A MACHINE INDEPENDENT EXPERT SYSTEM FOR DIAGNOSING ENVIRONMENTALLY INDUCED SPACECRAFT ANOMALIES

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Abstract

A new rule-based, machine independent analytical tool for diagnosing spacecraft anomalies, the EnviroNET expert system, has been developed. Expert systems provide an effective method for storing knowledge, allow computers to sift through large amounts of data pinpointing significant parts, and most importantly, use heuristics in addition to algorithms which allow approximate reasoning and inference, and the ability to attack problems not rigidly defined.

The EnviroNET expert system knowledge base currently contains over two-hundred (200) rules, and links to databases which include past environmental data, satellite data and previous known anomalies. The environmental causes considered are bulk charging, single event upsets (SEU), surface charging, and total radiation dose.

Introduction

In order to analyze spacecraft environmental anomalies effectively, a tremendous amount of information, databases and expert knowledge must be considered. Information regarding satellite design, specifications and orbital history need to be assimilated with previous anomalies data and environmental conditions, while addressing the specific circumstances of individual users.

Seldom are the environmental problems encountered by scientists rigidly defined, and thus they lack clear mathematical solutions. Under such circumstances, algorithmic programs are too limited by their sequential logic, becoming too cumbersome when trying to consider a wide range of variables of varying degrees of certainty. EnviroNET's Expert System is being developed as a new Artificial Intelligence (AI) technique to cope with this voluminous data and fluidity associated with spacecraft/environmental causality models.

Unlike it algorithmic predecessors, an expert system can be flexible in the way that it attacks complex problems. By virtue of its three basic parts (a knowledge base, a fact base, and a driver interface) an expert system more closely simulates the methods of human experts who use a combination of known, empirically derived formulae, hunches based on degrees of certainty and experience, and even judicious "fudging" when specific data is lacking. Figure 1 shows the expert system configuration.

The modularity of the expert system allows for easy knowledge and database updates and modifications. It not only provides scientists with needed risk analysis and probability diagnosing not found in the usual programs, but it is also an effective learning tool on environments, and the window implementation makes it very easy to use.

THE KNOWLEDGE BASE

The knowledge base, with its set of rules, is what makes a rule-based expert system unique. Best thought of as an independent collection of "if...then" statements, the rules are created by experts in their respective fields and reflect the current level of human experience, along with its uncertainties. Under the weight of these rules, and by the use of multi-field variables, an expert system can be said to "ponder the possibilities" presented by the databases and current knowledge which are too extensive to be readily assimilated by any single person. Rather than being limited to conclusions that must satisfy a set of tightly ordered mathematical statements, the system is free to offer suggestions, considerations, and likelihoods.

Expert Rules

The rules in the EnviroNET expert system comprise the knowledge base used to diagnose spacecraft anomalies. The rules themselves were received from Harry C. Koons and Dr. David J. Gorney who are also developing an expert system for Aerospace Corporation, though using a hardware dependent system and a Texas Instrument commercial package.

The rule format used in the expert system is shown in figure 2. Each rule has a subject associated with it (in this case one of the four causes considered), a description of the rule, and then the actual rule itself. The rules also have what is termed a 'confidence factor' associated with the right hand side of each rule. Algorithms, which normal programs are limited to using, have a 100% certainty to them, and are a subset of the general heuristic rules which the expert system uses.

This aspect of the rule-based expert system is very important in diagnosing anomalous behavior since much of the knowledge, rules and experience required to diagnose these anomalies have probabilities associated with them. The use of such probabilities in the expert system introduces the concept of 'risk assessment' to the diagnostic procedure and

