



INTERNATIONAL ASSOCIATION FOR THE ADVANCEMENT OF SPACE SAFETY

Professional Training Courses Catalog 2019



Professional Training Courses

SYSTEM SAFETY ENGINEERING

HUMAN SPACEFLIGHT SAFETY

LAUNCH AND RE-ENTRY SAFETY ANALYSIS

NUCLEAR SPACE SAFETY

EXPLOSIVES SAFETY

COMPOSITE OVERWRAPPED PRESSURE VESSELS

QUALITY ASSURANCE

RELIABILITY ENGINEERING

CONFIGURATION MANAGEMENT

SPACE DEBRIS

PROJECT RISK MANAGEMENT

SOFTWARE SYSTEM SAFETY ENGINEERING



For More Information and/or Registration:

<http://www.iaass.space-safety.org/events/courses/>



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Please visit
<http://iaass.space-safety.org/events/courses/>
for more information on course dates,
registration, and course fees



MESSAGE FROM THE DIRECTOR

Greetings and thank you for taking the time to examine the IAASS Professional Training Courses Catalog.

The IAASS has had a long history of Professional Technical Training with training being one of the principle objectives since its inception in 2004. The first course was held in conjunction with the 2nd IAASS Conference in Chicago, Illinois and since then we have conducted or sponsored courses all around the world.

This catalog contains courses that are offered either on a scheduled or on-demand basis.

On-demand courses are performed on request of an organization (company, university, agency, etc.) according to two possible schemes: *exclusive or sponsored*. In the case of an exclusive course, it is up to the organization to identify and register participants, and to provide the course venue.

No external participants are admitted. In the case of an on-demand sponsored course, the organization will buy a minimum number of seats in the course and allow the IAASS to bring additional external participants.

The instructors, drawn from the membership of the IAASS, are international leaders in their respective fields of knowledge.

The number of courses contained in the IAASS Training Catalog continues to grow. If there are subjects, related to Space Safety, that are not listed, please feel free to contact us via e-mail at iaass.academy@gmail.com.

Up-to-date information on current course offerings, registration, etc. can be found at <http://iaass.space-safety.org/events/courses/>

Thank-you for your interest and see you in class!



Megan K. Stroud

Megan K. Stroud

Director, Professional Training

“ **Tell me and I forget,
Teach me and I may remember,
Involve me and I learn.** ”

Benjamin Franklin



COMMERCIAL HUMAN SPACEFLIGHT SAFETY

Code 001



The Challenge

The course is designed to provide the participant with an understanding of established safety practices and processes that could be used for design, manufacturing and operations of commercial human sub-orbital and orbital vehicles.

Scope of the Course

For the past 15 years the debate on commercial human spaceflight safety has revolved around suborbital tourism vehicles and has been grounded on the (old-fashioned) concept that rules-based-design safety regulations should be developed, which necessarily require the accumulation of long operational experience. While the initial enthusiasm for suborbital spaceflight seems to be fading away following continuous delays, accidents and bankruptcies, the area of potential space commercial services is widening and gaining momentum. Within a decade, human spaceflight operation in Low Earth Orbit (LEO) may become predominantly commercial. There could be also important elements of private participation to government Moon and Mars exploration missions, which because of high costs could also include international partners. The commercial human spaceflight industry needs to take a broader view and a proactive stance on safety to fit into the mixed-users environment of exploration missions, and in the perspective of developing a robust point-to-point transportation market. Therefore there is a strong need to establish harmonized safety requirements and a rigorous system of independent peer-reviews. Through this course the participant will acquire a detailed understanding of current FAA/AST safety (policy) guidelines, and of modern risk-based performance requirements and processes used for the safety certification of commercial vehicles in the frame of NASA Commercial Crew Program (CCP). The course participants will also learn the pros and cons of the 4 possible future certifications schemes (Government Regulations, Consensus Standards and Third-Party Certification, Unregulated Self-Policing, Regulated Self-Policing), and will become acquainted with the current safety certification best-practices collected in the (de-facto) standard IAASS-SSI-1700.

Target Audience

- Design and operations engineers and managers new to space safety principles, processes and established practices.

- Safety managers and engineers with no previous experience in space projects.

What You Will Learn

- What is risk-based design, and importance of peer-review
- Hazard analysis principles and techniques.
- The safety evolution in space projects.
- Commercial safety certification practices (non-space).
- Current space safety guidelines and standards
- Future regulatory frameworks options

How You Will Learn It

- Verbal instructions using Power Point Presentations.
- Videos & Photographs.
- Case studies.
- Group exercises & problem solving.

Why You Need to Know This

- To implement cost/effective safety-by-design measures
- To understand the significance and procedures of safety management.
- To know the experts point of view.

What You Will Take With You

- A set of available standards and practices
- A USB flash drive with all the above.
- A Certificate of Course Completion

Course Duration

2 days

Instructor

T. Sgobba (ESA Ret. – NSTS/ISS Safety Review Panel Chair)



LAUNCH AND RE-ENTRY SAFETY ANALYSIS

Code 002



The Challenges

The course is intended to provide the participant with an understanding of analyses for launch and re-entry safety, understanding the significance and procedures of range safety processes; and identifying resources for implementing launch re-entry safety. The participant will gain an understanding of hazards associated with space launch and re-entry operations, the data required to quantify the hazards, methods for quantifying the risks from these operations, and effective means for mitigating the risk.

Introduction

Over the last fifty years the methods for understanding and managing the risks associated with the launch and re-entry of space systems have evolved significantly. These advances have been driven by a combination of larger and more complex space launchers and decreased buffer between populated areas and launch sites. Improved risk management has resulted from increased computational capacity and more refined modelling. The result has been an outstanding record of protecting the public from the inherently dangerous operations of launching and re-entering of space systems.

Scope of the Course

This course teaches the principles of launch and re-entry safety analysis and risk management:

- Risk Concepts
- Risk Mitigation Concepts
- Mathematical/Statistical Principles
- Computation/Presentation of Risk
- Risk Analysis Modelling
- Evaluating Catastrophic Risk

- General Launch Risk Analysis Procedure
- Impact Point Prediction and Impact Dispersions
- Impact Dispersions of Normal and Malfunctioning Vehicles
- Aircraft Probability of Impact and Vulnerability
- Impact Probabilities for Planned Jettisons
- Introduction to Debris List Development
- Failure Rate and Failure Mode Development
- Introduction to Exposure and Vulnerability
- Acceptable Risk
- Controlled Re-entry Risk Analysis Methods
- Uncontrolled Re-entry Risk Analysis Methods.

What You Will Learn

The following concepts will be learned:

- Approach to managing risks associated with launch and re-entry operations
- Definition of risk and risk measures (individual, collective, catastrophic)
- Process to perform quantitative flight safety risk analyses
- Sources of debris dispersion and methods of modelling
- Modelling impact probability distributions and computing probability of impacting people, buildings, ships and aircraft
- Consequence analyses: approaches to modelling vulnerability of people
- structures, ships and aircraft and the consequences of impacting inert and explosive debris
- Concepts for mitigating risk, such as mission/vehicle design, ship and aircraft
- management, and flight termination system design.

In addition this course is an enhanced version of the course first taught at US ranges and later in conjunction with IAASS conferences. Significant enhancements over the original course include:

- introduction to considerations of range safety system design
- updated material on characterizing vehicle breakup
- updated material on characterizing vehicle failure probabilities and response modes, and
- extended sample analysis integrated into the course.

Target Audience

- Engineers and Project Managers involved in launchers and spacecraft design & development
- Engineers and Managers with range safety responsibilities
- Safety Engineers performing and reviewing launch flight safety analyses

Prerequisites

Background in mechanical engineering or physics equivalent to a BS. Familiarity with matrix and vector operations.

Instructor

The course will be taught by Jerry Haber and by Randy Nyman.

Mr. Haber has over 30 years of experience leading risk analysis model development efforts, developing risk acceptability standards, and performing flight safety risk analyses for the full spectrum of U.S. launch vehicles and missiles. He has developed guidelines for flight safety risk analyses for U.S. National organiza-



Jerry Haber

tions and a leader in the development of U.S. consensus risk acceptability standards for launch and re-entry risks.

Mr. Nyman with 30 years of engineering practice, has made major contributions in re-entry risk, breakup modelling and toxic risk modelling. Mr. Nyman performed on behalf of ESA the independent re-entry risk analysis for ATV.



Randy Nyman

Both instructors are the authors or co-authors of numerous technical papers and reports. They have also co-authored the Elsevier graduate level textbook *Safety Design for Space Operations*.

How You Will Learn

- Verbal instructions using Power Point presentations
- Videos & Photographs
- Case studies

What You Will Take With You

- Data, model results and tools
- A USB flash drive of comprehensive briefing slides
- Certificate of Course Completion

Course Duration

4 Days (Monday afternoon – Friday noon)





LAUNCH SAFETY ANALYSIS

Code 002a



The Challenges

The course is intended to provide the participant with an introduction of analyses for launch safety, of the significance and procedures of range safety processes. The participant will gain an understanding of hazards associated with space launch operations, the data required to quantify the hazards, methods for quantifying the risks from these operations, and effective means for mitigating the risk.

Introduction

Over the last fifty years the methods for understanding and managing the risks associated with the launch of space systems have evolved significantly. These advances have been driven by a combination of larger and more complex space launchers and decreased buffer between populated areas and launch sites. Improved risk management has resulted from increased computational capacity and more refined modelling. The result has been an outstanding record of protecting the public from the inherently dangerous operations of launching and re-entering of space systems.

