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SATELLITE ASSEMBLY, INTEGRATION AND TEST (AIT)

SYSTEM QUALITY ASSURANCE APPROACHES

– A BRAZILIAN EXPERIENCE

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The Satellite Assembly, Integration and Test (AIT) activities are a logical and interrelated sequence of events. The main objective in this phase of a space program development is to achieve a high degree of confidence that the Satellite complies with its specified performance parameters. In order to reach this goal it implies having not only a very good test infrastructure and a adequate AIT Plan but also a qualified and efficient test team; it is necessary to set forth a AIT Quality Program which applies and coordinates at least the following main points – control of status of test facilities and means of support, strict control to the test execution, formal test analysis and review of test results, ensuring that the Satellite will be free of latent defects.

This process is devised to give confidence that the satellite operational objectives, survival to the launch environment, and correct operation during the designed satellite lifetime can be achieved.

This paper presents a Brazilian experience on AIT quality assurance, at system level, gets through satellite AIT activities executed at Brazilian National Institute for Space Research (INPE) - Integration and Test Laboratory (LIT) – an important satellite testing lab in South America. The paper contains the LIT AIT QA organization; Logbooks and records used, System AIT QA main tasks, Launch Base and GSE related issues, resuming the lessons learned with system AIT QA activities executed with success at LIT with Brazilian and international satellite programs.

INTRODUCTION AND HISTORICAL

BACKGROUND

The National Institute for Space Research – INPE is responsible for development of the Brazilian satellites, the associated ground segment and performs satellite integration and tests activities (AIT) at Integration and Test Laboratory (LIT). This Institute is part of the Ministry of Science and Technology.

The LIT was specially designed and built to accomplish the tasks related to the Brazilian Space Program. The phases of conception, design, construction and implementation of the laboratory took place in the period from 1982 to 1987. In the following years, LIT performed the

complete tests for development and qualification from components to integrated systems, of SCD1, the first Brazilian Satellite in the MECB Program (Brazilian Complete Space Mission) , launched successfully in 1993.

From this date, LIT extended its role the qualification of Brazilian satellites – SCD1 SCD2, SCD2A (data collecting satellites), SAC11 and 2 (scientific satellites), and BRASILSAT B1 and B2 (telecommunications satellites); Argentina satellites SAC-B and C (remote sensing satellites); and China-Brazil satellites CBERS 1 and 2 (remote sensing satellites).

This paper presents the results of all experience that was acquired performing AIT activities on above satellites programs

and in special will focus on the AIT quality work done at system level.

LIT AIT QUALITY ASSURANCE ORGANIZATION

The LIT AIT QA is part of LIT quality management system organization, having the following main responsibilities:

- Prepare the AIT QA Plan;
- Conduct quality control activities during AIT activities;
- Conduct AIT Test Reviews and AIT Test Readiness Reviews;
- Support the satellite program PA Team related to AIT QA.

The LIT AIT QA responsible is the interlocutor before the Satellite Program PA in all subject related to AIT Quality Assurance.

All satellite test/operations are under AIT QA supervision, in case of the occurrence of any satellite system assembly, integration and test anomaly this is addressed by Test Team Responsible to the AIT QA Responsible

The LIT AIT QA activities tree can be divided in 6 branches:

- AIT QA General activities.
- AIT QA Program Reviews support.
- AIT QA Controls.
- AIT QA Assembly, Integration and Testing Phase activities.
- AIT QA Launch Operations activities.
- AIT QA GSE control activities.

LIT AIT QUALITY ASSURANCE PROGRAM

Next items summarize all LIT AIT works performed during satellite integration and test of a satellite.

AIT QA Tasks – General

- **Quality Planning**

AIT Quality planning begins with participation by Quality Assurance personnel in the review of Satellite, PA and AIT general requirements. Review and generation of AIT documentation, and continues through the satellite assembly,

test and delivery phases of the completed hardware and documentation, in accordance with the Project's requirements.

- **Training and Certification**

The AIT Quality assurance control the qualification status of the personnel designated and verify the correct utilization of instructions and procedures applicable to a specific task defined by the respective Technical Responsible, including:

- Safety and security instructions;
- Handling instructions;
- Operational procedures;
- Clean area rules, etc.

- **Change Controls/Configuration Management**

AIT Quality assurance participates in change control by:

- Reviewing and tracking all AIT documentation changes.
- Verifying all approved changes are properly incorporated/implemented.

