TITAN

Turnaround **I**ntegration in **T**rajectory **A**nd **N**etwork

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TITAN Model Verification Test Report

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Reviewer	CRI	Nicolás Suárez	08/05/2012
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Cc	AENA/SESAR JU	Francisco Javier Fernández de Liger

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EXECUTIVE SUMMARY

This document presents the verification tests performed over the TITAN executable model.

Firstly the technique used is introduced and justified, and then tests ordered by its associated high level verification objectives are listed. For each high level verification objective the performed tests are shown in tables. These tables show the inputs used in each test, the hypothesis made and the measures done. Finally the results of the tests are presented together with some notes when the tests were not passed.

1. INTRODUCTION

1.1 Purpose

The main objective of the present document is to elaborate the verification test reports used to assess that the TITAN executable model has been built correctly. Since verification is based on determining if the operational logic of the model corresponds to the logic design, the purpose of these tests will be to find the mistakes in the model. This document describes the results of the tests performed over the TITAN executable model last version 0.0.490.

1.2 Document Structure

This document is divided into four parts:

- The first section is this introduction which presents the purpose, structure, audience, references, abbreviations and acronyms of the document.
- The second section introduces the technique used for the verification.
- The third section contains the verification test reports elaborated for the model.
- The forth section summarizes the findings obtained.

1.3 Intended Audience

This document may be distributed freely within the TITAN consortium, both to those who are involved in the use of the model as well as stakeholders to check consistency in the model.

1.4 Associated Documentation

[1] Laurie Williams, Testing Overview and Black-Box Testing Techniques, 2006

[2] TITAN D1.4 “Operational Concept Document (Issue 1)”, INECO, Version 1.0, October 2010

[3] TITAN D2.1 “Technical Requirements Document”, CRIDA, Version 1.0, July 2011

[4] TITAN D2.3 Single Aircraft Turnaround Model Verification Test Report

[5] TITAN D2.5 TITAN Model Software Design Document

[6] TITAN D3.2 “Validation Exercise Plan”, ISDEFE, Version 0.6, October 2011

1.5 Abbreviations and Acronyms

AOBT	Actual Off Block Time
AST	Actual Start Time
ECT	Estimated Completion Time
EIBT	Estimated In Block Time
EOBT	Estimated Off Block Time
SIBT	Scheduled In Block Time
SOBT	Scheduled Off Block Time

STTT	Scheduled Turnaround Time
TITAN	Turnaround Integration in Trajectory and Network
V&V	Validation and Verification
V&V	Validation and Verification
TITAN	Turnaround Integration in Trajectory and Network

2. VERIFICATION

Verification is the process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of a development phase.

Verification can be done in development, scale-up, or production phase of the product. It is often an internal process contrary to validation which acts as an external process ensuring that the system is built to satisfy the customer requirements.

Whereas verification can be expressed by the question 'Are we building the **system** right?' validation is expressed by the query 'Are we building the **right** system?'.

With the purpose of checking that the specifications are correctly implemented by the system, verification activities include testing and reviews.

2.1 The Logic model

When a model is verified, the aim is to determine if its logic has been correctly implemented. Therefore, next questions should be answered throughout this document:

- Are model events correctly processed?
- Are the relationships included in the model valid?

2.2 Software testing

Software testing, which is one of the software practices included in the V&V activities, is an important technique for assessing the quality of a software product.

This process analyzes a software item to detect the differences between existing and required conditions (that is, bugs) and to evaluate the features of the software item. Software testing is an activity that should be done throughout the whole development process.

2.2.1 Black box testing technique

This technique, also called functional testing, ignores the internal mechanism of a system or component and focuses solely on the outputs generated in response to selected inputs and execution conditions.

This will be the technique used to evaluate the Single Aircraft Turnaround Model as well as the TITAN executable model since the code is considered as a "big black box" where the information is an input to the black box, and the black box produces other information as output. Based on the requirements knowledge, we know what to expect the black box to send out and test the model to make sure the black box sends out what is expected.

3. VERIFICATION OF THE TITAN EXECUTABLE MODEL

The verification tests are presented in the tables shown below. They describe the hypothesis, measures and consequently the problems encountered when verifying the model. Verification criteria

The Single Aircraft Turnaround model has been verified with several tests which consider the technical requirements established in [3] that should be fulfilled by this model.