Scope of the Course

This course teaches the principles of launch and safety analysis and risk management:

- Risk Concepts
- Risk Mitigation Concepts
- Mathematical/Statistical Principles
- Computation/Presentation of Risk
- Risk Analysis Modelling
- Evaluating Catastrophic Risk
- General Launch Risk Analysis Procedure

- Impact Point Prediction and Impact Dispersions
- Impact Dispersions of Normal and Malfunctioning Vehicles
- Aircraft Probability of Impact and Vulnerability
- Impact Probabilities for Planned Jettisons
- Introduction to Debris List Development
- Failure Rate and Failure Mode Development
- Introduction to Exposure and Vulnerability
- Acceptable Risk

What You Will Learn

The following concepts will be learned:

- Approach to managing risks associated with launch operations
- Definition of risk and risk measures (individual, collective, catastrophic)
- Process to perform quantitative flight safety risk analyses
- Sources of debris dispersion and methods of modelling
- Modelling impact probability distributions and computing probability of impacting people, buildings, ships and aircraft
- Consequence analyses: approaches to modelling vulnerability of people
- structures, ships and aircraft and the consequences of impacting inert and explosive debris
- Concepts for mitigating risk, such as mission/vehicle design, ship and aircraft
- management, and flight termination system design.

In addition this course is an enhanced version of the course first taught at US ranges. Significant enhancements over the original course include:

- introduction to considerations of range safety system design
- updated material on characterizing vehicle breakup
- updated material on characterizing vehicle failure probabilities and response modes.



Target Audience

- Engineers and Project Managers involved in launchers and spacecraft design & development
- Engineers and Managers with range safety responsibilities
- Safety Engineers performing and reviewing launch flight safety analyses

Prerequisites

Background in mechanical engineering or physics equivalent to a BS. Familiarity with matrix and vector operations.

Instructor

The course will be taught by Jerry Haber and by Randy Nyman.

Mr. Haber has over 30 years of experience leading risk analysis model development efforts, developing risk acceptability standards, and performing flight safety risk analyses for the full spectrum of U.S. launch vehicles and missiles. He has developed guidelines for flight safety risk analyses for U.S. National organizations and a leader in the development of U.S. consensus risk acceptability standards for launch and re-entry risks.



Jerry Haber

Mr. Nyman with 30 years of engineering practice, has made major contributions in breakup modelling and toxic risk modelling.

Both instructors are the authors or co-authors of numerous technical papers and reports. They have also co-authored the Elsevier graduate level textbook *Safety Design for Space Operations*.



Randy Nyman

How You Will Learn

- Verbal instructions using Power Point presentations
- Videos & Photographs
- Case studies

What You Will Take With You

- Data, model results and tools
- A USB flash drive of comprehensive briefing slides

Course Duration

2 Days





RE-ENTRY SAFETY ANALYSIS

Code 003



The Challenges

The course is intended to provide the participant with an understanding of how to perform analyses for assessing the safety risk of space systems re-entry operations. Such analyses should be performed during the early stage of design as they may drive the decision to include controlled re-entry capability, to modify components design and materials selection to enhance demise to meet applicable regulatory risk thresholds, and consideration of alternative launch facilities and orbital inclinations. The participant will gain an understanding of the hazards, methods for quantifying the risks from re-entry operations and effective means for mitigating the risk.

Introduction

As the orbits of non-functional satellites, spent launch vehicle stages and other pieces of debris decay, they lose altitude and enter denser regions of the atmosphere where friction with atmospheric gases at high velocity generates a tremendous amount of heat. As a result, a major portion of the hardware (between 60% and 90%) will typically burn up. However, some components and parts can and do survive the re-entry heating. As the emphasis on accelerating removal of space debris from LEO orbit has gained acceptance to reduce collision risk and orbit pollution, the need to control the safety risk of re-entering space objects has come in focus and will very much impact the overall design of future spacecraft and launch vehicles upper stages. Estimating the re-entry risk with sufficient precision becomes a key design tool. Over the last fifty years the methods for understanding and managing the risks associated with the launch and return of space systems have evolved significantly. These advances have been driven by a combination of larger and more complex space launchers and payloads, increased space launch traffic, growing populations on Earth, and decreased buffer between populated areas and candidate launch sites and re-entry areas. Improved risk management has resulted from increased computational capacity and more refined modelling. The result has been an outstanding record of protecting the public from the inherently dangerous operations of launching while much remains to be done for the re-entry of space systems.

Scope of the Course

This unique course teaches the principles of re-entry safety analysis and risk management:

- Risk Concepts
- Risk Mitigation Concepts
- Mathematical/Statistical Principles
- Computation/Presentation of Risk
- Risk Analysis Modelling
- Risk Analysis Procedure
- Evaluating Catastrophic Risk
- Impact Point Prediction and Impact Dispersions
- Consequence Modeling for Impacting Debris
- Acceptable Risk
- Characterizing Populations at Risk
 - Exposure & Vulnerability
- Managing Ship and Aircraft Risk
- Re-entry Breakup and Demise
- Re-entry Risk Analysis Methods
 - Uncontrolled
 - Controlled

What You Will Learn

- Approach to managing re-entry risks:
- Definition of risk and risk measures (individual, collective, catastrophic)
- Process to perform quantitative flight safety risk analyses
- Sources of debris dispersion and methods of modelling
- Modelling impact probability distributions and computing probability of impacting people, buildings, ships and aircraft
- Consequence analyses: approaches to modelling vulnerability of people, structures, ships and aircraft and the consequences of impacting inert and explosive debris
- Concepts for mitigating risk, such as mission/vehicle design, ship and aircraft traffic management

In addition the results will be reviewed of the benchmarking exercise, performed by the IAASS Working Group, of existing risk assessments tools in US and Europe

This course is an enhanced version of the course first taught at



US Launch Ranges and later given internationally in conjunction with IAASS conferences. Enhancements include:

- focus on re-entry risks analysis as design driver
- re-entry breakup and demise
- extended sample problem

Target Audience

- Engineers and Project Managers involved in spacecraft and launchers design & development
- Engineers and Managers involved in space operations (e.g. SSA), or with operational safety responsibility
- Safety Engineers performing and reviewing re-entry flight safety analyses

Prerequisites

Background in mechanical engineering or physics equivalent to a BS. Familiarity with matrix and vector operations.

Instructors

The course will be taught by Jerry Haber and by Randy Nyman.

Mr. Haber has over 30 years of experience leading risk analysis model development efforts, developing risk acceptability standards, and performing flight safety risk analyses for the full spectrum of U.S. launch vehicles and missiles. He has developed guide-



Jerry Haber

lines for flight safety risk analyses for U.S. National organizations and a leader in the development of U.S. consensus risk acceptability standards for launch and re-entry risks.

Mr. Nyman with 30 years of engineering practice, has made major contributions in re-entry risk, breakup modelling and toxic risk modelling.

The instructors are authors/co-authors numerous technical papers and reports. They have co-authored the Elsevier graduate level textbook *Safety Design for Space Operations*.



Randy Nyman

How You Will Learn

- Verbal instructions using Power Point presentations
- Videos & Photographs
- Extended sample problem

What You Will Take With You

- Data, model results and tools
- A USB flash drive of comprehensive briefing slides
- Certificate of Course Completion
- Sample Problem Workbook

Course Duration

2 Days

COURSE AGENDA

DAY 1

09:00 Welcome & Course Introduction

09:15 General:

- Risk management concepts
- Risk measures
- Debris Risk Modelling Approaches
- General/Debris Risk Analysis

10:45 *Coffee Break*

11:15 Fundamentals:

- Debris Footprint Analysis Methodology
- Population Library
- Consequence Modelling for Inert Debris

13:00 *Lunch Break*

14:15 Protection Standards

- Risk Acceptability
- Ship Protection

18:00 *Adjourn*

DAY 2

09:00 Aircraft Risk Management

10:00 *Coffee Break*

10:30 Re-entry Risk

- Risk Modelling Functions
- Breakup and Demise Part 1

12:30 *Lunch Break*

14:00 Re-entry Risk

- Breakup and Demise Part 2
- Random Re-entry Risk
- Planned Re-entry Risk

18:00 Certificates of Completion for Re-entry Risk Course
Adjourn



ISS PAYLOADS DESIGN AND OPERATIONS SAFETY

Code 004



Tommaso Sgobba

Paul Kirkpatrick

The Challenge

The course is designed to provide the participant with an understanding of safety requirements, procedures and processes that are used for design and operations of payloads for the International Space Station.

Scope of the Course

This course is designed as a guide to the ISS payload/cargo safety review process. The student will gain an understanding of the applicable safety documents and key safety technical requirements, of payload/cargo safety as it relates to the overall development and integration process, how the payload/cargo safety review process works, and the roles and responsibilities of the various players. In addition the student will be instructed in the hands-on fundamentals of hazard analysis, hazard documentation, and presentation to the Payload Safety Review Panel.

Through this IAASS course the participant will acquire a detailed understanding of concepts and requirements in SSP 51700, SSP 30599, and supporting guidelines, and will familiarize with safety analysis techniques that can be used for their correct and consistent implementation.

Target Audience

- Safety engineers and managers, system engineers, QA personnel, project managers responsible for development, integration and operation of payloads/cargo for ISS;
- Other technical discipline personnel who contribute to the design and operations of ISS payload/cargo and need to understand the process by which hazards are identified and controlled.

