Communications and Tracking
Expert Systems Study
Preface

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COMMUNICATIONS AND TRACKING EXPERT SYSTEMS STUDY

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EXECUTIVE SUMMARY

The original objectives of the study consisted of five broad areas of investigation:

1. Criteria and issues for explanation of C & T system anomaly detection, isolation, and recovery;
2. Data storage simplification issues for fault detection expert systems;
3. Data selection procedures for decision tree pruning and optimization to enhance the abstraction of pertinent information for clear explanations;
4. Criteria for establishing levels of explanation suited to needs;
5. Analysis of expert system interaction and modularization.

Progress was made in areas 1, 2, 3 and 5, but to a lesser extent in area 4 during Phase I.

Among the types of expert systems studied were those related to anomaly or fault detection, isolation and recovery. Specifically, the interim results Harris and TRW T&C expert system studies were examined and work supplementing them with explanation facilities was initiated.

An expert system which is rule based may be thought of as a sequence of if-(condition)-then-(action and fact(s)) statements in an endless repeating loop. A given statement or rule, when its condition has been satisfied and it executes, is said to have "fired". The rule usually asserts "facts" which may satisfy the condition(s) of other if-statements or rules which in turn can assert actions and/or other facts and so on. The beauty of these systems is that they are flexible, easily expanded or modified, succinct, and readily understood by humans. Their problems are a general lack of structure, modularity for groups of related rules, and therefore poor maintainability. Also, in complex rule-based systems there are problems controlling the order in which the rules are applied. That is, a "resolution strategy" must be provided. Most expert systems of this type are each essentially one big program where object-oriented design and information hiding are relatively absent. These latter concepts are essential for data integrity of software systems. This is a major issue for any project as big as the Space Station, where the total software system size may be measured in millions of lines of code. The potential benefits of expert systems are too great to reject them out of hand, especially since the modularity issue is probably tractable. Modularity in such systems is being investigated as part of area number 5 above.
Results to date indicate that modularity is possible especially in the case of predictable expert systems (i.e., systems where rules cannot make new rules). In fact, virtually any predictable expert system is capable of being rewritten in a procedural language. In some cases that may be even desirable for part, if not all, of a given system. This was done in this study for a simple subsystem based upon a system simulator written by TRW. The simulator, written in C, was rewritten in Ada. Then, fault diagnosis and explanation facilities were implemented to investigate area number 1 (explanation facility) and area number 5 (interaction and modularization) described above. The source code for this system is in Appendix B as MAIN_SIM.MOD3.ADA. Results of this portion of the study are shown in item D of the body of this report. Briefly, the results indicate that, an explanation facility is best structured as an integral part of the system rather than as an appendage. Object-oriented modularization promotes data integrity, and that the capability of retrieving and using old data is probably best achieved through a procedural language. Object-oriented design was first suggested by Parnas and implies that each object (e.g., variable) should be controlled by one module and the resources necessary to modify or change any of its characteristics should reside only within that module.

The areas number 1 (expert explanation), number 2 (storage simplification) and number 3 (decision tree issues) were investigated by the implementation of a simple engine diagnosis program. The source code and concomitant comments for DIAG4.ART are in Appendix A. The results are shown in item B of the body of the report. Briefly, the results show that rules have a taxonomy (e.g., explanation rules, bookkeeping rules, action rules), and that the time stamping of facts is necessary for explanations of any past expert system actions. The need for functional or domain partitioning was one of the discoveries of this investigation.

Not much implementation of techniques for pruning decision trees of irrelevant decision nodes (area number 3) was accomplished; however, these and other data compression concepts were discussed extensively and some paths of investigation and experimentation are indicated. So-called spine optimization of the decision tree may provide a capability for explaining in retrospect how and why a decision has been reached or even perhaps why a particular decision was not reached. (A spine is defined as the conjunction of decisions for which the retrieval is a single conclusion.)

In the relatively short time this study has been in progress, what were originally nebulous issues have become more clear. This is not to say that they have become more tractable, but at least some of the issues are better defined than they were four months ago. We expect that this trend will continue.
A. Introduction

The original statement of activity objectives consisted of several items summarized as follows:

1. Examination of existing C&T systems configuration and monitoring problems--
The activity started with an examination of fault detection expert systems and historical database storage, which is one facet of the subject area of C&T system anomalous behaviour. An anomalous event may be defined as the situation when normal systems software has been unable to operate according to plan. Some tentative conclusions for structuring these activities have been determined. This activity continues.

2. Audit trail simplification policies--
Some experimental work has been accomplished for this activity. In particular, audit trails for fault detection expert systems have been analyzed. An hypothesis has been formulated, based on preliminary results which indicates that shallow explanations may be able to use a limited audit database but deeper explanation facilities may require a parallel expert system, otherwise the audit trail database might become too cumbersome. The question of the effect of utilizing distributed expert systems on practical explanation facilities has not yet been considered, but that is a subject which will need to be addressed once the resources needed by such facilities have been identified.

3. Data selection procedures--
This activity is closely related to item 2 but has been modified to focus upon decision tree pruning and storage depth of unchosen paths. For explanation purposes one hypothesis to be explored is to store chosen path nodes and one node level below each chosen path node for all unchosen paths. This would, at a minimum, double the storage required for a chosen decision tree but it would obviate the necessity for reexercising a duplicate of parts of the original expert system for shallow explanations. No general rule with specifics has yet been established but some simple subsystem simulations, namely, DIAG4.ART and MAIN SIM MOD3.ADA, have given some insight into this problem. This activity continues.

4. Criteria development for user-expert system interfaces--
This activity has been modified to focus upon identifying levels of explanation suited to various user's requirements. It will be assumed that user requirements will have already been identified. It will be assumed that short explanations will be supplied initially and that levels of depth may be requested at any point in the process. This activity has not seen much progress to date but will continue in the revised direction.
5. Expert system interaction--
Intercommunication and hierarchical decision priorities have been discussed but no definitive assertions have yet been determined. At first sight this issue seems related to partitioning and modularizing expert systems. This latter issue is one which is to be explored in the next phase of this study.

B. Explanation Facilities and Decision Trees

An explanation facility will be an important part of any system that is used to provide diagnostics for problems that may develop in the tracking and communication systems on the space station. Also, once the most probable source of a problem has been identified and corrective measures are begun, an explanation of why and how such actions have been taken will be necessary. It would appear that there are several levels of explanation that can be provided. At one extreme, a complete explanation with all the intricacies and details of all of the inferences used could be provided, such that the explanation would be effectively equivalent to providing a complete decision tree (in which only one path has been followed). At the other extreme, a brief, superficial explanation could be provided that would only indicate the most immediate reason why a particular path was selected. This might be of use in the case when a systems human monitor might have selected a different alternative than did the expert system and he seeks the reasons for the selection made by said expert system. In this latter case, it would be practical to store the path and the collection of decisions made along the path. However, simply quoting the path to the given conclusion will not, in general, provide a satisfactory explanation because there may be irrelevant decisions on the path and there may be a need for deeper explanations. It appears that the need for deeper explanations can only be satisfied if the complete reasoning process for reaching a given conclusion is available (i.e., either we provide access to all the rules that were used or we provide the complete decision tree). Such might be needed when a large scale manual intervention is planned for direct control of C&T systems and in that case irrelevant decisions would effectively be "noise" in the system. A procedure is available that would permit the removal of irrelevant decisions. It is called spine optimization, which consists of pruning the decision tree to obtain a "prime spine", and which prime spine is formed by delaying or removing irrelevant decision nodes in the tree. Most of the work so far on spines has been theoretical, so it is not clear that the benefits of such removal would justify the costs.

It may be, in some cases, that the option of providing the complete decision tree would not be practical in light of the large amount of storage that this would require for each of many points in the past. It is possible, however, that a few of the most recent decision processes could be stored in their entirety and that a number of older decision processes could be saved in an abbreviated form (perhaps with just a simple rundown on the decision path actually taken with only immediate explanations for taking a particular path provided).
If more elaborate explanations were required for older decisions, then it would still be possible, albeit time-consuming, to reload another knowledge base with the facts that were true at the time of interest and then begin to execute some of the explanation rules over again, only this time with the user interrupting that expert system and asking questions about the decisions which were made.

One of the dilemmas encountered with after-the-fact explanation facilities is that the explanation facility itself must provide some constructive filtering. Indeed, in order to remove irrelevant decision information the explanation program must prune and perhaps redo, albeit with a different perspective, some of what the diagnostic facility did in the first place. The simplest thing to do would be to supply the complete decision tree, but this would be barely one cut above the Automate Reasoning Tool (ART) dribble file as far as user utility is concerned.

An hypothesis or question which probably is worth considering is, "Should the explanation facility 'anticipate' queries so that it would effectively run in parallel to the diagnostic expert facility but without encumbering it?" Another possibility is to initiate the building of a more extensive event data base whenever an anomalous condition occurs.