The verification tests have been grouped according to their High Level Objective. These are classified into four categories which have been established depending on the type of verification they do. A brief explanation about each High Level Objectives is now presented in order to clarify the tables below:

- Data Input Verification: It refers to the information introduced into the model which serves as an input and allows the simulation.
- Data Output Verification: It refers to the information provided by the model after the simulation.
- Simulation Verification: It includes all the elements (processes, resources...) contributing to the simulation. It explicitly verifies the simulation.
- Verification of the consistency of the results: The results obtained after the simulation are analyzed.

Each High Level Objective is split into several Low Level Verification Objectives which provide a more specific description about the verification done. These Low Level Verification Objectives will be verified with different tests.

Each test contains its own hypothesis about the expected results. The Measures column explains what should be tested and the way of executing the tests.

The ‘Severity’ column defines the degree of need for the developers to correct the problems. The severity level is expressed as follows (in descending order of severity):

5- As soon as possible

4- Almost as soon as possible

3- When possible

2- Needed

1- If possible

3.1 Scenario dataset

According to the Validation Scenario data definition defined in [6], the data inputs to be considered by the model are listed below:

- Number of flights, number of passengers per flight, special passenger rate, number of passengers to perform the check-in per flight, number of passengers to perform the passport control per flight, SIBT, EIBT, SOBT, EOBT, AOBT.
- Flight type, stand type, aircraft type.

- Total check-in desks, security and passport control desks in the airport, total number of gates and its associated airlines and properties.
- Passenger travel distances in the airport (i.e. from check in desk to security control, from security control to boarding gate, etc.), mobile resources medium travel distances, estimated average time per passenger for boarding/de-boarding.
- Standard planned duration of the aircraft handling processes, standard processes planned duration, standard elapsed time.
- External delays, forced delay in all the processes, possible forced delay in % of the turnaround processes, STTT of any flight.
- Is de-icing scheduled?, standard required resources.
- Total number and type of boarding/de-boarding facilities and their availability for the airport, Total number and type of handling processes facilities and their availability for the airport, Total number of Airport safety facilities and their availability, Total number of de-icing facilities in the airport, Total number of Fuelling facilities and their availability.
- % of gate reallocation at short notice, % of passenger arriving late XX minutes, % of unavailability of a service.

Two turnaround baseline scenarios have been used to test the TITAN executable model:

- A simplified current turnaround model composed by three departure flights and three arrival flights. Each flight has ten passengers. This scenario has allowed the understanding and testing of the resource management carried out by the TITAN Model during the simulation.
- A complete TITAN turnaround model (with TITAN Services functionality enabled) composed by a real 24 hours traffic sample. It has been used to test TITAN Services.

For each test, the values of the flight, passengers, processes and gate properties, as well as the number and kind of resources available, change according to the tests hypothesis and goals. These properties vary by means of giving different values to the data inputs just presented above.

All the verification tests presented in this document have been realized for both scenarios except those tests that deal with TITAN services which were only performed for the second scenario.

3.2 High Level Objective: Data input verification

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
The model allows introducing the data inputs.	**DI-001**	Check if the inputs reflected in the validation scenarios can be introduced in the model.	The listed inputs in the Validation Scenarios can be introduced in the model.			Passed.
The model allows modifying the data inputs.	**DI-002**	Check if all the inputs introduced can be modified.	Once the data input can be introduced, they may be modified whenever it is needed.			Passed.
The model allows saving the data inputs.	**DI-003**	After introducing the inputs, the scenario is saved and then closed. After opening the saved Scenario, it is checked that the changes have been saved.	Once the scenario dataset is saved, the model is able to read and implement the scenario dataset.			Passed
The range of values of the data input parameters is consistent to the validation objectives.	**DI-004**	Check that the required range of values set in the validation objectives may be introduced in the model (e.g. number of passengers of an aircraft between 1 and 600 passengers, number of check in desks between 1 and 1000).	Data input can be introduced within a range of values coherent with the validation exercise objectives.			Passed.
The model does not accept any data input parameters out of the boundaries of the defined range of	**DI-005**	Check that it is not possible to introduce data input parameters which are not consistent with the validation objectives (e.g. number of passengers smaller	Data input cannot be introduced out of a range of values coherent with the validation exercise objectives.	All the values that we are going to use can be introduced. An error alarm appears when trying to introduce values out of the defined value range.		Passed.