What You Will Learn

- Why safety management is important
- The safety culture and philosophy
- The safety documentation
- Where to find requirements
- Basic hazard analysis techniques.
- How to identify hazards

- Common mistakes
- The Phased Review Process
- How to prepare for the Safety Panel Meeting

How You Will Learn It

- Verbal instructions using Power Point Presentations
- Videos & Photographs
- Case studies
- Group exercises & problem solving
- Preparing/completing forms
- Mock presentation to safety panel

Why You Need to Know This

- To design your payload/cargo for safety
- To understand the significance and procedures of the safety process
- To identify resources for implementing payload safety
- To know what the ISS Payload Safety Review Panel (PSRP) expects from you
- To get safety certification to fly

What You Will Take With You

- The course binder with the presentation charts.
- A selected set of documents
- A USB flash drive with all the above.
- A Certificate of Course Completion.

Course Duration

3.5 days

Instructors

T. Sgobba (ESA Ret. – Flight Safety Chair)

P. Kirkpatrick (NASA Ret. – Ground Safety Chair)



COURSE AGENDA

DAY 1

- 09:30** Course Introduction
- 09:45** System Engineering Key Concepts
- 10:45** General Definitions
- 11:15** *Coffee break*
- 11:30** Man-in-Space
- 12:15** Accidents & Close Calls
- 13:00** *Lunch break*
- 14:00** System Safety Basics
 - How it started
 - Definitions
 - Basic Technical Requirements
- 15:45** *Coffee break*
- 16:00** System Safety Basics (Continued)
 - Basic Technical Reqts (Continued)
 - Hazard-Mishap
- 17:30** *Adjourn*

DAY 2

- 09:00** System Safety Basics (cont'd)
 - Preliminary Hazards Analysis
- 09:45** Safety-by-Design
 - Materials Safety
 - Electrical System Safety
- 10 :45** *Coffee Break*
- 11 :00** Safety-by-Design (Continued)
 - Electrical Sys. Safety (Continued)
 - Batteries Safety

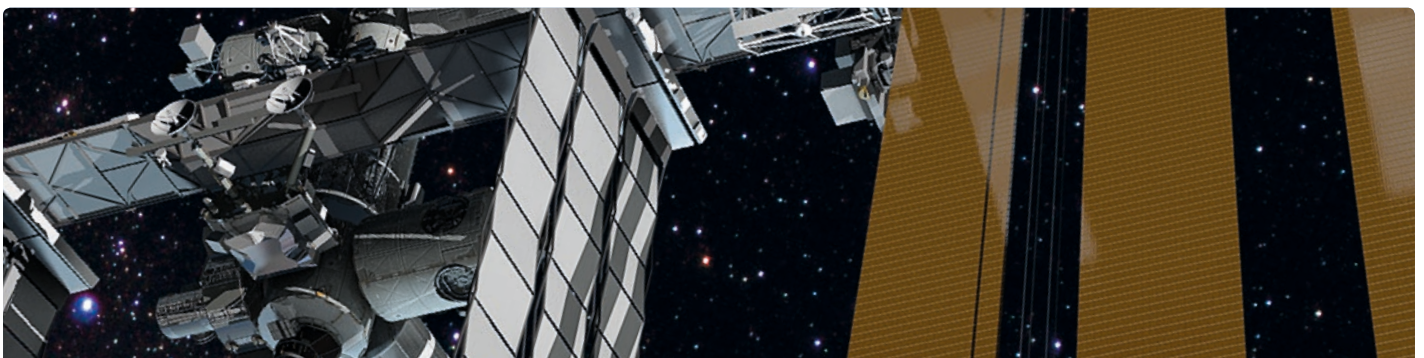
- 12:30** *Lunch break*
- 13:30** Safety-by-Design (Continued)
 - Pressurized Systems and Pressure Vessels
 - Containment design
 - Fracture Control
- 15:15** *Coffee break*
- 15:30** Operational Hazard Control
- 16:00** SSP 30599 Appendix J
- 17:30** *Adjourn*

DAY 3

- 09:00** SSP 30599 Appendix J (Continued)
- 10:45** *Coffee break*
- 11:00** ISS Payload Safety Policy & Rqts
 - SSP 51700
 - NSTS/ISS 18978
- 12:30** *Lunch break*
- 13:30** [Hazard Report Exercise]
- 16:00** Ground Safety Process & Rqts
- 17:30** *Adjourn*

DAY 4

- 09:00** [Hazard Report Exercise]
- 10:45** *Coffee break*
- 12:00** Course Wrap-Up





DESIGN AND OPERATIONS OF COMPOSITE OVERWRAPPED PRESSURE VESSELS

Code 005



The Challenge

High performance Composite Overwrapped Pressure Vessels (COPVs) have been utilized in the aerospace and automotive industries for many years, providing an inherently safe, lightweight and cost effective storage source for pressurized fluids. COPVs are commonly used for gas and propellant storage in spacecraft and launch vehicles. The consequence of a COPV rupture can be the release of caustic fluids, loss of necessary fluids and the release of stored energy equivalent to several pounds of trinitrotoluene (TNT) depending on the quantity, pressure and fluid contained in the COPV.

In the aerospace sector, the development of a commercial space industry has reinforced the need for light and low cost yet safe and reliable pressure vessels. In the automotive sector, new demands for alternative fuel vehicles driven by changes in the energy sector have given rise to opportunities for durable and low cost, and also safe and reliable pressure vessels, particularly for hydrogen and compressed natural gas.

Safety and high reliability are achieved by adhering to rigorous processes throughout the life cycle of a pressure vessel, including the design, manufacture, testing, handling, and operation phases.

Scope of the Course

This course will provide an introduction to the basic principles governing the design and operation of Composite Overwrapped Pressure Vessels (COPV). The comprehensive overview of current technological understanding will provide both engineering mechanics fundamentals and practical applications drawn from experience to educate program managers, design engineers, ground and flight operators, safety analysts, quality inspectors and users/customers.

Course Description

Fundamental to the use of COPVs in space applications is the relevant failure modes and the design techniques introduced to ensure safe operation. Flight safety can only be properly understood through appropriate engineering design and quality throughout the vessel lifecycle from design, qualification, manufacturing, acceptance testing, handling and finally operational use. Each step of

the product lifecycle has relevant safety considerations, which will ultimately affect the likelihood for catastrophic failure resulting in loss of life during operations.

This course has been developed based on requirements developed for space applications for COPVs. The relative requirements are documented in NASA- developed standards applicable to US and international partners for use on the International Space Station, as well as for future programs such as the NASA Commercial Requirements. These various standards reference the appropriate AIAA requirements and these will be directly addressed in this course. The course is directly relevant to individuals concerned with COPVs in automotive applications. The failure modes are common across these industries. However, there is a difference in usage and need for robustness of typical pressure vessels and a difference in materials commonly selected for these products. Consequently there are different standards and approaches to certification. The class will explore these differences.

Participants in this workshop will gain appreciation of a wide range of epoxy-matrix composites that are used in overwraps based on fibers such as: S-glass, aramids (e.g., Kevlar®49) and carbon (e.g., T1000), and also various current liner materials including metals such as aluminum, stainless steel, titanium and Inconel, and polymers such as high density polyethylene. Attention will be paid to the potential effects of processing variables (e.g., heat treatment, welding, annealing) on ultimate liner performance as influenced also by the fiber used in the overwrap.

Various steps in the COPV design and manufacturing processes will be discussed, particularly aspects strongly influenced by end-use requirements and vessel geometry (cylindrical vs. spherical). To manufacture the overwrap, both wet filament winding and prepreg winding methods will be discussed, including their respective pros and cons and their relative importance in various designs. Another topic discussed will be the potential for liner distortion and buckling during winding, the consequences and candidate countermeasures to protect this phenomenon from occurring. Advantages and risks in bonding the overwrap to the liner will be discussed with respect to the overall design and potential failure mechanisms. Autofrettage and proof-testing will be discussed in terms of plastic yielding of the liner that induces a significant compressive stress component beneficial to improving fatigue life. In this context, the Bauschinger effect on the final liner stress state and the potential for liner buckling will also be discussed.

The relevant analysis and test methods used to demonstrate com-

pliance to appropriate certification standards are presented. These include factors of safety set to mitigate against stress rupture failure modes of the overwrap and Leak-Before-Burst liner/overwrap concepts and demonstration, and finally FEA/NDE approaches to establish Safe Life with respect to risk of liner fatigue failure from crack initiation and growth.

Current non-destructive evaluation (NDE) techniques will be discussed as are used to detect flaws and damage in the liner and overwrap. NDE methods for detecting flaws and small cracks in liners include: visual, dye penetrant, X-ray, ultrasonic, eddy current, and borescope inspection. NDE methods for the overwrap include: Acoustic emission, Flash/Infrared thermography, laser shearography, digital image correlation of overwrap strains, and Raman spectroscopy to measure residual fiber stress.

Students will gain familiarity with the computational design tools that are used to analyze COPV. The majority of the examples in the course are created using the commercially available Abaqus FEA product suite and associated Wound Composite Module (from Dassault Systemes). Computational results with this tool will be discussed to underscore the importance of proper design, manufacture, and operations to prevent the occurrence of various failure modes. Through these structured learning examples, users will gain an appreciation for the complexities of modeling these vessels.

The AIAA is currently updating the national standards which are used to certify metallic and composite overwrapped pressure vessels. The course will also review the updates to these standards which will be released by the time of the teaching of the course.

Target Audience

- Engineers and Managers who are interested in the latest techniques for COPV design, development, manufacture and test
- System engineers who develop requirements for systems which incorporate the use of pressure vessels
- Safety, reliability and quality engineers who want to understand the approach to safety and mission assurance of systems which incorporate the use of pressure vessels
- Ground Operators and test engineers who performed non-destructive evaluation of pressure vessels. The course would be beneficial to both seasoned experts in the field and new engineers to the technology.