At this point, without making a definite statement, let us offer a conjecture. We are of the opinion that storing the entire decision tree may be a viable solution, after all. It's not really as bad as storing the entire state at several points in time -- which might be needed since some problems will be building up over time -- in order to be able to provide explanations. The decision tree information would be kept active for a minimal time, presumably until time had passed when an explanation might be required, and then archived. We think that the decision tree also has just those rules used/needed to provide the explanation. If the other approach is used, we would have to ferret out those rules that were relevant or reload the entire expert system.

C. The ART Environment and the Attempt to Implement an Elementary Simulation, Diagnostic and Explanation System

The ART Environment

There are many advantages and some deficiencies to the Automated Reasoning Tool (ART) environment. The flexibility allows both forward and backward chaining with schema (which provides memory slots similar to frame-based languages), and viewpoints. The viewpoints may provide a way of recalling how a particular expert system operated at a given time in the past. This is something which would be useful for providing an explanation of a past event. Unfortunately, the first diagnostic and explanation example program did not use viewpoints and the lack of the availability of file input-output limited the scope of the program. Useful knowledge was obtained, nevertheless, and that should help the development of future explanation experiments.
Recommendations on Expert Systems Languages

A few observations have resulted from the first diagnostic-explanation system. The ART language coupled with the Symbolics system is a very versatile, albeit sometimes clumsy, approach to expert system development. The feasibility of developing an in-house (Ada-based) rule-based language should be investigated. This would allow data structures and I/O requirements to be tailored for the application.

This could also allow the development of subprocedure calls for both subprocedures written in sequential languages and those written in the development language (in other words, calling other expert system programs).

The DIAG4.ART Diagnostic-Explanation Program

Objectives

The goal of this program was to demonstrate at least a rudimentary explanation facility on a limited domain, mainly as a means of exploring the concepts involved, and also as a means of learning the ART language and Symbolics system.

Description

The program, written in ART, simulates the operation of a four-stroke, two-valve, single-piston internal-combustion engine. It also diagnoses failures in the ignition phase of the engine operation, and implements corrective action. It is then capable of explaining the diagnosis and the corrective action taken.

The program was also written so as to reflect some logical organization: The explanation rules are at the beginning of the program, followed by the bookkeeping rules (those responsible for updating the current parental and subgoals), followed by the initializing "split" rules, followed by the rules for action at each stroke of the cycle. The "split" rules were made necessary because the condition portion of a rule in ART does not have a provision to match on two OR'ed schema slots.

Program Outline

The engine state is modeled by a schema named CURRENT which is modified by the action of the stroke and ignition rules to reflect the operation of the engine. Each relevant component of the engine state is stored in a slot of the schema. At the same time, each slot in CURRENT is compared to a similar slot of the IDEAL engine state. Discrepancies, such as the spark plug not firing, cause error flags to be set which allow the diagnostic rules to fire. In this case, each flag triggers one diagnosis, but combinations of flags could also do this.

Diagnostic rules printout specific error messages and take corrective action (replacing the spark plug). They also query if an explanation is required. If one is, another flag is set.

The combination of the error and explanation flags allow the firing of explanation rules, of which there are two in this program.
Conclusions

The program served as a learning process, but ended up with serious deficiencies:

The fault tree was never more than two levels deep (both spark plugs fail) and did not demonstrate any combinatorial failures nor did it ever have to "guess". There couldn't be a wrong diagnosis.

All explanations were developed as the program "sequenced" through the simulation. No explanations could be given after the cycle continued: the program has no memory of what has already happened; it can only respond to the current state. This could be remedied by time-stamping all facts (saving the telemetry stream), but this would also require a new set of rules to react with past data in addition to those already existing which react with current data, effectively doubling the size of the program (at least).

All explanations either exist from the beginning or they could not be given. The drawback with programming in this style is that all possible faults and fault combinations must be figured in advance and coded into the program. This is trivial for a program this size, but is not practical for a large program. This increases the size of the program exponentially with the number of components. It also requires being able to simulate the "correct" functioning of the system at all times in order to detect discrepancies.

The source code for this program is shown in Appendix A.

Proposed Further Avenues of Exploration

The concept employed with this program would only allow explanations to be given "on the fly", that is, only after each diagnosis and/or fault correction. Explanation cannot be generated past that point in time; there is no memory of the transaction.

To avoid this fault then in order to generate explanations of past events either:

1. Save all explanations for possible future recall, or;
2. It must be possible to generate explanations from saved data.

There are a number of unexplored avenues here, such as the optimum way of generating explanations, the best way of storing data, etc.

Another concept to be explored is that of partitioning the expert system. The program, as currently written, does not support this, but the idea of breaking the system into modules, either functionally, where a module would perform certain tasks, or by domain, where each module would service a system or subsystem of the overall domain. The ability to do so would have quite an effect on the memory requirements and speed of the system.
D. Ada Implementation of a C&T Subsystem Simulator (TRW), Fault Detection and Explanation Facility with User Interaction

Motivation (objective)
This demonstration program was initiated for two reasons. First to demonstrate how a sequential software system could effectively duplicate the results of a simulation written in C and an expert system written in a specialized rule-based language such as ART (Automated Reasoning Tool by Inference Corp.). The second reason was to demonstrate that in contrast to conventional rule-based systems a sequential system can more easily store facts in a database and access them for an explanation facility. An ancillary reason was to examine how modularization could be used when implementing both diagnostic and explanation facilities.

Structure (program outline)
The program, written in Ada, consists of five modules called packages.

1. MAIN SIM MOD3
   This is really not a module but rather the driver program for the demonstration system. It essentially structures the system by calling subprograms. A simplified algorithm for this program is given in the following enumerated steps.
   (1) Initialize the communications system database;
   (2) Check for inconsistencies in the data, and if there are any, call a subprogram to ask the human monitor to correct the data;
   (3) Call the equipment emulator program;
   (4) Based upon the measured equipment output and the status of the switches, determine the condition of the equipment (i.e., diagnose the probable cause of failure, if any);
   (5) Call a subprogram to display the status of the equipment to the human monitor;
   (6) Call subprograms to provide an explanation of the diagnosis if requested;
   (7) Call a subprogram to interact with the human monitor to see if another simulation is to be run;
   (8) If the human monitor wishes to stop the program then terminate else call a subprogram to ask the monitor to update the simulation parameters and then go to step (2).
2. **Y OUT MOD**
   This package contains the equipment emulator subprogram. It effectively simulates the action of the hardware given the parameters in the equipment status database.

3. **FAULT-ANALYZE**
   This package contains the subprograms which measure the observable parameters and determines the probable fault, if any.

4. **EXPLAIN DIAGNOSIS**
   This package presents an analysis of the reasons behind the fault diagnosis when requested by the human monitor.

5. **IO SIM MOD**
   This package is the one which accesses and updates the simulated equipment parameters.

The source code for this system is shown in Appendix B.

**Observations Based Upon Results**

Not too much can be asserted with certainty but there are a few points which the work suggests. Among those are:

1. To explain even a moderately complex fault analysis decision it may be simpler to parallel a part of the decision process rather than try to filter the information from information written into the database. Again, a trade-off exists between the classical performance parameters of execution time versus memory (primary and secondary storage). For example, in the diagnostic package called FAULT_ANALYZE the principal program DIASONISIS tests the output power EQUIP_Y_OUT_LEVEL and if it is less than -145 dbm it calls a “low level” program to examine the on-off switches in SWITCH_STATUS. If the main power switch is “ON” then the oscillator switches are tested. If the selected oscillator is “ON” then the program “reasons” that the selected oscillator is inoperative. Now when an explanation of this event is requested the EXPLAIN_DIAGNOSIS package is activated. Examining the code for procedure EXPLAIN_DIAGNOSIS we see that it parallels the reasoning of procedures DIASONISIS and SWITCH_STATUS in package FAULT_ANALYZE, that is to say, it has the same nested “if” structure. The only thing it adds is the diagnostic message, “We found the selected oscillator switch to be ON, the power output was in the noise level, so potentially we had a catastrophic oscillator failure.” If the DIASONISIS and SWITCH_STATUS programs had been more cooperative they could have selected the appropriate literal value for an enumeration variable and stored this “hook” in the data base for access by the EXPLAIN_DIAGNOSIS package. Then all the EXPLAIN_DIAGNOSIS procedure would have to do is examine this variable by virtue of a simple “case” statement and supply the quoted explanation, “We found..etc.”
Such a "type" definition for the desired variable might be:

```
type Switch_Permutation_Type is
  (POWER_OFF,
   POWER_ON_OSC_OFF,
   POWER_ON_OSC_ON);
```

A variable of this type could be set equal to one of the enumeration literals by procedure SWITCH_STATUS in package FAULT_ANALYZE.

2. Communicating with a user and writing facts to files and/or ephemeral data storage which facts are useful for explanation facilities may require interfacing a given expert system to procedural language I/O routines.

