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Results from Eurocontrol Application SARPs Validation

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SUMMARY

This paper reports on the validation results to date of the Eurocontrol Trials End System (TES) prototyping project.

The project has demonstrated that the selected Air-Ground application SARPs are sufficiently complete and unambiguous to allow implementations to be produced.

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1. INTRODUCTION

1.1. Scope

This paper reports the validation results to date of the Eurocontrol Trials End System (TES) prototyping project.

1.2. Background

The Eurocontrol Trials End System (TES) project is involved in a number of activities, some of which are in direct support of the validation of the draft ICAO Air-Ground SARPs and supporting ATN Upper Layers. Two of these are:

- Prototype Implementation. The TES Prototyping contract is implementing the functionality specified in ADS, CM, CPDLC and Upper Layer SARPs.
- Interoperability Test Scenarios. Scenarios are being developed to support validation by means of inter-operating independent implementations of the Air-Ground SARPs.

These are reported in sections 2 and 3 of this paper.

1.3. Results

The TES prototyping project has demonstrated that the selected Air-Ground application SARPs are sufficiently complete and unambiguous to allow implementations to be produced.

A partial version of the TES software was delivered to Eurocontrol in January 1997. This includes full CM functionality (Configuration XXVIII ground and I air), together with upper layers.

This Beta version is now being used for Interoperability testing with other, independent CM / Upper Layer implementations.

The Beta software has also been integrated with the Eurocontrol TAR/TTS (Trials ATN Router / Trails Transport Service) system, to give a complete 7-layer CNS/ATM-1 Package protocol stack. This is believed to be the first complete implementation of a CNS/ATM-1 end system.

Currently, the TES implementors are performing final system tests of the ADS and CPDLC applications. Final delivery to Eurocontrol is expected early in April 1997.

Throughout the implementation and testing activities, validation of the SARPs has been a key objective. A number of SARPs defects have been identified during the lifetime of the project, and have mostly been rectified in the ICAO Version 1.0 SARPs. The defect reports are summarised in section 4 of this paper.

2. PROTOTYPE IMPLEMENTATION

2.1. Approach

The objectives of the Eurocontrol Trials End System (TES) project are:

- the validation of the ATN draft SARPs for air-ground applications and supporting upper layers,
- the production of prototype implementations and simulation models,
- the free issue of the software to Eurocontrol member Administrations.

The contract for the prototype development was awarded by the TES project of the Eurocontrol ATN End Systems task (FCO.ET3.STO4) to a consortium led by Thomson Airsys.

The TES prototyping project is producing prototype software implementations of the following CNS/ATM-1 Package SARPs:

- Automatic Dependent Surveillance (ADS), excluding report forwarding;
- Context Management (CM) Application;
- Controller-Pilot Datalink communication (CPDLC), excluding ground forwarding;
- Upper Layer Communications Service (ULCS).

Each of the implementations includes both air and ground based end system components.

A major goal was to identify any problems in the draft SARPs during the analysis, design and implementation of the prototypes. The applications will then be available for interoperability testing with other, independent implementations.

The TES prototype system software is aimed at the validation of the SARPs and would not necessarily be used in an operational environment.

2.2. Architecture

The TES Prototype System comprises hardware platforms, base software and custom software, whose main use initially is for the validation of the ICAO draft SARPs for the ATN Upper Layers and Air-Ground ATM applications.

The TES environment consists of two major components, the air-based end system and the ground-based end system. The architecture of each of these components is illustrated in Figure 1.

