वै गु आ   निर्देशिका

सॉफ़्टवेयर के लिए

स्वतंत्र सत्यापन और विधिमान्यकरण (भू उपस्कर)

AQA DIRECTIVE

ON

SOFTWARE INDEPENDENT VERIFICATION AND VALIDATION

(GROUND EQUIPMENT)

अंक-1, संशोधन-0, नवम्बर 2023
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वैमानिक गुणवत्ता आश्वासन महानिदेशालय

भारत सरकार, रक्षा मंत्रालय
'ए' ब्लॉक, सातवीं मंज़िल, रक्षा कार्यालय परिसर
कस्तूरबा गाँधी मार्ग , नई दिल्ली- 110001

DIRECTORATE GENERAL OF
AERONAUTICAL QUALITY ASSURANCE

GOVERNMENT OF INDIA, MINISTRY OF DEFENCE,

PREFACE

DGAQA as regulatory authority for Quality Assurance and Final Acceptance of military aviation stores during design, Development, Production, Manufacture/ Repair/ Overhaul/ up-gradation/ modification/ life extension etc. at various DPSUs/OFs/DRDO Labs etc. have encountered number of issues related to software quality assurance & validation.

2.   All the systems are now software based as received and felt for having requisite guidelines on Independent Verification and Validation of software which plays a predominant role in the design and development of Airborne and related Ground Equipment. A well-defined procedure for carrying out IV & V will enhance in achieving defect free software in the equipment it resides and to avoid flight safety ramification.

3.   Military aviation production agencies must produce and continually improve safe and reliable stores that meet customer and regulatory requirements thereby assuring customer satisfaction.

4.   This AQA directive is issued for general guidance during Quality Assurance activities of software residing in Test Rigs, Tools, Testers, Ground Equipment and Simulators.

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(संजय चावला)
महानिदेशक, वै. गु. आ.

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LIST OF AMENDMENTS

Sl No	Amendment No	Date of Amendment	Brief of Amendments	Authority

Table of Contents

Acronyms

ATP / R	Acceptance Test Procedure / Report
CCB	Configuration Control Board
CEMILAC	Centre for Military Airworthiness and Certification
CFE	Customer Furnished Equipment
COTS	Commercial-off-the-shelf
CSCI	Computer Software Configurable Item
DDPMAS	Design, Development & Production of Military Air systems & airborne Stores
D&D	Design and Development
DGAQA	Directorate General of Aeronautical Quality Assurance
ENTEST	Environmental Test
FDA	Flight Data Analysis
FTI	Flight Test Instrumentation
GOS	Ground Operating System
GSQR	General Staff Qualitative Requirements
GSS	Ground Support System
HATS	Hardware Acceptance Test Software
HLD	High Level Design
HSI	Hardware Software Integration
IV&V	Independent Verification and Validation
JSQR	Joint Services Qualitative Requirements
LLD	Low Level Design
PFMG	Pre Flight-Message Generator
PSQR	Preliminary Services Qualitative Requirements
QT	Qualification Tests
SCI	Software Configuration Index
SCMP	Software Configuration Management Plan
SCN	Software Change Note
SCR	Software Change Request
SDD	Software Design Description/Document
SDLC	Software Development Life Cycle
SDP	Software Development Plan
SDS	Software Design Standards
SECI	Software Life Cycle Environment Configuration Index
SoFT	Safety of Flight Tests
SQA	Software Quality Assurance
SQAP	Software Quality Assurance Plan
SQR	Services Qualitative Requirements
SRD	Software Requirement Data/Document
SRS	Software Requirement Specification
STLC	Software Test Life Cycle
STP	Software Test Plan
STR	Software Test Report
SVP	Software Verification Plan
SVR	Software Verification Results
SyRD	System Requirement Data/Document
TAA	Technical Airworthiness Authority
TTGE	Test Rigs and Tools, Testers & Ground Equipment
V&V	Verification and Validation
VDD	Version Description Document

1. Introduction

Verification and Validation (V&V) is a system engineering discipline which helps design & development organization to build quality into the system/software during the system/software life cycle. Verification is concerned with checking that the system is well engineered and Validation is concerned with checking that the system/software meets the user needs. Independent Verification and Validation (IV&V) is the process of checking that a product, service or system meets specifications and that it fulfills its intended purpose. IV&V services must be provided, managed and financed by organizations that are technically, managerially and financially independent of the design and development organization.