3. It seems that it should be possible to modularize a given expert system to some extent. For example, a FAULT_ANALYZE subsystem could in large measure be separate from an EXPLAIN_DIAGNOSIS subsystem. There would probably be some shared data and possibly even some shared utility routines, but the main thread of each subsystem could be separate.

4. One of the deficiencies of this implementation is that explanations are done with the same database as the fault analysis system, and before any recovery corrections are made. Thus, the database is unchanged when the explanations are made. The programming system could easily be altered to allow changes in the data and still allow an explanation after the fact. The technique employed would be to create two variables for each entity, one for the old value and one for the current value. This is easily done in Ada or in any procedural language but is more difficult in a so-called expert systems language. This may indicate that any production system would require its expert systems language to provide an interface to procedural language subprograms.

Future Direction

The next task which may be proposed is to expand this demonstration program to include more realistic fault detection with more realistic "hook" data generation. Then the explanation subsystem could be restructured to use these improvements. A parallel system in ART will also be implemented (if feasible).
SUMMARY OF OVERALL RESULTS AND RECOMMENDATIONS

A. The issue of storing the complete decision tree versus only storing the knowledge base for an explanation facility has not been resolved, but a few alternatives to be explored have been identified.

1. Store the decision tree in its entirety with perhaps one branch node for paths not taken at each node in the decision tree.

2. Build and store a complete knowledge data base whenever an anomaly occurs. (This could be any undesirable outcome such as the software system displaying unanticipated behavior. This could be signalled by the astronaut monitor or the expert system itself such as when a system failure is detected by the low level systems.)

3. Store only the facts with appropriate time stamps, and when an explanation is required, load a system containing rules similar to the original expert system so as to effectively parallel the operation of the original expert system but this time allowing the user to interrupt this parallel system to ask for appropriate explanations about paths not taken.

These alternatives are not mutually exclusive but all should be examined in future work.

B. The issue of the features of an expert systems language which language is appropriate for development and perhaps implementation of software systems which meet C & T functional requirements needs to be addressed. This recommendation is based upon the experience acquired by the structuring of a simple simulation and diagnostic-explanation program written in ART, (DIAG4.ART in Appendix A), the program had to be all in one module. In addition, there were the file I/O deficiencies of ART and the difficulty of storing more than one value for a given parameter. As a minimum any such language should be capable of interfacing with a compiler language program in a straightforward manner.

C. It is recommended that the issues of object-oriented design for expert systems be raised and investigated. In addition, the concept of supplying adequate "hooks" for explanation should be addressed early. Explanation facilities are best implemented when they are built in and not just "added" as a separate entity. If this is not done the explanation facility requires additional resources and must parallel some previously "paths" already trodden by other systems. The issues of object-oriented design, modularization, and so-called information hiding may not be just academic but a necessity for implementation of any large and perhaps distributed control and monitoring system, be it a procedural and/or rule-based software system. The topic of object-oriented design for expert systems addressing anomaly detection, recovery and explanation was examined by structuring a procedural software system in Ada. The system consisted of a driver and hardware status simulator, fault diagnosis, and fault explanation modules for a small radio frequency communication subsystem. Implementing expert system functions in Ada indicated that modularization and object-oriented design indeed are feasible without compromising effectiveness.
APPENDIX A

Source Code for DIAG4.ART

an Engine Diagnostic/Explanation Program
(defschema engine-state "state of engine - beginning of intake-stroke"
  (carburation good)
  (piston-direction descending)
  (sparkplug1 good)
  (sparkplug2 standby))

(defschema current
  (instance-of engine-state))

(defschema ideal
  (instance-of engine-state))

(deffacts state
  (state-name intake))

(defrule compare-ok "compares current and ideal if same"
  (schema current (carburation ?state3))
  (schema ideal (carburation ?state3))
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ?state4))
  =>
  (printout t t "compared ok" t t))

(defun compare-not-carburation
  (schema current (carburation ?state3))
  (schema ideal (carburation ~?state3))
  =>
  (printout t t "carburation compared not ok" t t)
  (assert (error-trap carburation)))

(defun compare-not-direction
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ~?state4))
  =>
  (printout t t "piston-direction compared not ok" t t)
  (assert (error-trap direction)))

(defun no-ignition
  (state-name power)
  (ignition <- (ignition fail))
  =>
  (printout t t "sparkplug did not fire" t t)
  (assert (error-trap ignition))
  (retract ?ignition))

(defun intake-stroke
  (state-name <- (state-name intake)
  (schema current (carburation ?state3))
  (schema ideal (carburation ?state3))
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ?state4))
  =>
  (printout t t "1st Stroke - Intake Completed" t t)
  (modify
    (schema current
      (piston-direction ascending)))
  (modify
    (schema ideal
      (piston-direction ascending)))
  (retract ?state-name)
  (assert (state-name compression)))

(defun compression-stroke
  (state-name <- (state-name compression)
  (schema current (carburation ?state3))
  (schema ideal (carburation ?state3))
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ?state4))
  =>
  (printout t t "2nd Stroke - Compression" t t)
  (modify
    (schema current
      (piston-direction descending)))
  (modify
    (schema ideal
      (piston-direction descending)))
  (assert (state-name compression)))
(schema ideal
  (piston-direction descending)))
(retract ?state-name)
(assert (state-name power)))

; (printout t t "Did sparkplug : fire or fail?" t t)
; (assert (ignition =(read))))

(defun rule power-stroke
  (?state-name <- (state-name power)
  ?ignition <- (ignition fire)
  (schema current (carburation ?state3))
  (schema ideal (carburation ?state3))
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ?state4)))

  =>
  (printout t t "3rd Stroke - Power" t t)
  (modify
   (schema current
     (piston-direction ascending)))
  (modify
   (schema ideal
     (piston-direction ascending)))
  (retract ?state-name)
  (assert (state-name exhaust))
  (retract ?ignition))

(defun rule exhaust-stroke
  (?state-name <- (state-name exhaust)
  (schema current (carburation ?state3))
  (schema ideal (carburation ?state3))
  (schema current (piston-direction ?state4))
  (schema ideal (piston-direction ?state4)))

  =>
  (printout t t "4th Stroke - Exhaust" t t)
  (modify
   (schema current
     (piston-direction descending)))
  (modify
   (schema ideal
     (piston-direction descending)))
  (retract ?state-name)
  (assert (state-name intake)))

(defun rule switch-plugs
  (?error-flag <- (error-trap ignition)
  (?state-name <- (state-name ?name)
  (schema current (sparkplug2 standby))

  =>
  (modify
   (schema current
     (sparkplug1 fail))
   (sparkplug2 good)))
  (retract ?error-flag)
  (retract ?state-name)
  (assert (state-name compression))
  (printout t t "Sparkplug1 set to Failed" t t)
  (printout t t "Sparkplug2 reset from standby to good" t t)
  (printout t t "Is an explanation desired? yes or no" t t)
  (assert (explanation-flag =(read))))

(defun rule no-plugs
  (?error-flag <- (error-trap ignition)
  (?state-name <- (state-name ?name)
  (schema current (sparkplug2 good))
  (schema current (sparkplug1 fail)))

  =>
  (modify
   (schema current
     (sparkplug2 fail)))
  (retract ?error-flag)
  (retract ?name)
  (assert (state-name compression))
  (printout t t "Sparkplug2 set to Failed" t t)
  (printout t t "Is an explanation desired? yes or no" t t)
  (assert (explanation-flag =(read))))
(defrule ignition-fire
  (state-name power)
  (split ((sparkplug1 current good) =>)
    ((sparkplug2 current good) =>))

  (printout t t "Did sparkplug 1 fire or fail?" t t)
  (assert (ignition =(read)))))

(defrule explanation-I
  ?error-flag <- (error-trap ignition)
  ?ignition <- (ignition ?fire)
  (schema current (sparkplug1 fail))
  (schema current (sparkplug2 good))
  ?expl-flag <- (explanation-flag yes)

  (printout t t "Sparkplug 1 did not fire. Therefore it was replaced by the backup." t t)
  (retract ?error-flag)
  (retract ?expl-flag))

(defrule explanation-2
  ?error-flag <- (error-trap ignition)
  ?ignition <- (ignition ?fire)
  (schema current (sparkplug1 fail))
  (schema current (sparkplug2 fail))
  ?expl-flag <- (explanation-flag yes)

  (printout t t "Sparkplug 2 did not fire. Since it is the backup sparkplug,
  sparkplug 1 has already been considered failed)
  there is no remedy. However, since it is unusual to have both sparkplugs failed, the problem may reside elsewhere." t t)
  (retract ?error-flag)
  (retract ?expl-flag))
APPENDIX B

Source Code for System MAIN_SIM_MOD3.ADA

a Communication Amplifier Diagnostic/Explanation Software System
package TYP_DEF_SIM is

  type SWITCH is (ON, OFF);
  type FAULT is (ACTIVE, INACTIVE);
  type SOURCE is (A, B);
  type CONTINUE is (YES, NO);

end TYP_DEF_SIM;