- **Metrology Controls**

- All electrical, electronic, linear, mechanical, optical, temperature and vacuum/pressure equipment used to determine or verify satellite conformance/acceptability is subject to calibration/certification control. All equipment shall be within the valid calibration period at the time it is used for determination of satellite conformance/acceptability. All test equipment calibration on the Project is controlled in accordance with institutional policies and procedures as a minimum.
- In particular, provisions are made for testing, approval and configuration control of the software involved.

- **Handling, Packaging, Shipping, Conservation Controls**

- The Quality assurance review and approve, prior to their release, all technical documents pertaining to handling, storage, preservation,

- marking, labeling, and packaging operations.
- All equipment or material, whether experimental, flight-type, or ground support equipment, is submitted to Quality Assurance prior to shipment.
- Handling and hoisting or lifting equipment used to handle flight hardware shall be marked to indicate the maximum load capacity and the due date of the next rated or periodic load test. The Quality assurance verifies that the required test and maintenance are accomplished at the specified frequency.
- The Quality assurance verifies that packaging and packing material, procedures, and instructions are correctly used. Special attention is given to critical, sensitive, dangerous, and high valued articles. Reusable containers are inspected prior to each use.
- Quality assurance verify that marking and labeling for packaging, storage, and shipping of articles and materials are in accordance with applicable specifications.

- **Flight Unit Receiving Inspection**

After major transportation, all subsystems, including spare equipment, is subjected to Incoming Inspection Tests.

AIT Quality Assurance responsibilities include the following:

- Inspection of incoming hardware for compliance to applicable drawings, specifications, etc.
- Documenting, segregating, and obtaining disposition of non-conforming hardware and/or material.
- Generating the necessary Inspection Reports to certify hardware inspection.

- **Controlled Storage**

Satellite flight hardware shall be maintained in controlled storage areas. The storage areas have the necessary environmental, security and ESD controls required to meet Project requirements. Access is controlled

and limited to those persons involved in fabrication, test and quality assurance tasks. The controls include the following:

- Limited personnel access;
- Controlled acceptance into and withdrawal from the storage area;
- Positive identification of limited-life material and removal of materials with expired shelf life;
- Periodic inspection of stored material, housekeeping, and record keeping;
- Special environments and systematic maintenance inspection and/or testing necessary to ensure preservation.
- Inventory list of articles in the area;

The Quality assurance verifies that articles and materials subject to deterioration, corrosion, or contamination are preserved by documented methods.

- **Process Control**

- Processes where uniform, high quality cannot be assured by inspection of articles alone, quality assurance implement controls for those.
- These processes include, but are not limited to, soldering, welding, potting, bonding, and surface treating processes.
- These controls assure that special processes are performed by certified personnel; that facilities, equipment, materials, and procedures are adequate, maintained, and properly used; and that records are controlled

- **Nonconforming Treatment**

- A closed-loop system for identifying documenting, controlling, and correcting non-conformances is implemented.
- Each non-conformance is reviewed, dispositioned, and corrective and preventative action taken to prevent recurrence of similar discrepancies.
- AIT Quality Assurance personnel maintain status of all AIT program related non-conformances.

- Non-conformances treatment during AIT follows PA Program requirements.
- **Material Review Board (MRB)**
 - In the event that satellite engineering and AIT Quality Assurance personnel are unable to reach concurrence on a disposition, a Material Review Board is composed.
 - Members of the MRB may consult with other organizations and personnel as required to arrive at optimum decisions.
 - Dispositions that may be made include all those applicable to initial dispositions and any other the MRB may elect.
- **Control of Temporary Removals**
 - The Quality assurance maintain a log of articles or components that are temporarily installed or removed from satellite to facilitate manufacturing, testing, shipping, or handling.
 - The control is initiated upon installation or removal of the first temporarily installed or removed item and shall be maintained through delivery to prevent them from becoming a part of the final configuration.
 - All articles or components that are temporarily installed or removed from satellite are performed per the applicable Quality Assurance and institutional policies and procedures.
- **Record Maintenance**
 - Quality assurance assist engineering in maintaining records that provide evidence of inspections, tests, as-built, configuration and hardware status during all phases of assembly, integration, and test.
 - All records is readily accessible for audit review. The records clearly
- identify the hardware to its assigned Project.
- The Quality assurance verifies that the required test and maintenance are accomplished at the specified frequency.
- **Facilities and Means of Support**
 - The Quality assurance verifies if facilities comply with specifications (grounding, no-break system, security surveillance, etc.) before starting a task with flight hardware.
- **Cleanliness and Contamination Control**
 - The Quality assurance ensure that contaminant-sensitive items are controlled and cleaned, in accordance with documented procedures, to the levels specified in the applicable technical documents and are maintained at these cleanliness levels. These procedures cover hardware, equipment, personnel, and control of areas for fabrication, assembly, inspection, test, and storage.
 - Specific cleanliness levels to be maintained for items shall be indicated in drawings, specifications, or other documents controlling the manufacture and test of those items.
 - Quality assurance ensures that clean room disciplines and procedures are properly implemented and monitored to assure continuing compliance with requirements.
- **Proprietary Material Control**

