

Hybrid Rocket Propulsion

April 29-30, 2010

Course Description

The “Hybrid Rocket Propulsion” short course is quintessential for all professionals specializing in chemical propulsion. The mechanisms associated with hybrid combustion and propulsion are diverse and affect our abilities to successfully advance and sustain the development of hybrid technology. It is our penultimate goal to promote the science of hybrid rocketry which is safe enough to be used in academia and the private sector. A historical demonstration of hybrid rocket capability is the 2004 X-prize winner SpaceShipOne. This course reviews the fundamentals of hybrid rocket propulsion with special emphasis on application-based design and system integration, propellant selection, flow field and regression rate modeling, solid fuel pyrolysis, scaling effects, transient behavior, and combustion instability. The course will provide *Fundamentals of Hybrid Rocket Combustion and Propulsion* to the course attendees.

Key Topics

Introduction, Classification, Challenges, and Advantages of Hybrids

Similarity and Scaling Effects in Hybrid Rocket Motors

Analytical Flowfield Modeling of Classical and Non-Classical Hybrid Rockets

Solid Fuel Pyrolysis Phenomena and Regression Rate: Mechanisms & Measurement Techniques

Combustion Instability and Transient Behavior in Hybrid Rocket Motors

Metals, Other Energetic Additives, and Special Binders Used in Solid Fuels for Hybrid Rocket Applications

Who Should Attend

This short-course is aimed at bringing together professionals with mutual interest in chemical combustion and propulsion, including modern techniques for measuring hybrid rocket performance, flame and flow field modeling, testing, and stability analysis. The course will provide a platform for learning and exchanging hybrid rocket experiences.

About the Instructors

Dr. Joe Majdalani

Dr. Majdalani is the H. H. Arnold Chair of Excellence in Advanced Propulsion, UTSI. He is known for his work on acoustic instability theory, wave propagation, and vortex engine technology. His research encompasses both mean and unsteady flowfield motions in solid, liquid and hybrid rocket applications. Dr. Majdalani is the Chair of Education within the AIAA Hybrid Rocket Technical Committee and a Fellow of ASME.

Dr. Arif Karabeyoglu

Dr. Karabeyoglu is the President and Chief Technical Officer of Space Propulsion Group, Inc. He is a Consulting Professor at Stanford University and has performed extensive research in the field of hybrid rocket combustion and propulsion ranging from theoretical studies to practical investigations and testing. He is the chairman of the AIAA Hybrid Technical Committee and a member of the Expert Advisory Board that oversees the development of the SpaceShipTwo propulsion system.

Course Outline

Introduction, Classification, and Advantages of Hybrids

Similarity and Scale Effects in Hybrid Rocket Motors

Analytical Models for Hybrid Rockets

Vortex Injection Hybrid Rockets

High Speed Flow Effects in Hybrid Rockets

Review of Solid-Fuel Regression Rate Behavior in Classical and Non-Classical Hybrid Rocket Motors

Solid Fuel Pyrolysis Phenomena and Regression Rate: Mechanisms & Measurement Techniques

Propellant Burn Rate Enthalpy Balance Model
Correlation of Heat Transfer to Skin Friction (Reynolds Analogy)
Longitudinally Averaged Skin Friction Mixture Ratio as a Function of Burn Rate
Effect of Port Length on Mixture Ratio

Metals, Other Energetic Additives, and Special Binders Used in Solid Fuels for Hybrid Rocket Applications

Combustion Instability and Transient Behavior in Hybrid Rocket Motors

Large-Scale Hybrid Motor Testing

N2O/HTPB Hybrid example
Introduction to Chemical Equilibrium Analysis with Applications Code (Cequel/CEA)
Exhaust Gas Properties as a Function of Mixture Ratio
Transient Response
Correlation of Burn Rate to Oxidizer Mass Velocity
Hybrid Rocket Throttling and its Applications

Office of Continuing Education

Reservations may be made by using the registration form. The registration fee of \$1195.00 includes all necessary supplies. Early reservations are recommended. Refund of registration fee can be made if cancellation notice is received ten working days prior to beginning of the course. Cancellation received less than 10 working days prior to the course will be assessed 20% of the registration fee. Registration within the **10 working days prior to the course** is also subject to the same cancellation policy. Substitution may be made at any time.

Please register by mail, fax, or telephone. A telephoned, mailed, or faxed reservation made **by an official training office** is considered a firm registration and cancellation policy will apply. A letter of acknowledgment will be mailed to the individual for whom the reservation is made, or to the training office, as we are instructed. Class size will be limited to ensure optimum interaction among participants. UTSI reserves the right to cancel the course. The liability of The University of Tennessee Space Institute is limited to the registration fee. UTSI will not be responsible for airline ticket cancellation fees or any other expenses incurred because of course cancellation. Enrollees will be notified and a full refund will be made. Late applicants will be considered on a space available basis.

The course is payable in advance and includes the cost of notes, classroom material, refreshments, and lunches. The fee does not include expenses for motel accommodations or other meals. Payment may be made by check, money order, or credit card. Be sure to include attendee name(s) and course title with check. Please make checks payable to The University of Tennessee Space Institute. **VISA, MasterCard, and Discover are accepted.**

UTSI reserves the right to substitute speakers in the event of unusual circumstances. UTSI does not sell the course notes. You must attend the course in order to receive the material. Training taken to maintain or improve professional knowledge and skills is usually tax-deductible. Consult your tax advisor. **Please notify us if you require special meals, wheelchair access, or other accommodations.** Casual dress is appropriate.

Enrollment may be made by individuals or companies. Any number of persons may enroll from a single organization so long as there are vacancies. We suggest that you phone us of your intention to enroll as soon as you initiate your organization procedure so we can hold a place for you and be better able to plan the arrangements. Phone the Continuing Education Director at (931) 393-7276 and then follow with the written application.

A place in the course will be reserved for industry personnel and government employees who require time to obtain authorization. Organizations may enroll for a given number of individuals, supplying the names at a later date, if necessary. For all such enrollments or reservations, the individual names should be received by the Institute as soon as possible to ensure a place in the course. For additional applications, use separate sheet giving all particulars required on the application form.