NATO STANDARD

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IFF MARK XIIA and Mode S INTEROPERABILITY TEST GUIDANCE

Edition A Version 1
SEPTEMBER 2019

NORTH ATLANTIC TREATY ORGANIZATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

26 September 2019

1. The enclosed Allied Electronic Publication AEtP-12, Edition A, Version 1, IFF MK XIIA and MODE S INTEROPERABILITY TEST GUIDANCE, which has been approved by the nations in the Consultation Command and Control (C3) Board, is promulgated herewith. The recommendation of nations to use this publication is recorded in STANREC 5647.

2. AEtP-12, Edition A, Version 1, is effective upon receipt.

3.

4. This publication shall be handled in accordance with C-M(2002)60.

Zoltán GULYÁS
Brigadier General, HUNAF
Director, NATO Standardization Office

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RESERVED FOR NATIONAL LETTER OF PROMULGATION

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

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1 INTRODUCTION

The Mark XIIA IFF system is recognized to be significantly more complex than its predecessor system. Therefore, it is reasonable to be concerned that diverse equipment, developed by different vendors across several NATO nations, may fail to be interoperable in some way. For this reason, the IFF Mark XIIA Interoperability Test Guidance was developed that provides the background and the references required to conduct a comprehensive interoperability testing programme for Mark XIIA IFF equipment.

IFF is used between platforms, i.e. aircraft, ships, and ground-based radars, to identify friends and thus to prevent fratricide. Therefore, this Test Guidance will start from the national platform acquisition process to define a verification process that will ensure IFF Mark XIIA interoperability at the platform level and at the lower integration level, i.e. box level.

In order for the nations using IFF Mark XIIA to rely on the interoperability of various national IFF systems, the IFF equipment validation of each nation has to be of sufficient quality. This NATO Test Guidance together with the NATO Test Requirements (Annexes A-F) and Certification policy (Ref. A) supports national testing and certification.

1.1 Interoperability strategy and reference documents

This Test Guidance is one of the NATO reference documents for the IFF Mark XIIA system. These reference documents were developed as part of an interoperability strategy that is described in an Interoperability Strategy paper (Ref. B). In this strategy paper the organisations, the roadmap, and the tasks to assure IFF Mk XIIA interoperability within NATO were identified. The Interoperability Strategy paper and the NATO IFF Mark XIIA reference documents are described in this section.

According to the Interoperability Strategy paper, there are a number of organisations that play a key role in the development and interoperability of IFF Mark XIIA. The organisations mentioned in the Strategy Paper have not changed, but some name changes have occurred. The following organisations are involved:

- NATO C3 Board
- NATO CP/2 IFF CAT
- NATO organisations: NCI Agency, NSPA, ACO, and ACT
- NATO security and key distribution organisations: SECAN and DACAN
- National product development organisations
- National procurement organisations
- National security and key distribution organisations

Most if not all of these organisations have a role to play in the interoperability testing of IFF equipment as described in this IFF Interoperability Test Guidance. Note that this role can vary from facilitating platform tests in large test campaigns, providing key distribution, specifying test requirements, certifying IFF equipment, to performing bench and platform tests.

Many parts of the Strategy Roadmap have been realised. For the IFF Interoperability Test Guidance, the following Strategy Roadmap milestones are of particular importance:

- STANAG 4193 Edition 3 has been promulgated (Ref. C)
- STANREC 5635 AEtP-11 Edition 2 has been produced and agreed by NATO C3B (Ref. D)
- NATO Identification Security Classification Guide has been produced and agreed by NATO C3B (Ref. E)
- NATO Mark XIIA IFF Mode 4/5 Key Management Plan has been produced and agreed by NATO C3B (Ref. F)
- NATO Identification Security Classification Guide has been produced and agreed by NATO C3B (Ref. G)

The realisation of a NATO Interoperability Test Guidance was also part of this roadmap. This Test Guidance document is the outcome of that task.