What You Will Learn

- Failure modes in COPVs and requirements for safe operation in space environments
- Designing for Maximum Operational Pressure and Relevant Factors of Safety
- Approaches to Liner Fatigue Modeling under Pressure Cycling
- Liner Buckling: Models, Trigger and Methods of Prevention
- Composite Stress-Rupture Phenomenon and Reliability Modeling
- Nondestructive Evaluation (NDE)
- Considerations for Ground Operations and Damage Control Mitigation Techniques.

Course Length and Duration

5 days

Instructors

Instructors: The course instructors are internationally recognized experts in the field of COPV Design and Operations:

S. Leigh Phoenix (PhD Cornell) is professor of Mechanical and Aerospace Engineering at Cornell University, where he has been on the faculty since 1974, and teaches courses in composite materials, solid mechanics and applied mathematics. Much of his research involves micromechanically-based statistical modeling and experiments on long-term reliability of fibrous composites (e.g., aramids, carbon, S-glass, PBO) under high stress in difficult environments. Examples include



S. Leigh Phoenix

composite-overwrapped pressure vessels, pressurized hydraulic lines and wind turbine blades. He also models ballistic impact into fibrous materials in support of developing improved materials and architectures for soft body armor and flexible composite panels. In 1983 Phoenix received the Fiber Society Award for Distinguished Achievement in Basic or Applied Fiber Science, and in 1992 he won the ASTM Harold DeWitt Smith Award in fiber mechanics. In 2005 he was awarded the NASA-NESC Engineering Excellence Award for his pressure vessel work in support of the Shuttle's Return to Flight.

Michael T. Kezirian (PhD MIT) was an Associate Technical Fellow with the Boeing Company when he started his own company to apply space technology to the energy sector. He has brought extensive experience in composite materials, propulsion systems and system safety to address safety concerns for the Space Shuttle, International Space Station and Commercial Crew CST-100 Starliner Programs.



Michael T. Kezirian

As an Adjunct Associate Professor of Astronautical Engineering at the University of Southern California, he has taught undergraduate and graduate classes in Polymer Science, Spacecraft Dynamics and Safety of Space Systems and Space Missions. He is the founding Editor-in-Chief of the *Journal of Space Safety Engineering*. Dr. Kezirian is an Associate Fellow of the AIAA and Fellow Member of IAASS. In 2009 he was awarded the NASA Astronaut Personal Achievement Award (Silver Snoopy).



COURSE AGENDA

Day 1 Afternoon

1. General Introduction

- a. Definitions and Examples
- b. Spherical and Cylindrical COPV architecture and wind patterns
 - Overwrap wind patterns and implications
- c. Overwrap materials (and fiber properties): carbon, Kevlar®, S2-Glass
- d. Liner materials (and properties): aluminum, titanium, Inconel, stainless steel
- e. Manufacturing processes: wet winding, and prepreg, elevated temperature curing
- f. Manufacturing: autofrettage

2. Failure Modes

- a. Liner fatigue (parent material and welds)
- b. Composite Stress Rupture
- c. Collateral damage/impact damage
- d. Liner failure during autofrettage or first pressurization
- e. Liner buckling

3. Standards

- a. NASA Requirements
 - Commercial Crew Requirements (ESMD-CCTSCR-12.10) and flow down to CCT-REQ-1130 and others
 - ISS Visiting Vehicle Requirements (SSP 50808 and 30558/30559)
 - Unmanned Programs
- b. AIAA Standard (S-080, S-081a and future versions)
- c. MIL-STD-1522
- d. Other requirements and standards (ISO, EU, UN)

Day 2 Morning

4A. COPV Design & Analysis using FEA Software – Part A Spherical Vessels

4B. COPV Design & Analysis using FEA Software – Part B Cylindrical Vessels

- a. Basic Concepts and Definitions
 - Elastic vs. Plastic Response of composite
- b. Introduction to orthotropic elasticity of a lamina
 - Unidirectional composite forms (tow, band, lamina)
 - Definition of various moduli and Poisson's ratios
 - Layered composite stiffness properties
 - Through thickness compression (important to thick overwraps)
- c. Thermal effects in overwrap mechanical response
 - Thermal expansion coefficients (fibers, liners and COPV)
 - Effects of temperature excursions on overwrap and liner response

Day 2 Afternoon

5. Overwrap Design Considerations

- Considerations for Thick-Walled vs. Thin Walled COPV

6. Winding Pattern Effects

- a. Implications on overwrap shear stress profiles within layers and between layers
- b. Isotenoid and other dome designs in cylindrical pressure vessels
- c. Theoretical models for liner and overwrap response
- d. Shear stress behavior and influence on the liner
- e. Potential for delamination and debonding
- f. Effects of winding pattern on impact damage sensitivity

7. Autofrettage and Proof Testing

- a. Effect on stress state
- b. Role of Bauschinger effect
- c. Connection to buckling risk and fatigue risk

Day 3 Morning

8. Liner Fatigue Modeling

- a. Advanced fracture mechanics approaches, modeling fatigue crack growth (connection to Safe Life and Leak Before Burst concepts)
- b. Description of NASA-developed NASGRO, fracture mechanics and fatigue crack growth analysis software
- c. NDE methods for detecting small cracks and flaws (probabilities of detection)
- d. Strain-life models (Morrow, Fatemi-Socie)
- e. Cyclic stress-strain laws (Ramberg-Osgood)
- f. MLE-based statistical analysis approaches, reliability modeling, test data generation, including size effects, uncertainty

9. Liner Buckling

- a. Mechanical models (including effects of autofrettage)
- b. Bonded vs. unbonded liners
- c. Triggers and methods of prevention
- d. Rippling effects from wrap pattern imprint

Day 3 Afternoon

10. Composite Stress Rupture Phenomena and Reliability Modeling

- a. Background and Definitions
- b. Mechanisms and Micro-Mechanics
- c. Fiber, Tow and Vessel (including sub-scale) Testing
- d. Factors affecting stress rupture and testing
- e. Weibul based probability models



- f. Effects of Proof Testing
- g. Model Parameter Estimation to Enable Reliability Calculation (and incorporating uncertainty)
- h. Relevance to Standards

Day 4 Morning

11. NonDestructive Evaluation – Liner

- a. Visual (dents, scuff marks)
- b. Dye penetrant methods
- c. X-ray and ultrasonic
- d. Eddy current
- e. Borescope based profilometry

12. NonDestructive Evaluation – Liner Special Topic Laser Profilometry

Day 4 Afternoon

13. NonDestructive Evaluation – Overwrap Raman Spectroscopy

14. Mechanical Impact Damage Control

- a. Purpose
- b. Element of a Damage Control Plan
- c. Failure Consequences
- d. Quantifying Consequences
- e. Threat Assessment
- f. Reporting
- g. Protective Covers

Day 5 Morning

15. Risk to the Public

- a. Range Safety Approaches
- b. Risk Factors
- c. Failure Consequences
- d. Quantifying Consequences

16. Micro Meteoroid and Orbital Debris (MMOD)

- a. The (Un) Natural Environment
 - Measurement
 - Sources
 - Characterization
- b. Modeling
- c. Government Regulations (US and International)
- d. Space Vehicle Protection
 - Thermal expansion coefficients (fibers, liners and COPV)
 - Effects of temperature excursions on overwrap and liner response
- e. Recent Hyper Velocity Impact Experiments on Metallic Pressure Vessels
- f. Implications for Pressure Vessel/COPV operations in Space

17. Special Topics

18. Summary

Computational Workshop:

Students will be provided the student version of Abaqus FEA (Dassault Systèmes (3DS)) and workbooks on the Wound Composite Modeler (WCM). Results of Abaqus simulations are used throughout the course.

Computational Workbook A

In this workshop, the user step through the process of generating an axisymmetric model of a COPV and post processing the results using the Wound Composite Modeler (WCM). The model will consist of both helical and hoop layers.

Computational Workbook B

In this workshop, the user steps through the process of generating a three-dimensional model of a COPV and post processing the results using the WCM.

Computational Workbook C

The focus of this workshop is the use of the WCM as a COPV design tool. The WCM will be used to gauge the effect of parameters such as wind angle, number of layers, and liner materials on the stresses during operations (changes in COPV pressure).

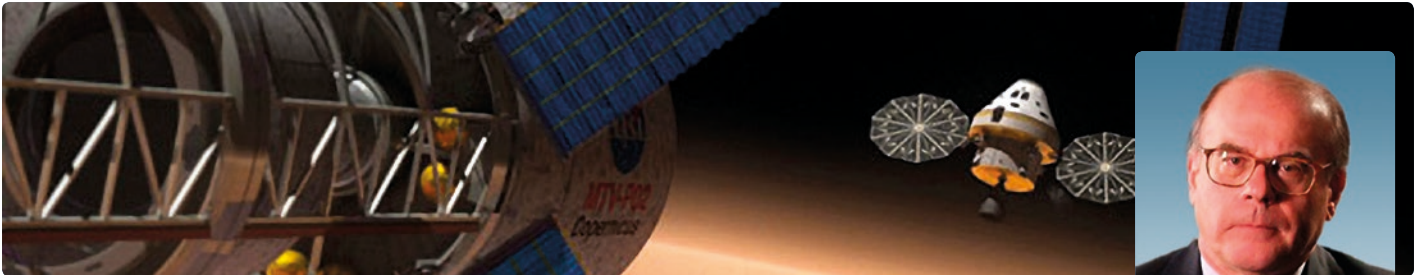
Computational Workbook D

This workshop explores the concept of autofrettage. An autofrettage analysis will be performed to demonstrate how tensile stresses in the liner may be reduced in order to extend the fatigue life of a COPV.



QUALITY ASSURANCE (QA) FOR SPACE PROJECTS

Code 006



Tommaso Sgobba

The Challenges

The course is designed to provide the participant with an understanding of basic principles of Quality Management, Quality Assurance and Quality Control, as they are usually applied to space projects. (The course material copyright is owned by IAASS).