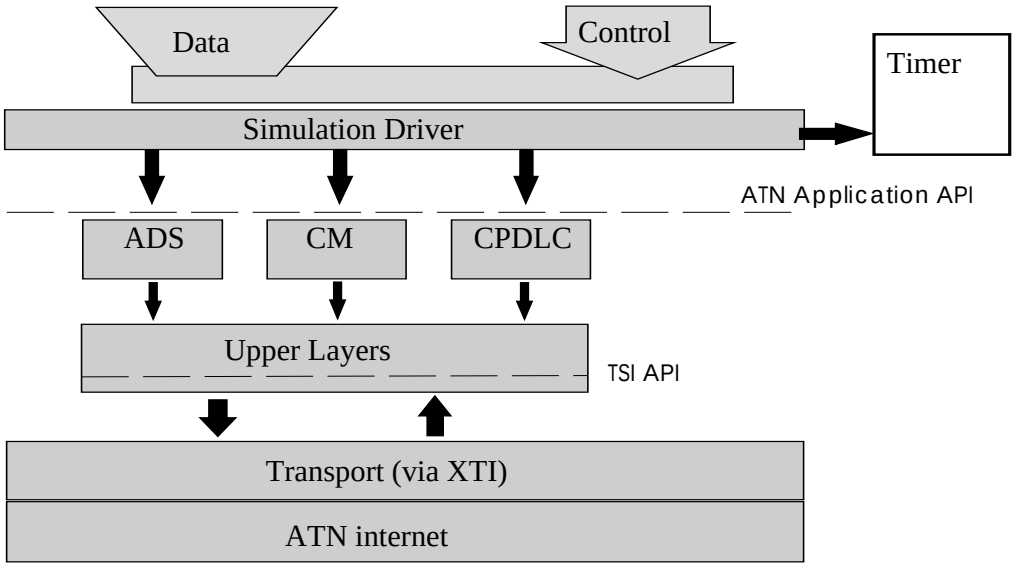

Figure 1: Trials End System Architecture

The ATN application SARPs define Abstract Service Interfaces (ASIs) between the "communications part" and the "user part". The "communications part" is modelled as an application service element (ASE) in the OSI environment. The ASIs provide convenient points to examine the behaviour of the prototype applications and simulate the actions of the ATN application user, and have been realised as Application Programming Interfaces (APIs) in the TES architecture. ATN End System APIs have been defined to validate the

ATN application SARPs, although in an operational system the APIs would not necessarily be implemented in this way.

The SARPs use the ISO-standard Abstract Syntax Notation (ASN.1) to define messages exchanged between the applications.

For the TES Prototype System, the air and ground end systems communicate using a lower layer protocol stack which can be used in a variety of configurations, in place of the ATN Internet. This point is important, since the objective of the TES project is to validate the SARPs for ATM applications and ATN upper layers, and not the ATN Internet.

At the lower boundary, a Transport Service Interface (TSI) has been specified. This TSI intercepts ATN-specific communication options, and maps the transport service assumed by TES onto a real transport service provider. Transport services currently supported are:

- the standardised XTI interface provided on the HP-OTS 9000 product
- the ATN transport interface provided by the Eurocontrol TAR/TTS system.

TSI is an internal interface allowing the ATN applications to operate transparently with XTI products whether or not they support the ATN communication options.

The ATN Upper Layers rely on the services provided by the ATN Internet, and provide communication services to the ATM applications. The ATN Upper Layers ensure the end-to-end communication between the two end systems over a number of ATN routers connected via ATN compatible subnetworks.

2.3. Use for SARPs Validation

The validation procedure comprises the following stages:

- analysis of the draft SARPs requirements;
- production of functional specifications;
- production of design specifications;
- implementation;
- stand-alone tests;
- interoperability tests (using defined simulation scenarios).

Each of these stages may identify different types of errors or omissions in the draft SARPs, and will provide documented evidence in the form of reports on the completeness and accuracy of the draft SARPs, including any assumptions and interpretations which it was necessary to make.

The TES developers have independently analysed the draft SARPs, in order to produce functional and design specifications based on the draft SARPs and to implement the software realisations. The TES prototypes can then be used to test the functionality, interoperability and performance resulting from the draft SARPs

The TES prototypes implement application programming interfaces (APIs) which correspond closely to the upper abstract service interfaces (ASIs) specified in the draft air-ground application SARPs. These APIs provide a common interface which allow simulation and test tools to be developed separately from the TES prototypes.