There is a document on System and Performance parameters (Ref. H) that is useful in the context of interoperability testing as it provides a set of definitions. These definitions, which help in a common understanding and a more effective cooperation between nations, commands, agencies, and staffs, consist of:

- Harmonized definitions and descriptions of test and simulation parameters (parameters required to model an SSR or IFF interrogator, transponder, for the quantification of transponder, interrogator and system performance).
- Definitions and descriptions for a minimum set of test and simulation parameters and information, which intend to quantify signal load and system performance.
- Definitions of the most important parameters output by simulations, quantifying signal load and performance of civil SSR and military IFF systems.

1.2 Scope of Test Guidance

This IFF Test Guidance document provides the background and the references required to conduct a comprehensive interoperability testing programme for the Mark XIIA IFF systems. Note that an acquisition programme of IFF transponders, interrogators, or integrated platforms has to deal with many more aspects than interoperability:

- Price
- Performance
- Form, Fit, and Function
- Reliability
- Maintainability

However, interoperability has to be a central theme in the acquisition process. Therefore, the role of interoperability verification and validation in the acquisition process is treated in the next chapter.

The scope of this document is the IFF Mark XIIA interoperability testing, which is a challenging one since it requires cooperation between the nations and/or manufacturers. Interoperability testing and especially cooperative multinational testing is instrumental in assuring interoperability of IFF equipment produced by different vendors and nations.

This document provides a description of the purpose and the environment to ensure IFF interoperability through testing. It describes the framework necessary to support the development of IFF Mark XIIA systems, strategy and standards required to demonstrate the interoperability between systems compliant with STANAG 4193. It includes several tools aiming at helping nations and vendors to demonstrate and validate interoperability. It also provides a general description of the necessary testing phases from bench testing to flight tests for the verification of compliance with STANAG 4193 requirements and AEtP-11 recommendations. This includes a description of the process required to evaluate the interoperability and to certify the systems at both the end item (box) and the integrated platform level.

1.3 Structure of the Test Guidance document

Chapter 2 describes in a general sense the acquisition process of platforms that are equipped with IFF Mark XIIA. Note that this acquisition process is not specific to IFF equipped platforms. This chapter shows that the IFF interoperability test can be naturally split into box-level and platform-level tests as is shown in the NATO Test Requirements documents published as AEtP-12.1 to AEtP-12.9:

NATO IFF Test Requirements – Transponder – Box (NR)	AEtP-12.1
NATO IFF Test Requirements – Transponder – Box – Add1(anti-jam) (NS)	AEtP-12.2
NATO IFF Test Requirements – Transponder - Platform Integration (NR)	AEtP-12.3
NATO IFF Test Requirements – Transponder – Flight (NR)	AEtP-12.4
NATO IFF Test Requirements – Interrogator – Box (NR)	AEtP-12.5
NATO IFF Test Requirements – Interrogator – Box – Add1(anti-jam) (NS)	AEtP-12.6
NATO IFF Test Requirements – Interrogator – Box – Add2 (evaluation) (NS)	AEtP-12.7
NATO IFF Test Requirements – Interrogator - Platform Integration (NR)	AEtP-12.8
NATO IFF Test Requirements – Interrogator – Flight (NR)	AEtP-12.9

Chapter 3 describes the verification process and documentation in more detail.

Chapter 4 describes the use of cryptography in the interoperability testing of IFF Mark XIIA.

2 ACQUISITION PROCESS

2.1 Best Practices

All NATO nations that acquire IFF Mark XIIA equipped platforms use a process that runs from top-level capability requirements to bottom-level detailed design and components to achieve top-level system validation. This V-shape process is illustrated in Figure 1.

