Instar *Engineering and Consulting, Inc.*

Doing Things Right in Space Programs:
SDV—System Development and Verification

Course Overview: This course bridges the fields of systems engineering, specialized engineering, and quality assurance, with an overriding theme of mission success and effective engineering. After examining the driving issues in system development for space missions, the instructor introduces ten principles for doing things right, and then presents a sound engineering process for system development that is consistent with those principles. The instructor shares many examples and real-life experiences to drive home the key points. Special emphasis is placed on requirements development, verification planning, and technical communication, with several group exercises on those topics. The objectives are to build understanding, provide a fresh focus on quality and mission success, spur thought, and help your program improve its processes—from the top level of management on down to how every engineer approaches his or her job.

The ten principles for Doing Things Right in Space Programs:

1. Adopt the right attitude
2. Invest in knowledge and understanding
3. Instill ownership and responsibility
4. Constantly seek ways to improve teamwork
5. Follow a sound engineering approach
6. Reduce total cost through good engineering, not by compromising quality
7. Keep everything as simple as possible
8. Establish an effective quality system that involves everyone
9. Be willing to accept risks, but only those you truly understand
10. Make sure you—and everyone else—have enough time, resources, and freedom to do things right

The SDV course addresses the following:

- The problems presented by developing a space system, those that are unique and those that are common to system development in other industries. Three key unique problems that will be addressed are
  - The inability to service a spacecraft after launch, thus presenting the need to get things right the first time (thus the importance of the right attitude—mission success first—and taking personal responsibility).
  - Because your customer is funding development of the system, your customer demands and deserves to be made confident throughout development that you will get it right the first time. Thus, working issues without taking time to communicate your confidence to the customer is not acceptable.
  - Low production volume. Thus, because we can't amortize development costs, we must accept and address risks taken throughout development of uncertainty and uncontrolled variation.
- What "verification" means in the space industry. Many organizations define it as proof that a product meets a requirement. Because we believe true requirements pertain to something the system must be able to do after it's no longer in our hands (after launch), we define "verification" as "establishing confidence," not proof. You can't prove the mission will be successful. Of course, "establishing confidence" is subjective, so, to avoid disagreement and unanticipated cost, it's important to establish early an acceptable verification plan along with criteria for ensuring verification is adequate.
- Building effective teams at multiple levels (between product engineers, engineers and managers, contractors and customers)
- Building ownership (and motivate individuals) by making the contractor responsible for establishing the verification plan—and then selling it to the customer. The verification plan must be acceptable to the customer because the customer has the most at stake.
- How to distinguish between a true requirement (something the system must be able to do or some constraint on the system) and a verification criterion (ground rule for establishing appropriate confidence that the system will meet a requirement). (Note that this distinction is not made by most organizations; it's not acknowledged in any government standard that I'm aware of. We believe it's important, though, because it allows us to simplify and focus on the true requirements and ensure the right people are fully responsible for verification.)

- How to identify required functions, levels of performance, and constraints at the system level, and how to allocate requirements progressively down to the system's elements. Included is understanding of how this process is intertwined with design, with iteration necessary.
- How to write requirements that conform to standard "specification language" and that are clear.
- How to manange weight growth for flight systems.
- How to plan a verification program that is focused on requirements rather than tradition—while at the same time considering wisdom gained from past programs—thus ensuring higher likelihood of success.
- That verification can be proactive (effective early engineering that leads to better designs and manufacturing controls) as well as reactive (testing the end product), and that the best approach in the space industry is a combination.
- What "quality" means in the space industry, and how your company will go out of business if you ignore it—particularly when challenged with low budget.
- What it takes to have an effective "quality system," over and above certification to ISO9000, and what it takes to understand whether manufacturing processes are truly "controlled."
- What it means to assess a risk and take risks responsibly, and why accepting unknown risks is irresponsible.

Target Audience: All engineers involved in procuring, specifying, designing, producing, or testing space products

Course Developers and Instructors:

Tom Sarafin has worked full time in the space industry since 1979, with over 13 years at Martin Marietta Astronautics, where he contributed to and led activities in structural analysis, design, and test, mostly for large spacecraft. Since founding Instar in 1993, he has consulted for Space Imaging, DigitalGlobe, AeroAstro, AFRL, and other organizations. He has helped the United States Air Force Academy design, develop, and verify a series of small satellites and has been an advisor to DARPA. He is the editor and principal author of *Spacecraft Structures and Mechanisms: From Concept to Launch* and is a contributing author to *Space Mission Analysis and Design* (all three editions). Since 1995, he has taught well over 100 short courses to more than 2500 engineers and managers in the space industry.