PSECT MAP

<table>
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<th>Hex Size</th>
<th>Dec Size</th>
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<tr>
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<td>0000000C</td>
<td>12</td>
<td>TYP_DEF_SIM_.$CONSTANT</td>
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</table>

%ADAC-I-CL-ADDED, Package specification TYP_DEF_SIM added to library
Replaces older version compiled 17-Nov-1986 00:53

PORTABILITY SUMMARY

There are no uses of potentially non-portable constructs
-- Main program for Equipment Simulator/Diagnose

-- Function
-- To simulate operation and measurements of a radio frequency
-- power source and analyze any anomalies. An explanation facility
-- is in place.
--
-- Input
-- Initial rf source simulation parameters are read from a file
-- by procedure I_O_INIT in package I_O_SIM; thereafter revised
-- values of these parameters are entered interactively via the
-- keyboard.
--
-- Processing
-- The input parameter oscillator switch positions are checked for validity
-- then, when set properly, the input parameters are fed to the simulator
-- package Y_OUT_MOD which at present only consists of procedure EQUIPMENT_Y_O.
-- Upon return from this procedure the output power and switch positions
-- are monitored. Base upon the readings a tentative diagnosis is made.
-- If an explanation is requested, same is supplied via EXPLAIN_DIAGNOSIS.
--
-- Output
-- The results of the diagnosis made by procedures FWR_SWITCH_STATUS and
-- OUT_LEVEL in package I_O_SIM_MOD is communicated by them to the CRT
-- output device screen.
--
-- Algorithm MAIN_SIM_MOD
--
-- The algorithm used for the driver program is:
--
-- 1. Initialize the simulator by reading the equipment parameters from
--    a file.
--
-- 2. While the human monitor desires to continue
--    repeat 2 thru 9;
--
-- 3. Test if both A & B sources are switched on and if so force a
--    choice;
--
-- 4. Run the simulator in package Y_OUT_MOD;
--
-- 5. Test the results of the simulator (package FAULT_ANALYZE):
--     1. If the output is noise (i.e. -145.0 dbm) then check switches and
--        notify the monitor if the master switch is off or if on if both
--        the A & B switches are in the off position;
--
--     2. If all switches are proper and output is greater than noise but less
--        than the output caused by an output amplifier failure then presumably the
--        selected oscillator output is below the threshold needed to excite
--        the amplifier so advise the monitor to switch to the alternate oscillator;
--
--     3. If output is greater than that caused by oscillator substandard
--        output but less than that for normal operation then the failure
--        of the output amplifier may have occurred;
--
--     4. If the output is at normal level then report normal operation
6. Write out the equipment status to the CRT (procedure OUT_PARAMS
   in package I_O_SIM_MOD).
7. Interactively ask the monitor whether an explanation of the diagnosis
   is desired. If so then supply same.
8. Interactively ask the monitor if the simulation is to be continued.
9. If the monitor chooses not to continue then exit.
10. If the choice is to run another simulation the ask what parameters
    are to be changed (i.e. call NEW_PARAMS in package I_O_SIM_MOD).
11. Go back to item 2.

end algorithm MAIN_SIM_MOD

with TYP DEF SIM; with Y_OUT_MOD; with I_O_SIM_MOD; with FAULT_ANALYZE;
with EXPLAIN_DIAGNOSIS;
use TYP_DEF_SIM; use Y_OUT_MOD;

Procedure MAIN_SIM_MOD3 is

   AGAIN : CONTINUE:= YES;
   EXPLAIN : CONTINUE:= YES;
   EQPT Y,
   FREQ_SRC_A,
   FREQ_SRC_B : SWITCH;
   REF_FREQ_LEVEL_A, REF_FREQ_LEVEL_B : FLOAT;
   EQPT_Y_OUT_LEVEL_FAIL : FAULT ;
   EQUIP_Y_OUT_LEVEL,
   EQUIP_Y_OUT_LEVEL_SIM,
   EQUIP_X_OUT_LEVEL : FLOAT;

begin

   I_O_SIM_MOD,I_O_INIT(EQPT Y,FREQ_SRC_A,FREQ_SRC_B,EQPT_Y_OUT_LEVEL_FAIL,
   REF_FREQ_LEVEL_A,REF_FREQ_LEVEL_B,
   EQUIP_Y_OUT_LEVEL_SIM,EQUIP_X_OUT_LEVEL);

while AGAIN = YES

   loop

   if FREQ_SRC_A=ON and FREQ_SRC_B=ON
      then I_O_SIM_MOD.I_O_SWITCH(FREQ_SRC_A,FREQ_SRC_B);
   end if;

   end loop

end if;   -- If both "ON" force a choice between A or B "ON"

I_O_SIM_MOD.NEWPAGE:
EQUIPMENT_Y_MOD(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B),
    REF_FREQ_LEVEL_A,REF_FREQ_LEVEL_B,EQPT_Y_OUT_LEVEL_FAIL,
    EQUIP_Y_OUT_LEVEL,EQUIP_Y_OUT_LEVEL_SIM,
    EQUIP_Y_OUT_LEVEL) ; -- Run the simulator

FAULT_ANALYZE_DIAGNOSIS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B,
    EQUIP_Y_OUT_LEVEL_SIM,
    EQUIP_Y_OUT_LEVEL,EQUIP_X_OUT_LEVEL); -- Diagnose fault

I_O_SIM_MOD.OUT_PARAMS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B,EQPT_Y_OUT_LEVEL_FAIL,
    REF_FREQ_LEVEL_A,REF_FREQ_LEVEL_B,
    EQUIP_Y_OUT_LEVEL_SIM,EQUIP_X_OUT_LEVEL,EQUIP_Y_OUT_LEVEL) ;

I_O_SIM_MOD.QUERY_EXPLAIN(EXPLAIN) ; -- Does monitor want an explanation

if EXPLAIN =YES
    then
        EXPLAIN_DIAGNOSIS.EXPLAIN_DIAGNOSIS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B,REF_FREQ_LEVEL_A,REF_FREQ_LEVEL_B,
        EQUIP_Y_OUT_LEVEL_SIM,EQUIP_X_OUT_LEVEL,
        EQUIP_Y_OUT_LEVEL,EXPLAIN) ; -- If explanation desired

end if;

I_O_SIM_MOD.AGAIN_I_O(AGAIN) ; -- Ask human if wants to repeat simulation

exit when AGAIN = NO;

I_O_SIM_MOD.NEW_PARAMS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B,EQPT_Y_OUT_LEVEL_FAIL,
    REF_FREQ_LEVEL_A,REF_FREQ_LEVEL_B,
    EQUIP_Y_OUT_LEVEL_SIM,EQUIP_X_OUT_LEVEL);

end loop;

end MAIN_SIM_MOD3;

PSELECT MAP

Psect Hex Size  Dec Size  Name
  0 000001F3  499 MAIN_SIM_MOD3.$CODE

%ADAC-I-CL_ADDED, Procedure body MAIN_SIM_MOD3 added to library

PORTABILITY SUMMARY

There are no uses of potentially non-portable constructs

LIBRARY SUMMARY

USER2:[TFL.ADADIR.ADALIB]

<table>
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<tr>
<th>Unit name</th>
<th>Nodes</th>
<th>Percent read</th>
<th>Blocks</th>
<th>read</th>
<th>Unit kind</th>
</tr>
</thead>
</table>

with TYP_DEF_SIM; use TYP_DEF_SIM;

Package I_O_SIM.MOD is

-- Procedure to initialize the simulator
  procedure I_O_INIT(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : out SWITCH); -- Equipmt sw's
  EQPT_Y_OUT_LEVEL_FAIL : out FAULT; -- HW failure
  REP_FREQ_LEVEL_A, REP_FREQ_LEVEL_B, -- Osc Output
  EQPT_Y_OUT_LEVEL_SIM, -- HW failure output level
  EQUIP_X_OUT_LEVEL : out FLOAT); -- Normal Out

-- Procedure to test if both or none of ref oscillators are on
  procedure I_O_SWITCH( FREQ_SRC_A, FREQ_SRC_B : in out SWITCH); -- SW off B or A

-- Obvious what this does
  procedure NEWPAGE;

-- Test and report
  procedure FAULT_MSG_LIST(MESSAGE_NO : in INTEGER);

-- Ask if explanation desired
  procedure QUERY_EXPLAIN(EXPLAIN : out CONTINUE);

-- Present Explanation if requested
  procedure EXPLAIN_MSG_LIST(MESSAGE_NO : in INTEGER);

-- Present output parameters all at once
  procedure OUT_PARAMS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in SWITCH); -- Equipmt sw's
  EQPT_Y_OUT_LEVEL_FAIL : in FAULT; -- HW failure
  REP_FREQ_LEVEL_A, REP_FREQ_LEVEL_B, -- Osc Output
  EQPT_Y_OUT_LEVEL_SIM, -- HW failure output level
  EQUIP_X_OUT_LEVEL, -- Normal Output Power
  EQUIP_Y_OUT_LEVEL: in FLOAT); -- Actual Output

  procedure PARAM_OUT(PWR_LEVEL : in FLOAT);