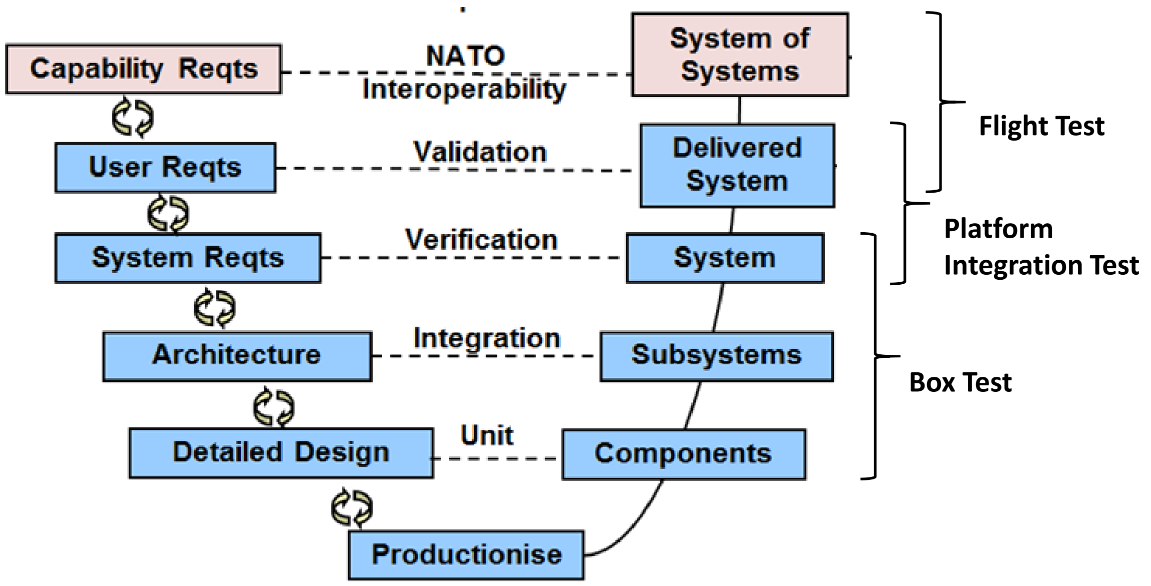

Figure 1: General acquisition process in V-shape.

This V-shape acquisition model is an excellent match with the NATO Test Requirements (Annexes A-F) that describe the interrogator and the transponder tests at various integration levels: box-level, platform-level integration tests, and platform-level flight tests.

2.2 Iterative vs. waterfall

The V-shape model is called the waterfall method in system/software development. In the waterfall model, there is always a separate testing phase after a build phase. However, a new iterative development method is becoming more popular in particular in software development. This iterative method is known as agile software development.

One of the differences between agile software development methods and waterfall is the approach to quality and testing. In the waterfall model, there is always a separate testing phase after a build phase; however, in agile software development testing is completed in the same iteration as programming. Because testing is done in every iteration, which develops a small piece of the software, users can frequently use those new pieces of software and validate the value. After the users know the real value of the updated piece of software, they can make better decisions about the software's future.

This iterative approach provides greater flexibility throughout the development process. In the waterfall method, however, the requirements are defined and locked down from the very beginning, making it difficult to change them later. However, given the fact that platform tests are very costly and that the interoperability requirements are fixed, the iterative approach will not match the acquisition of IFF-equipped platforms. Therefore, the V-shape model and the associated NATO Test Requirements documentation remain quite appropriate.

2.3 Strategy in Testing

Test and Evaluation is the process by which a system or components are compared against requirements and specifications through testing. The results are evaluated to assess progress of design, performance, supportability, etc. This is often separated in two test phases, which matches the V-shape acquisition model:

- Developmental test and evaluation is an engineering tool used to reduce risk throughout the defence acquisition cycle.
- Operational test and evaluation is the actual or simulated employment, by typical users, of a system under realistic operational conditions.

The reason for separating the testing in phases is based on efficiency and risk reduction. The complexity of the IFF system is such that only testing the system when it is entering its operational phase will very likely reveal a large number of faults. These faults need to be solved resulting in corrective actions in earlier phases of the development process, setting the programme back several years. Furthermore, the complexity of the IFF system will make it very time consuming to test it operationally under a wide range of conditions.