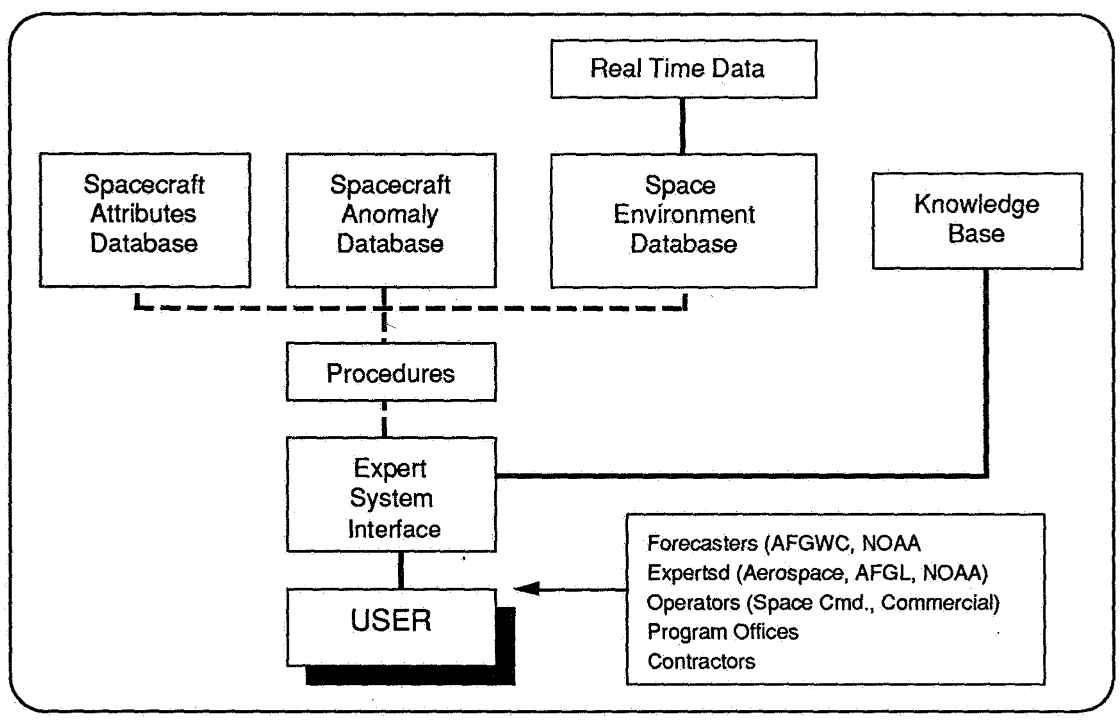

Figure 1. Expert System Configuration

the inclusion of knowledge which otherwise would be lost, since it is, at the very least, extremely difficult to represent such knowledge using mathematical formulae.

Another advantage of using a rule-based system is that it allows direct access to and easy comprehension of the knowledge and expertise used to diagnose the anomalies as opposed to the very complicated, and sometimes esoteric coding of most normal programs. Not only does this provide a way of storing the knowledge, but it also allows the system to be easily and quickly updated. These updates are accomplished by simply adding, deleting or modifying rules to which the system then automatically adjusts.

Expert Shell

In order to facilitate the use of such rules, an environment must exist where they can reside and be accessed. Such an environment is called an expert shell. The expert shell that is being used by our system is called C Language Integrated Production System (CLIPS). CLIPS was developed by the NASA Johnson AI Laboratory in Houston, Texas. We chose CLIPS for many reasons, one of which is that the software is provided free of charge, unlike the expensive Texas Instrument's commercial expert shell that Koons and Gorney use.

Though CLIPS is considered a basic expert shell, its capabilities are more than adequate for handling the requirements of this system. CLIPS is not only compatible with both C and Fortran languages, but is machine independent, allowing it to be ported to EnviroNET's multiuser system. It also has features which include the ability to compile the rules and save them in a binary image file, thus allowing faster execution than a typical rule interpretive system.

Variables

The EnviroNET expert system's use of variables is another area which makes this system unique, allowing it to handle non-

```
    RULE201
    =======
      SUBJECT :: BULK_CHARGING-RULES
      DESCRIPTION :: (recurs when fluence high)
If    1) the recurrence of the anomaly, and
      2) the recurrence is OF_HIGH_PENETRATING_FLUX, and
      3)  1) the seven-day accumulated fluence of penetrating electrons is
             HIGH, or
          2) the seven-day accumulated fluence of penetrating electrons is
             VERY_HIGH,
Then there is suggestive evidence (60%) that the cause of the anomaly is
BULK_CHARGING.

      IF   :: (RECURRENCE AND PERIODICITY = OF_HIGH_PENETRATING_FLUX AND
               (ACCUM_FLUEN = HIGH OR ACCUM_FLUEN = VERY_HIGH ) )
      THEN :: (CAUSE = BULK_CHARGING CF 60)


    RULE110
    =======
      SUBJECT :: TOTAL_DOSE-RULES
      DESCRIPTION :: (Local time recurrence rules out total radiation dose.
If    1) the recurrence of the anomaly, and
      2) the recurrence of an anomaly in a specific local-time sector.,
Then it is definite (100%) that the cause of the anomaly is not TOTAL_DOSE.

      IF   :: (RECURRENCE AND LT_RECUR)
      THEN :: (CAUSE != TOTAL_DOSE)
```