-- Read from the keyboard whether eqpt monitor wants to continue the simulation or not
  procedure AGAIN_I_O(AGAIN : out CONTINUE);

-- If the simulation is to run again this procedure is called to read in new values
  procedure NEW_PARAMS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in out SWITCH); -- Equipmt sw's
  EQPT_Y_OUT_LEVEL_FAIL : in FAULT; -- HW failure
  REP_FREQ_LEVEL_A, REP_FREQ_LEVEL_B, -- Osc Output
  EQUIP_Y_OUT_LEVEL_SIM, -- HW failure output level
  EQUIP_X_OUT_LEVEL : in out FLOAT); -- Normal Out

end I_O_SIM.MOD;
with TEXT_IO; use TEXT_IO;

Package body I_O_SIM_MOD is

package SWC_ENUM_IO is new ENUMERATION_IO(SWITCH);
package SRC_ENUM_IO is new ENUMERATION_IO(SOURCE);
package FAULT_ENUM_IO is new ENUMERATION_IO(FAULT);
package AGAIN_IO is new ENUMERATION_IO(CONTINUE);
package PARAM_IO is new FLOAT_IO(FLOAT);

INITIAL : FILE_TYPE; -- File of initial parameters for the eqpt simulator

-- This package contains initialization and I/O programs

procedure I_O_INIT(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : out SWITCH; -- Equip't sw's
EQPT_Y_OUT_LEVEL_FAIL : out FAULT; -- HW failure
REF_FREQ_LEVEL_A, REF_FREQ_LEVEL_B, -- Osc Output
EQUIP_Y_OUT_LEVEL_SIM, -- HW failure output level
EQUIP_Y_OUT_LEVEL : out FLOAT) is -- Normal Output

begin -- Get initial parameter values for the simulator

OPEN(INITIAL, IN FILE, "INITIAL.SIM.DAT");
SWC_ENUM_IO.GET(INITIAL, EQPT_Y); SKIP_LINE(INITIAL);
SRC_ENUM_IO.GET(INITIAL, FREQ_SRC_A); SKIP_LINE(INITIAL);
SWC_ENUM_IO.GET(INITIAL, FREQ_SRC_B); SKIP_LINE(INITIAL);
FAULT_ENUM_IO.GET(INITIAL, EQPT_Y_OUT_LEVEL_FAIL); SKIP_LINE(INITIAL);
PARAM_IO.GET(INITIAL, REF_FREQ_LEVEL_A); SKIP_LINE(INITIAL);
PARAM_IO.GET(INITIAL, REF_FREQ_LEVEL_B); SKIP_LINE(INITIAL);
PARAM_IO.GET(INITIAL, EQUIP_Y_OUT_LEVEL_SIM); SKIP_LINE(INITIAL);
PARAM_IO.GET(INITIAL, EQUIP_Y_OUT_LEVEL); SKIP_LINE(INITIAL);
CLOSE(INITIAL);

end I_O_INIT;

procedure I_O_SWITCH(FREQ_SRC_A, FREQ_SRC_B : in out SWITCH) is

FREQ_SRC_SEL : SOURCE; -- A or B

begin -- This procedure is called from MAIN_SIM

-- This procedure only called when both A & B switches ar ON

PUT(" Both frequency sources A & B are 'ON' & inconsistent");
NEW_LINE; PUT(" Which one do you want 'ON'? (type 'A' or 'B')");
SRC_ENUM_IO.GET(FREQ_SRC_SEL); SKIP_LINE; NEW_LINE;
if FREQ_SRC_SEL = A
then FREQ_SRC_B := OFF;
else FREQ_SRC_A := OFF;
end if;

end I_O_SWITCH; -- This procedure shouldn't have logic but pass

FREQ_SRC_SEL to another package supporting the simulation. May change this later

procedure NEWPAGE is

begin

NEW PAGE;

end NEWPAGE;
procedure FAULT_MSG_LIST(MESSAGE_NO : in INTEGER) is
    -- Test all on/off switch states, then decide upon
    -- what diagnosis to transmit to equipment monitor

    case MESSAGE_NO is

    when 1 =>
        NEW_LINE; PUT(" Equipment output power is down in the noise level."); -- i.e. -125 dbm
        NEW_LINE;

    when 2 =>
        NEW_LINE; PUT(" The main switch is 'ON' so an internal failure occurred");
        NEW_LINE;

    when 3 =>
        NEW_LINE; PUT(" Both oscillators A and B are OFF so no wonder !!");
        NEW_LINE; PUT(" Next pass try turning on either oscillator.");
        NEW_LINE;

    when 4 =>
        NEW_LINE; PUT(" The selected oscillator may have completely failed");
        NEW_LINE; PUT(" Next pass try turning on the other oscillator");
        NEW_LINE;

    when 5 =>
        NEW_LINE; PUT(" The Main switch is 'OFF' so no wonder the output is noise");
        NEW_LINE;

    when 6 =>
        NEW_LINE; PUT(" The OPERATIONAL DIAGNOSIS is");
        NEW_LINE; PUT(" Since the power output is ");
        NEW_LINE;

    when 7 =>
        NEW_LINE; PUT(" The selected oscillator level is probably below threshold ");
        NEW_LINE; PUT(" so next pass switch to the other oscillator.");
        NEW_LINE;

    when 8 =>
        NEW_LINE; PUT(" A degradation of output has occurred ");
        NEW_LINE; PUT(" probably NOT caused by an oscillator failure ");
        NEW_LINE; PUT(" switch to backup unit if it's available");
        NEW_LINE;

    when 9 =>
        NEW_LINE; PUT(" Normal operation with normal output. ");
        NEW_LINE;

    when others =>
        NEW_LINE; PUT(" ERROR in value of MESSAGE_NO");
        NEW_LINE;

    end case;

end FAULT_MSG_LIST;
procedure QUERY_EXPLAIN(EXPLAIN : out CONTINUE) is
begin -- This communicates with the human monitor asking if an
       -- explanation desired
       PUT(" Do you want to know the reasoning behind the diagnostic decision? (YES/NO));
       AGAIN_IO.GET(EXPLAIN);NEW_LINE(2);
end QUERY_EXPLAIN;

procedure EXPLAIN_MSG_LIST(MESSAGE_NO : in INTEGER) is
begin -- This procedure contains some of the diagnostic logic
       -- for analyzing a substandard power output
       case MESSAGE_NO is
          when 10 =>
              NEW_LINE;PUT(" The OPERATIONAL DIAGNOSIS EXPLANATION is:");
              NEW_LINE;
          when 11 =>
              NEW_LINE;PUT(" The output measured was very low and noisy");
              NEW_LINE;PUT(" yet the master switch was ‘ON’,");
              NEW_LINE;PUT(" so the failure was something else.");
          when 12 =>
              NEW_LINE;PUT(" We then found that both the oscillator switches were ‘OFF’,");
              NEW_LINE;PUT(" so the malfunction was a set-up error.");
              NEW_LINE;
          when 13 =>
              NEW_LINE;PUT(" We found the selected oscillator switch to be ‘ON’,");
              NEW_LINE;PUT(" so, since output is noise, potentially we had a catastrophic oscillator failure");
              NEW_LINE;
          when 14 =>
              NEW_LINE;PUT(" We found the master switch in the ‘OFF’ position so ");
              NEW_LINE;PUT(" the malfunction was a set-up error. ");
              NEW_LINE;
          when 15 =>
              NEW_LINE;PUT(" The output was between -145.0 dbm and -90.0 dbm. Thus the output");
              NEW_LINE;PUT(" device was probably OK but the oscillator was below threshold.");
              NEW_LINE;PUT(" The oscillator output was insufficient to drive the output device.");
              NEW_LINE;PUT(" The logical action is to select the other oscillator on the next pass.");
              NEW_LINE;

when 16 =>
    NEW_LINE; PUT(" A degradation of output had occurred; however the output was above -90.0 dbm");
    NEW_LINE; PUT(" but this is the output when output device failure occurs.");
    NEW_LINE; PUT(" This indicates that the selected oscillator was probably OK");
    NEW_LINE; PUT(" since there was some signal leaking through the circuitry.");
    NEW_LINE; PUT(" but there was probably an output device failure.");
    NEW_LINE;
when 17 =>
    NEW_LINE; PUT(" Normal operation with normal output has occurred.");
    NEW_LINE;
when others =>
    NEW_LINE; PUT(" ERROR in EXPLAIN_DIAGNOSIS with MESSAGE_NO.");
    NEW_LINE;
end case;
end EXPLAIN_MSG_LIST;