In order to overcome these difficulties in operational testing, tests should be done first at the early development stages and at component level where applicable. In this way the cost of a test failure will be less as it can be restored in the early development stage and at the component level. This can be understood as a risk reduction approach as the probability of a test failure in the operational stage is reduced where it has high cost by increasing the probability of a test failure in the development stage where it has low cost.

The concept of risk reduction is central to defining the boundary between first article testing and subsequent article testing. In principle every transponder and every interrogator could be tested rigorously using the complete set of tests. However, this is very costly and the probability of a failure decreases after the first article has been successfully tested. Therefore, subsequent articles are tested with fewer tests. This principle is also the basis for certification, where the successful (rigorous) testing of a transponder leads to a certification of all transponders of the same type. There is no definite answer which tests to apply for a subsequent article, however, some guidelines can be given:

- Statistical sampling can be used to avoid testing each individual unit.
- Use the appropriate form of testing: live operation testing, bench testing, analysis, demonstration, or inspection.
- Use high level tests that validate many lower level requirements.

3 VERIFICATION PROCESS

3.1 Documentation in verification process

Figure 2 shows the general set of documentation that is required in the verification process of the acquisition of a platform.

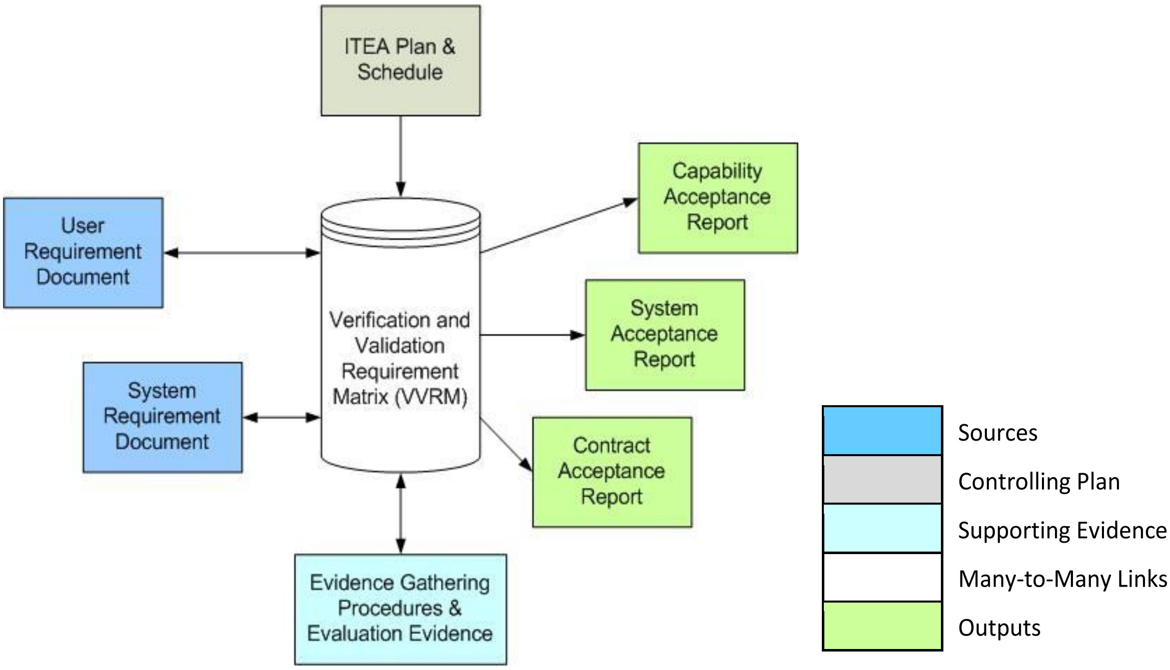

Figure 2: General documentation supporting the verification process.

