Proceedings of the 1988 Winter Simulation Conference
M. Abrams, P. Haigh, and J. Comfort (eds.)

A tutorial on TESS: The extended simulation support system

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ABSTRACT

This paper presents a discussion of TESS™, The Extended Simulation Support System. TESS is a software product which creates an environment for conducting all tasks related to a successful simulation study in an integrated and consistent fashion. It is recognized that there are different types of users for such a support system, from model builders and input data collectors, to model experimentors or users, to output analyzers and decision makers. This paper will provide an example demonstrating the capabilities of TESS to support simulation projects.

1. INTRODUCTION

TESS, The Extended Simulation Support System (Standridge and Pritsker 1987 and Standridge et al 1988), provides a comprehensive, flexible, and integrated framework for performing simulation projects. Figure 1 shows the TESS problem solving environment. This framework is based upon database and graphics capabilities in conjunction with integration with the simulation languages SLAM II® (Pritsker 1986), MAP/1™ (Rolston and Miner 1988), and GPSS/H™ (Henrikson and Crain 1983). Simulation project activities supported include model building, simulation control specification, simulation execution, collecting and maintaining simulation data (both input and output), statistical analysis of data, and selection and preparation of report presentations (tabular, graphical, or animated). This framework provides a consistent environment for project tasks to be performed, relieving the users of the requirement of detailed knowledge of file management and job control capabilities of a computer operating system normally necessary to combine the activities if they were implemented on an ad hoc basis. This framework is also consistent across a variety of computing and graphics hardware.

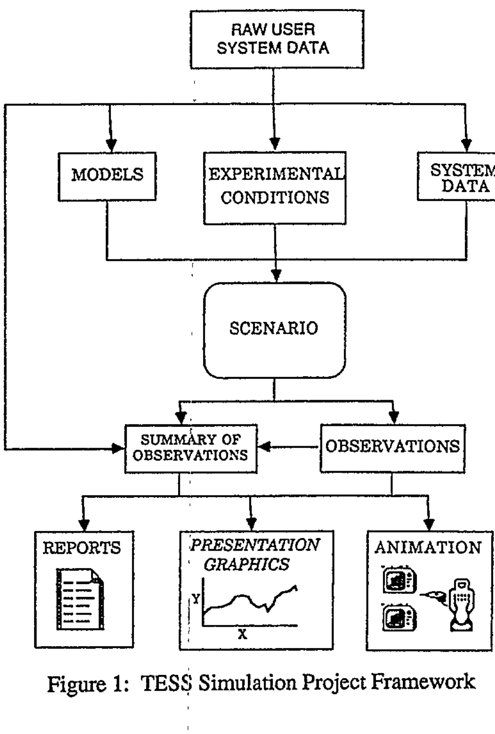

Figure 1: TESS Simulation Project Framework

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SLAM II is a registered trademark of Pritsker & Associates, Inc.
MAP/1 is a trademark of Pritsker & Associates, Inc.
GPSS/H is a trademark of Wolverine Software Corporation

2. TESS SUPPORT FOR MODELING

Modeling elements provide for describing systems, from a graphical and/or statistical point of view. Modeling elements provided for in TESS include SLAM II networks, facilities, and structural definitions of analyst described data.

The network management component of TESS provides for the graphical construction and modification of SLAM II network models of systems. In addition, networks can be graphed on a plotter to provide a hard copy form of the model. Graphical models may be created from previously existing SLAM II statement models, as well as transforming a graphical network representation into a statement model. In the graphical construction mode, network symbols are chosen from a menu of options and parameters are entered in response to prompts issued by the TESS network builder. Optional grid markings and snap-to-grid symbol location may be used to create effective documentation of a model.

Facilities are schematic, graphical models of systems often used to show structure and spatial relationships between system elements. Facilities may be used as informal models of a system for discussion or documentation purposes, as well as for eventually displaying animation of dynamic aspects of performance of the system under study. TESS provides a mechanism to construct and modify facilities composed of symbols such as rectangles, triangles, circles, or shapes of more complex definitions. A standard library of already defined symbols is available to a modeler for use in building a facility. Facilities may be incorporated within other facilities, allowing a schematic diagram to be built in a hierarchical fashion, or allowing a facility to be referenced by more than one facility. Facilities may be built to any level of desired complexity. TESS also provides for the translation of CAD drawings, in the Initial Graphics Exchange Specification (IGES) format, into TESS facility diagrams.

