-Sight Reconstruction for Faster Homing Guidance.** A comparison in both the time and frequency domain of different methods for providing the main guidance signal input.

33. **Theater Missile Defense.** Why ballistic targets are challenging- even if they don't maneuver. How guidance laws can be developed to shape the trajectory and influence the impact angle.
34. **Simple Trajectory Shaping Guidance Against Stationary Targets.** How biased proportional navigation can be used to shape the missile trajectory without the need for time to go information.

Thursday March 14 (Morning)

35. **A Filtering Approach For Getting Small Miss Distance.** Making use of a priori information for improved guidance system performance against ballistic targets.
36. **Smallest Possible Radar Homing Missile Miss Distances.** A simple technique for predicting the minimum achievable miss distance for a radar hoing missile.
37. **Flight Control Compensation.** A simple yet controversial method for canceling out flight control dynamics.
38. **Shaping Filters For Target Maneuver Representation.** When shaping filters can and cannot be used to reprsent stochastic target maneuvers in missile homing loop analysis.

Thursday March 14 (Afternoon)

39. **Other Methods For Guidance Law Development.** How optimal control techniques and other methods can be use to derive more advanced guidance laws.
40. **T4 (Try This Try That) Guidance.** Using a Predictor-Corrector approach for a certain class of problems
41. **Comparison of Boost Phase Prediction Methods.** A comparison of two boost phase prediction methods for intercepting a boosting target.
42. **Differential Game Guidance.** Showing how differential game guidance can be used to improve system performance under conditions in which there is a low missile to target acceleration advantage