In order to ensure IFF Mark XIIA interoperability, the NATO IFF Test Requirements (Annexes A-F) have to be part of the System Requirement Document. Furthermore, the IFF test results have to be reported in the System Acceptance Report.

3.2 Phases in testing

The qualification and certification process of any IFF system should follow the phases listed in the table below.

Table 1: Phases in Testing

Phase	Description	System level	Test requirements (transponder / interrogator)
1	Box Test	Box-level	Annex A / Annex D
2	Platform Integration Test	Platform-level	Annex B / Annex E
3	Flight Test	Platform-level	Annex C / Annex F

Each test phase presented in the table above corresponds to a specific phase of the project/program. A detailed description of each of them is provided below. Note that there is a classified addendum to Annex A. In addition, there are two classified addenda to Annex D

3.2.1 Phase 1 – Box Test

The first phase of the testing aims at evaluating the performance and interoperability of the equipment, i.e. transponder or interrogator. To that extent the testing will verify the compliance of the box with the STANAG 4193.

Phase of the project:

- During the development phase of the transponder or interrogator.

- At the end of the development phase of the equipment.

Equipment to be tested:

- First of series.
- Each time a transponder or interrogator is updated (e.g. when a new functionality is added)

Prerequisite:

- Relevant documentation:
  - Acceptance Test Procedure
  - Test diagrams / Installation drawings
  - Verification Description document
  - Software Design Description
  - Factory Acceptance Testing
  - Analysis / White paper
  - EMI (Electromagnetic Interference) Testing Results
  - Final Test Report

Type of testing:

- Laboratory bench test.
- Opportunity tests when other IFF systems are available for testing (see note below).

Note: these opportunity tests are recommended to provide confidence in the ability of the new IFF equipment to be interoperable with other existing IFF equipment. However, it is impossible to test the interoperability of equipment with all the other existing IFF equipment. Therefore, it is highly recommended to perform as many trials as possible to ensure a comprehensive interoperability.

Authority in charge of the tests:

- The industry developing the equipment or the entity conducting the test, together with an official authority empowered to deliver a certification for the equipment.

Objective of the test:

- Checking the compliance of the equipment with the STANAG 4193. It is also referred to as box certification for the performance of the equipment.
- Can be referred to as box-level certification for the interoperability of the equipment.

3.2.2 Phase 2 – Platform Integration Test

The second phase of the testing aims at evaluating the performance and interoperability of the equipment at the platform level. To that extent, the testing will verify that once the equipment is integrated on a platform, it complies with STANAG 4193.

Phase of the project:

- At the end of the integration phase of the equipment.

Equipment to be tested:

- First time equipment is integrated on a specific platform type. The tests will be conducted for each platform on which the equipment will be integrated.

Type of testing:

- Ground/Surface level testing.

Authority in charge of the tests:

- The industry developing the equipment or the entity conducting the test, together with an official authority empowered to deliver a certification for the equipment.

Objective of the test:

- Evaluate the performance and interoperability of the equipment once it is integrated on a platform, to grant platform certification to the integrated equipment.

3.2.3 Phase 3 – Flight Test

The third phase of the testing is the final qualification evaluating the overall performance of the system. It has to be performed on every single platform where an IFF system has been installed.

Phase of the project:

- During the qualification phase of the equipment.

Equipment to be tested:

- Each time an IFF system is integrated on a platform.
- All the other systems that will interact with the IFF system.

Type of testing:

- For each specific air platform type: flight-level testing.
- For each specific surface platforms and ground-based radars: testing with dedicated flights.

Authority in charge of the tests:

- The industry integrating the equipment in the system, supported by the industry developing the equipment, or the entity conducting the test, together with the authority in charge of the qualification of the equipment (and the platform).

Objective of the test:

- Evaluate the performance and interoperability of the equipment once it is integrated on a platform to check the compliance with STANAG 4193. This also includes the interface with other equipment that could be associated with the IFF system.