Scope of the Course

- The key role of management in setting quality objectives for the organisation, how to establish policy, goals, organisation and allocate responsibilities.
- Key principles of quality control/assurance, and their evolution. Measuring the quality and promoting improvements.
- Formal quality systems. European (ECSS), NASA requirements standards, international standard (ISO).
- The need for a Quality and relationship to contractual QA Plans. Conducting internal and external quality audits.
- Quality in design. Specifications, the V-cycle, support to Projects Reviews.
- Managing the non-conformities resolution process.
- The importance of alerts systems.
- Quality Assurance. Quality records, process control, workmanship standards, traceability, inspections, measuring equipment calibration system.
- Statistical methods in brief.
- Space environment effects on materials. Including materials used in space, requirements and testing, materials evaluation, and process control.

In summary, the participant will acquire an understanding of quality principles, requirements and techniques, and how to apply them for achieving product conformity, customer satisfaction and for increasing productivity.

Target Audience

- Managers and engineers new to quality principles and processes.
- QA managers and engineers with no previous experience in space projects

What You Will Learn

- Why Quality is important.
- The Quality culture, philosophy and organisation.
- The Quality standards.
- Basic principles and techniques.
- How to satisfy the Customer
- Common mistakes.

How You Will Learn It

- Verbal instructions using Power Point Presentations.
- Videos & Photographs.
- Case studies.
- Group exercises & problem solving.

Why You Need to Know This

- To prepare and implementing cost/effective QA plans
- To understand the significance and procedures of quality assurance.
- To identify and justify resources for implementing a quality system.
- To know what ESA expects from you.
- To convince your management of the benefits.

What You Will Learn

- The course binder with the presentation charts.
- A set of ECSS standards.
- A USB flash drive with all the above.
- A Certificate of Course Completion.

Course Duration

3 days

Instructors

Tommaso Sgobba (ESA Ret. - PA/QA Manager)

COURSE AGENDA

DAY 1

09:30 Course Introduction

09:45 General Introduction

- The space environment
- Some key concepts in system development
- Consideration on failures and causes
- What is Product Assurance?

11:15 Coffee break

11:30 Basic concepts

- What is Quality?
- Evolution of quality systems

13:00 Lunch break

14:00 Basic values and principles

15:00 Main elements and techniques (Part I)
- Organisation

15:45 Coffee break

16:00 Main elements and techniques (Part I) (Continued)
- Manual, procedures, plans and records

17:30 Adjourn

DAY 2

09:00 Main elements and techniques (Part 1) (Continued)
- Audits
- Non-conformance control
- Training
- Qualification/Certifications

10:45 Coffee Break

11:00 QA standards

12:30 Lunch break

13:30 Non-Conformance control [Exercise]

15:15 Coffee break

15:30 Main elements and techniques
- Inspection
- Metrology/Calibration

17:30 Adjourn

DAY 3

9:00 QA during major project phases

10:45 Coffee break

11:00 ECSS-Q-20B

11:30 Special techniques
- Statistical techniques

12:30 Lunch break

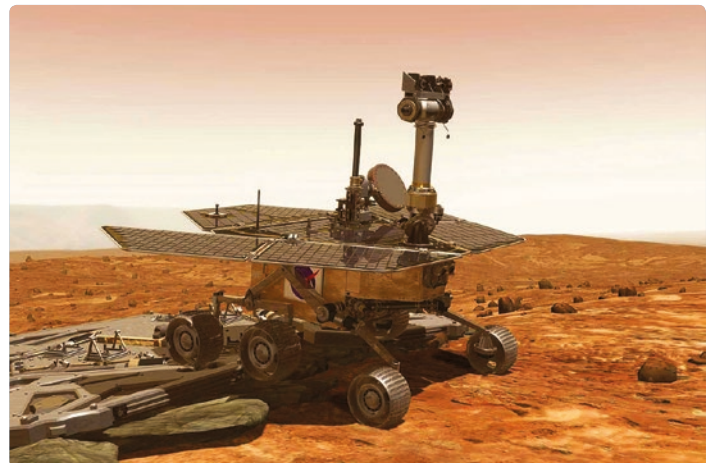
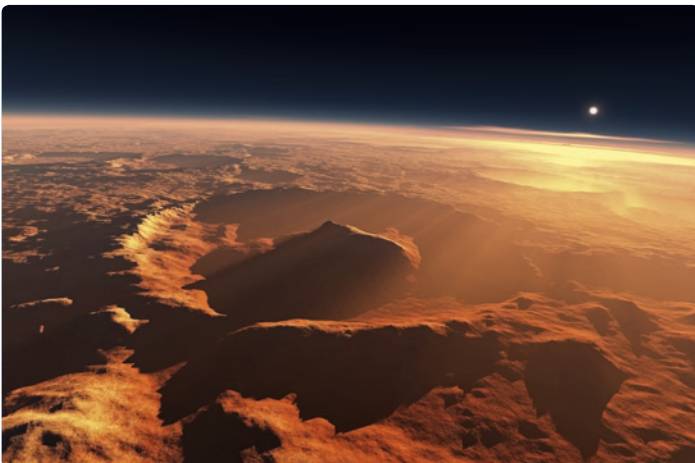
13:30 Special techniques (Continued)
- Cost of Quality
- Alert systems

15:15 Coffee break

15:30 Audit [Exercise]

16:45 Space environment effects on materials
- Materials used in space
- Requirements and testing
- Evaluation of materials
- Processes for space

17:30 End of QA course





CONFIGURATION MANAGEMENT FOR SPACE PROJECTS

Code 007



The Challenges

The course is intended to provide the participant with an understanding of how to conduct the technical-administrative discipline of Configuration Management (CM). The course will be held in two parts. First part will be a generic, common sense approach to CM based on more than three decades of CM experience gained by the instructor. The second part will compare the lessons learned in part one with the ECSS CM standard ECSS-M-ST-40C. The participant will gain an understanding of the principles and procedures applied through CM to space projects; the interdisciplinary activities between CM and other project activities; and will get an idea of CM requirements tailoring for the level of project complexity.

Introduction

The technical-administrative discipline Configuration Management was born in the post WWII era when technical system's complexity increased. Driver for CM establishment were the US armed forces followed by NASA in the second half of the fifties. CM at these days was all mechanical and electrical oriented and so were the CM practitioners. This proved later on to become a problem when electronics and, in conjunction with this, software started to take more and more share within systems. As software is a non-tangible product, CM procedures had to be rethought.

The next break in CM proceedings was caused by the proliferation of Personal Computer. While configuration status was mainly done by use of file cards for less complex projects, mainframe computer were utilised to manage configuration metadata of bigger systems. Nowadays, almost every CM exercising organization utilizes either tailored off-the-shelf, or self-developed programs for accountability of configurations controlled by them.

Whereas CM for software (and firmware embedded code) at component and unit level has, due to its unique processes, mostly been established as an independent discipline, the battle at the level of software integration with hardware is still going on.

Scope of the Course

This course lectures the five plus one CM functions:

- Configuration Identification
- Configuration Control
- Configuration Status Accounting
- Configuration Verification & Audit
- CM Planning and Organizing
- plus
- CM of Digital Product Data

and the principles for implementing these functions.

What You Will Learn

- How to structure and document a system.
- How to control the evolution of such a system.
- How to enable the reporting of a certain configuration at a certain point of the product's life-cycle.
- How to verify that a desired configuration state has been achieved.
- How to plan a CM organization and how to anchor it in contract language.
- How to manage the configuration of digitized product definitions.

Target Audience

- Engineering manager and project engineers involved in spacecraft and launcher development and design.
- Engineers and project staff involved in production planning and control.
- Engineers and technicians responsible for verification of product compliance with documented requirements and design.

Prerequisites

Engineers or technicians with good skills in reading and understanding of technical documentation (specifications, drawings/lists, diagrams).



COURSE AGENDA

DAY 1

09:30 Welcome and Course Introduction

09:45 Configuration Management (CM) Basics
- Explaining Configuration Management
- Policy and Principles of CM

11:00 Coffee Break

11:20 The five plus one functions of CM
- Configuration Identification
- Configuration Control
- Configuration Status Accounting
- Configuration Verification & CM Process Audit

13:00 Lunch Break

14:00 The five plus one functions of CM (cont'd)

16:00 Coffee Break

16:20 The five plus one functions of CM (cont'd)

17:30 Adjourn

DAY 2

09:00 CM Planning and Organizing

11:00 Coffee Break

11:20 CM of Digital Product Definition Data

13:00 Lunch Break

14:00 Change Control/CCB Exercise

16:00 Coffee Break

16:20 Project activities with significant CM involvement

17:00 Tailoring of CM requirements

17:30 Adjourn

DAY 3

09:00 Space Project CM at ESA
- Understanding ECSS-M-ST-40
- Walking through the standard

11:00 Coffee Break

11:20 Comparing the ECSS requirements with Day 1 lessons
- Discussing the differences and evaluating them
- Tailoring to suit the project size and needs

13:00 Lunch Break

14:00 Space Project CM at NASA
- Understanding NASA-STD-0005 and the SAE/EIA-649 Set of Documents
- Walking through the standards

15:00 Summary of the CM Course – the lessons learned

16:00 Course ends

How You Will Learn It

- Verbal instructions by use of Power Point presentations.
- Shown samples of configuration controlled documents.
- Shown samples of configuration reports.