Figure 2. Rule Format

algorithmic, equivocal problems. A variable in this system can take on one of three settings. It can be '*unset*', meaning that it has not been input by the user and that no rule has been able to determine a value for it; it can be '*unknown*' which means the user was prompted for the variable but did not know it; or it can have one or more '*values*'. The unique aspects of the system are that not only can the expert system continue to execute when variables are unknown, but when variables do have values, each value has a confidence factor associated with it. Figure 3 shows examples of variable formats.

In the variable format, the translation and prompt string are self-explanatory. Each variable also has a type associated with it, either 'single-valued', 'multi-valued', or 'yes/no'. The 'expect' field is a list of the possible values for that variable which the user can select when and if he/she is prompted for that variable. The 'updated_by' field is a list of rules which are able to determine values for that variable, while the 'used_by' field contains rules which require this variable in order to fire. (It is possible that in order for a rule to fire, a variable must be '*unknown*'). The 'help' field is the information displayed when the user presses the help key, requesting more information on the variable being prompted for. The 'certainty-factor-range' (CFR) is particular to this system, and can have a value of '*unknown*', '*positive*', or '*full*'. The CFR being '*unknown*' means that this is a possible input for that variable. If the CFR is '*positive*', the user can input degrees of confidence from 0 to 100 for each of the inputted values for that variable. Finally, if the CFR is '*full*' the user can input degrees of confidence from -100 to 100 which mean a range from being 100% certain the variable is *not* a specific value to being 100% certain that the variable *is* a specific value.

The confidence factors relay the confidence the user has in a certain value of the variable. This is very important since there is

```
INCLINATION
===========
  TRANSLATION :: (the inclination of the plane of the orbit with respect
                 to the earth's equatorial plane )
  PROMPT :: (Select the inclination of the satellite with respect to the
            earth's equatorial plane. )
  TYPE :: SINGLEVALUED
  EXPECT :: (EQUATORIAL LOW_INCLINATION HIGH_INCLINATION POLAR OTHER)
  UPDATED-BY :: (RULE041 RULE133 RULE134 RULE135 RULE136 RULE132 RULE138
                RULE139 RULE140 RULE141 RULE142 RULE137 )
  ANTECEDENT-BY :: (RULE026 RULE030)
  USED-BY :: (RULE017 RULE016 RULE091 RULE089)
  HELP :: ("Low inclination orbits are below 30 deg.  High
          inclination orbits are above 60 deg.  Polar orbits
          are above 80 deg.  Interplanetary orbits are undefined." )
  CERTAINTY-FACTOR-RANGE :: UNKNOWN


LT_RECUR
========
  TRANSLATION :: (the recurrence of an anomaly in a specific local-time
                 sector. )
  PROMPT :: ("Indicate the degree of certainty that you have that this
             type of anomaly has a strong tendency to recur in one local
             time sector, for example the nightside or the dayside of the
             earth?" )
  TYPE :: YES/NO
  USED-BY :: (RULE019 RULE020 RULE110 RULE054 RULE188 RULE189 RULE190
             RULE191 RULE192 RULE193 RULE194 RULE043 )
  HELP :: (The anomaly should have occurred a few times (i.e. six or more)
          before you have confidence that the recurrence is related to a
          specific local-time sector.  Generally we are asking if the
          anomaly has a very strong tendency to occur within a 12 hour range
          in local time. )
  CERTAINTY-FACTOR-RANGE :: POSITIVE
```

Figure 3. Variable Format

most likely information of which the user is not 100% sure. Such information is lost in normal programs. The combination of the confidence factors of variables and those of the rules propagates the confidence factors (or probabilities) to other variables which are determined by these rules and ultimately to the cause of the anomaly.