Definitions are the characteristcs of analyst defined data and summaries used as simulation inputs or collected as simulation outputs. These definitions may be generated and/or populated interactively. In addition, these tasks may be accomplished by access to the TESS database support environment through a set of TESS user-callable FORTRAN subroutines. The routines in the library are typically used within a simulation program to retrieve simulation inputs or to store simulation results; however, these routines may be called from any program.

3. TESS SUPPORT FOR SIMULATION

Simulation experimentation parameters may be constructed and managed in the TESS environment. These functions include specification of simulation control elements, the management of data input required by a simulation model, the management of simulation results, and the statistical analysis of simulation related data.

Control components are an interface provided to construct SLAM II control elements and to specify what data should be automatically collected during the simulation run and stored in the database for subsequent analysis. SLAM II control parameters such as run length, initial conditions and file ranking are specified. Control statements are available for data collection specifications for SLAM II, MAP/1 and GPSS/H models.

Data occurrences contain sets of values which correspond to data definitions created by the analyst or by the automatic data collection procedures. Summary occurrences are statistical and/or frequency summaries of data. Data and summary occurrences may be constructed by the analyst or by the automatic data collection methods. These data and summary occurrences may result as outputs of simulation experiments and/or be used as inputs for a simulation experiment.

A single simulation experiment or scenario may be defined by combining control elements with combinations of input data specifications. For SLAM II, a network model element may also be included in the scenario specification. Thus it is possible to maintain a level of independence between a model and the experimental framework in which it is exercised. For example, a single SLAM II network model may be specified as part of several scenarios in which any additional input data and/or the run control specifications are different. The execution of a scenario will produce observations of data and/or summaries of observations. The observations can be individual variable values or time histories (traces).

4. TESS SUPPORT FOR ANALYSIS AND PRESENTATION

TESS provides selection and computational procedures for the analysis of data or summary occurrences from one or more scenario experiments. Different groupings of simulation outputs into subintervals or batches are easily obtained, such as for analysis of initial, steady-state or process completion time frames.

Reports and presentation graphics are ways of presenting observations and summaries. Methods of selection of data for presentation include capabilities of grouping data sets from different replicates of a scenario and/or different scenarios. Default formats are provided for a variety of standard data presentation forms, including histograms, pie charts, bar charts, line graphs, or network display. TESS supports the use of stylized or tailored formats which may be constructed for specific applications.

Animation is another way to effectively condense and present details of the performance of a simulated system. A facility is the background upon which this function is displayed. A simulation time history (trace data) is also necessary to drive an animation. Rule elements may be developed which relate simulation trace data elements to facility model elements to express an animated display of the performance of a simulated system. Because the operation of the model can now be viewed, the animation of a simulation run may help in validating the model. The animation observation may be performed in a post-simulation environment or in a concurrent simulation environment. In the concurrent environment, opportunities for interaction with the simulation are available, with capabilities for creating a tailored interface for this user interaction.

5. TESS SUPPORT FOR MULTIPLE PROJECT REQUIREMENTS

TESS functions are available to manage all these simulation elements. They may be defined, updated, modified and extended, or be used as the basis for additional or future simulation elements. These elements may be constructed interactively and graphically. Many of these elements may be appropriate for reuse from simulation project to simulation project. The consistent environment provided by TESS for the simulationist leads to more efficient project performance, and the communication between members of a project should be enhanced.

6. AN EXAMPLE APPLICATION

An example set of simulation tasks will be described, and it will be shown how TESS supports the performance of each.

6.1 System Description

An air cargo terminal has two types of aircraft with different capacities which carry the cargo to its destinations. Cargo arrives at the terminal in unit loads at a given rate. Planes take off as soon as they can be loaded to capacity. The planes return to this cargo terminal to service other loads when the current load is delivered. The loading policy is to employ one category of plane whenever possible.

6.2 Model Construction

A SLAM II network model is constructed to represent this system to be studied. The model must be able to address performance measures such as the storage space needed for unit loads waiting for transport, and the utilization of the aircraft available. As much parameterization as possible is incorporated to allow effective scenario construction. The network model as constructed through the use of TESS is shown in Figure 2.