procedure OUT_PARAMS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in SWITCH; -- Equipment sw's
    EQPT_Y_OUT_LEVEL_FAIL : in FAULT; -- HW failure
    REF_FREQ_LEVEL_A, REF_FREQ_LEVEL_B, -- Osc output
    EQUIP_Y_OUT_LEVEL_SIM, -- HW failure output level
    EQUIP_Y_OUT_LEVEL, -- Normal Output Power
    EQUIP_Y_OUT_LEVEL : in FLOAT) is
begin -- This procedure outputs the status of all simulation variable
     -- database for the current pass of the simulator code
     NEW_LINE;
     PUT(" The Status of the system is "); NEW_LINE[2];
     PUT("Equipment Switch is "); SWC_ENUM_IO.PUT(EQPT_Y); NEW_LINE;
     PUT("Frequency Source A is "); SWC_ENUM_IO.PUT(FREQ_SRC_A); -- Switches
     PUT(" Frequency Source B is "); SWC_ENUM_IO.PUT(FREQ_SRC_B); NEW_LINE;
     PUT(" The actual power output of the system is ");
     PARAM_IO.PUT(EQUIP_Y_OUT_LEVEL); NEW_LINE;
     NEW_LINE[2];
     PUT(" The status of the equipment and simulator data is: ");
     NEW_LINE; PUT(" these data normally unavailable to observer");
     NEW_LINE;
     PUT(" The GREMLIN is "); FAULT_ENUM_IO.PUT(EQPT_Y_OUT_LEVEL_FAIL); NEW_LINE;
     PUT(" The GREMLIN, if active causes system output of (ca "); -- power levels
     PARAM_IO.PUT(EQUIP_Y_OUT_LEVEL_SIM); NEW_LINE;
     PUT(" The Oscillator A normal output is "); PARAM_IO.PUT(REF_FREQ_LEVEL_A);
     NEW_LINE;
     PUT(" The Oscillator B normal output is "); PARAM_IO.PUT(REF_FREQ_LEVEL_B);
     NEW_LINE;
     PUT(" The normal system output is "); PARAM_IO.PUT(EQUIP_Y_OUT_LEVEL);
     NEW_LINE[2];
end OUT_PARAMS;
procedure PARAM_OUT(PWR_LEVEL : in FLOAT) is
   begin
      PARAM_IO.PUT(PWR_LEVEL);
   end PARAM_OUT;

procedure AGAIN_I_O(AGAIN: out CONTINUE) is
   begin
      -- Ask the equipment monitor whether or not to continue
      NEW_LINE;
      PUT("Do you wish to change some parameters and try again? ");
      PUT("(type in YES/NO )");AGAIN_IO.GET(AGAIN); SKIP_LINE;
      NEW_LINE(2);
   end AGAIN_I_O;

procedure NEW_PARAMS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in out SWITCH; -- Equipmt sw's
   EQPT_Y_OUT_LEVEL_FAIL : in out FAULT; -- HW failure
   REF_FREQ_LEVEL_A, REF_FREQ_LEVEL_B, -- Osc output
   EQPT_Y_OUT_LEVEL_SIM, -- HW failure output level
   EQPT_Y_OUT_LEVEL : in out FLOAT) is -- Normal out

   SubType INPUT_STRING is STRING(1..9);
   STRLEN : NATURAL ; -- Length of the string read from the keyboard buffer
   LOCAL_STRING: INPUT_STRING; -- Declaration of max length to be read
   CONVLEN : POSITIVE ; -- Dummy local var containing len of enum attrib

   begin -- Display present parameter values and solicit new ones
      PUT("Enter new values and <CR> or just <CR> to let value stand as is");NEW_LINE(2);
      -- Show master switch position (ON/OFF) and ask for new value
      PUT("Equipment switch is ");SWC_ENUM_IO.PUT(EQPT_Y);NEW_LINE;
      PUT("Enter new value (ON/OFF) ");
      GET_LINE(LOCAL_STRING,STRLEN); -- Get new input
      if STRLEN /= INPUT_STRING'FIRST-1 -- if an input (i.e. not just a <CR>)
         then SWC_ENUM_IO.GET(LOCAL_STRING,EQPT_Y,CONVLEN); -- then enter into DBMS
         end if;
      LOCAL_STRING := ":NEW_LINE; -- reinitialize string object
      -- Show Frequency sources switch positions and ask for new values
      PUT("Freq source A is ");SWC_ENUM_IO.PUT(FREQ_SRC_A);NEW_LINE;
      PUT("Enter new value (ON/OFF) ");GET_LINE(LOCAL_STRING,STRLEN);
      if STRLEN /= INPUT_STRING'FIRST-1 -- if an input then get it as a string
         then SWC_ENUM_IO.GET(LOCAL_STRING,FREQ_SRC_A,CONVLEN); -- convert string to its enumeration type
         end if;
      LOCAL_STRING := ":NEW_LINE;
      PUT("Freq source B is ");SWC_ENUM_IO.PUT(FREQ_SRC_B);NEW_LINE;
      PUT("Enter new value (ON/OFF) ");GET_LINE(LOCAL_STRING,STRLEN);
      if STRLEN /= INPUT_STRING'FIRST-1 -- if an input then get it as a string
         then SWC_ENUM_IO.GET(LOCAL_STRING,FREQ_SRC_B,CONVLEN);
         end if;
      LOCAL_STRING := ":NEW_LINE;
      -- Present the simulated failure status (ACTIVE/INACTIVE) ask which?
      PUT("The GREMLIN is ");FAULT_ENUM_IO.PUT(EQPT_Y_OUT_LEVEL_FAIL);
      NEW_LINE;
PUT("Enter new value (ACTIVE/INACTIVE) "); GET_LINE(LOCAL_STRING, STRLEN);
if STRLEN /= INPUT_STRING'FIRST-1
then FAULT_ENUM_IO.GET(LOCAL_STRING,EQPT_Y_OUT_LEVEL_FAIL,CONVLLEN);
end if; LOCAL_STRING := " "; NEW_LINE;

-- Present the output power levels for each oscillator and ask for updates

PUT("The Oscillator A output is "); PARAM_IO.PUT(REF_FREQ_LEVEL_A);
NEW_LINE;
PUT(" Enter a new value for Oscillator A power output in dbm "); NEW_LINE;
PUT(" (must be > -145.0 ) "); GET_LINE(LOCAL_STRING, STRLEN);
if STRLEN /= INPUT_STRING'FIRST-1
then PARAM_IO.GET(LOCAL_STRING,REF_FREQ_LEVEL_A,CONVLLEN);
end if; LOCAL_STRING := " "; NEW_LINE;
PUT("The Oscillator B output is "); PARAM_IO.PUT(REF_FREQ_LEVEL_B);
NEW_LINE;
PUT(" Enter a new value for Oscillator B power output in dbm "); NEW_LINE;
PUT(" (must be > -145.0 ) "); GET_LINE(LOCAL_STRING, STRLEN);
if STRLEN /= INPUT_STRING'FIRST-1
then PARAM_IO.GET(LOCAL_STRING,REF_FREQ_LEVEL_B,CONVLLEN);
end if; LOCAL_STRING := " "; NEW_LINE;

-- Present the normal operation power and ask for parameter change

PUT("The normal system power output is "); PARAM_IO.PUT(EQUIP_X_OUT_LEVEL);
NEW_LINE;
PUT(" Enter a new value for system power output if desired, ");
GET_LINE(LOCAL_STRING, STRLEN);
if STRLEN /= INPUT_STRING'FIRST-1
then PARAM_IO.GET(LOCAL_STRING,EQUIP_X_OUT_LEVEL,CONVLLEN);
end if; LOCAL_STRING := " "; NEW_LINE;

-- Present the output power level when an output device fails (dbm) and inquire

PUT("The output power when output device has failed, "); NEW_LINE;
PUT(" i.e. ACTIVE GREMLIN is "); PARAM_IO.PUT(EQUIP_Y_OUT_LEVEL_SIM);
NEW_LINE;
PUT(" Enter a new value for this 'GREMLIN' power output if desired,");
NEW_LINE; PUT("note that it must be less than normal power out,");
NEW_LINE; PUT(" but must also be > -90.0 "); GET_LINE(LOCAL_STRING, STRLEN);
if STRLEN /= INPUT_STRING'FIRST-1
then PARAM_IO.GET(LOCAL_STRING,EQUIP_Y_OUT_LEVEL_SIM,CONVLLEN);
end if; LOCAL_STRING := " "; NEW_LINE(2);

-- Ready to loop back and do it again

PUT_LINE(" Ready or not; Here we go again !! ");
NEW_LINE;
end NEW_PARAMS;
end I_O_SIM_MOD;
with TYP_DEF_SIM; use TYP_DEF_SIM;

Package Y_OUT_MOD is

procedure EQUIPMENT_Y -- EQPT_Y : in SWITCH; -- Equipment Switch
  FREQ_SRC_A, FREQ_SRC_B: in SWITCH; -- Osc Sw's
  REF_FREQ_LEVEL_A,
  REF_FREQ_LEVEL_B : in FLOAT; -- Osc Outputs in dbm
  EQPT_Y_OUT_LEVEL_FAIL : in FAULT; -- Fail Flag
  EQUIP_Y_OUT_LEVEL_NORMAL -- Normal output > 20.0
  EQUIP_Y_OUT_LEVEL_SIM : in FLOAT; -- Fail Out Pwr < 20.0
  EQUIP_Y_OUT_LEVEL : out FLOAT; -- Equip Pwr Out (actual)
end Y_OUT_MOD;