The TES prototypes are delivered with a test harness - a COTS product from Marben known as ATTOL System Test. This enables test scenarios to be defined, executed and monitored. Test scenarios are based upon real-life situations, including time based events, single instance of a flight and summation of all flights. Where possible, the test data is based on samples of real data.

The test interface is used to introduce both normal and abnormal events into the TES prototype. These are used to check the behaviour of the TES prototype and the draft SARPs.

2.4. Current status

The TES prototypes are implemented to run on Hewlett-Packard 9000-series platforms, under the UNIX operating system HP-UX 9.0.

Implementation and integration of the TES applications is complete, and testing is in progress.

A first Beta version of the TES software was delivered to Eurocontrol on 17th December 1996. This comprised the CM Core Functionality (CM-Logon functionality), Upper Layers and a test harness.

An updated Beta version of the TES software was delivered to Eurocontrol on 27th January 1997. This includes complete CM functionality, together with upper layers.

This Beta version is now being used for Interoperability testing of the Context Management application with other, independent implementations (see next section).

The Beta software has also been integrated with the TAR/TTS system, to give a complete 7-layer CNS/ATM-1 Package protocol stack.

Currently, the TES implementors are testing the ADS and CPDLC applications. The TES prototyping project is now in its System Testing ("Qualification") phase, in which test scenarios which represent the majority of the SARPs functionality are being run, and software bugs and SARPs defects are being identified. The majority of these tests now run successfully, and produce the expected results.

Following the Qualification Phase, the project will enter its final Acceptance Phase. Final delivery to Eurocontrol is expected in early April 1997.

3. INTEROPERABILITY TEST SCENARIOS

As the TES prototype applications become available, it is planned to use them for interoperability testing, to achieve further levels of validation. These interworking tests will be carried out between different instances of the TES software, and also with other States and Organisations who have SARPs-conformant implementations available for interworking tests.

A series of tests of varying complexity needs to be defined and agreed between the interoperability test partners. Tests on a single implementation may be defined and devised by the organisation responsible for that implementation. Tests requiring interworking between independent implementations need to be collaboratively agreed between the partners.

It has been recognised that there will not be a one-for-one correspondence of tests to SARPs requirements. With several hundred "shall" statements in a typical ATN Application SARPs, such an approach would probably still be in test in 1999! Instead, an approach using a small number of more complex "scenarios" is used, each of which, on successful completion, should give a high degree of confidence in a large number of requirements.

Interoperability tests are specified to ensure that the exchange of information between implementations meets SARPs requirements. A test method similar to that used for OSI interoperability testing may be appropriate, either back-to-back with the same implementation, or testing with an independent implementation.

Performance tests are needed to validate performance aspects of the SARPs, e.g. is it feasible to achieve the required round trip time with current network technology? These

tests are likely to be carried out over a real ATN Internet and subnetworks, or else over a network simulator.

3.1. SARPs Baseline

For interoperability to be possible, the interoperating applications must implement a common set of functionality, and must be based on the same SARPs versions. An in-depth understanding is needed of the effect of any SARPs defect resolutions which have been implemented, as these in some cases will affect the “bits-on-the-wire” and therefore will have an impact on the degree of interworking possible.

The contract for the TES implementations was awarded in June 1996, at which time the stable baseline for Air-Ground SARPs was the output from the 7th (Munich) meeting of ATNP/WG3. The TES therefore currently implements version 3.0 of the air/ground applications SARPs and version 4.0 of the Upper Layer Communication Service SARPs.

However, even if strictly implemented as described in the SARPs, the final product would not work. Indeed, the SARPs documentation is being validated by various methods (paper analysis, simulation, modelling, prototyping) and a non negligible number of defects have been sent to the SARPs editors, some of them addressing serious problems in the specification of the protocols. A new version was released in November 1996 implementing all these defects resolutions (ICAO version 1.0).