Poti Doukas worked at Lockheed Martin Space Systems Company (formerly Martin Marietta Astronautics) from 1978 to 2006. He served as Engineering Manager for the Phoenix Mars Lander program, Mechanical Engineering Lead for the Genesis mission, Structures and Mechanisms Subsystem Lead for the Stardust program, and Structural Analysis Lead for the Mars Global Surveyor. He's a contributing author to *Space Mission Analysis and Design* (1st and 2nd editions) and to *Spacecraft Structures and Mechanisms: From Concept to Launch*. He joined Instar Engineering in July 2006.

Course Formats: Three full days or five 5-hour days

Comments from Past SDV Courses

"Every part of the course was insightful." " 'Must take' course for all disciplines."

"Great course! I am highly recommending it to others."

"This course does a good job of relaying that no process is going to work unless the people implementing it take pride and ownership in making it work."

"Make everyone at (my company) take this! This is a great course!"

(The strongest point was) "emphasis on improving the process of developing useful requirements."

"The instructor has tremendous knowledge and conveys his points in a way that makes you want to pay attention."

(The best part of the class was) "verification and QA—this section was extremely helpful to me and I hope I can convey the info to my teammates so we can make a difference."

"A good dose of how to do things right early in the game should serve me well."

"This is a powerful philosophy that can have a tremendous impact on the industry as a whole. Well done!"

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Course Outline

1. **Understanding the Problem**
   - Problem: How do we reduce cost while ensuring a successful mission?
   - Taking time to understand the problem
   - Recurring problems in space programs
   - Common elements and root causes
2. **Finding Solutions: Doing Things Right in Space Programs**
   - Establishing a vision
   - Understanding verification
   - Instilling ownership and responsibility
   - Ten principles for doing things right in aerospace programs
3. **Adopting the Right Attitude**
   - What business are you in?
   - What it really means to have a "commercial mentality"
   - What "quality" means in the space industry
   - Quality starts with the right attitude
4. **Building an Effective Organization**
   - Building effective engineers
   - Establishing an effective team
   - Nailing down roles and responsibilities
   - Empowering
   - Cultivating relationships
   - Opening lines of communication
5. **Overview of the Engineering Process**
   - A process for system development
   - Requirements hierarchy
   - Bottoms-up verification
   - Goals of the engineering process
6. **Developing Requirements**
   - The flow of requirements
   - Sources of requirements
   - Identifying life-cycle events
   - Launch and space environments
   - Characterizing requirements
   - Allocating requirements
   - Evaluating concepts and requirements with trade studies
7. **Specifying Requirements**
   - Contents of a specification
   - Specification language
   - Guidelines for writing requirements
   - Maintaining traceability
   - Specifying the need for a verification plan
   - Controlling interfaces
   - Class exercise: developing and specifying requirements
8. **Managing Growth Areas**
   - Identifying growth areas
   - Mass properties and power
9. **Reducing Cost and Risk by Design**
   - Simplifying
   - Standardizing
   - Designing for producibility
   - Designing for adaptability and accessibility
   - Reducing risk associated with launch loads
10. **Verification, Quality Assurance, and Safety**
    - Whose job is this?
    - Taking responsibility
    - Attending to details
    - Managing the process with a quality system
    - Instituting process controls (parts, materials, manufacturing processes, configuration)
    - Proactive versus reactive verification
    - Verification logic
    - Philosophies for product inspection
    - End-item testing
    - Qualification vs. acceptance testing
    - Deployment tests: Test as you fly
    - Class exercise: exploring alternative verification processes when build volume increases
11. **Communicating and Documenting Effectively**
    - Communication as part of the engineering process
    - Guidelines for effective communication
    - Writing clearly and concisely
    - Making presentations
12. **Responsibly Accepting Risk**
    - Verification means providing confidence, not proof
    - What it means to understand a risk
    - Estimating probability of failure
    - Example: negative structural margin of safety

Summary
- What about the tenth principle?
- Making sure you have enough time to do things right
- Raising the red flag
- Key points from this course
- Ten principles for doing things right