It will also be desirable to animate the performance of this system to observe its behavior. A schematic facility diagram is also constructed to allow better understanding of the structure and behavior of this system. The facility as constructed through the use of TESS is shown in Figure 3.

Part of the model construction task might be to represent a portion of the model for which there may be historical data. For instance, the time delay associated with the departure of an aircraft and its eventual return to its home base may be best represented by a sample from a statistical distribution. TESS has the capability to assist in this task by application of curve fitting techniques to identify an appropriate distribution. Figure 4 shows a screen image as seen by the user in this environment.

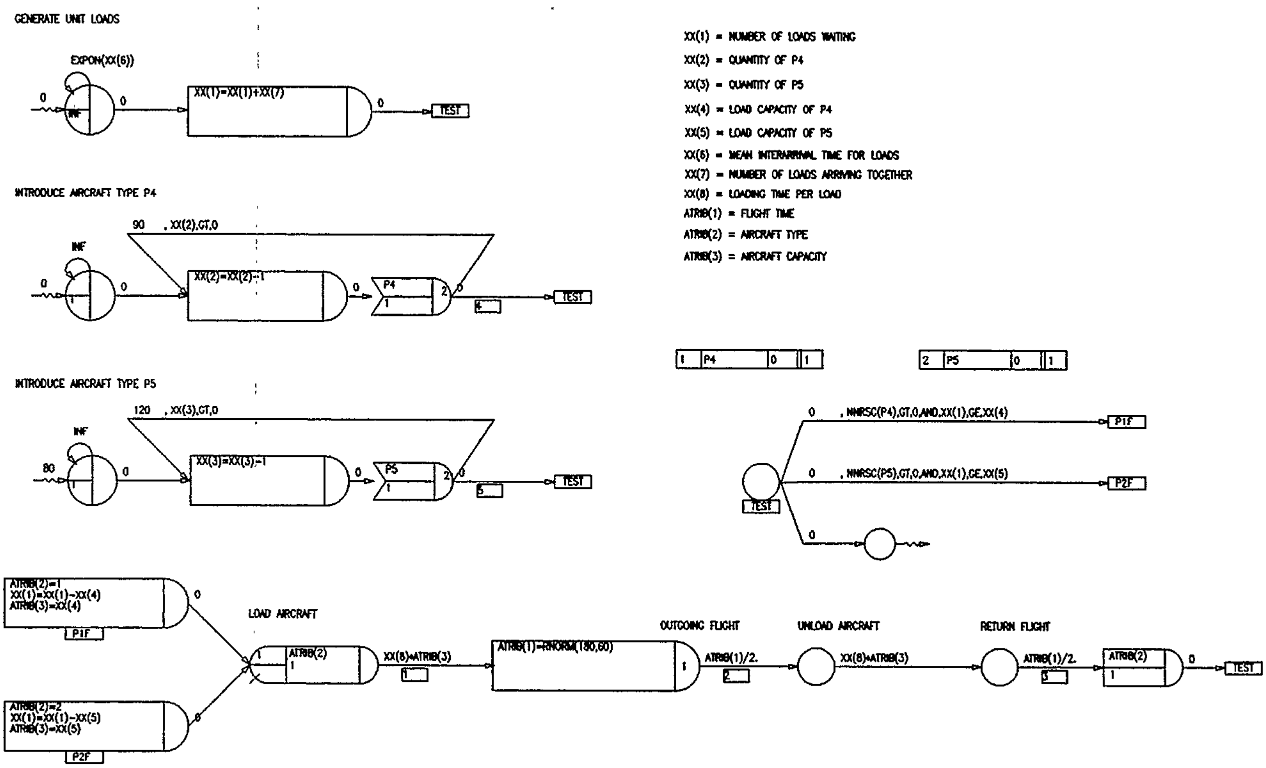

Figure 2: Network Model Constructed Through Use of the TESS Network Builder

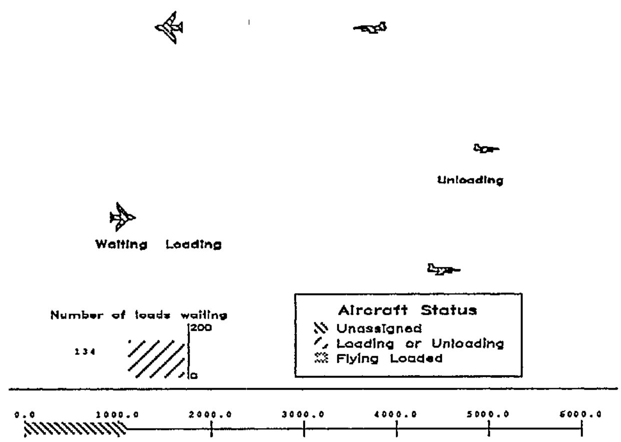

Figure 3: Facility Constructed Through the Use of TESS Facility Builder

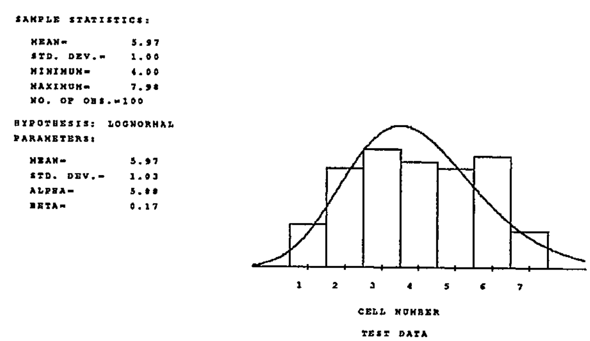

Figure 4: Sample Display from TESS Distribution Fitting Function

6.3 Control Specification

Simulation experimentation for this model is described by a set of control statements. In this case, SLAM II control statements as well as TESS data collection instructions are necessary. SLAM II control statements include an INTLC statement to provide parametric data for this simulation run. Data requirements include collection of number of unit loads awaiting aircraft, the utilization of the aircraft themselves, and a time history of the performance of the system. The control set created for one scenario is displayed in Figure 5.

```
REPORT OF CONTROLS: WSC

GEN,grant,wsc example,12/1/1988,1,Y,Y,Y/Y,Y,Y/1,72;