IV&V is a "Process" as well as "Product" oriented activity. It is viewed as performing a "Technology Audit" by QA regulatory bodies with a focus on safety aspects.

2. Scope

This document gives an outline of IV&V processes and QA activities involved during the Design and Development of Software/Firmware used in Ground equipment, Rigs, Simulators, Ground Test equipment of Airborne Stores. This document shall be read in conjunction with DDPMAS and in case of conflict the later shall take precedence.

3. Objective

This document provides an overview of IV&V activities and the associated role of DGAQA. The document also briefs the role of DGAQA when the software is developed by following DO-178C/ DO-278 standards. The primary objective of an IV&V activity is to provide an objective assessment of products and processes throughout the project life cycle. In addition, IV&V will facilitate early detection and correction of errors, enhance management insight into risks and ensure compliance with project performance, schedule and budget requirements.

4. Types of Software

Airborne Embedded Software is customized/ specialized software meant to control the airborne hardware to carry out specific assigned tasks, for example Mission Computer Software, Air Data Computer Software, customized Operating System etc. Clearance of such software including its SDLC documentation and ground system software which controls such airborne equipment is given by CEMILAC on the basis of IV&V report examined & coordinated by all stakeholders namely system experts, domain experts, testing experts including DGAQA rep. (Chapter 21.C.6 of IMTAR-21 Version-2.0)

Software Criticality

i. **Critical Software**: The software whose malfunctioning may affect safety, reliability, maintainability, interchangeability and operational effectiveness is termed as critical software. Example: HUMS software, Aircraft simulator software, IFF encryptor software loader, FADEC etc.

ii. **Non-Critical Software**: The software which is not classified as critical and if it's malfunctioning will not affect the safety of the aircraft/crew or the execution of the mission then such software is termed as non-critical software Example: Ground tester software, TTGE software etc.

5. Flow of activities in V&V and IV&V Process

Figure below is a V- model of software development life cycle, which shows verification and validation activities are part of every stage in the SDLC and STLC process.
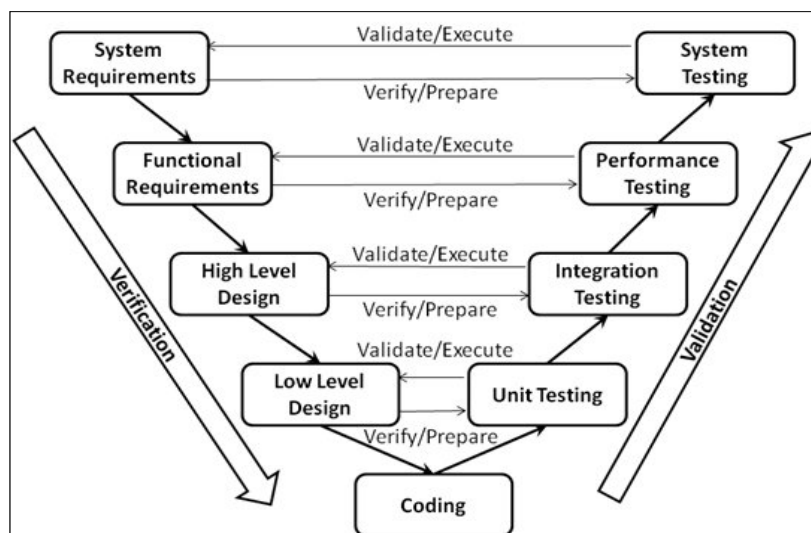
SDLC / STLC V-Model

Difference between Verification and Validation

Verification	Validation
Verification includes checking documents, design, codes and programs.	Validation includes testing and validating the actual software product.
Verification is the static testing.	Validation is the dynamic testing.
It does *not* include the execution of the code.	It includes the execution of the code.
Methods used in verification are reviews, walkthroughs, inspections and desk-checking.	Methods used in validation are Black Box Testing, White Box Testing and non-functional testing.