In order to get a workable and interoperable system, and with the objective to deviate as little as possible from the baseline SARPs (Munich version), the TES project has decided to implement the resolution of defect reports as follows:

- 4 defect reports related to the CM SARPs,
- 7 defect reports related to the CPDLC SARPs,
- 12 defect reports related to the ADS SARPs, and
- 11 defect reports related to the ULCS SARPs.

Amongst these defect reports, some have been clearly identified as impacting the inter-operability capability. It is recommended that before starting any interoperability testing activity with the TES system, the implementation of these defect reports in the remote SARPs-compliant system is checked.

It is therefore necessary to identify unambiguously the version of the Upper Layers and air-ground Applications and the associated defects implemented in the interworking implementations.

For each implementation, a statement of defect resolutions along with a completed Protocol Implementation Conformance Statement (PICS) should be used to study the degree of interoperability possible.

3.2. Rationale for Selecting Defects

The rationale for selecting a defect resolution (whatever its origin is) for implementation in the TES system is based on the following considerations:

1. Like most of the other validation programs undertaken by other States and Organisations, the TES Prototyping system is based on version 3.0 of the SARPs for the air-ground applications and version 4.0 for the ULCS SARPs (WG3 Munich output version). In order to get the maximum chance of successful inter-operability, the defects selection process is based on the following main rule:

   It is required that each independent implementation deviates as little as possible from the baseline version.

2. Only those defect resolutions which are formally endorsed by the relevant ICAO subgroup can be implemented. This means that:

- the defect report is unambiguously identified: a reference has been assigned to the defect report by the editor (in addition to the originator reference),
- the processing of the defect report is complete, i.e. the defect report has been reviewed during an SG meeting and the defect status is CLOSED,
- the defect report handling is complete[1]: the solution agreed in the relevant sub-group (SG2 or SG3) has been documented in the defect form and the final version of the defect with the agreed solution is available.

3. Modifications resulting from defects detected in the protocol specification which could jeopardise the inter-operability between SARPs-compliant systems should be implemented in these systems:
   - If the modification can be done within the resources of the project, the modification is implemented.
   - Otherwise, the modification is clearly identified as being “not implemented”. Later on, a detailed analysis will be performed on a case by case basis to assess the impact on the interoperability for a given remote implementation.
4. Modifications resulting from defects limiting the functionality significantly should be implemented when possible (e.g. a requirement defined in the SARPs may subsequently be identified as being inapplicable when the system is in a certain state)
5. Modifications resulting from defects on functions not retained in the TES profile are not implemented (for instance: defects on the CPDLC ground forwarding service or on the ADS ground forwarding function).
6. Modifications resulting from defects related to additional functionality are not implemented in the scope of the main TES contract. It should be noted that if the additional functionality causes the modification of the ASN.1 definition, then interoperability with a system implementing this function may be not possible. These defect reports are considered on a case by case basis to decide whether the defect resolution is to be implemented.
7. Defects related to the optimisation of a function are not implemented in the scope of the main TES contract. If the optimisation requires the modification of the ASN.1 definition, then interoperability with a system implementing this function may be not possible. These defect reports will be considered on a case by case basis to decide whether the defect resolution is to be implemented.
8. Defects related to the format of the SARPs (typos, incorrect cross references, ICAO editorial instructions not followed (e.g. section or note numbering, the specific use of the words 'shall', 'should'), incorrect comments in the ASN.1 description, redundant requirements, errors introduced during Word to WordPerfect conversion, etc.) are not implemented. Such defects, even if implemented, would not impact the specifications nor the code of the SARPs compliant systems. However, they have to be considered seriously by the development teams since they bring clarity and explanations to the SARPs material.
9. Defects related to chapter 7 "Requirements on the service users" are not implemented. These requirements are not part of the TES system. They may be taken into account by the ATTOL scenarios which simulate these users during the validation exercises.