Following completion of the qualification phase, the last part of the verification process will be the acceptance of the equipment. Then, all the testing reports as well as documents regarding training, maintenance and documentation should be provided and assessed in order to grant acceptance of the IFF system.

3.3 Interoperability Operational Exercise (post-certification)

In the exercise the IFF system of systems is validated, not just the individual IFF-equipped platforms. Therefore, it is not part of the certification of the platform. However, it is an important part of the verification of the IFF system as a whole. Furthermore, it is a verification that the operational community can use the system in the intended operational environment. In the exercise the CONOPS, SOPs, ACP-160 NATO Supplement and other operational IFF policies and procedures are verified.

Therefore, it is encouraged that the IFF community organizes Interoperability Operational Exercises and that as many platform types as possible participate.

4 USE OF CRYPTOGRAPHY IN TESTING

4.1 Prerequisite

In the verification and validation of IFF equipment the cryptographic unit and the associated keys have a distinct role as the keys and the algorithms have to be protected (Ref. F-G). Therefore, there is an additional process for the certification of the cryptographic unit. In this process the cryptographic unit (or ECU, End Cryptographic Unit) is evaluated by SECAN and approved by the NATO Military Committee. This is sometimes referred to as the SECAN certification of the ECU.

Note that SECAN certification does not involve the Mode 5 interoperability of the ECU and IFF box. This interoperability test of ECU and IFF box is an additional test that is done previous to SECAN certification. This test will involve testing using operational keys in a secure environment.

For the purpose of the Test Guidance, the ECU certification and testing has been performed.

4.2 Box testing

The use of a SECAN approved ECU is the preferred test set-up. For these tests, the test keys are used and not the operational keys. For specific tests, the ECU is replaced by a crypto-emulator that does not require keys or only dummy keys. The crypto-emulator has more testing options than an ECU in these specific tests like freezing the waveform, freezing the data, etc. There is a technical description for a crypto-emulator in Ref. I.

4.3 Platform and Flight testing

Test keys are normally used during phase 2 or phase 3 testing. Operational keys are only loaded into a system that has been validated/certified to meet the requirements of STANAG 4193. The use of operational keys during phase 3 testing in order to achieve platform certification is allowed, in accordance with the NATO Mk XIIA Mode 4 / Mode 5 Key Management Plan.

4.4 Interoperability Operational exercise

The decision to use operational or test keys during the interoperability operational exercise of certified platforms will be made by the exercise coordinator or another cognizant authority. Recommended is to use the operational keys.

5 REFERENCES

A. NATO IFF Mode 5 Certification Policy, AC/322-D(2018)0047, 20 October 2018.
B. IFF Mode 5 Interoperability Strategy, AC/322(SC/7)N(2008)0027 (NU), 25 June 2008.
C. STANAG 4193 Edition 3, Technical Characteristics of IFF Mark XIIA.
D. STANREC 5635, AEtP-11 Edition 2, Implementation Options and Guidance for Integrating IFF Mk XIIA Mode 5 on Military Platforms.
E. NATO Identification Security Classification Guide for NATO Identification Systems, AC/322-D(2018)0026 (NU), 25 April 2018.
F. NATO Mark XIIA IFF Mode 4/5 Key Management Plan Edition 2, AC/322-D(2019)0004 (NU), 15 January 2019.
G. NATO Mark XIIA IFF Mode 4/5 Security Doctrine – Edition 1, AC/322-D(2016)0052 (NU), 26 October 2016.
H. Development of Mode 5 - Definition of System and Performance Parameters, AC/322(CP/2)D(2012)0005 (NU), 3 December 2012.
I. Technical Description of Mode 4/5 Cryptographic Computer Emulator Equations, AC/322(CP/2)N(2011)0034 (NR), 1 August 2011.