The Quality assurance ensures that a documented system for controlling INPE property and associated documentation has been established and is maintained as follows:

 - Upon receipt, the QA inspect INPE items to detect damage in transit and to verify that the article and its document package are complete and as specified in the shipping documents.

- Reusable items will be preserved and repacked unless the items are to be used immediately. In case of evidence of damage in transit, the article will be inspected to determine the extent of damage and issue a report of the damage.
- Receiving inspection results will be recorded in the historical record for the article.
- Articles found to be damaged or otherwise unsuitable for the intended use, shall be identified as nonconforming, segregated to the extent practicable, held for review, and analyzed to ascertain the probable cause of damage.

- **Subsystem Acceptance Inspection/Certification Reviews**

Quality Assurance personnel shall participate in and support Subsystem Acceptance Inspection/Certification Reviews. Specifically, AIT Quality Assurance personnel should support the Project PA for the accomplishment of the following:

- Assure submittal to the Subsystem Acceptance Inspection/Certification Review Board of supporting data that reflects the complete quality history of the hardware, which includes inspection status, configuration verification, and MRB activities.
- Assure identification to the Subsystem Acceptance Inspection/Certification Review Board of any and all discrepancies that arise from incomplete certification and/or deliverable documentation requirements.
- Identification of any waivers, deviations or exceptions to established Project requirements.
- Indication, by signature, on the Subsystem Acceptance Inspection/Certification Review Board Review form that the hardware meets the applicable requirements and a satisfactory certification has been obtained.
- Assure an Inspection Report has been generated which denotes inspection acceptance of the

hardware or identifies any discrepancies and their dispositions.

- The Project Manager shall determine satellite hardware that requires Subsystem Acceptance Inspection /Certification Review.

AIT QA Tasks – Program Review Support

Program reviews are conducted as defined in the Satellite Development Plan. The AIT QA participates in these reviews, at a minimum, to extent indicated below:

- **Formal Reviews**

The AIT QA participates in formal reviews by providing information relating to AIT QA tasks performed, resulting accomplishments, risks identified, and future plans, in special on the following reviews:

- Satellite Assembly & Integration Phase Review (Sys AIR) – after finish satellite main assembly and electrical activities – before start satellite environmental testing phase.
- System Acceptance Review (Sys PSR)/Pre-Shipment Review – at the end of AIT activities, before satellite transportation to Launch Site.
- System Flight Readiness Review (Sys FRR) – Satellite ready to launch.

- **Management Reviews**

Management reviews are conducted as defined in the Project Implementation Plan, and Mission Assurance Plan. These typically consist of Weekly Coordination meetings, Monthly Management Reviews, or individual status meetings. The data provided is normally at a much more detailed level than provided at formal reviews.

The AIT QA participates in management reviews by providing information relating to AIT QA tasks performed, resulting accomplishments, risks identified, and future plans.

AIT QA Tasks – Logbooks and Records

The following AIT QA control documents, as a minimum, are used during LIT AIT activities:

- **Satellite Configuration Control Logs**

- [01] **S/C Flight Hardware assembly status log.**

- Satellite flight hardware installation and/or removal control status.

- [02] **S/C Flight connectors mate/demate control Log.**

- Satellite flight connectors mate and demate control status, per subsystem.

- [03] **Thermistors connections status log.**

- Satellite thermistor installation control status and connection to SCS, per subsystem.

- [04] **S/C MLIs installation status log.**

- Satellite MLIs installation control status, per subsystem

- [05] **S/C Flight Units grounding/bonding status log.**

- Satellite units bonding/grounding measurements control status, per subsystem.

- [06] **S/C Controlled screws log.**

- Satellite units controlled screws assembly control status, per subsystem.