[1] In exceptional circumstances (e.g. the editor is not able to consider the DR quickly and the software development process is blocked), the an interim solution may be implemented. When the agreed WG3 solution is made available, the compatibility of the implemented solution with the agreed solution is verified.

3.3. Results

The development of interoperability test scenarios is in progress within Eurocontrol. A preliminary set of scenarios was presented to the Working Group in an earlier paper (WG3/WP5-22 “Use of Interoperability Testing as a Validation Tool”, WG3/WP4-16 “Proposed Scenarios for the CNS/ATM-1 Package Draft SARPs Validation”).

In addition, the TES Prototyping project has produced a number of test scripts which drive the application ASEs from the ASI interface, and correspond to pre-defined pseudo-operational scenarios.

At the time of writing, interoperability testing between TES and an independent (FAA-sponsored) implementation of the CM application is in progress. The first step is to exchange CM-Logon request and response PDUs in both directions, and ensure that they are interpreted correctly by the remote test partner. This is likely to be completed before the start of the WG3 Thailand meeting in March 1997.

4. CONTRIBUTIONS TO SARPS VALIDATION

4.1. SARPs Verification

The main contribution of the TES Prototyping project to SARPs validation has been to demonstrate that those areas of functionality selected for implementation are well-defined in the SARPs, i.e. that the requirements are clear and unambiguous. Thus, the TES results to date give a high level of confidence in the following CNS/ATM-1 SARPs:

- Automatic Dependent Surveillance (ADS), excluding report forwarding;
- Context Management (CM) Application;
- Controller-Pilot Datalink communication (CPDLC), excluding ground forwarding;
- Upper Layer Communications Service (ULCS).

4.2. Defect Identification and Resolution

During the specification and the development of the TES prototype, technical questions have been raised on the baseline SARPs. Some of those have caused the generation of defect reports managed in the form of Proposed Change Requests (PCR) and sent by the TES Internal Conformance Manager (ICM) to the appropriate SARPs editor in the format expected by the ATNP WG3 sub-groups.

The following tables summarise Defect Reports that have been raised as a result of the TES prototyping activities. Those that have been selected for implementation in the current TES release, using the criteria described above, are identified, and classified as follows:

YES - BASELINE	The DR is implemented in TES, as it clarifies the TES specification. It does not impact the code nor the interoperability with other SARPs compliant systems.
YES - INTEROP	The DR is implemented in TES as it addresses an error in the protocol specification which would impact interoperability, and the impact on the project resources is manageable.
YES - ASN.1	The DR is implemented in TES to get an ASN.1 description syntactically correct.
NO - CLARIFY	Not implemented. The DR consists of details added for clarification purposes only.

NO - CHAPTER7 Not implemented. Not applicable to TES as the DR addresses an error in the SARPs chapter 7 (User requirements).

NO - EDITORIAL Not implemented. The DR points to typos and to errors in the reference to a SARPs section or chapter (editorial).

NO - NEW Not implemented. The DR proposes addition or modification in the protocol specification or in the ASN.1 description resulting of the enhancement or the optimisation of the application functionality.

NO - STATETABLE Not implemented. The DR addresses an error in the state tables but the corresponding text in the protocol specification is correct.

Defects Reported in the CM application SARPs

TES reference	ICAO reference	Implemented in TES?
PCR-42	CM-012	YES - BASELINE
PCR-24	CM-025	YES - INTEROP
PCR-65	CM-037	YES - INTEROP
PCR-34	CM-020	NO- CLARIFY
PCR-01 PCR-03 PCR-07	CM-022	NO -EDITORIAL
PCR-22 PCR-23	CM-023	NO - CLARIFY
PCR-37	CM-024	NO - CLARIFY
PCR-62	CM-035	NO - CLARIFY
PCR-64	CM-036	NO - CHAPTER7