Line 2

0000  Y_OUT_MOD $ELAB:
C000  0000  .entry Y_OUT_MOD $ELAB, 'm(dv,iv)
  5E 00 C2 0002 subl2 $12,sp
  5C 00000000 EP DE 0005 moval $CONSTANT, ap
  5C 6C DE 000C moval (ap), ap
  5C 5C D0 000F movl ap, ap
  F4 AD 5C D0 0012 movl ap, -12(fp)
  5C 00000000* EP 7E 0016 movaq ADA$HANDLER, ap
  6D 5C D0 001D movl ap, (fp)
  5C 00000000 EP DE 0020 moval $CONSTANT, ap
  5C 04 AC 9E 0027 movab 4(ap), ap
  5C 5C D0 002B movl ap, ap
  F4 AD 5C D0 002E movl ap, -12(fp)

Line 13

F4 AD 00 D0 0032 movl 0,-12(fp)
0036  Y_OUT_MOD $ELAB$RTN LBL25:
  04 0036 ret

PSECT MAP

Psect Hex Size  Dec Size  Name
  0 00000037  55  Y_OUT_MOD .$CODE
  1 0000000C  12  Y_OUT_MOD .$CONSTANT

%ADAC-I-CL_ADDED, Package specification Y_OUT_MOD added to library
  Replaces older version compiled 27-Nov-1986 00:15

PORTABILITY SUMMARY

There are no uses of potentially non-portable constructs

LIBRARY SUMMARY

USER2:[TFL.ADADIR.ADALIB]
Package body Y_OUT_MOD is

procedure EQUIPMENT_Y (EQPT_Y: in SWITCH; -- Equipment Switch
  FREQ_SRC_A, FREQ_SRC_B: in SWITCH; -- Osc Sw's
  REF_FREQ_LEVEL_A,
  REF_FREQ_LEVEL_B: in FLOAT; -- Osc Output in dbm
  EQPT_Y_OUT_LEVEL_FAIL: in FAULT; -- Fail Flag
  EQUIP_Y_OUT_LEVEL, -- Normal output > 20.0
  EQUIP_Y_OUT_LEVEL_SIM: in FLOAT; -- Fail Out Pwr
  EQUIP_Y_OUT_LEVEL: out FLOAT) is -- Equip Pwr Out (actual)
  Ref_freq_level, Equip_Y_output_internal: FLOAT; -- Internal variables

begin
  if EQPT_Y = ON
    then if FREQ_SRC_A = ON
      then Ref_freq_level := REF_FREQ_LEVEL_A;
      else if FREQ_SRC_B = ON
        then Ref_freq_level := REF_FREQ_LEVEL_B;
      else Ref_freq_level := -145.0;
      end if;
    end if;
  if (FREQ_SRC_A = ON) and (REF_FREQ_LEVEL_A <= -120.0)
    then Ref_freq_level := -145.0;
  else if (FREQ_SRC_B = ON) and (REF_FREQ_LEVEL_B <= -120.0)
    then Ref_freq_level := -145.0;
  end if;
  if Ref_freq_level <= -145.0
    then Equip_Y_output_internal := -145.0;
  else if Ref_freq_level <= -5.0
    then Equip_Y_output_internal := -90.0;
  else if EQPT_Y_OUT_LEVEL_FAIL = ACTIVE
    then Equip_Y_output_internal := EQUIP_Y_OUT_LEVEL_SIM;
  else Equip_Y_output_internal := EQUIP_X_OUT_LEVEL;
  end if;
  end if;
  end EQUIPMENT_Y_O;
end Y_OUT_MOD;

Psect Hex Size Dec Size Name
0 0000010B 267 Y_OUT_MOD.$CODE
1 0000000C 12 Y_OUT_MOD.$CONSTANT
2 00000001 1 Y_OUT_MOD.$DATA

%ADAC-I-CL_ADDED, Package body Y_OUT_MOD added to library
Corresponds to package specification Y_OUT_MOD compiled 27-Nov-1986 00:25
with TYP_DEF_SIM; use TYP_DEF_SIM;
with I_O_SIM_MOD;
procedure SWITCH_STATUS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B : in SWITCH);
procedure OUT_LEVEL(EQUIP_Y_OUT_LEVEL_SIM,
        EQUIP_Y_OUT_LEVEL,
        EQUIP_X_OUT_LEVEL : in FLOAT);
procedure DIAGNOSIS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B : in SWITCH;
        EQUIP_Y_OUT_LEVEL_SIM,
        EQUIP_Y_OUT_LEVEL,
        EQUIP_X_OUT_LEVEL : in FLOAT);
end FAULT_ANALYZE;

PSECT MAP

Psect   Hex Size   Dec Size   Name
0  00000020     32  FAULT_ANALYZE_.$CODE
1  000000C      12  FAULT_ANALYZE_.$CONSTANT

$ADAC-I-CL_ADDED, Package specification FAULT_ANALYZE added to library
Replaces older version compiled 18-Jan-1987 21:21

PORTABILITY SUMMARY

There are no uses of potentially non-portable constructs

LIBRARY SUMMARY

USER2:[TFL.ADA1R.ADALIB]

<table>
<thead>
<tr>
<th>Unit name</th>
<th>Nodes</th>
<th>Percent read</th>
<th>Blocks</th>
<th>read</th>
<th>Unit kind</th>
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<td>41</td>
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<td>I_O_SIM_MOD</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td></td>
<td>Package specification</td>
</tr>
</tbody>
</table>
package body FAULT_ANALYZE is

  MESSAGE_NO : INTEGER;

  procedure SWITCH_STATUS(EQPT_Y,FREQ_SRC_A,FREQ_SRC_B : in SWITCH) is
  begin -- what diagnosis to transmit to equipment monitor
    begin -- called by MAIN_SIM
      -- test all on/off switch status, then decide upon
      begin -- what diagnosis to transmit to equipment monitor
      MESSAGE_NO := 1; -- put("Equipment output power is down in the noise level.");
      I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
      if EQPT_Y = ON
        then
          MESSAGE_NO := 2; -- main switch is on so must be other failure
          I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
          if (FREQ_SRC_A=OFF) and (FREQ_SRC_B=OFF)
            then
              MESSAGE_NO := 3;
              -- put("Both oscillators A and B are OFF so no wonder!!!");
              -- put("Next pass try turning on either oscillator.");
              I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
            else
              MESSAGE_NO := 4; -- selected oscillator must be inoperative so
              -- next time select the other oscillator
              I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
          end if;
        else
          MESSAGE_NO := 5; -- main Switch is 'OFF' that explains the poor output
          I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
        end if;
      end;
    end

  procedure OUT_LEVEL(EQUIP_Y_OUT_LEVEL_SIM, EQUIP_Y_OUT_LEVEL,
                          EQUIP_X_OUT_LEVEL : in FLOAT) is
  begin -- this procedure contains some of the diagnostic logic
    -- for analyzing a substandard power output
    MESSAGE_NO := 6;
    -- put("The operational diagnosis is:");
    -- put("The power output is ");
    I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
    I_O_SIM.MOD.PARAM.OUT(EQUIP_Y_OUT_LEVEL);
    if EQUIP_Y_OUT_LEVEL <= -90.0
      then
        MESSAGE_NO := 7;
        -- put("The reference oscillator level is below threshold");
        -- put("So next pass choose other oscillator.");
        I_O_SIM.MOD.FAULT_MSG_LIST(MESSAGE_NO);
      else
        if EQUIP_X_OUT_LEVEL <= EQUIP_Y_OUT_LEVEL_SIM
          then
            MESSAGE_NO := 8;
            -- put("A degradation of output has occurred.");
            -- put("caused by an output device Failure.");
I_O_SIM_MOD.FAULT_MSG_LIST(MESSAGE_NO);
else
    if EQUIP_Y_OUT_LEVEL <= EQUIP_X_OUT_LEVEL
        then
            MESSAGE_NO := 9;
            --PUT(" Normal operation with normal output.");
        I_O_SIM_MOD.FAULT_MSG_LIST(MESSAGE_NO);
        end if;
    end if;
end if;
end OUT_LEVEL;

procedure DIAGNOSIS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in SWITCH;
    EQUIP_Y_OUT_LEVEL_SIM,
    EQUIP_Y_OUT_LEVEL,
    EQUIP_X_OUT_LEVEL : in FLOAT) is

    begin
        if EQUIP_Y_OUT_LEVEL <= -145.0
            then SWITCH_STATUS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B);
        else OUT_LEVEL(EQUIP_Y_OUT_LEVEL_SIM, EQUIP_Y_OUT_LEVEL,
                        EQUIP_X_OUT_LEVEL);
        end if;
    end DIAGNOSIS;
end FAULT_ANALYZE;