6 TEST FACILITIES

NATO and National Laboratories and Facilities suitable for Multinational Mode 5 Interoperability testing:

USA

Naval Air Warfare Center Aircraft Division (NAWCAD)

Mode 5 Engineering Laboratory
St Inigoes, Maryland, USA
POC: Rocky McCumbee, NAWCAD 4.5.9.1, rocky.mccumbee@navy.mil

GBR

RADEX (Radio Experimental) IFF/SSR flight trials facility.

QinetiQ, Boscombe Down, Wiltshire
POC Rob Firkins RHFIRKINS@QINETIQ.COM

The IFF/SSR capability consists of two long range Mk XIIAS (Mark XIIA with Mode S) interrogators, a surveillance and slaved tracking interrogator. This system is used to carry out detailed evaluation of airborne transponder installations and measure airborne platform transponder antenna coverage.

Maritime Shore Integration Facility.

Portsdown Technology Park, Portsmouth, Hampshire

POC Rob Firkins RHFIRKINS@QINETIQ.COM

Facility used to evaluate maritime systems including IFF/SSR. Facility includes a Mk XIIAS surveillance interrogator.

Mk XIIAS Bench Test Capability

QinetiQ, Malvern, Worcestershire
POC Rob Firkins RHFIRKINS@QINETIQ.COM

Based on the Aeroflex IFR45 Test Set.

MISPEC

"Merit of Individual System PErformance Characteristics" or "MISPEC" computer model.
Fanfield Ltd, Maldon, Essex
POC Ross Sutherland DESAPS-IDENT3@mod.gov.uk

Designed specifically for predicting overall system performance of IFF on a "probability" basis for a specific platform. It predicts the uplink and downlink probability and the link margin for an interrogator and transponder platform pair in a defined environment. The analysis considers 3D antenna patterns on platforms, equipment parameters (either measured or realistic), system characteristics, full conditions of manoeuvre, the operating environment, terrain or sea conditions, any operating scenario and ECM interference. It can be used to predict installed performance for a fleet-wide fit.

FRA

STATIFF (IFF Station)

Mk XIIAS long range interrogator
DGA EV, La Teste, France (Flight test base of French procurement agency)

This facility is used to:

- Test transponders
- Certify civil and military transponders
- Make performance measurements
- Check transponders airborne integration
- Analyse and verify air/ground data transmissions

DEU

WTD 81, GF 320

Bergstr. 18, 91171 Greding
POC: WTD81320@bundeswehr.org

This IFF/SSR facility is used to evaluate both interrogator and transponder platforms:

1. Long range Mk XIIA and Mode S interrogator (MSSR2000 ID)
2. Mode 5 Level 1 and Level 2 (triggered only, no squittered / passive reception possible)
3. Transponder Mode 5 LTR400-C (free space, Level 1 and Level 2, Far Field monitoring)

4. Bench test setup based on Aeroflex IFF-45TS (interrogator and transponder)
5. Flight Line Testsets Aeroflex APM-424(V)5 and Hensoldt BTI 1000 I
6. Intersoft RES with Mode 5 extension
7. Various Crypto Appliqués and Crypto Simulators

7 ACRONYMS

ACO – NATO Allied Command Operations

ACT – NATO Allied Command Transformation

AEtP – NATO Allied Electronic Publication

CAT – Capability Area Team (as in IFF CAT)

CP/2 – NATO Capability Area Program 2

DACAN – NATO Military Committee Distribution and Accounting Agency

ECM – Electronic Countermeasures

EMI – Electromagnetic Interference

FRUIT – Friendly Replies Unsynchronised In Time

IFF – Identification Friend or Foe

Mk XIIAS – Mark XIIA with Mode S

NATO – North Atlantic Treaty Organization

NCI – NATO Communications and Information (as in NCI Agency or NCIA)

NSPA – NATO Support and Procurement Agency

SECAN – Military Committee Communication and Information Systems Security and Evaluation Agency

SSR – Secondary Surveillance Radar

STANAG – Standardization Agreement

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