It can find the bugs in the early stage of the development.	It can only find the bugs that could not be found by the verification process.
V&V/ IV&V team does verification and DGAQA oversees the task	Validation to be done by IV&V/ IV&V team in coordination with DGAQA.
Verification comes before Validation.	Validation to be carried out after the verification of each SDLC phase.

6. Involvement of DGAQA and other stake holders in IV&V during SDLC Activities

SI #	SDLC Phase	Activity	Responsibility	Remarks
1	System or User Requirements	System/User Requirements Document (SyRD/URD) DO 178, IEEE 12207, DSSD or any other process acceptable to RCMA/ CEMILAC (21.C6.1.7-b of IMAP)	This document is submitted by the User to the Main Contractor.\n\nUsing SyRD Designer will prepare SRD and SDP documents and Test Team prepares ATP/STP document.	For example, GSQR, ASQR, JSQR etc. Approval of STP (ATP) is by CEMILAC/ DGAQA, as applicable
2	Software Quality Assurance Plan (SQAP)	Includes SQA activities as per the provided template	This document is prepared by the Main contractor / D & D Agency QC/QA team	Approved by DGAQA.
3	Software Configuration Management Plan (SCMP)	Includes Configuration identification, Baselines and traceability, Problem reporting, change control, Change review, Supplier control, Archive, retrieval, and release	This document is generated by the designer team approved by CEMILAC Design Categorized under DOA (Design Organization Approval) and approved by CEMILAC/DGAQA (as applicable).\n\nMain Contractor shall use configuration management tools/applications to manage the activities mentioned.\n\nVDD is generated as part of SCMP by design team.	Changes in software configuration shall be controlled through SCR and SCN. The VDD Document/SCM tool shall be made available to DGAQA for verification.
4	Software Requirements Specification / Document (SRS/SRD/VDD)	User Requirements are technically specified in detail.	This document is generated by the designer team and reviewed by IV&V team (SRS approval not required for COTS and legacy TTGEs)	CEMILAC approves this document.

Sl #	SDLC Phase	Activity	Responsibility	Remarks
5	Code Walk-through	Check if the the coding of Test rigs/TTGEs 1) is done in line with established coding standards/practices 2) exactly meets the specifications laid down by SRS, SDD, Interface control documents etc.	Code to be generated by design team & reviewed by IV&V team in coordination with DGAQA.	SRS to be approved by CEMILAC
6	Unit Testing, Integration and Functional Testing documents	Unit Test cases, Integration test cases and Functional Test Cases are developed by Test Team	I V&V team prepares and approves this document	SDD, HLD, LLD and testing documents shall be made available to DGAQA while witnessing the tests.
7	Software Test Plan (STP) (Also called Requirements Based Testing (RBT))	Includes test environment/test-setup, testing method, traceability and coverage analysis as applicable. Verifies that the delivered system meets User's requirement and system is ready for real world use.	This document is generated by the IV&V team for configuration-controlled software with a registered Checksum* and Version. Registered checksum should be a part of the STP document and is verified before starting the tests	DGAQA approves this document, as applicable. DGAQA compares the registered checksum of the software with the generated checksum.
8	Software Test Report (STR) Software Quality Assurance Report (SQAR)	Includes the executed test cases and respective results. Prepared by QA team to bring out compliance to the SQAP.	STR is generated by the IV&V team SQAR is generated by main contractor QA team	DGAQA approves this document.

• Main Contractor shall constitute V&V team for non-critical software and IV&V team for critical software for the verification and validation of the all types of software. **Test Rig and Type-C TTGE software**. IV&V team shall consist of system experts, domain experts, testing experts from relevant stake holder of D & D organizations (like Design groups of ADA, HAL, BEL etc.), CEMILAC and DGAQA representatives.

- IV&V team shall carry out IV&V planning, carry out independent reviews, analysis verification, testing reporting activities and participate in Software review meetings, during the various phases of Software life cycle.

- DGAQA ensures proper IV&V / V&V throughout the SDLC/STLC phases.