What You Will Take With You

- A USB flash drive with Power Point presentation
- Certificate of Course Completion

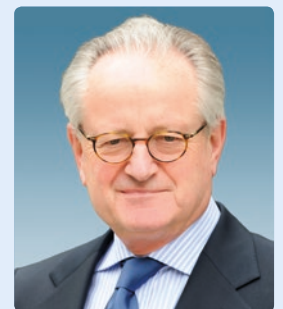
Instructor

The course will be taught by Mr. **Wolfgang Weiss**.

Mr. Weiss has over 35 years of experience in CM matters from big size projects such as the Boeing E-3 "AWACS" to medium size, multi-national missile projects such as the RIM-116 "RAM", to

small projects such as aerospace components.

Mr. Weiss was contracted by ESA in the early 90s for developing an ESA standard CM discipline including a set of 8 ESA PSS type of documents. Due to the switch from ESA PSS to ECSS standards, these PSS's were not formally released but did provide a sound basis for developing ECSS-M-40A.



Mr. Weiss was co-author of ECSS-M-40A and -40B, participant in authoring of various US military CM and TDM standards of the past, and is voting member of the SAE (formerly EIA, GEIA, TechAmerica) G-33 committee on CM.

Wolfgang Weiss



INTRODUCTION TO CONFIGURATION MANAGEMENT

Code 007a



The Challenges

The course is intended to provide the participant with an introduction of Configuration Management (CM). The participant will gain an understanding of the principles and procedures applied through CM to space projects; the interdisciplinary activities between CM and other project activities; and will get an idea of CM requirements tailoring for the level of project complexity.

Introduction

The technical-administrative discipline Configuration Management was born in the post WWII era when technical system's complexity increased. Driver for CM establishment were the US armed forces followed by NASA in the second half of the fifties.

Scope of the Course

This course lectures the five CM functions:

- Configuration Identification
- Configuration Control
- Configuration Status Accounting
- Configuration Verification & Audit
- CM Planning and Organizing

and the principles for implementing these functions.

What You Will Learn

- How to structure and document a system.
- How to control the evolution of such a system.
- How to enable the reporting of a certain configuration at a certain point of the product's life-cycle.
- How to verify that a desired configuration state has been achieved.
- How to plan a CM organization and how to anchor it in contract language.
- How to manage the configuration of digitized product definitions.

Target Audience

- Engineering manager and project engineers involved in spacecraft and launcher development and design.

- Engineers and project staff involved in production planning and control.
- Engineers and technicians responsible for verification of product compliance with documented requirements and design.

Prerequisites

Engineers or technicians with good skills in reading and understanding of technical documentation (specifications, drawings/ lists, diagrams).

How You Will Learn It

- Verbal instructions by use of Power Point presentations.
- Class exercises.

What You Will Take With You

- A USB flash drive with Power Point presentation
- Certificate of Course Completion

Course Duration

1 day.

Instructor

The course will be taught by Mr. **Tommaso Sgobba**.

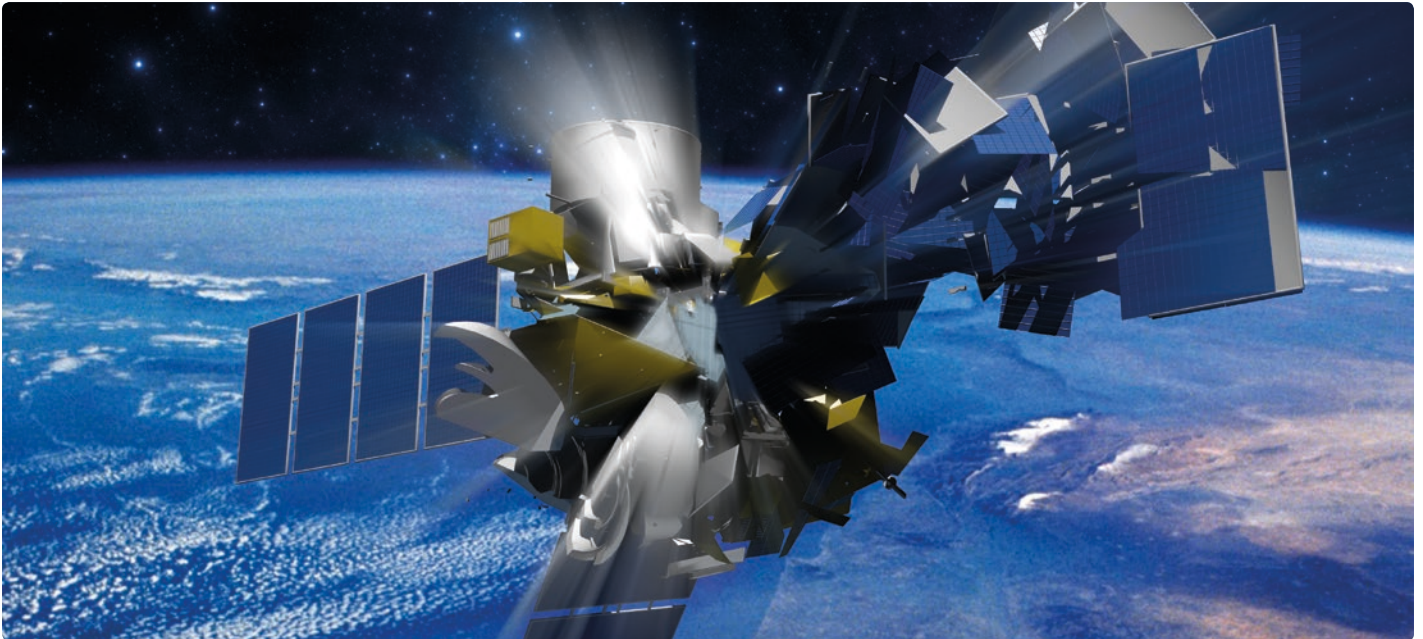
Mr. Sgobba career spans four decades in aerospace. Starting as structural engineer in the aviation industry, at the age of 31 he became chief inspector of military transport aircraft final assembly line, and later Quality Assurance manager for plants manufacturing advanced composites materials and jet engines. After moving to the European Space Agency, he worked on the Hermes spaceplane, on the development of solid rocket motors, and on Earth observation and meteorological satellites. Later he became head of Product Assurance and Safety for all major ESA manned missions on Space Shuttle, Russian space station MIR, and International Space Station (ISS).



Tommaso Sgobba

SPACE DEBRIS: RISK ANALYSIS AND MITIGATION

Code 008



The Challenges

The course is designed to provide the participant with an understanding of the orbital debris environment, and of the hazards that space debris represent for spacecraft on orbit and for public on ground. The course explains the regulations for space debris mitigation, ways of compliance, and the application of risk analysis methods and tools.

Scope of the Course

The student will gain an understanding of the following topics:

- Main sources of space debris location in space, orbital lifetime
- Observation means: radar, optical, on-ground or in-orbit, system
- On orbit and reentry risks analysis
- Protection and prevention measures
- Introduction to remediation measures
- Overview of regulations and standards
- On orbit risk analysis models and tools

Target Audience

Design and operations engineers and managers new to space debris risks and mitigation principles, processes and regulations.

What You Will Learn

- Definition of space debris, main sources, distribution in space, lifetime, comparison with meteoroid, future evolution
- Definition of risks: in-orbit collisions, atmospheric reentries, other risks
- Observation means: radar, optical, on-ground or in-orbit, system

- Distribution and models for space debris
- How to evaluate probability and consequences of collisions with small and large debris
- Concepts for protection, prevention, remediation and their application
- Process of destructive reentry, risks to people on ground and to airplanes
- How to predict uncontrolled reentries and mitigate the risks
- How to applied international and national regulations, standards and guidelines
- How to find and use main tools for prevention of risks and application of mitigation measures

How You Will Learn It

- Verbal instructions using PowerPoint presentations
- Videos and photographs
- Cases studies
- Software tools demonstrations

Why You Need to Know This

- To understand the threat linked with space debris population
- To applied in an efficient way space debris mitigation requirements

What You Will Take With You

- A USB flash drive with all the above and a set of available standards and practices
- A certificate of course completion



COURSE AGENDA

DAY 1

- 09:30** Welcome and course introduction
- 09:45** General introduction
- 10:30** Space surveillance
- 11:00** *Coffee break*
- 11:30** Space surveillance (Continued)
- 12:00** Risks analysis on orbit
- 13:00** *Lunch Break*
- 14:00** Risks analysis on ground
- 15:00** Risks mitigation: Protection
- 16:00** *Coffee break*
- 16:30** Risks mitigation: Prevention
- 17:30** *Adjourn*

DAY 2

- 09:00** Risks mitigation: Prevention (Continued)
- 10:00** Active debris removal
- 11:00** *Coffee break*
- 11:30** Risk mitigation on ground
- 12:30** Risk mitigation at launch
- 13:00** *Lunch Break*
- 14:00** Regulations and standards
- 15:30** Models and tools
- 16:00** *Coffee break*
- 16:30** Models and tools (Continued)
- 17:00** Attendances certificate and end of courses

Instructors

The course will be taught by **Fernand Alby** and **Bruno Lazare**.

Mr. **Alby** has devoted most of his career to space debris studies. He was responsible of space debris and space surveillance activities at the French Space Agency (CNES) until his retirement in 2014. His field of work included flight dynamics studies, operations and regulations. He participated to all important committees dealing with space debris such as UN-COPUOS, IADC and ISO. Mr. Alby is Honorary Member of IAASS, and winner of the J. Loftus Space Sustainability Award.



Fernand Alby

Mr. **Lazare** has over 30 years of experience in the field of space safety and quality management, performing launch and reentry risk analysis, drafting launch safety standards and developing a Launch and reentry risk assessment tool. He participates to several committees dealing with space debris and safety such as UN-COPUOS, IADC, ISO and IAASS.