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
values.		than 1).				
The model does not accept invalid values.	**DI-006**	Check the model behaviour when introducing data inputs with invalid values (e.g. end time before start time, character instead of integer).	Data input with invalid values are not accepted by the model.			Passed.
The model allows introducing resource parameters to allow resource management during the simulation.	**DI-007**	Check if the required resource management rules can be introduced according to the validation scenarios.	The subsequent resource management rules provide additional functionality to the model: A resource can be defined to be used by one entity at the same time or by several entities depending on the kind of resource. A maximum number of resources can be defined to be used by the entities of the same process. It is possible to specify if a resource is required by a process to start or not. It can be defined if the resources are occupied only when being used by an entity or during the whole duration of the turnaround process. In case of TITAN Services			Passed.

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
			enabled, the user is able to prioritize resources during the simulation run.			
The model allows the decision-making associated to the TITAN Milestones and according to the TITAN Services definition.	**DI-008**	Check if changes can be introduced during the simulation according to TITAN Services definition.	TITAN Milestones are associated to interaction windows that are displayed under defined conditions (depending on simulation performances). These displayed windows allow the user to interact with the model by making decisions during the simulation.			Passed.

Table 1: Data Input Verification Tests

3.3 High level Objective: Data Output Verification

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
The model provides the data outputs in graphical and text formats.	**DO-001**	After introducing the data input, the simulation is run and the data output are analysed.	The model provides graphical information during the simulation about the status of the turnaround processes. The file obtained after the simulation shows the data outputs in text format.			Passed.
The data outputs are consistent with the data inputs.	**DO-002**	After introducing the data input, the simulation is run and the data output are analysed.	The model reacts as it is expected according to the data input introduced.	Capacity property for resources (e.g.: to set up a maximum number of passengers using the bus) did not work as expected. The 'Batch node' has been created to solve this issue. This node batches entities in a container. The entities packed pass through the following node of the network (normally a resource node) as a unique entity (container).	1	Passed with conditions.

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
				Resource node did not work as expected, taking one entity per resource. It was solved by creating 'One time node'' which takes the resource from the beginning of the process until the last entity passes through it. However, 'One time node' does not account for waiting queues (passengers or other entities using the resource). A workaround has been used to simulate the time per passenger using the resource. It creates a queue before the 'One time Node'.	1	
Data outputs are provided at the precise moment and with the frequency required to monitor and analyse the results.	**DO-003**	After introducing the data input, the simulation is run and the data output are analysed on the moment they appear.	The data output are obtained when expected.			Passed.
Data output files contain validation metrics.	**DO-004**	After running a simulation, the data output files are opened and their content is analysed.	Validation objectives can be assessed using the output files if following information is available: - Start and end of each process. - Register of the used resources.			Passed

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
			- Register of flights. - Register of disruptions or unexpected events.			
Data output files can be used easily for the output analysis.	**DO-005**	After running a simulation, the data output files are opened and analysed. The data inserted in excel tables may be filtered upon several criteria.	Validation objectives can be assessed in a user-friendly way by using the output files.	An entity filter was created to configure the data output presentation. Data outputs are not always obtained in the appropriate way in the following cases: High lack of resources or high traffic density (30% increment). In those cases data regarding last flight processes of the traffic sample is not provided sometimes. Therefore, a great number of simulation runs is needed to obtain valid results.	1	Passed with conditions.

Table 2: Data Output Verification Tests

3.4 High level Objective: Simulation Verification

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
The process editor works as expected	**SV-001**	Define each one of the node types in the process editor by changing its properties.	The model allows adding and deleting nodes as well as editing its properties.			Passed
	SV-002	Define the interaction between nodes (network) by modelling several turnaround processes (e.g. check-in, security, boarding...).	The model allows establishing several links between nodes. Each node, depending on its type, can be linked to one or two subsequent nodes.			Passed
	SV-003	After defining several node types and the network relating them, the model is run and the entity output file is analysed. Several entities with different properties are filtered and its flow through the nodes is analysed.	The entities flow through the nodes during the simulation. The path followed depends on the rules applied in each node as well as the network defined.			Passed
The nodes work adequately	**SV-004**	After defining several node types and the network relating to them, the model is run and the entity output file is analysed. The time spent for each entity in each node is observed.	The time spent by the entities in the nodes obeys node criteria according to entity properties.			Passed
	SV-005	After defining several node types and the network relating to them, the model is run and the entity output file is analysed. Specific rules corresponding to	Node rules are obeyed according to the nature of each node type.	Some parameters do not work regarding the resource tab such as time to aircraft, time at	1	Passed with conditions.

