



Procedures and Guidelines

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1 PURPOSE

This procedure defines the process of flight hardware Integration and Test (I&T) and the role of an I&T Manager.

2 REFERENCE

- a. GPG 8700.1, Design Planning and Interface Management
- b. GPG 8700.3, Design Validation

3 SCOPE

This procedure applies to all flight hardware at the subsystem level and higher.

4. DEFINITIONS

- a. Integration and Test (I&T) – The process by which all flight hardware is assembled and where subsequent verification of proper function and suitability for intended purpose is demonstrated and verified. This includes both functional and environmental testing.
- b. I&T Manager [herein also referred to simply as ‘Manager’]– Any person with the direct responsibility of ensuring that a particular space flight item successfully completes the I&T process. Responsibilities include process planning from high level flow to detailed daily operations, organization of the I&T team, scheduling of resources and personnel for each task, development of I&T plans and procedures, implementation and control of all I&T activities.

To properly perform these responsibilities, the Manager should be involved in the planning and early design stages (planning phase) of all space flight items. In this phase, the I&T Manager assures that I&T requirements are understood and incorporated in the design process.

During the actual I&T process (implementation phase), the Manager directs the I&T team and approves all I&T test plans & procedures. The manager is the sole point of contact for I&T operations at the I&T facility, and is often the single point of contact for launch site operations.

The roles and responsibilities of the Manager may be performed by an Observatory/Spacecraft/Instrument Integration and Test Manager, Instrument Manager, subsystem

technical Manager etc. depending upon the level of assembly. For example, for a scientific Instrument without an Instrument I&T Manager, the Instrument Manager would perform the functions of a I&T Manager as defined in this document in order to deliver a product which is ready for Integration with a spacecraft, payload, or the next level of assembly.

- c. I&T Team – A multidisciplinary staff assigned to Integration and Test, upon which the I&T Manager relies for their expertise. Disciplines typically required include Systems, Mechanical, Thermal, Guidance Navigation and Control, Electrical and Ground Support Equipment. The Manager utilizes this support for day-to-day activities, technical insight, planning, problem resolution and oversight of specific activities and processes. Discipline support engineers are responsible for the technical performance of all spaceflight items. Additional support may be required from Verification Managers, Environmental Test Directors, Quality Assurance and Contamination Control.

5 AUTHORITIES AND RESPONSIBILITIES

N/A

6 IMPLEMENTATION

6.1 The I&T Process

This section describes the major tasks which are considered as part of the I&T process. It is the role of the I&T Manager to manage these tasks to the extent applicable to the Project to which the I&T Manager is assigned. Upon assumption of duties as a I&T Manager several tasks shall be accomplished and are outlined in this document. Depending upon the project phase some of these tasks may already be completed or designed. The I&T Manager shall determine the status and applicability of all tasks before proceeding.

The I&T Manager Should have a working knowledge of all aspects (electrical, mechanical, thermal, science objectives etc) of the system to be taken through the I&T process. The function of I&T Manager cannot be performed properly without such an understanding.

The I&T process consists of two major phases, the Planning Phase and the Implementation phase.

6.1.1 Planning Phase

The planning phase occurs in conjunction with the early stages of space flight item planning, design and development. Activities that may be undertaken in this phase include:

High level I&T flow definition: details of major assembly, test items, and sequences. An I&T flow shall determine the planned sequence of assembly and test events and reflects a logical flow and realistic duration for activities. It must be developed in association with Project management for coordination of scheduled deliveries and proper funding. It may be modified by the Project through the incorporation of program philosophies (risks and tradeoffs). The I&T flow is a dynamic document and may change depending upon actual circumstances (late

deliveries of hardware or software), changes in management philosophies, budgetary constraints, etc.

Identification of test equipment that will be required for I&T operations.

Make/buy/re-use decisions for identified test equipment.