LIMITS,1,3,200;
;COMMENT- initialize model parameters
INTLC,XX(1)=0,XX(2)=3,XX(3)=2,
XX(4)=80,XX(5)=140,XX(6)=1,
XX(7)=2,XX(8)=0.1,=,
TIMST,XX(1),loads waiting,10//20;
INIT,0.00,6000,Y/25/Y,Y;
;COMMENT- store trace data in database
DOEVENT,HISTORY,trace history of wsc example,ACT/S,1,5,
ACT/C,1,3,
DOATRIB,ATRIB(2),PLANE,type of plane,
XX(1),QLEN,number of loads,
;COMMENT- store data in database
DOTIMST,LOADQ,queue length of loads,0,
XX(1),QLEN,length of queue,
DOTIMST,LOADQP,queue length of loads,600,
XX(1),QLEN,length of queue,
DOTIMST,PLUT,aircraft utilization,,
NRUSE(1),P4,type 1 aircraft in use,
NRUSE(2),P5,type 2 aircraft in use,
;COMMENT- store summary data in database
DSTIMST,LOADQSUM,summary of load queue,100,
XX(1),QLEN,number of loads,
FIN;
```

Figure 5: Example SLAM II Simulation Control Set

6.4 Scenario Specification and Simulation Execution

A scenario is constructed by specifying the network model component and the control set desired. The simulation is then executed causing the simulation results to be stored in the TESS database. It is desirable in this situation to construct several scenarios with different resource capacities or interarrival rates to be able to evaluate the performance of multiple versions of this system's configuration.

6.5 Result Presentation

A variety of graphical displays may be created concerning the performance of this system. For instance, it will be desirable to evaluate the space requirements for loads waiting for aircraft. Several combinations of aircraft will be considered, and it will make comparisons easy if this type of information can be displayed for many scenarios at the same time. Figure 6 shows an example in which the inventory levels for several configurations are shown together.