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
		each node type (e.g. resource booking, conditionals, queues...) are checked.		aircraft and time to gate. However new solutions/workarounds were implemented to allow modelling these scenario parameters (e.g. new kind of resource nodes).		
Process relationships work properly.	**SV-006**	After defining several node types and the network relating to them, the model is run and the process and entity output files are analysed. The start and end times of processes are observed and compared to the first and last entity passing through the concerned process.	Time constraints between processes are carried out.			Passed
	SV-007	After defining several node types and the network relating to them, the model is run and the process and entity output files are analysed. Processes times (start and end times) are observed to check if the process rules are being carried out.	Rules about processes are obeyed (e.g. close a process when all the entities have passed or wait until the last entity passes).			Passed.
Processes durations are coherent with the data input introduced.	**SV-008**	After defining several node types and the network relating to them, the model is run and the process output file is analysed. Processes durations are	Processes last according to data input durations introduced.			Passed

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
		observed and compared to the data input time defined..				
Resource Management is working properly.	**SV-009**	After defining several node types and the network relating to them, the model is run and the resource output file is analysed. Durations of the use of the fixed resource are observed as well as the way in which each resource is used (how it is transferred from one entity to another)	Fixed resource management is carried out as expected.			Passed
	SV-010	After defining several node types and the network relating to them, the model is run and the resource output file is analysed. Durations of the use of the mobile resource are observed as well as the way in which each resource is used (how it is transferred from one entity to another)	Mobile resource management is carried out as expected.			Passed
The data inputs are interpreted according to their values.	**SV-011**	After defining several node types and the network relating to them, the model is run and the input and output files are analysed taking into account the data input values introduced. It is ensured that the distributions, data values, etc. are well	The model interprets correctly the data input values (e.g. mobile resource capacity, EIBT, departure management manifest distributions...)			Passed

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
		interpreted by the model.				
	SV-012	During a simulation run, different decisions are introduced into the TITAN Services displayed, and then the data outputs are analysed.	TITAN Services allow interacting with the model in different ways, e.g. changing resource prioritization/processes prioritization, closing a process or waiting for an entity to close a process. These changes should affect the data outputs of the subsequent processes of the simulation.			Passed
TITAN Model is able to update information whenever needed.	**SV-013**	Check that TITAN Model may update information according to the simulation events taking place.	The model reacts to unexpected situations or taken decisions by updating information, such as distance or time in processes or resources (e.g. Gate reallocation may imply a distance update between the security desk and boarding gate).			Passed
TITAN Model allows modelling TITAN Services.	**SV-014**	Check that TITAN Model allows modelling the TITAN services as defined in the TITAN Operational Concept [2].	TITAN Services are supported by model characteristics (e.g. A Boarding Agent alerts if a passenger or a bag is stopped somewhere between check-in and boarding). TITAN Services are characterised by the modelling of a set of Interaction Points between the user and the			Passed

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
			simulation. These interaction points consist of displaying an information window that allows the user to make a decision and interact with the simulation.			
The interaction between TITAN model and the user is well defined.	**SV-015**	Check that all TITAN Milestones can be modelled as defined in [2].	TITAN Milestones and their linked decision points are modelled. The model allows the user to interact with the simulation at those points as it is defined in [2].			Passed
	SV-016	Check that all the interaction points are displayed when applicable according to the simulation events.	Interaction points are displayed at the beginning or end of processes when a planned time is not going to be achieved. Then, the model provides information about the status of the processes, entities and resources at this time.			
	SV-017	Check that all the data shown in the displayed windows are coherent with the nature of the milestone and with the simulated events.	The model allows the user to take an action that is expected to have a positive impact on the simulation (decrease delays).			
Flight connections work as expected.	**SV-018**	Check that connections between different flights do not entail any problem.	Passengers in transfer follow the process flow according to the process definition.			Passed
Stand allocation and its management is performed as	**SV-019**	Define several flights allocated to the same stand at the same time and check that the model is	There can only be one flight in a stand at the same time.			Passed

Low Level Verification Objective	Test Id.	Measures	Expected results	Notes	Severity	Results
expected.		able to manage it.	Second flight allocated to the same stand performs in-block process when previous flight has finished off block or push back turnaround process (if it is enabled). When TITAN Services are enabled the model allows several ways to perform gate reallocation (manually or upon several criteria).			