- V&V process at various stages of Software Development Life Cycle (SDLC) is carried out in two-tier configuration - first by in-house V&V team (System experts & Domain experts of main contractor) and then by IV&V team (System experts, Domain experts of main contractor, IV&V rep, CEMILAC rep, DGAQA rep etc.) based on the criticality level of the software.

- The criticality level of the test rig used for a subsystem of an Air System or an Airborne Store shall be arrived at based on the criticality level of such subsystem/Airborne Store.

- An IV&V plan shall be made specific to the project after identifying the criticality of the software.

- Designer V&V activities for any phase shall be completed before delivering the products for IV&V activities. Designer V&V reports shall be provided to IV&V.

- The Test Rig/Simulator/TTGE software shall be developed and tested in accordance with an established Software Development Life Cycle Process in coordination with DGAQA.

- Modified and incremental versions of the software shall also be reviewed based on regression testing or change Impact Analysis as applicable by IV & V Team.

- Ensure that Development and Testing Tool Verification/Qualification, Compiler Validation, Object Code Verification (OCV) are addressed.

- Software shall follow a systematic design, development, testing and certification based on its criticality and the software should be under configuration control and should have a checksum.

- Ensure complete dynamic real time testing of the software on a "Certified/Approved Test Rig".

- IV&V recommendations will form an essential input to **CEMILAC** and **DGAQA** for clearance of software based on its criticality.

- DGAQA may delegate the Verification & Validation responsibility of software to IV&V/ approved inspector of SQA group of the Main Contractor depending on the criticality of software under DGAQA-AFQMS approval.

* **Checksum** is like a digital finger print of a file or code. It's a calculated value, made of numbers and letters, and is used to verify the integrity of a file. The registered checksum of a file or code generated originally is compared with the presently generated checksum before using the software (code) for testing, to ensure the right version is being used.

7. Software Configuration Management

Main Contractor shall establish and implement a means by which the configuration of the CSCI/Software artifacts (including documentation, source code, executable code, other records etc.) is managed over the product life cycle to ensure its continued life support. The Software which is uniquely identified (name, version and checksum) and archived through a configuration control process only shall be cleared for integration on Test Rigs/Simulators/TTGES or delivery to User Services. The configuration management includes processes by which the configuration is identified, change is managed and configuration status is accounted and disseminated to all stakeholders. Verification/Audit of configuration status is conducted by DGAQA.

Software and its associated documents should be under configuration control preferably by using tools to establish its integrity. If tools are used, version of source code and documents is done automatically by the tool else the diagram below which is self-explanatory can be the guidelines for version.
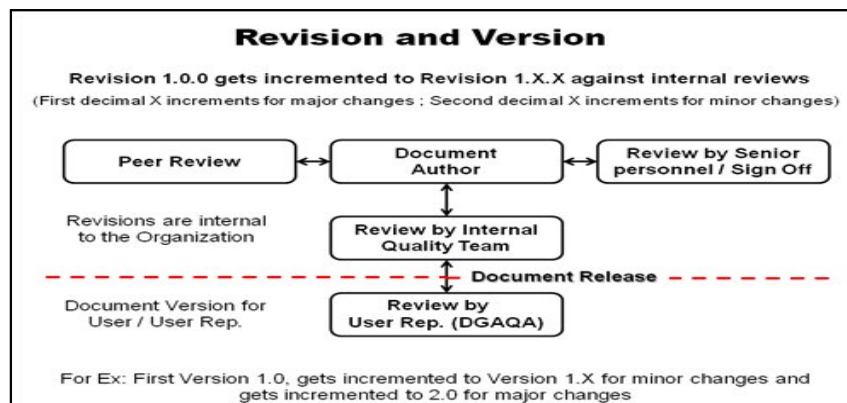
Problem Reporting and Change Tracking: All the problems/failures or changes encountered during the development and testing phase should be documented, analyzed and resolved to its closure by following the approved process mentioned in SCMP.

Any change to the source code of software shall be controlled through Software Change Requests (SCRs) and Software Change Notes (SCNs). For the software bug/problem reported, SCR will be initiated by the Design team and, if required, CCB may be convened. The SCR approved by Main Contractor QA will be provided to DGAQA, for the approval of SCN, as applicable.