- [07] **S/C Flight Mechanisms control log.**

- Satellite flight mechanics utilization control status.

- [08] **S/C Flight Hardware storage status log.**

- Satellite flight storage control status per subsystem and equipment.

- [09] **S/C Non-Flight materials temporary assembling status log.**

- Non-flight item assembling and disassembling status control.

- [10] **S/C Photography Assembly/Test Operation log.**

- Satellite assembly and test operation photography register.

- **Satellite Testing Control Logs**

- [01] **S/C AIT Activities Log.**

- General logbook, with the objective of a daily register of all actions performed, related to space hardware during AIT tasks development.

- [02] **S/C AIT Open points control Log.**

- AIT mechanical, integration, electrical, documentation, etc, open points occurred during all AIT phases.

- [03] **S/C AIT Non Conformances control Log.**

- AIT mechanical, electrical, etc, non-conformances occurred during all AIT phases.

- [04] **S/C AIT Waiver/Deviation/Change control Log.**

- Satellite Engineering change request, waiver request and deviation request sheets occurred during all AIT phases.

- [05] **S/C Special Test Request (STR).**

- Test plan/procedure, and report, concerning non-predicted tasks in the test plan.

- [06] **S/C Configured Flight & Test Software modification Log.**

- Satellite flight software and OCOE/SCOEs configured test software modification/update control log.

- [07] **S/C TRB/TRRBs control Log.**

- TRB/TRRB minutes of meeting reporting preparation activities to run a test and post test results review.

- [08] **S/C Flight Battery charge/discharge control Log.**

- Satellite flight battery charge/discharge cycle control log.

- [09] **S/C Flight Units operation time utilization control log.**

- Satellite units operation time control status, per subsystem.

- **GSE/ AIT Test Facility Control Logs**

- [1] **GSE Equipment Calibration/Certification status Log.**

- Calibration/certification status log of all electrical, electronic, linear, mechanical, optical, temperature and vacuum/pressure equipment

used to determine or verify satellite conformance/acceptability.

[2] GSE Equipment maintenance status Log.

- GSE equipment maintaining records that provide evidence of inspections, tests, as-built, configuration and hardware status during all phases of assembly, integration.

[3] GSE / AIT Test Facility Cleanliness/Contamination status Log.

- Cleanliness / Contamination status log of the equipment, personnel, areas for fabrication, assembly, inspection, and test.

[4] AIT Test Facility Grounding / No Break status Log.

- Grounding / No-Break status log of all AIT Test Facilities.

[6] AIT Materials Proprietary control Log.

- Receiving and withdraw status results of AIT articles will be recorded in the historical record for the material.

● **Equipment EIDP Control Logs**

[1] Equipment Transportation Record.

- Flight Equipment transportation control Log.

[2] Equipment Operation Log.

- Flight Equipment Operation Time control Log.

[3] Equipment Connector Mate/Demate Log.

- Flight Equipment connector Mate/Demate operation control Log.

[4] Equipment Non-Conformance History.

- Flight Equipment Non-Conformance History control Log.

AIT QA Tasks – Satellite Testing

The AIT Quality Assurance provides the necessary support, as determined by the Project to assure a correct and safe system integration and test of satellite models.

AIT Quality Assurance activities during satellite system integration and testing shall include, but not be limited to:

● **Review Test Plan/Procedures**

To verify, as a minimum, the following:

- Consistency of Test Plan and Procedures.
- Stress and boundary testing adequacy.
- Inherited (reuse) software is tested in the project environment, and that new interfaces have been verified.
- Fault Protection Functions are adequately tested, including failure modes.
- All of the requirements are adequately tested by the procedure.
- The procedure steps shall be sufficiently detailed that they can be exactly repeated.
- The results of each step are sufficiently detailed that a Pass/Fail is apparent.
- Provide assessment of the Hardware Configuration Management process to verify the hardware version being tested is under configuration control.
- Verify the configuration of the Test Environment is as specified in the Test Plan/Procedure.