Bruno Lazare

The instructors are authors and co-authors of numerous technical papers and reports. They have been major contributors to the drafting of the French Space Operations Act technical regulations.





A SYSTEMS APPROACH TO SPACE SAFETY

Code 009



The Challenges

With the increasing complexity of space systems today and the extensive use of software, traditional approaches to system safety engineering and software safety (most of which were created 50-70 years ago) are no longer as effective as they originally were, leading to avoidable losses. A new systems approach is needed that integrates the human, hardware, and software components of space system engineering in order to prevent such losses. The new techniques to be taught in this course are quickly being adopted in other fields including automobiles, aviation, and defense, where complex, software-intensive systems are challenging traditional safety engineering approaches. International standards for the approach to be taught in this course have been created or are in progress in other fields. Some space agencies are already successfully using them.

Scope of the Course

This course will teach a general approach to engineering safety into space systems, including new system engineering and hazard analysis techniques. The course is an abbreviated version of a class at MIT that is taught to graduate students in aerospace engineering and other fields.

Target Audience

Aerospace safety professionals of all sorts including system engineers, human factors engineers, and software engineers.

Prerequisites

None. The class will teach a new approach to safety engineering and thus should be understandable by anyone, even those without an extensive background in traditional safety engineering approaches.

What You Will Learn

- Why accidents occur in complex, engineered systems
- Handling complexity: Analytic Decomposition vs. Systems Theory
- A top-down, integrated approach to analyzing and designing safety into complex systems containing hardware, software, and human components.
- Designing safety into space systems from the beginning of the concept development process and using analysis to drive the functional design requirements and design process.
- A more powerful hazard analysis technique called STPA (System Theoretic Process Analysis)
- A new approach to investigating and analyzing losses called CAST (Causal Analysis based on System Theory)
- Integrating safety and security aspects for complex systems.

How You Will Learn It

- Power point presentations
- Case studies of the use of STPA and CAST in current space programs
- Group exercises and problem solving

Why You Need to Know This

The world of engineering has changed from the one that existed 50-70 years ago, when the current approaches to space safety were first created. Each new generation of spacecraft and space activities are becoming more complex and more software-intensive. Space projects are too expensive and too long in duration for learning from losses to be an acceptable approach or trying to add safety onto completed spacecraft designs. Safety needs to be designed in from the beginning and new approaches are necessary to allow this possibility.

What You Will Take With You

Power point presentations
Solutions for class exercises and examples
Certificate of Course Completion



Course Duration

2 days

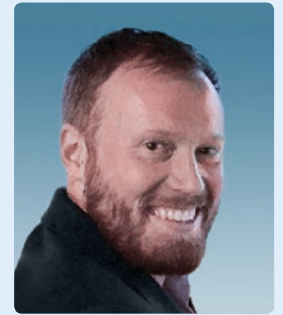
Instructors

Prof. Nancy Leveson has been teaching system safety engineering for over 30 years. She is currently a professor in the MIT Aeronautics and Astronautics Department and an elected member of the National Academy of Engineering. She has served on the NASA Aerospace Safety Advisory Panel (ASAP) and has participated on many NASA committees, including being an advisor to the CAIB. She has also worked extensively with JAXA on space safety. She is a past recipient of the IAASS Vladimir Syromyatnikov Safety-By-Design Award.



Nancy Leveson

Dr. John Thomas is a Research Engineer in MIT's department of Aeronautics and Astronautics. His work includes efficient methods to engineer human interactions and automated behaviors, to generate requirements, and to identify potential flaws early while solutions are least expensive and most effective. He has collaborated with JAXA, NASA, and others including recent applications on unmanned spacecraft, ISS crew operations, weather and astronomy satellites, aircraft systems, and autonomous vehicles. He has been involved in safety engineering research for 15 years and worked at Lincoln Laboratory, Raytheon, and the Air Force Research Labs prior to joining MIT.



John Thomas





RELIABILITY ENGINEERING

Code 010



This course is offered in partnership through the Safety Engineering & Analysis Center (SEAC). The SEAC training schedule is available online at www.apr-research.com/training.

The Challenges

The Reliability Engineering training course is designed for professionals wanting to advance their understanding and knowledge in reliability engineering tools and techniques and their application in technical assessments and special studies.

Scope of the Course

The course includes an introductory module of key definitions, basic statistics, and a review of the basic principles of the reliability engineering discipline, including a description of a reliability case for establishing and managing a reliability engineering program. The rest of the course modules focus on reliability engineering tools and techniques used by engineering professionals throughout government and industry. Emphasis is placed on applications of the methodology to solving practical problems found in diverse settings.

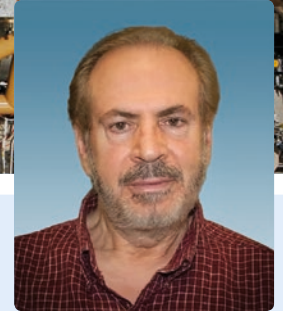
Target Audience

- Design Engineers;
- Safety and Mission Assurance Engineers;
- Engineers performing and reviewing reliability analyses;
- Engineers and managers involved in reliability assessment and special studies or with reliability engineering responsibility; and
- Engineers new to reliability principles, tools, and techniques.

What You Will Learn

- Probability Basics
- Reliability Engineering Overview
- Failure Modes and Effects Analysis (FMEA)
- Reliability Allocation
- Reliability Prediction
- Reliability Demonstration
- Reliability Growth
- Fault Tree Analysis (FTA)
- Event Tree Analysis (ETA)
- Probabilistic Risk Assessment (PRA)
- Human Reliability
- Accelerated Testing (ALT, HALT, HASS)

- Parts Derating
- Sneak Circuit Analysis
- Availability Analysis



Fayssal Safie

How You Will Learn It

- Verbal instructions using Power Point presentations
- Case Studies and Lessons Learned
- Group exercises and problem solving

Why You Need to Know This

- To understand reliability as an engineering discipline that provides a critical design function
- To apply engineering principles, tools, and techniques to the design and processing of products, both hardware and software, for the purpose of meeting product reliability requirements or goals
- To prepare for the Reliability Engineer Certification provided by the American Society for Quality

What You Will Take With You

- The course binder with the presentation charts
- A certificate of course completion

Course Duration

Three days

Instructor

Dr. Safie is a Principal Reliability Engineer at A-P-T Research, Inc. with over 30 years' experience in the areas of reliability, safety, and quality engineering. He holds Bachelor, Master, and Doctorate degrees in Systems Engineering. He received over 50 honors and awards from NASA and retired from Marshall Space Flight Center in 2017 as the Agency Technical Fellow for Reliability and Maintainability Engineering.



EXPLOSIVES SAFETY

Code 011



This course is offered in partnership through the Safety Engineering & Analysis Center (SEAC). The SEAC training schedule is available online at www.apr-research.com/training.

The Challenges

The Explosives Safety Course is an overview of hazards inherent to explosives operations, associated safety precautions, and methods to analyze, test, and obtain approval for explosives activities.

Scope of the Course

Subjects covered in the class include:

- Explosive item recognition
- Hazardous Stimuli
- Reaction Effects
- Personnel Protection
- Construction criteria
- Lightning protection
- Quantity-Distance
- Risk Analysis
- Explosives modeling
- An introduction to explosive testing
- Hazard classification
- Insensitive munitions

Target Audience

Designed primarily for individuals who develop, assemble, test, inspect, approve, transport, store or in some other way handle explosives items or materials

What You Will Learn

- Hazards and risks involved with explosives handling, storage, transportation and processing
- Overview of the basic principles of explosives safety
- Overview of the fundamental requirements governing explosives
- Overview of various federal hazard classification systems for explosive materials

How You Will Learn It

- Verbal instructions using Power Point presentations
- Group exercises and problem solving

Why You Need to Know This

- Increased safety awareness, accident reduction
- Help maintain safe work practices

What You Will Take With You

- The course binder with the presentation charts
- A certificate of course completion

Course Duration

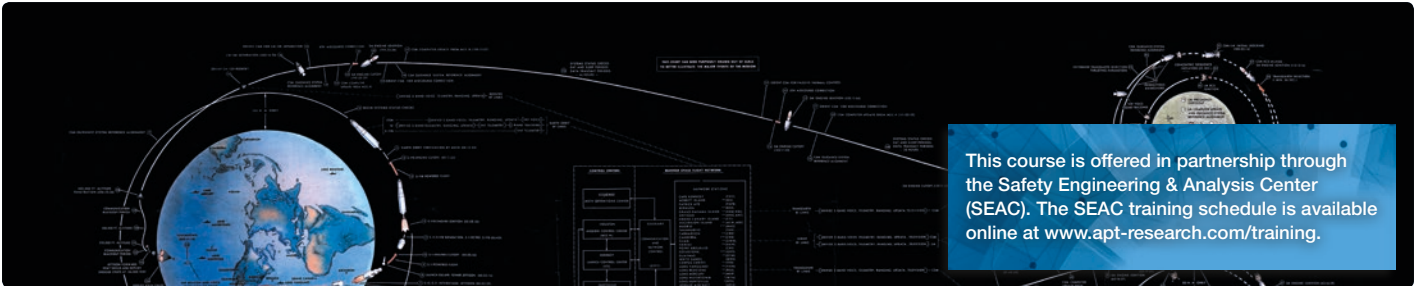
Three days





SYSTEM SAFETY ENGINEERING

Code 012



This course is offered in partnership through the Safety Engineering & Analysis Center (SEAC). The SEAC training schedule is available online at www.apt-research.com/training.