Figure 4 shows an input screen for a single-valued variable (which assumes 100% confidence — as are all inputs in normal programs), and a CFR of '*unknown*'.

```
Select the name of the satellite that has experienced the anomaly.

   OSCAR_32         GSTAR_1
   OSCAR_31         LEASAT_3
   DMSP             SCATHA
   GOES_7           UNKNOWN
   FLTSATCOM_7
   POLAR_BEAR
-> NOAA_10
   GSTAR_2
   SATCOM_K1
   SATCOM_K2
   NAVSTAR_11
   ASC_1
   OSCAR_30
   OSCAR_24
   TELSTAR_3D

1. Use arrow key to position cursor.
2. press ENTER to continue.
```

Figure 4. Single-valued input

Figure 5 is an example of the input screen for a multi-valued variable with a '*positive*' CFR. Notice how the variable in figure 5 can have more than one value, and each value has its own confidence factor associated with it.

FACT BASE

The fact base, a collection of informative sources related to the topic of interest, is the second basic part of an expert system. It can consist of as many separate data bases as may

```
Set your confidence level for all of the times that have been identified
for the recurrence of this specific anomaly.

        Yes
0---------- SATELLITE_SPIN_PERIOD
0|||------- DIURNAL
0---------- SOLAR_ROTATION
0||||||||-- SOLAR_CYCLE
0---------- SPRING/FALL
0---------- MAGNETICALLY_DISTURBED
0---------- OF_HIGH_PENETRATING_FLUX

1. Use arrow key to position cursor.
2. Indicate certainty factors on all lines that apply.
3. After making selections, press ENTER to continue.
```

Figure 5. Multi-valued input with confidence

be deemed pertinent to solving the problem at hand. In the case of spacecraft anomalies, a fact base might contain information on the hardware currently in use, other active and past satellite systems, and historical data for orbital environments.

The database screen is shown in figure 6, which shows the databases available for this system along with an example of the expert system help facility which is available for any variable.

```
Select all of the databases that are available for this system.

  Yes
   X   ANOMALY
-      FLARE       The ANOMLY database is the NOAA Satellite
   X   KP          Anomaly database from the National Geophysical
                   Data Center.  The FLARE database contains X
                   class x-ray flares.  The KP database contains
                   values of the planetary magnetic index, Kp,
                   since 1932.

                   <RETURN> TO END

1. Use arrow key to position cursor.
2. Select all applicable responses.
3. After making selections, press ENTER to continue.
```

Figure 6. Database selection screen

An important advantage obtained in using the expert system is that once it has been established which databases are available, the rules determine which information is pertinent, access the database for the relevant information and apply this information, (all of which is transparent to the user). Also, the database accessing is modular and easily expandable, thus if more databases need to be added, only the selection screen needs to be changed, and the new rules added to the knowledge base.

These capabilities free the user from sifting through large amounts of data and ensure that only pertinent information and all pertinent information is used in the diagnosis.

THE INTERFACE

The interface is one of the aspects which makes all expert systems different from one another. Since the expert shell, databases and knowledge base are independent and modular, the main purpose of the interface is to create a coordinating system which is not only user friendly, but also provides the necessary features to assist the user in understanding the system and the results.

The Driver

The system's current interface driver translates forward chaining rules into a backward chaining sequence, prompting the user for information pertinent to the causes he/she wishes to consider. The main purpose of the driver is to maintain information regarding the variables which are being determined, the rules which can determine these variables, the status of the variables, and which rules can be fired.

Some variables are designated as initial variables or goal variables. The system first prompts the user for the initial variables. The driver then stacks the goal variables on the run time stack and searches the knowledge base for rules which determine (or 'update') these variables, and then puts them on the stack as well. The system focuses on those possibilities of high probability and then assists the user by directing him/her to areas of consideration that directly affect the particular problem. The goal (variable) in our system is the CAUSE of the anomaly, a multi-valued field variable with a '*full*' CFR, since it can take on any number of the four possible causes where each cause has its own confidence factor associated with it ranging from -100 to 100.

If a variable on the left hand side of a stacked rule is unset, this variable becomes the current goal variable and is put on the stack, and the process continues. If a variable is on the stack and has not determined by any rules, or by the available database, and it has a prompt string, the user is prompted for it. This can be thought of as a transformation of the forward chaining rules in the knowledge base into a backward chaining variable sequence. Once a variable has a value, it is removed from the stack and the rules which use this variable are fired, discarded, or require the driver to put the next variable on that rule's left hand side onto the stack. The chaining process continues until the stack is empty.