Artifacts under Software Configuration Management (SCM) Control
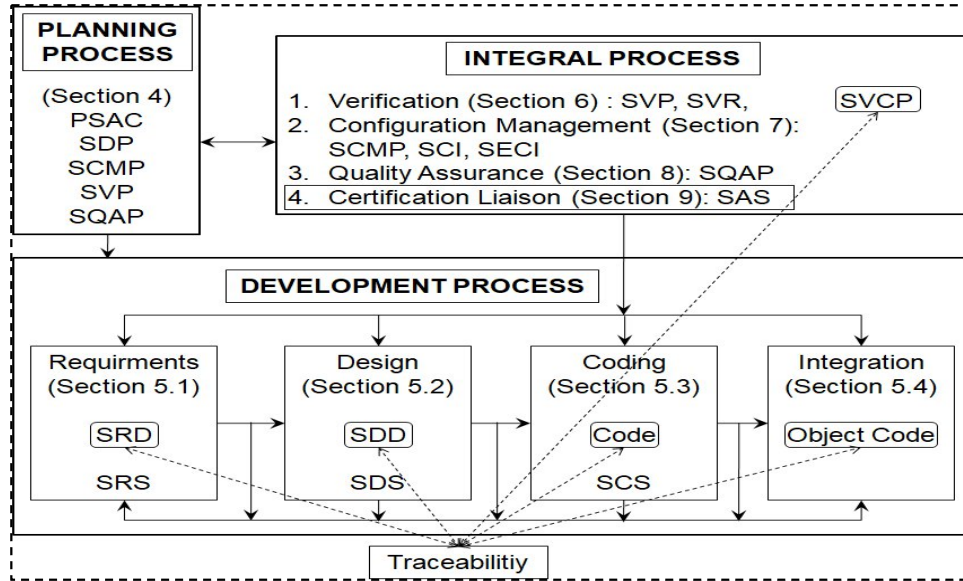
Artifacts under SCM

•   The software planning process defines and coordinates the activities of the software development and integral processes.

•   The software development processes produce the software products/artifacts.

•   The integral processes ensure the correctness, control and confidence of the software life cycle processes and their outputs.

•   These artifacts are as per RTCA DO-178C Standards and may vary depending on the software standards followed.

Testing activities as per DO-178C Criticality Levels, A to D as shown in table below-

Testing Activities as per RTCA DO-178C Criticality Levels A - D	
Criticality Level D	• Review High and Low Requirements • Test High Level Requirements
Criticality Level C	• Same as Level D, Plus • Test Low Level requirements • Statement Coverage • Verify Data and Control Coupling
Criticality Level B	• Same as Level C, Plus • Target Hardware / Platform Testing • Decision Coverage
Criticality Level A	• Same as Level B, Plus • Modified Condition – Decision Coverage

8. Software certification/Clearance Methodology

The main contractor should submit the system/software life cycle artifacts/documents. The artifacts involve both "Process" and "Product" documentation.

Process Documentation – Verification (Not limited to the following reports/documents)
- Planning Documents (e.g.: SQAP, SCMP, STP etc.) as detailed in Table 3
- Audit reports and Meeting Points, as applicable

Product Documentation – Validation (Not limited to the following reports/documents)
- Software development phase artifacts as detailed in Table 3
- Software testing phase artifacts as detailed in Table 3
  - Unit Testing, Integration Testing and System Testing
    - User Manuals
    - Maintenance/Trouble shooting Manuals
    - System/Software Admin manuals

DGAQA after ensuring the above Process and Product compliance requirements shall issue the clearance certificate, as applicable.

