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SPACELAB DATA PROCESSING FACILITY (SLDPF)

QUALITY ASSURANCE EXPERT SYSTEMS

DEVELOPMENT

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ABSTRACT

The Spacelab Data Processing Facility (SLDPF) has developed expert system prototypes to aid in the performance of the quality assurance function of Spacelab and/or Attached Shuttle Payloads (ASP) processed telemetry data. The SLDPF functions include the capturing, quality monitoring, processing, accounting, and forwarding of data from Spacelab and ASP missions to various user facilities. The SLDPF consists of two functional elements: the Spacelab Input Processing System (SIPS) and the Spacelab Output Processing System (SOPS). The two expert system prototypes were designed to determine their feasibility and potential in the quality assurance of processed telemetry data. The SIPS expert system, Knowledge System Prototype, (KSP), uses an IBM PC/AT with the commercial expert system shell OPS5+. Extraction of knowledge from SIPS experts was implemented emulating the duties of quality assurance analysts. In an interactive mode, an analyst responds to queries resulting in instructions and decisions governing the reprocessing, releasing or further analysis/troubleshooting of data. Released data is forwarded for further processing on the SOPS Sperry 1100/82. The data are edited, time ordered with overlapping data removed, decommutated, and quality checked before shipment. The SOPS QA analysts isolate problems and select the appropriate action: either accept the data or request the data to be reprocessed. The SOPS expert system emulates this process by using an expert system shell, CLIPS, and the Macintosh personal computer. To date, these prototypes indicate potential beneficial results; e,g., increase analyst productivity, decrease the burden of tedious analysis, provide consistent evaluations of data, provide concise historical records, provide training for new analysts, and expedite the operational retraining of reassigned Spacelab analysts. The logic implemented in the prototypes, the limitations of the personal computers utilized, and the degree of accessibility to input data have led to an operational configuration. This configuration is currently under development and on completion will enhance the efficiency, both in time and quality, of releasing Spacelab/ASP data.

1.0 INTRODUCTON

Expert system applications in the Information Processing Division were first considered for their potential to expedite the SLDPF operations, in particular, the quality assurance (QA) and data accounting (DA) analyst functions of both the Spacelab Input Processing System (SIPS) and the Spacelab Output Processing System (SOPS). The QA/DA task is often demanding and tediously repetitive. The objective of the operational expert systems is to assist the analyst by making decisions and suggesting logical analysis paths based on given data quality information.

The expert system application to assist the QA function of SIPS was assigned to Lockheed under the direction of Code 564; Lockheed Quality Assurance Analysts (QAAs) serve as experts, and system engineers perform the knowledge engineering, coding and project management. The application to assist the QA/DA function of SOPS was tasked to Code 522, Code 564 and Lockheed; Lockheed QA analysts serve as experts, Code 522 performs the knowledge engineering and coding, and Code 564 provides the project management. Code 564 SLDPF personnel provide the technical and overall guidance of the two projects.
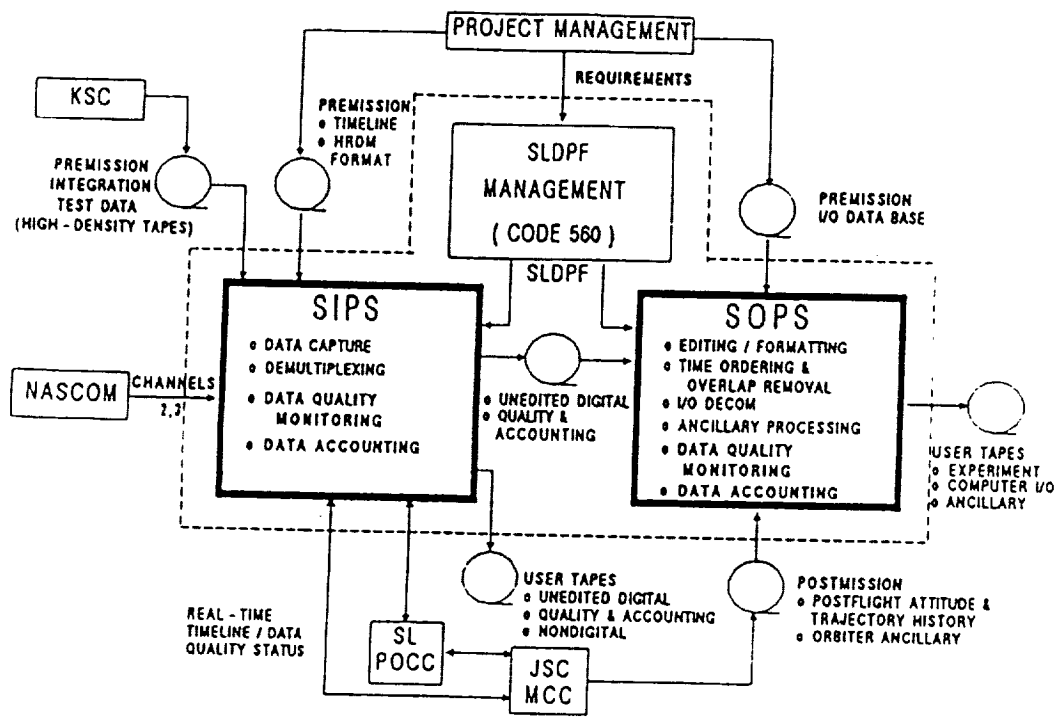
1.1 Implementation