Identification of areas of concern either technical (requirements derived from a particular technology, launch vehicle etc.) or logistical (unique transportation requirements, foreign launch sites etc.) and should incorporate lessons learned from previous programs if applicable and available.

Determination of size and composition of I&T team.

Hiring/Phase in plan for I&T team

Cost planning for the defined I&T flow. This task should insure that proper funding for activities identified in the previous steps is obtained. Funding should include some allowance for re-testing of failed components, delivery delays, unexpected shift work, launch delays and other unplanned events inherent in the implementation phase of the I&T process. The amount set aside for such purposes should be in proportion to the assumed risk associated with the particular space flight item, selected launch vehicle and importance of the overall project to NASA. As a guide, this additional amount should be approximately 20% of the planned I&T costs.

Set-up and equipping facilities to be used in the integration process including set-up of necessary infrastructure such as communications and data lines, air handling and temperature control, cleaning facilities and office space. New equipment for use in these facilities should be selected and procured during this phase.

The I&T Plan should be written and approved by the Project in this phase. The I&T Manager shall develop an Integration and Test Plan document (Described in section 6.2) which will completely describe the activities, documentation and considerations involved in the implementation phase of the I&T process. The I&T Manager shall determine if any ISO 9000 or other Project documents exist which would address the elements listed in section 6.2, and may use them to assist in developing unique requirements in the I&T plan.

All decisions and support needed to implement the plan should be finalized before the start of the implementation phase. The I&T Plan shall address all the items described in the I&T flow developed previous to this step. The I&T plan is a dynamic document and may change depending upon actual circumstances (late deliveries of hardware or software), changes in management philosophies, budgetary constraints, etc..

The I&T plan will be used by other Project organizations to help in planning, or to request services. In the former case, discipline and Project support personnel will make staffing, budget and logistic plans and design GSE based on the I&T plan. For the latter, services including logistics support and launch site services will be requested based on this document.

Conversely, this document cannot be created without the input of all discipline and Project support personnel to insure that their requirements are met.

6.1.2 Implementation Phase

The implementation phase begins as early as possible, often it begins when the first piece of flight hardware is interfaced to another piece. The interface can be electrical, mechanical or optical or any combination of these. The implementation phase consists primarily of executing the I&T plan. Since I&T is a dynamic process, frequent and often major changes will occur. It is the responsibility of the I&T Manager to execute this plan to ensure that the space flight item successfully completes the I&T process regardless of any changes or complications that may occur.

To mitigate risk, alleviate schedule problems, or for other engineering reasons, limited I&T may be performed on Engineering Test Units (ETU) or flight back-up spares. In these cases, the I&T process is the same as for flight hardware except that it may be appropriate to skip some activities such as mechanical integration (if performing electrical checks for example). The Manager should plan I&T activities with the purpose of the test (and possible future uses of the hardware) in mind so that the proper amount of detailed testing is performed.

6.2 I&T Plan

The I&T plan is a written document which outlines, the intended I&T process to be used in the implementation phase as described in previous sections of this document. The outline presented in this document is only a typical example. When constructing a new Plan, the I&T MANAGER shall follow this outline, carefully excluding those items that are not relevant to the Project, and add unique items that may be omitted in this outline.

The I&T plan is a valuable document for all discipline support personnel to use in planning for the implementation phase of I&T. The I&T Manager will find the effort involved in construction of this document to be invaluable since it will lead to a clear understanding of the tasks involved and uncover tasks and potential problems that had not previously been identified.

6.2.1 Example Outline

The I&T Plan should contain the following information as applicable and may be arranged in any order. Due to the scope, staffing and budget of a particular space flight program, some items may be omitted, or performed in a less formal fashion. For example, a bonded storage area and log would be appropriate for an observatory such as EOS, but not for a class D program such as Hitchhiker. The I&T manager should take program scope into account when putting together an I&T plan. However, it is not acceptable to omit an activity that directly impacts the quality, safety or success of the program, regardless of scope.