9. Software/Product/System Validation

Software/Product/System validation is concerned with checking the user requirements with the deliverable. This aspect can be established by tracing the customer requirements to the test cases (forward traceability) and also by tracing the test cases to the customer requirements (backward traceability) and record the same. All the test cases must "Pass" without any unacceptable deviation. This should be addressed in STP/STR document and should be concurred by DGAQA. Validation of the product i.e., **delivery of "Right Product" to the User is a very important activity of DGAQA.**
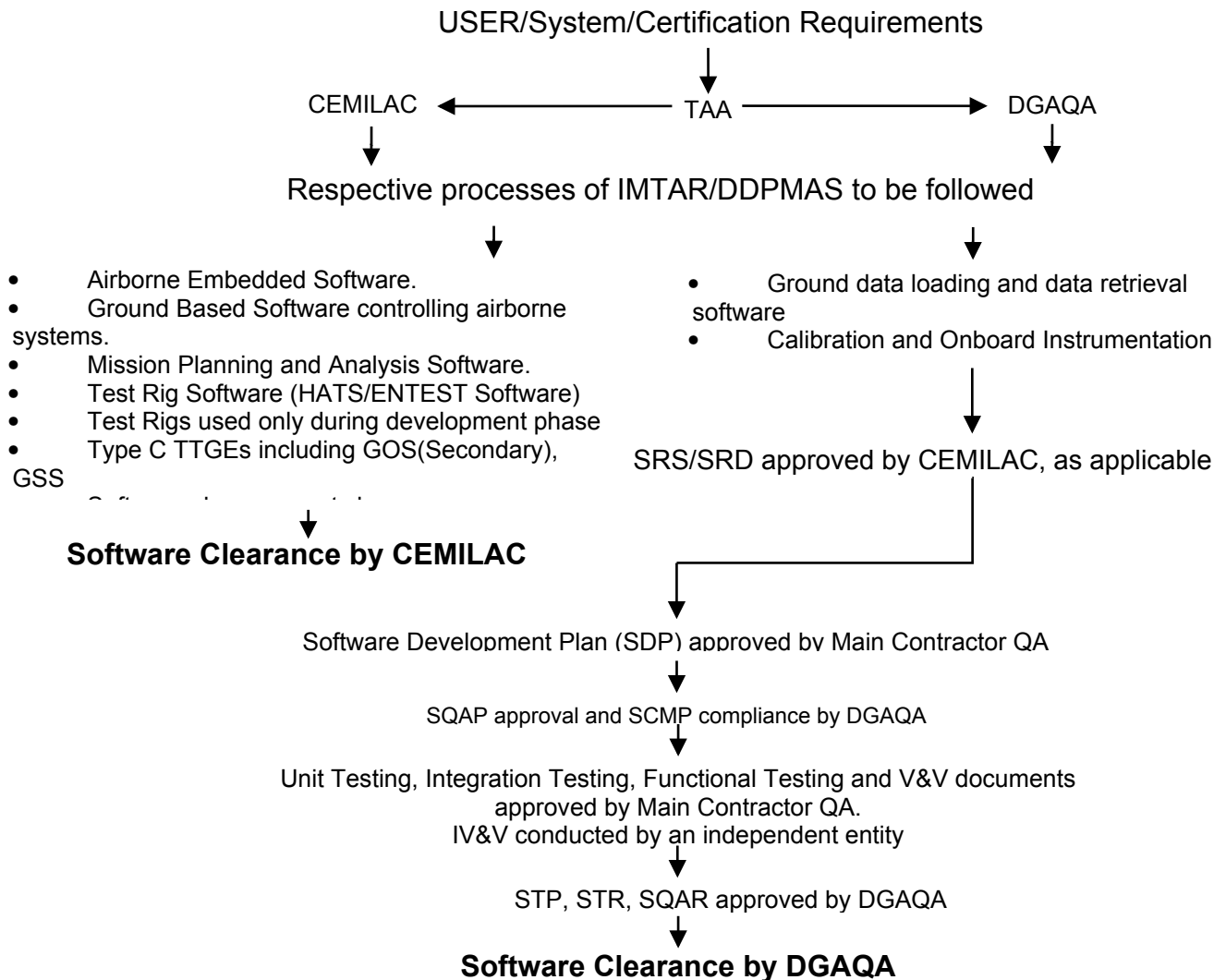
The entire documentation starting with the Software Requirement, Specification, Software Design, Software Functionality, Software Integration, Software Testing, Software Maintenance etc., should be described in respective artifacts and should be formally reviewed before submitting it for clearance to CEMILAC and DGAQA.