Defects Reported in the CPDLC application SARPs

TES reference	ICAO reference	Implemented in TES?
PCR-17	V3-7	YES - INTEROP
PCR-16	V3-15	YES - INTEROP
PCR-21	V3-16	YES - INTEROP
PCR-43	V3-17	YES - BASELINE
PCR-15	V3-14	NO - CLARIFY
PCR-25	V3-24	NO - CLARIFY
PCR-20	V3-32	NO - EDITORIAL
PCR-18	V3-35	NO - STATETABLE
PCR-53	IV1-??	NO - CHAPTER7

Defects Reported in the ADS application SARPs

TES reference	ICAO reference	Implemented in TES?
PCR-44	ADS-0036	YES - INTEROP
PCR-12	ADS-0048	YES - INTEROP

PCR-63	ADS-0059	YES - INTEROP
PCR-67	ADS-????	YES - INTEROP
PCR-69	ADS-????	YES - BASELINE
PCR-71	ADS-????	YES - INTEROP
PCR-72	ADS-????	YES - INTEROP
PCR-74	ADS-????	YES - INTEROP
PCR-75	ADS-????	YES - INTEROP
PCR-77	ADS-????	YES - INTEROP
PCR-10 (*)	ADS-0032	NO - EDITORIAL
PCR-10 (*)	ADS-0047	NO - EDITORIAL
PCR-30	ADS-0049	NO - EDITORIAL
PCR-31	ADS-0050	NO - CLARIFY
PCR-52	ADS-0055	NO - CLARIFY
PCR-54	ADS-0057	NO - NEW
PCR-66	ADS-????	NO - STATETABLE
PCR-68	ADS-????	NO - NEW
PCR-70	ADS-????	NO - EDITORIAL
PCR-78	ADS-????	NO - EDITORIAL

Defects Reported in the ULCS SARPs

TES reference	ICAO reference	Implemented in TES?
PCR-47	UL-DR 94	YES - INTEROP
PCR-51	UL-DR 98	YES - INTEROP
PCR-45	UL-DR 102	YES - BASELINE
PCR-46	UL-DR 103	YES - BASELINE
PCR-56	UL-DR 104	YES - BASELINE
PCR-57	UL-DR 111	YES - ASN.1
PCR-80	UL-DR 108	YES - INTEROP
PCR-48	UL-DR 095	NO - CLARIFY
PCR-49	UL-DR 096	NO - EDITORIAL
PCR-50	UL-DR 097	NO - CLARIFY
PCR-55	UL-DR 101	NO - CLARIFY

5. FUTURE PLANS

The TES and its components will support a number of configurations on the user side or Human Computer Interface (HCI), which will allow it to be used beyond the initial SARPs validation. These user configurations will include:

- the validation environment;

- a demonstration environment, with user interfaces possibly based on Eurocontrol Brétigny HCIs;
- future experiments based on CNS/ATM-1 Package SARPs;

It is intended that the TES prototype system and its hosted applications will evolve into an ATN Application Reference System, providing a stable implementation of the CNS/ATM-1 Package SARPs once validation is complete, against which other implementations can be tested.

Thus, future uses foreseen for the TES prototypes include:

- Further SARPs evaluation and experimentation
- Integration with end-user (HMI) software
- Use in operational simulations
- Use in pre-operational trials.

6. CONCLUSIONS

EUROCONTROL, the European Organisation for the Safety of Air Navigation, now has available an implementation of the first set of CNS/ATM datalink applications to be standardised by the ICAO ATN panel. This is believed to be the first available development which is fully compliant to the complete CNS/ATM-1 Package suite, from networking protocols to application software, and is offered to EUROCONTROL Member States to assist in their evaluation, planning and deployment of the ATN.

This paper has presented validation results from the Eurocontrol TES project. The work will continue in the coming months with the aim of completing the validation activities and exploiting the prototype ATN applications in trials and simulations.

The WG is invited to review these results and to consider them as inputs to the overall Validation Report to be presented to ICAO.