- Brief description of the science objectives
- Brief description of Spaceflight Item the plan covers
- Definition of scope of document
- Other applicable NASA, GSFC, Project, Launch site and Outside documents (such as ANSI standards or OSHA requirements) and drawings.
- Quality Assurance, Safety and other hazards:

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- Quality Assurance including quality assurance witnessing and monitoring, resolution of conflicts, cessation of work, work order authorizations and procedures, logs, records, and reports. (May be covered, in part, by existing ISO documentation)
- Mechanical Handling including equipment and spaceflight item moves during the I&T process. Emphasis on special handling procedures, fixtures, safety concerns and operator certifications.
- Contamination Control including personnel apparel, facility cleanliness (may be covered by existing ISO documents), purge requirements etc.
- Harness related activities including verification, use of connector savers, requirements for breakout boxes, requirements for I&T verification test cables, connector mate/demate operations and logs
- Special Safety Considerations including personnel safety, pyrotechnic device handling, general safety, optical hazards (lasers), propellants, non-breathable gasses, cryogenics, mechanical operations safety, electrical hazards, radiation and chemical safety.
- Handling of emergency conditions including fire, medical emergency, inclement weather, facility power loss, gse malfunctions, facility malfunctions, chemical releases, non-breathable atmospheres..
- Other precautions including grounding, Electrostatic Discharge (ESD) protection, soldering operations and other unique safety concerns.
- Ground Support Equipment (GSE) requirements including lists of equipment required, Failure Mode and Effects Analysis (FMEA) for electrical and computer GSE, safe-to-mate procedures, operations constraints, shipping or special operational environmental requirements (example: must operate outdoors on a launch pad).
- Thermal blanket and thermal coatings precautions (usually relates to cleanliness and may be adequately addressed in cleanliness requirements)
- Daily I&T activities and considerations:
 - Creation and maintenance of logs (many of which may be automatically generated by computer) including
 - Subsystem/instrument engineering logs
 - Integration logs
 - Work Order Authorization (WOA), problem record, Failure Reporting, Materials Review Board report, traceability logs (may be covered by existing ISO documents)
 - Operations logs
 - Space Flight item operators log
 - GSE logbook
 - Automatically generated logs from computer systems
 - Flight connector/harness mate/demate log
 - Bonded storage log
 - Current Configuration log
 - Photographic/videotape logs
 - Red tag/Green tag list (items that are non-flight and need to be removed before flight)

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<http://gdms.gsfc.nasa.gov/gdms> TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

- Description of the Work Order Authorization process
- Discrepancy and failure reporting and record keeping process including problem records, material review board, problem/failure reports (may be defined in other ISO documents)
- Waiver/deviation request process
- Contingency operations and troubleshooting
- Schedule and purpose of I&T meetings including daily, test readiness reviews, pre-environmental testing reviews etc.
- Staffing plans and areas of responsibility for I&T team including:
 - Spaceflight item operators/Test Conductors
 - Instrument System Engineers (if applicable)
 - Subsystem Engineers including Electrical, Mechanical, Thermal, Power, Contamination Control, GN&C, Propulsion, Flight Software, Ground Software, GSE
 - Subsystem Technicians including Electrical, Mechanical, Thermal, Power, Contamination Control, GN&C, Propulsion, Flight Software, Ground Software, GSE
 - Other specialties and staff as required

NOTE: The staffing plan must list the minimum number of personnel (and their technical area of responsibility) required to be present in order for the flight hardware to be powered up for any reason.