Table 3: Simulation Verification Tests

3.5 High level objective: Verification of the consistency of the results

Low Level Verification Objective	Test Id.	Measures	Hypothesis	Notes	Criticality	Results
The simulation of one generic airport delivers results similar to reality.	**RC-001**	Data input are introduced and the simulation is run.	The results obtained after the simulation (e.g. times spent in the processes, resources used...) correspond to reality.			Passed.
The model behaviour is as expected (with respect to today's operations).	**RC-002**	Data input are introduced and the simulation is run. Disruptions, lack of resources or delays are introduced and the way in which the model simulates these scenarios is analysed.	The model results maintain consistency with the data input introduced (e.g. Number of delays increase in more restrictive scenarios).	Two issues have been found regarding the consistency of the results: - Sometimes results are more optimistic than expected in scenarios with high number of flight delayed. This is because when the parameter 'Close immediately' is enabled, if AST>ECT for a turnaround process, its duration is zero. - Model behaviour becomes unpredictable for more restrictive scenarios (high lack or resources or high number of delays). This sets up the interval in which the analysis can be performed. Validation scenario definition and analysis should be performed taking into account these facts.	2	Passed with conditions

Low Level Verification Objective	Test Id.	Measures	Hypothesis	Notes	Criticality	Results
Errors are adequately reported.	**RC-003**	Data input are introduced with non valid relations between them. The simulation is run and Error file is analysed.	The model reports errors when there is no consistency between the data input or the processes involved in the turnaround.			Passed
The order of the turnaround processes is the established in the TITAN Operational concept [2].	**RC-004**	Data input are introduced and the simulation is run.	The order of the turnaround processes which appears at the end of the simulation is the established one in the TITAN Operational concept [2] (e.g. check in is realised always before boarding)			Passed
Total number of resources available and their estimated average travel times and time of use have an impact on the performance of the simulation.	**RC-005**	Check that the number of available resources and their associated travel time are specified. Once the simulation is run, analyse the data output by varying the total number of resources and their estimated travel and usage times.	Resources are shared and therefore a lack of resources has a negative impact on the airport performance.			Passed
The three types of entities (passenger, baggage, operation) act according to the TITAN Operational Concept [2]	**RC-006**	Check the lifecycle for the entities when the TITAN Services are modelled.	The entities are created at the beginning of the turnaround, pass though the process according to the scenario definition and the decisions introduced by the user through TITAN Services, and disappear when the last			Passed

Low Level Verification Objective	Test Id.	Measures	Hypothesis	Notes	Criticality	Results
			process uses them.			
The start and end time of the turnaround processes occur with temporal coherence.	**RC-007**	Check all estimated process start and completion times in a logical/ appropriate way.	The start and end time of the turnaround processes, which are obtained after the model simulation, meet the logical flow of the turnaround. All processes pass through the different phases: initialised, running and finished. Furthermore, the interdependencies between processes are correct.			Passed
The relationships between the different entities involved in the turnaround work as expected.	**RC-008**	Check if the entities may interact during the turnaround.	The three types of entities (passenger, operation and baggage) flow through the turnaround interacting when it is needed.			Passed

Table 4: Consistency Verification Tests

4. CONCLUSIONS

High and low level verification objectives have been checked. Most of the results of the verification are positive (36 out of 40 tests were passed); however some of them have been passed with conditions. These issues have been solved with restrictions, which have been classified in severity levels, and finally do not jeopardize the validation exercises success.

The following table summarizes the issues found at the TITAN executable model last version 0.0.490.

Test Id.	Issue	Severity
DO-002	Capacity property for resources (e.g.: to set up a maximum number of passengers using the bus) did not work as expected. The 'Batch node' has been created to solve this issue.	1
	Resource node did not work as expected, taking one entity per resource. It was solved by creating "One time node'.	1
DO-005	Data outputs are not obtained in appropriate way in the following cases: High lack of resources or high traffic density (30% increment). In these cases data regarding last flight processes of the traffic sample is not provided sometimes. Therefore, a great number of simulation runs is needed to obtained valid results.	1
SV-005	Some parameters do not work in resource node such as time to aircraft, time at aircraft and time to gate. However solutions/workarounds were implemented to allow modelling these scenario parameters.	1
RC-002	- Sometimes results are more optimistic than expected in scenarios with high number of flight delayed. This is because when the parameter 'Close immediately' is enabled, if AST>ECT for a turnaround process, its duration is zero. - Model behaviour becomes unpredictable for more restrictive scenarios (high lack or resources or high number of delays). This sets up the interval in which the analysis can be performed.	2

Table 5: TITAN executable model issues found

The final conclusion is that the model passes the verification test with enough accuracy to carry out the simulations.