Any rule on the stack that can be fired does so transparently to the user, where the confidence factors of the individual variables on its left hand side (LHS) are used for determining the confidence or validity of the entire LHS. When a rule fires, it executes the right hand side (RHS), and the confidence factor associated with its LHS is used in conjunction with the confidence factor of the rule to propagate the confidence to the RHS. This

RHS execution can entail the setting of variables, the use of mathematical calculations, or the accessing of databases.

Learning Tool

One of the most beneficial aspects of the system is its use as a learning tool for diagnosing spacecraft anomalies. A user is initially given a choice between either 'novice' or 'expert' mode for the current session. If the user selects the novice mode the system automatically gives detailed explanations and descriptions of terms and reasoning as the session progresses, in a sense teaching the user about the topic or topics. The expert mode, on

```
Select all of the causes that you wish to consider for this anomaly.

  Yes
-       ALL
  X     BULK_CHARGING
-       SURFACE_CHARGING
-       SEU
  X     TOTAL_DOSE
-       PARTICLES/PLASMA

1. Use arrow key to position cursor.
2. Select all applicable responses.
3. After making selections, press ENTER to continue.
```

Figure 7. Causes selection screen

the other hand, simply executes the session without giving these extra explanations, unless the user specifically requests them.

The user is also given the option of selecting which causes are to be considered. (See figure 7.) This selection determines a knowledge base sub-group, so that only rules in this specific environmental area are considered. In this way the user can learn what variables, information and data affect, and are important to, that cause. In addition to this, in the features described next, the user is actually able to access the relevant rules him/herself and other variables and facts which were determined by using these rules.

Features

The ability to add intricate features and options is primarily due to the modularity of the system which the expert shell and expert system knowledge base concept itself provide. These features are the most impressive in demonstrating the capabilities of the EnviroNET expert system and its advantages over the usual, strictly mathematical, programming techniques.

One feature which is vital for perceiving trends in environmental conditions which may have an effect on the satellite's anomalous behavior is graphics. This system has such capability.

For example, if the user inputs that one of the databases available is Kp, the system will ask if he/she wishes to see the Kp historical graph for the time around which the anomaly occurred. If the input is 'yes', then a graph similar to the one shown in figure 8 will be displayed. (If ,however, the date is '*unset*', then

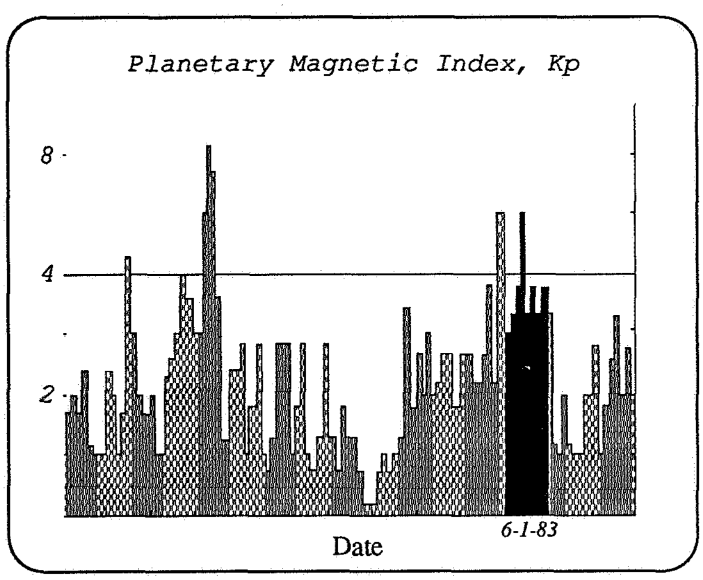

Figure 8. Kp Graph

the system will first ask for it, and if the date is '*unknown*' the system will ignore this line of questioning altogether.) This gives the user a much needed overall view of environmental information and conditions around the date in question.

```
Setting  TOTAL_DOSE_TECHNOLOGY  =  AMORPHOUS_TTL  cf  100
Testing  RULE119
RULE119  FAILS
Testing  RULE128
RULE128  FAILS
Testing  RULE129
RULE129  FAILS
Testing  RULE131
Applying  RULE131
Setting  TOTAL_DOSE_THRESHOLD  =  1000000  cf  100
Testing  RULE120
Applying  RULE120
Setting  CAUSE  =  TOTAL_DOSE  cf  -86
old cf  -30
Mark_antec_rules_for  CAUSE  RULE027
Try_marked_antec_rules
Testing  RULE027
RULE027  FAILS
End_marked_antec_rules
Testing  RULE121
** More - press ENTER to continue.
```