The Challenges

Risk Management and System Safety Engineering comprise both a doctrine of management practice and a supporting family of analytical techniques. Together, the management doctrine and the analytical techniques are aimed at ensuring that hazards will be discovered before they induce harm, that the risks posed by those hazards will be assessed, and that for risks falling above an established tolerance threshold, measures will be developed and implemented to render them acceptable.

Scope of the Course

This course first reviews a working understanding of the doctrine of management practice. Methods of its practical application are presented. Next presented are brief overviews of two analytical techniques currently in widespread use. These are Preliminary Hazard Analysis, and Failure Modes and Effects Analysis.

This overview is followed by more in-depth treatments of the analytical methods: Fault Tree Analysis, Event Tree Analysis, and Cause-Consequence Diagramming. Diagnostic approaches used with each of these are presented. Then specific advantages of each technique for practical system analysis is discussed.

Shortcomings, often overlooked flaws in analyses, and common abuses in the use of each technique are identified. Methods of identifying and correcting analysis flaws are taken up. Through the use of classroom demonstrations and workshop problems, the participant is prepared to carry out analyses on his own and to review and critique analyses performed by others.

Emphasis is placed on applications of the methodology to solving practical problems found in diverse settings

Target Audience

This course is designed for safety professionals wanting to advance their skill and knowledge in techniques supporting hazard discovery, assessment, and control of risk.

What You Will Learn

- Concepts in Risk Management
- Initiating a System Safety Program
- Working with the Risk Assessment Matrix
- Energy Sources
- Operating and Support Hazard Analysis
- Failure Modes and Effects Analysis
- System Safety Risk Assessments
- Safety Assessment Reports
- Fault Tree Analysis
- Introduction to Software Safety
- Event Tree Analysis
- Introduction to Sneak Circuit Analysis
- Cause-Consequence Analysis
- Introduction to Markov Analysis
- Failure Probability Assessments
- Human Factors
- Writing Procedures
- Selected Analysis Methods
- Weighted Scoring
- Risk Management Strategy Selection
- Accepting Risk

How You Will Learn It

- Verbal instructions using Power Point presentations
- Group exercises and problem solving

Why You Need to Know This

To understand aspects of risk management including ways to identify, analyze, reduce, and accept hazards.

What You Will Take With You

- The course binder with the presentation charts
- A certificate of course completion

Course Duration

Four and ½ days



SOFTWARE SYSTEM SAFETY ENGINEERING

Code 013



This course is offered in partnership through the Safety Engineering & Analysis Center (SEAC). The SEAC training schedule is available online at www.apr-research.com/training.

The Challenges

The Software System Safety (SwSS) Engineering training course is an integrated combination of system safety, software safety, and software engineering technologies.

Scope of the Course

The course describes generic SwSS processes adaptable to a variety of customer needs, and is tailorable to specific projects and software development processes. Each course module contains material designed to provide the student with the information and detail needed to understand and apply the material. The course is constantly updated to include new techniques, in-depth processes, and real-life examples.

Target Audience

Safety professionals interfacing with safety wanting to advance their skill and knowledge in techniques of software system safety

What You Will Learn

The SwSS course begins with an overview of course objectives, the need for SwSS, and a description of the relationship between system safety and SwSS. After a discussion of directives, documents, policies and regulations related to SwSS, the course provides detailed instruction on the SwSS process, including a variety of analyses and tools. The instruction concludes with planning details for a SwSS program, hazard identification and tracking, risk assessment, risk reduction, and risk acceptance as applicable to

SwSS. In keeping with APT's commitment to excellence, recent updates to the course include modules titled "Programmable Logic Devices," "Model-Based Software Safety," and "The Future of Software System Safety."

How You Will Learn It

- Verbal instructions using Power Point presentations
- Group exercises and problem solving

Why You Need to Know This

- To design your system for safety
- To understand the significance and procedures of the safety process
- To identify resources for implementing system safety including software system safety
- To know what the safety review boards expects from you
- To get safety certification to field

What You Will Take With You

- The course binder with the presentation charts
- A certificate of course completion

Course Duration

Two days





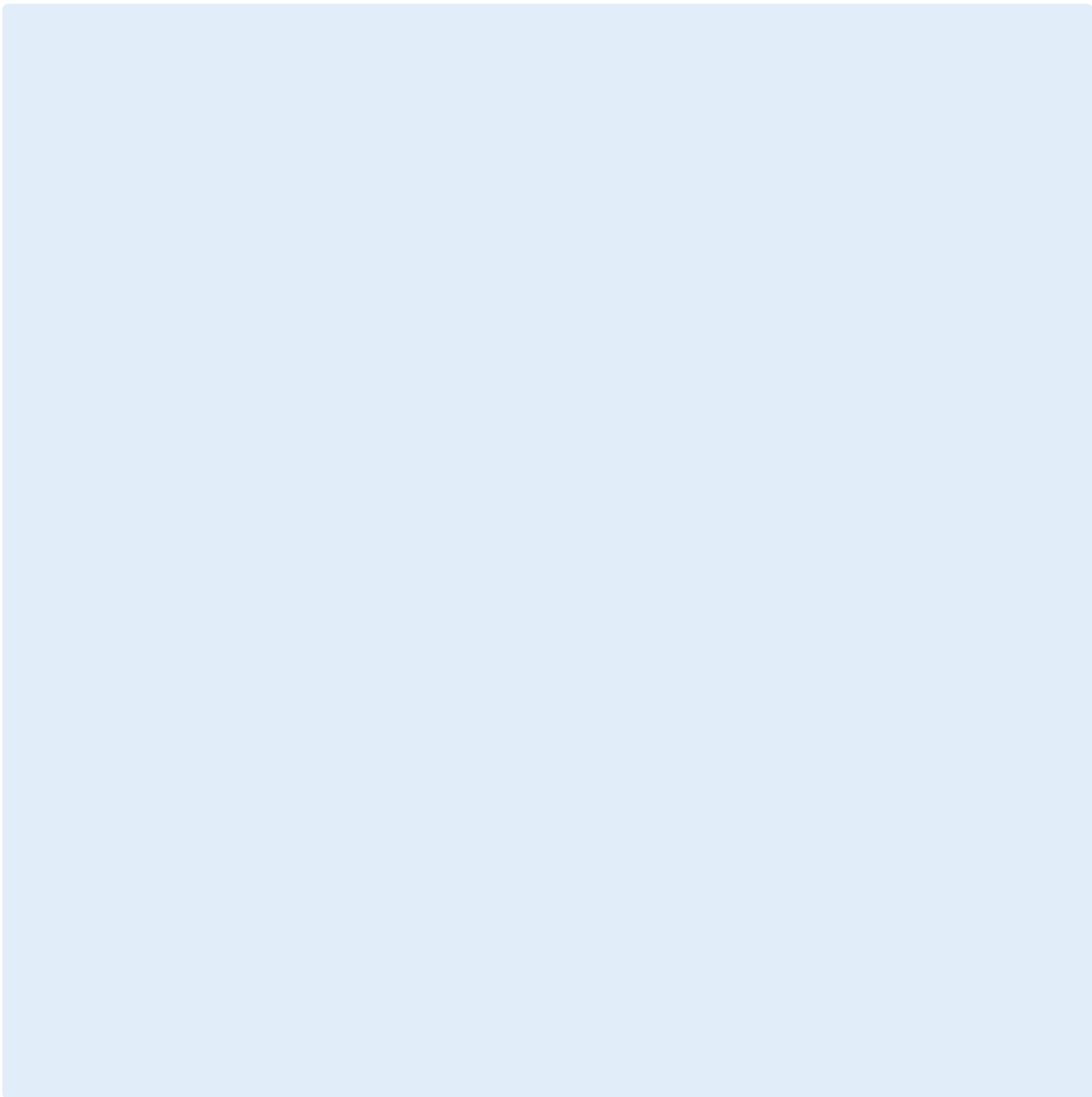
SPACE NUCLEAR POWER SYSTEMS SAFETY

Code 014



RISK MANAGEMENT FOR SPACE PROJECTS

Code 015





INTERNATIONAL ASSOCIATION FOR THE ADVANCEMENT OF SPACE SAFETY

Professional Training Courses Catalog

ALSO AVAILABLE IN BOOKSTORES



Safety Design for Space Systems
Elsevier 2009

Progress in space safety lies in the acceptance of safety design and engineering as an integral part of the design and implementation process for new space systems. Safety must be seen as the principle design driver of utmost importance from the outset of the design process, which is only achieved through a culture change that moves all stakeholders toward front-end loaded safety concepts. Superb quality information for engineers, programme managers, suppliers and aerospace technologists.



Safety Design for Space Systems, Chinese Edition
2011

Progress in space safety lies in the acceptance of safety design and engineering as an integral part of the design and implementation process for new space systems. Safety must be seen as the principle design driver of utmost importance from the outset of the design process, which is only achieved through a culture change that moves all stakeholders toward front-end loaded safety concepts. Superb quality information for engineers, programme managers, suppliers and aerospace technologists.



Space Safety Regulations and Standards
Elsevier 2011

Space Safety Regulations and Standards is the definitive book on regulatory initiatives involving space safety, new space safety standards, and safety related to new space technologies under development. More than 30 world experts come together in this book to share their detailed knowledge of regulatory and standard making processes in the area, combining otherwise disparate information into one essential reference and providing case studies to illustrate applications throughout space programs internationally.



Safety Design for Space Operations
Elsevier 2013

Safety Design for Space Operations provides the practical how-to guidance and knowledge base needed to facilitate effective launch-site and operations safety in line with current regulations. With information on space operations safety design currently disparate and difficult to find in one place, this unique reference brings together essential material on: Best design practices, Advanced analysis methods, Implementation of safe operation procedures, Safety considerations relating to the general public and the environment in addition to personnel and asset protection, in launch operations.