PSECT MAP

<table>
<thead>
<tr>
<th>Psect Hex Size</th>
<th>Dec Size</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 00000269</td>
<td>617</td>
<td>FAULT_ANALYZE.$CODE</td>
</tr>
<tr>
<td>1 00000000C</td>
<td>12</td>
<td>FAULT_ANALYZE.$CONSTANT</td>
</tr>
<tr>
<td>2 00000008</td>
<td>8</td>
<td>FAULT_ANALYZE.$DATA</td>
</tr>
</tbody>
</table>

/%ADAC-I-CL ADDED, Package body FAULT_ANALYZE added to library
Corresponds to package specification FAULT_ANALYZE compiled 18-Jan-1987 21:22

PORTABILITY SUMMARY

There are no uses of potentially non-portable constructs

LIBRARY SUMMARY

USER2:[TFL.ADA_DIR.ADALIB]
```ada
with TYP_DEF_SIM; use TYP_DEF_SIM;
with I_O_SIM_MOD;

Package EXPLAIN_DIAGNOSIS is

  procedure EXPLAIN_DIAGNOSIS(EQPT_Y, FREQ_SRC_A, FREQ_SRC_B : in SWITCH; -- Equipmt sw's
  5   REF_FREQ LEVEL A, REF_FREQ LEVEL B, -- Osc Out
  8   EQUIP Y OUT LEVEL SIM, -- HW failure out level
  9   EQUIP X OUT LEVEL, -- Normal Out Power
  10  EQUIP Y OUT LEVEL : in FLOAT;
  11  EXPLAIN : in out CONTINUE);

end EXPLAIN_DIAGNOSIS;
```

**Psect Map**

<table>
<thead>
<tr>
<th>Psect Hex Size</th>
<th>Dec Size</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 00000020</td>
<td>32</td>
<td>EXPLAIN_DIAGNOSIS_.$CODE</td>
</tr>
<tr>
<td>1 0000000C</td>
<td>12</td>
<td>EXPLAIN_DIAGNOSIS_.$CONSTANT</td>
</tr>
</tbody>
</table>

`%ADAC-I-CL ADDED, Package specification EXPLAIN_DIAGNOSIS added to library
Replaces older version compiled 11-Jan-1987 02:22`

**PORTABILITY SUMMARY**

There are no uses of potentially non-portable constructs

**LIBRARY SUMMARY**

**USER2:[TFL.ADA_DIR.ADALIB]**

<table>
<thead>
<tr>
<th>Unit name</th>
<th>Nodes</th>
<th>Percent read</th>
<th>Blocks</th>
<th>Unit kind</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYP_DEF_SIM</td>
<td>10</td>
<td>58</td>
<td>7</td>
<td>Package specification</td>
</tr>
<tr>
<td>I_O_SIM_MOD</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>Package specification</td>
</tr>
</tbody>
</table>
Package body Explain_Diagnosis is

procedure EXPLAIN_DIAGNOSIS(EQPT Y, FREQ_SRC_A,FREQ_SRC_B : in SWITCH; -- Equipmt sw's
  -- REF_FREQ_LEVEL_A, REF_FREQ_LEVEL_B, -- Osc Out
  EQUIP_Y_OUT_LEVEL_SIM, -- HW failure out level
  EQUIP_X_OUT_LEVEL , -- Normal Out Power
  EQUIP_Y_OUT_LEVEL : in FLOAT;
  EXPLAIN : in out CONTINUE) is

  MESSAGE_NO : INTEGER; -- Local variable to contain number of msg
    -- for the message print procedure

  -- This procedure provides an explanation of the reasoning behind the
  -- diagnosis of the equipment's ills.
  -- It is called from MAIN_SIM.

  begin

    MESSAGE_NO := 10;
    I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);-- Print Header
    if EQUIP_Y_OUT_LEVEL <= -145.0
      then
        if EQPT_Y = ON
          then
            MESSAGE_NO := 11;
            -- The output measured was very low and noisy, );
            -- yet the master switch was ON,);
            -- Obviously was some other failure,);
            I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
          if ('FREQ_SRC_A=OFF' and 'FREQ_SRC_B=OFF')
            then
              MESSAGE_NO := 12;
              -- We then found both the oscillator switches were OFF, );
              -- so the malfunction was a set up error,);
              I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
            else
              MESSAGE_NO := 13;
              -- (We found the selected oscillator switch to be ON,);
              -- (so potentially we had a catastrophic oscillator failure,);
              I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
          end if;
        else
          MESSAGE_NO := 14;
          -- The master switch was found to be OFF so the malfunction);
          -- (was a set up error,)
          I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
        end if;
      else
        if EQUIP_Y_OUT_LEVEL <= -90.0
          then
            MESSAGE_NO := 15;
            -- (The out was between -145.0 dbm and -90.0 dbm. Thus the out );
            -- ( device was probably OK but the oscillator was below threshold,);
            -- (The oscillator out was insufficient to drive the out device);)
            I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
```ada
else
  if EQUIP_Y_OUT_LEVEL <= EQUIP_Y_OUT_LEVEL_SIM
    then
      MESSAGE_NO := 16;
      -- (A degradation of out had occurred, the out was above);
      -- (This indicates that the selected oscillator was OK,);
      -- (since some signal was 'leaking' through the circuitry);
      -- (but there was probably an out device failure.);
      I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
  end if;
else
  if EQUIP_X_OUT_LEVEL <= EQUIP_Y_OUT_LEVEL
    then
      MESSAGE_NO := 17;
      -- (Normal operation with normal or near normal out);
      -- (since the out is above the out failure level.)
      I_O_SIM_MOD.EXPLAIN_MSG_LIST(MESSAGE_NO);
      end if;
  end if;
end if;
end EXPLAIN_DIAGNOSIS;
end Explain_Diagnosis;
```

**PSECT MAP**

<table>
<thead>
<tr>
<th>Psect</th>
<th>Hex Size</th>
<th>Dec Size</th>
<th>Name</th>
</tr>
</thead>
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<tr>
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<tr>
<td>2</td>
<td>00000001</td>
<td>1</td>
<td>Explain_Diagnosis.SDATA</td>
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</tbody>
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*ADAC-I-CL_ADDED*, Package body EXPLAIN DIAGNOSIS added to library
Replaces older version compiled 11-Jan-1987 02:22
Corresponds to package specification EXPLAIN_DIAGNOSIS compiled 11-Jan-1987 02:29

**PORTABILITY SUMMARY**

There are no uses of potentially non-portable constructs

**LIBRARY SUMMARY**

<table>
<thead>
<tr>
<th>Unit name</th>
<th>Nodes</th>
<th>Percent</th>
<th>Blocks</th>
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<tr>
<td>Module Name</td>
<td>Ident</td>
<td>Bytes</td>
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<tr>
<td>ADA$ELAB_MAIN_SIM_MOD3</td>
<td>01</td>
<td>82</td>
<td>[TLF.ADADIR]MAIN_SIM_MOD3.OBJ:1</td>
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<td>67</td>
<td>TYP_DEF_SIM.OBJ:2</td>
<td>17-Nov-1986 15:34</td>
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<td>IO_EXCEPTIONS</td>
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<td>SYSLIB.ADALIB.IO_EXCEPTIONS.OBJ:1</td>
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<td>[TLF.ADADIR.ADALIB]Y_OUT_MOD.OBJ:2</td>
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<td>[TLF.ADADIR.ADALIB]TEXT_IO.OBJ:1</td>
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<table>
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<tr>
<th>Psect Name</th>
<th>Module Name</th>
<th>Base</th>
<th>End</th>
<th>Length</th>
<th>Align</th>
<th>Attributes</th>
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<td>LONG 2</td>
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</table>
Virtual memory allocated:
Stack size:
Image header virtual block limits:
Image binary virtual block limits:
Image name and identification:
Number of files:
Number of modules:
Number of program sections:
Number of global symbols:
Number of image sections:
User transfer address:
Debugger transfer address:
Number of code references to shareable images:
OTS transfer address - LIB$INITIALIZE:
Image type:
Map format:
Estimated map length:

Performance Indicators

---
Command processing:
Pass 1:
Allocation/Relocation:
Pass 2:
Map data after object module synopsis:
Symbol table output:
Total run values:
---

Using a working set limited to 1350 pages and 686 pages of data storage (excluding image)

Total number object records read (both passes): 944
of which 41 were in libraries and 211 were DEBUG data records containing 26139 bytes
2835 bytes of DEBUG data were written, starting at VBN 38 with 6 blocks allocated

Number of modules extracted explicitly = 0
with 2 extracted to resolve undefined symbols
0 library searches were for symbols not in the library searched
A total of 0 global symbol table records was written

LINK/MAP=[]MAIN_SIM_MOD3/EXEC=[]MAIN_SIM_MOD3 SYSSPOUTPUT:/OPTIONS