Figure 9. Trace example

Another feature which makes the expert system unique is its trace capability. The user can turn on the trace and send it to the screen or a file. The trace shows the rules as they are tested, variables as they are pushed onto the runtime stack and determined, and searches of the databases. (See figure 9.) This allows the user to understand what is happening at any step and see the knowledge that is being used, thus giving the user confidence in the system. This type of capability is obviously not available in the purely algorithmic programs.

Due to the amount of information the user could be prompted for and depending on the particular session, the user may want to review his/her inputs. This capability is available in the 'REVIEW' facility. This option also provides the user with a simple way of comparing different inputs of different sessions.

A feature which demonstrates a definite advantage of the rule-based expert system is what is called the 'WHY' option. Any time the system prompts the user for a variable, the user can ask the expert system why the system needs this variable. The system then uses its run time stack (a backward chaining stack) to follow and show the reasoning backward to the goal; that is, the cause of the anomaly. Figures 10-11 show an example of this. This is not only vital to understanding and having confidence in the system, but it also is an important part of the expert system's use as a learning tool.

```
Enter a value between 0 and 400 for the maximum value of the planetary
magnetic index Ap in the three day period preceding the anomaly.
If unknown press RETURN.

the three hour planetary index Ap is needed to determine the level of
magnetic activity in the magnetosphere

RULE094
If   the three hour planetary index Ap is greater than 30,
Then it is definite (100%) that the level of magnetic activity in the
magnetosphere is DISTURBED.

<RETURN> TO END
```

Figure 10. Backward reasoning

```
Enter a value between 0 and 400 for the maximum value of the planetary
magnetic index Ap in the three day period preceding the anomaly.
If unknown press RETURN.

the level of magnetic activity in the magnetosphere is needed to
determine the cause of the anomaly

RULE021
If   the level of magnetic activity in the magnetosphere is QUIET,
Then there is suggestive evidence (50%) that the cause of the anomaly
is not BULK_CHARGING.

<RETURN> TO END
```

Figure 11. Backward reasoning (con't.)

A final feature which sets the expert system apart is the 'HOW' command. As with all programs, the expert system is constantly determining variables by means other than the user inputting them, whether by the heuristics and algorithms in the rules or by extracting values from the databases. This command allows the users to, at any time, see what variables have been determined by means other than user input, their values, and which rules (or databases) were used to determine them. Figures 12-14 show an example of this feature. The user first selects which variables he/she wants to look at and then the system proceeds to show which rules determined them. Notice how it is possible for variables to be determined (or updated) by more than one rule. The user of course can choose any number of variables, though for this example only one variable, the cause of the anomaly, was selected.

This feature not only gives the user complete control over the system, but allows him/her to see all the facts and knowledge that can be inferred from the inputs they have given, the available databases, and the expertise in the rules.

As a final option, the user is also allowed, at any point, to exit from the program or begin a new session without ever leaving the program's window screen.

RESULTS

The diagnostic results are in the form of probabilities due to both the confidence assigned to rules by the experts and also the confidence of variables input by the user. Both the rule/heuristic probabilities and the input of certainty/confidence factors are needed to

```
Select the term that best describes the radiation shielding of the circuit
that experienced the anomaly.

  Yes
-    the number of the KP interval for the da  ::  (1 100 RULE097)
-    the local time interval in which the ano  ::  (0-3 100 RULE097)
-    inclination of the satellite as read fro  ::  (98.7 100 SATELLITE)
-    the apogee of the satellite............   ::  (826 100 SATELLITE)
-    the perigee of the satellite...........   ::  (808 100 SATELLITE)
-    the date the satellite was launched.....  ::  (91786 100 SATELLITE
-    the orbit of the satellite.............   ::  (DMSP 100 RULE181)
-    The altitude of the satellite..........   ::  (LOW_ALTITUDE 100 RU
-    the inclination of the plane of the orbi  ::  (HIGH_INCLINATION 10
-    the level of magnetic activity in the ma  ::  (NORMAL 100 RULE004)
  X  the cause of the anomaly...............   ::  (BULK_CHARGING -13 R
-    the Julian date........................   ::  (2447237 100 RULE115
** More - press ENTER to continue.
```