10. Software Approval Authority

The approval agency against each type of software are as shown below-

Sl.	Types of Software		Approved by
1	Clearance of Airborne Software: (21.C6.3.1-b of IMTR Ver 2.0) Hardware Acceptance Test Software (HATS) Software: This resides in the airborne equipment only during the Qualification/ Acceptance tests to validate all hardware resources and works in tandem with the test rig software. This software will be disabled / erased, as applicable, before providing the LRU to User Services.		CEMILAC
2	Clearance of Test Rig Software (for Airborne items)/ HSI Software/ Simulation Software (21.C6.3.2 (g) & 21.T2.5 of IMTR Ver 2.0) and GCS software of UAVs		CEMILAC
3	Software residing in TTGEs: (21.T2.3 of IMTR Ver 2.0: Categorization of TTGEs)	Type A and Type B (21.T2.9 of IMTR Ver 2.0) E.g., Licensed procurement of the shelf etc.	Approved Designer QC. (Acceptance based on CoC)
		Type C (21.C6.3.5 & 6 Maintenance and Pilot Crew Training Software clearance by DGAQA) Indigenous design development of the software for the ground system. E.g., GOS(Secondary) and GSS, Mother Fill Gun and Child Fill Gun for Cripto unit of IFF etc. #	Designer QC/ DGAQA
		# Ground data loading and data retrieval software (Only SRS Approval by CEMILAC)	DGAQA

Flow chart on role of TAA during SDLC/STLC

USER/System/Certification Requirements

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CEMILAC ←——————→ TAA ————————→ DGAQA

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Respective processes of IMTAR/DDPMAS to be followed

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- Airborne Embedded Software.
- Ground Based Software controlling airborne systems.
- Mission Planning and Analysis Software.
- Test Rig Software (HATS/ENTEST Software)
- Test Rigs used only during development phase
- Type C TTGEs including GOS(Secondary), GSS

- Ground data loading and data retrieval software
- Calibration and Onboard Instrumentation

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SRS/SRD approved by CEMILAC, as applicable

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Software Clearance by CEMILAC

Software Development Plan (SDP) approved by Main Contractor QA

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SQAP approval and SCMP compliance by DGAQA

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Unit Testing, Integration Testing, Functional Testing and V&V documents approved by Main Contractor QA.
IV&V conducted by an independent entity

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STP, STR, SQAR approved by DGAQA

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Software Clearance by DGAQA

11. Conclusion

This directive gives a general guidance on software QA activities to be followed during software Quality Assurance activities with special emphasis on IV&V that may be uniformly followed. Suggestions / Improvements, if any, may please be forwarded to Director (IT) HQ DGAQA.

12. References

- Framework and Procedure for Design, Development and Production of Military Air Systems & Airborne Stores, Version 1.0
- Indian Military Technical Airworthiness Requirements IMTAR, IMAP
- Software Considerations in Airborne Systems and Equipment Certification – DO178C
- Guidelines for Qualification Test Procedure & Acceptance Test Procedure of ground Equipment/Test equipment (jigs) for Airborne items (electrical & electronic)- AQA directive issued on January 2015
- Open literature available on the subject in public domain.
- JSG: 0811

नोट: नवीनतम अद्यतन मानकों, प्रौद्योगिकी आदि के साथ दस्तावेज को बेहतर बनाने के लिए सुझाव, यदि कोई हो । इसे अग्रेषित किया जा सकता है:

Note: Suggestion, if any, to improve the document with latest updated standards, technology etc. may be forwarded to:

निदेशक (सूचना प्रौद्योगिकी) , वैमानिक गुणवत्ता आश्वासन महानिदेशालय रक्षा मंत्रालय, सातवीं मंजिल, "ए" ब्लॉक, रक्षा कार्यालय परिसर, कस्तूरबा गांधी मार्ग, नई दिल्ली -110001 ईमेल आई.डी: dirit.dgaqa@gov.in	Director (IT), Directorate General of Aeronautical Quality Assurance, Ministry of Defence, 7th Floor,`A' Block, Defence offices Complex, K G Marg, New Delhi-110 001 Email ID: dirit.dgaqa@gov.in