- Integration and Test facilities descriptions, capabilities and requirements. Includes trucklocks and loading areas, high bays, GSE areas, office space, space flight item test conductor/operator space environmental test facilities, and launch site facilities. Should include drawings showing equipment layout, cabling, access points, feed-thru and penetration plates. Details of additional requirements, restrictions or capabilities should be included.
- Environmental test facilities descriptions should contain more detailed information about the facilities, equipment layout, and planned testing. Examples of such facilities include, mass properties EMI/EMC, optical alignment, vibration, acoustics, pyrotechnic mechanical shock, magnetics, thermal balance / thermal vacuum, antenna/solar array deployment test area, compatibility test van, propulsion system leak and calibration test.
- Power and Communications Requirements
- AC Power Requirements including number of circuits, voltage and current. Uninterruptable power supply requirements. Must address all I&T locations and facilities.
- Communications links within facilities and between facilities including voice, data, Internet, intercom systems, data lines for mission operations or simulations, closed circuit television.
- Ground Support Equipment Requirements should include size, weight, special heating/cooling/security/safety precautions etc. for all equipment needed in the I&T process. Examples of this equipment include:
- Command generation and telemetry reception equipment

- Spaceflight item power control and monitoring.
- Data recorders including disk and tape archives and stripchart recorders
- Radio Frequency test equipment.
- Interface Simulators
- End-to-end test/mission operations equipment
- Generic test equipment including volt/ohm meters, oscilloscopes, break-out boxes, pyrotechnic testers, optical test equipment, data bus monitors and similar equipment.
- Mechanical equipment including mockups, lifting fixtures, dollies, gravity negation systems, access scaffolding for general and specific I&T activities, protective covers, special fixtures to support specific tests, transportation, shipping containers, basic tools and hardware. Should address space required, safety precautions, certifications and power requirements.
- Battery Support Equipment including status and monitoring equipment, air conditioning, space and power requirements.
- Integration Procedures need to be created for all I&T activities. These should be created by the individual most familiar with the spaceflight item being integrated. Procedures that involve multiple systems or processes under the direction of the I&T Manager should be written by the I&T Manager or designee with input from the systems engineer (if appropriate). The I&T plan shall describe the procedure approval, execution, and problem reporting processes. Procedures need to cover the following types of activities:
 - Mechanical Integration
 - Electrical Integration
 - Data bus Integration (especially if special such as an Optical Data Bus)
 - Functional tests such as short form functional, full functional, aliveness, launch configuration, deployment, pyrotechnic, safety inhibit, pressurization, RF compatibility etc.
 - Integration and Test Process- The Integration process should be described in detail including the objectives, planned flow and activities. Activities that should be described include:
 - Mechanical Integration, Test and alignment
 - Electrical Integration and Test
 - Subsystem Integration and Test
 - Full system acceptance and functional testing.
 - Environmental Testing
 - The environmental testing sequence should be described including staffing, equipment required safety precautions, deviations from flight configuration should be described in detail for all applicable tests. Examples of tests that may be required are:
 - EMI/EMC

- Magnetics
- Thermal Balance / Thermal Vacuum
- Mass Properties
- Vibration Acoustics
- Mechanical Shock
- Any other testing as required by the verification matrix (matrix usually produced the project Quality Assurance group.)
- Other unique tests
- Launch Site Activities should include descriptions of all facilities used by flight hardware and GSE including shipping & receiving, unpacking, cleaning, integration, launch, blockhouse/firing room and hazardous operations areas. Available resources including power, air handling, temperature/humidity controls, communications lines and systems, purge and other gasses, office space, integration space and safety hazards, controls and aid stations should be discussed.
- A launch site activities flow shall be developed that shows the planned integration sequence and configurations, relevant tests, final alignments and assemblies, thermal blanket closeouts, hazardous operations (fueling, installing pyrotechnics) and pre-flight removal of inhibits/safe plugs/covers and other remove before flight items.
- Contingency plans should be written for all phases of the I&T process for items that are determined to be high risk as well as general plans for unplanned events such, late delivery of flight hardware, how to proceed with integration with hardware components missing (for whatever reason, repair etc), GSE malfunctions, restrictions due to weather, flight hardware failures.

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CHANGE HISTORY LOG

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Baseline	10/06/1998	Initial Release