Figure 12. HOW facility

```
Select the term that best describes the radiation shielding of the circuit
that experienced the anomaly.

the cause of the anomaly is determined by:

RULE016
If    1)  1) the altitude of the satellite is LOW_ALTITUDE, or
          2) the altitude of the satellite is INTERMEDIATE_ALTITUDE,
             and
      2)  1) the inclination of the plane of the orbit with respect to
             the earth's equatorial plane is HIGH_INCLINATION, or
          2) the inclination of the plane of the orbit with respect to
             the earth's equatorial plane is POLAR,
Then there is weakly suggestive evidence (30%) that the cause of the
anomaly is not BULK CHARGING.
** End - press ENTER to continue.
```

Figure 13. HOW facility (con't.)

```
Select the term that best describes the radiation shielding of the circuit
that experienced the anomaly.

*** also determined by:

RULE006
If   the seven-day accumulated fluence of penetrating electrons is
HIGH,
Then there is weakly suggestive evidence (20%) that the cause of the
anomaly is BULK_CHARGING.

** End - press ENTER to continue.
```

Figure 14. HOW facility (con't.)

diagnose anomalies as they contain vital knowledge which can only be represented as such. The results window is shown in figure 15.

```
The orbit of the satellite is as follows:   DMSP

The possible causes of the anomaly that you wish to consider is as follows:
BULK_CHARGING  TOTAL_DOSE

The cause of the anomaly is as follows:
BULK_CHARGING  (75.%)
Not TOTAL_DOSE  (80.%)

** End - press ENTER to continue.
```

Figure 15. Results screen

The results window in our system includes, in addition to the cause(s) of the anomaly, the orbit of the satellite, whether input by the user or determined by rules, and a list of the causes considered in the diagnostics. The window can easily be modified to display any other information which is considered important. In the example, the cause of the anomaly was determined to be bulk charging with a confidence of 75%, and determined *not* to be total radiation dose with a confidence of 80%. The knowledge base does, of course, contain rules and formulae which can determine the cause of the anomaly with 100% confidence, or completely rule out a particular cause. For these situations the system will simply say that the cause, for example, *is* bulk charging or *is not* total dose.

CONCLUDING REMARKS

The expert system currently contains rules to diagnose anomalies resulting from surface charging, bulk charging, single event upsets, and total radiation. The system is extremely flexible; it can be easily expanded to include other causes as soon as the rules are obtained by simply adding these rules to the knowledge base. It can also obtain results even when information is not known.

The main concern with the system is the actual confidence and validity of the rules themselves. Since experts in any field are likely to disagree over certain areas, there may be rules to which other experts would apply slightly higher or lower degrees of confidence. This is certainly a consideration when using such a system, though it must be remembered that it is due to such a confidence/certainty question in the field that this type of expert system is needed. In addition, the features provided by the interface allow the user to see exactly what rules are being used so there is complete awareness and understanding of the formulae and knowledge being used.

Another reason this particular system is extraordinary is that its interface is completely general. Not only can the system run on many machines, the interface can be used in any field since the rules and knowledge base are completely independent of it. By substituting rules from another field, the system becomes an expert system for that field able to diagnose or solve problems towards which its tailored rules converge. In this sense the software is completely reusable and thus extends greatly beyond the scope of algorithmic programs.

The EnviroNET expert system combines the algorithmic capabilities of mathematical programs and diagnostic models with expert heuristic knowledge, and uses confidence factors in variables and rules to calculate probabilistic results. Since the causes of environmentally induced spacecraft anomalies depend not only on algorithms, but also on environmental conditions, rules and information which can rarely be known with 100% certainty, this new expert system technique which incorporates the human aspects of probabilities and expert knowledge is possibly the most comprehensive and thorough method for doing such diagnostics.

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