● **Perform Test Readiness Review**

- Assess the configuration and readiness of the items to be tested.
- The readiness of the Test Plan and Test Procedures.
- The validity of the Functional Test Pass/Fail Criteria.
- The readiness of test facilities, test equipment, and test resources.
- The Anomaly/Problem Status - review the status of non-conformances and verify that open non-conformances have no impact whatever on the validity of the test.
- Problem Failure Reports, are initiated when required and within the required time frame.
- Review and eliminate or reduce and control hazards, which may exist for the respective test.
- All applicable specifications and procedures have been properly authorized prior to use, and all deviations/waivers from the

- specifications and procedures are authorized.
- Notify PA program when its test observation is required
- The test area is controlled to the extent necessary to protect the test article from damage or degradation.
- Requirements governing safety, handling and storage, calibration, cleanliness, and environmental controls are followed.
- Test equipment and support instrumentation are within current calibration cycles, and identified in the test data. Verify also that all personnel certification, if applicable, is valid.
- Fixture evaluations, as evidenced by documentation, meet the requirements of the applicable specifications.
- The Environmental Test Authorization has been approved, completed, and signed by the required Project personnel.
- Facility, Operational and ESD surveys have been completed.
- Test data and acceptance criteria shall be documented.
- Safety, hardware handling and required storage provisions are in effect.
- Contamination control and environmental control requirements are followed
- Procedural and specification changes are properly documented.
- **Perform Test Monitoring**
 - Monitor the development effort to verify that defined processes and standards are being followed.
 - Verify that testing is performed in accordance with approved test procedures
 - Verify that procedure deviations are recorded,
 - Verify that test data are accurately recorded, and that all non-conformances are documented
- **Perform Post-Test Hardware Inspections**

Post-Test Hardware Inspections shall be performed to detect and document the

condition of the hardware after environmental testing, with emphasis on documenting discrepancies that may have resulted from the testing.

The Project Environmental Engineer shall review significant discrepancies to determine the retest requirements.

- **Perform Test Review**
 - Review test data packages and logbooks and verify the results from the intermediate test data evaluation;
 - Ensure the completeness of all test data and the adequacy of decisions due to non-conformances;
 - Define the acceptance of the test;
 - Grant readiness to initiate the next AIT task.

AIT QA Tasks – Launch Operations Activities

The Quality assurance provides the necessary support, as determined by the Project to assure a correct and safe integration of Satellite with the Launch Vehicle. Quality Assurance activities include, but not are limited to:

- Post-transportation inspection.
- Performing and documenting necessary inspections.
- Perform test readiness review and verify if all action items have been closed or dispositioned as “OK to Proceed”.
- Surveillance and monitoring of all satellite required hardware and software integration/functional testing.
- Perform Test Review.
- Assure Program Handling Constraints are clearly identified and complied with integration procedures.
- Monitoring and ensuring Spacecraft/Payload contamination control procedures are followed.
- Verification of compliance to procedures and requirements regarding Spacecraft/Payload in preparation for Launch Vehicle integration.
- Participation in Launch Vehicle Integration Readiness Reviews.
- Surveillance of Satellite/Launcher testing.
- Participation in Satellite Flight Readiness Reviews.

AIT QA Tasks – Ground Support Equipment

Quality Assurance involvement in Ground Support Equipment (GSE) includes, but not is limited to:

- Flight hardware interfaces, mechanical and/or electrical, are compliant to requirements.
- Ensure that test equipment, including computer-aided testing techniques and data are validated prior to use and controlled during their use in testing.
- Current calibration of Electrical GSE.
- Current proof-load of Mechanical GSE.
- Cleanliness and contamination control requirements are compliant.
- Proper and legible identification of the product.
- Safety requirements are satisfied and potential hazards are identified.

AIT QA DOCUMENTATION

The QA AIT documentation structure that is used during satellite AIT activities is described on next items.

- **AIT QA Plan**
The AIT QA Plan describes all QA activities planned to be an integral part of satellite AIT. It presents the QA structure, procedures, and the tasks to be performed according to Program PA requirements.

- **AIT QA Procedures**
AIT QA procedures describe the methods to assure availability, accuracy, and validity of data and supplemental information to follow the development of AIT tasks, and the methods for treatment of quality problems.

- **AIT QA Controls, Logbooks, Registers and Reports**
These are the mechanisms used to present the results of the Quality Control (QC) activity, providing objective information for AIT management actions and for an historical register of satellite AIT.

CONCLUSIONS

The LIT AIT quality assurance process described on previous items reflects the lessons learned during the execution of the AIT activities on Brazilian satellites at LIT and it was consolidating during the CBERS 2 AIT activities performed at LIT during 14 months - 2002/2003. This satellite was successively launched in 2003 and right now this process is been executed again on CBERS 2B satellite.