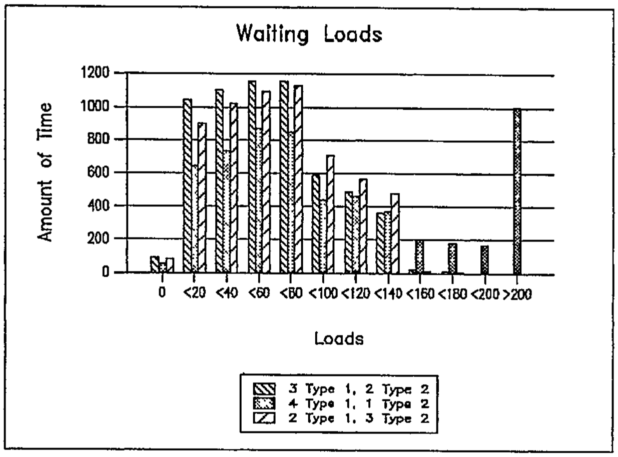

Figure 6: Multi-Scenario Comparison of Inventory Levels

In additon to showing comparisons on the same graph, it is possible to create multiple graphs on the same physical page or screen. Figure 7 shows such a combination of the time history and categorization of the inventory level along with the utilization of both types of aircraft. Notice that all these graphs have been tailored for the application by use of a prepared format using labels and text specific to the application.

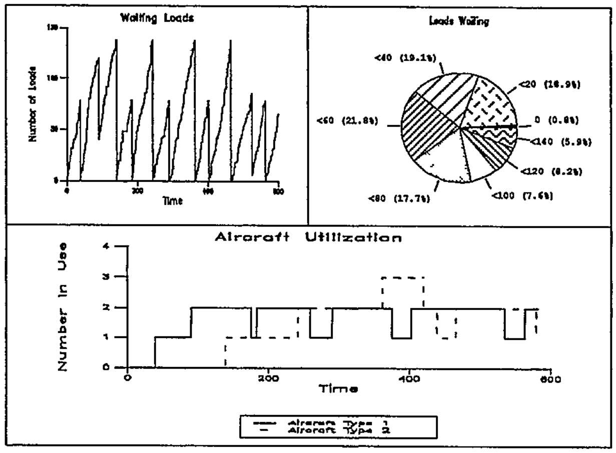

Figure 7: Multiple Graphical Displays Available Through TESS

Animation captures the dynamics of the performance of a system as represented by the model of the system. The air cargo terminal example demonstrates some of the commonly used techniques used for animation. Components of the facility include a waiting area for idle aircraft, a loading area for the aircraft, a representation of loads waiting for aircraft, and a depiction of the aircraft enroute to delivery and return to their home station. An animation may be performed using this facility description and a set of simulation trace data corresponding to the performance of the system, or sequence of events. There must be a corresponding set of instructions to translate this sequence of simulation events into animation events. An example animation rule set is shown in Figure 8.

```
REPORT OF RULES: WSC    TYPE: SLAM

IN:ACT/S,4,PLANES,1,PLANES,RED;
IN:ACT/S,5,PLANES,1,PLANEL,RED;
MONITOR:LOADS,QLEN,,,ABSOLUTE;
TANK:LOADTANK,QLEN,YELLOW,0,200;
IF PLANE.EQ.1
INCLUDE:PLANE,PLANES,,,,,,
ELSE;
INCLUDE:PLANE,PLANEL,,,,,,
ENDIF;

REPORT OF RULES: PLANE    TYPE: SLAM

OUT:ACT/S,1,PLANES,1,+P1,RED;
IN:ACT/S,1,LOADING,1,+P1,YELLOW;
OUT:ACT/S,2,LOADING,1,+P1,YELLOW;
MOVEMENT:ACT/S,2,FLIGHT,1,3,INDEX,REMOVE,
  BLUE,ACTDUR,50,+P1,NO,ERASE,NO,NO,
IN:ACT/C,2,UNLOADING,1,+P1,YELLOW;
OUT:ACT/S,3,UNLOADING,1,+P1,YELLOW;
MOVEMENT:ACT/S,3,FLIGHT2,1,3,INDEX,REMOVE,
  RED,ACTDUR,50,+P1R,NO,ERASE,NO,NO,
IN:ACT/C,3,PLANES,1,+P1,RED;
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Figure 8: Example SLAM II Animation Rule Set

7. CONCLUSION

TESS is a simulation support system that provides a framework for performing simulation projects. This framework is a formalized, problem-solving technique which provides for the entry and embellishment of models, for the organization and management of simulation input and results data, and for the presentation of these data in various ways. TESS allows a simulation project to be broken down into tasks that are performed by different members of a project team. It simplifies documentation and creates an atmosphere for using developments and data from earlier projects.

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