The strategy formulated to accomplish the prototypes was to use commercial expert system shells, code the QA knowledge bases within the shells and implement the shells on personal computers. The SIPS expert system effort is identified as Knowledge System Prototype (KSP). The KSP uses OPS 5+ Development System with a C language interface installed on an IBM PC/AT. The SOPS expert system (ES) was implemented on an Apple Macintosh with CLIPS, an expert system building tool, and an interface written by Code 522.

1.2 Spacelab Data Processing Facility (SLDPF) Overview

The SLDPF processes experiment payload data from Spacelab and ASP missions. The SLDPF functions include the capturing, quality monitoring, processing, accounting, and forwarding of data to various user facilities. The SLDPF consists of two major functional elements; the Spacelab Input Processing System (SIPS) and the Spacelab Output Processing System (SOPS). See Figure 1.

During initial SIPS processing, Ku-band channel 2 and/or channel 3 data are captured onto high-density tapes (HDTs). The primary functions in this phase are the real-time capture, the monitoring of data for quality and status coordination with the Spacelab external interfaces such as the Spacelab Payload Operations Control Center (POCC), the Mission Control Center, and the Network elements. After real-time capture, the HDTs, including playback and direct access channel data are post-processed to produce Spacelab Experiment Data Tapes (SEDTs) and/or Spacelab Input/Output Data Tapes (SIDTs).

To complete SIPS processing, analysts perform quality assurance analysis by the manual evaluation of Spacelab Quality and Accounting Records (SQARs). This analysis is aided with information from several Spacelab reports and logs. The results of the QA analysis determines the release of SEDTs, SIDTs and Spacelab Quality and Accounting Tapes (SQATs) to the SOPS or to users.

PROJECT MANAGEMENT

KSC

REQUIREMENTS

PREMISSION
• TIMELINE
• HRDM
FORMAT

PREMISSION
INTEGRATION
TEST DATA
(HIGH - DENSITY TAPES)

SLDPF
MANAGEMENT
(CODE 560)

SLDPF

PREMISSION
I/O DATA BASE

SIPS

• DATA CAPTURE
• DEMULTIPLEXING
• DATA QUALITY
  MONITORING
• DATA ACCOUNTING

NASCOM | CHANNELS 2,3

• UNEDITED DIGITAL
• QUALITY &
  ACCOUNTING

SOPS

• EDITING / FORMATTING
• TIME ORDERING &
  OVERLAP REMOVAL
• I/O DECOM
• ANCILLARY PROCESSING
• DATA QUALITY
  MONITORING
• DATA ACCOUNTING

USER TAPES
• EXPERIMENT
• COMPUTER I/O
• ANCILLARY

USER TAPES
• UNEDITED DIGITAL
• QUALITY & ACCOUNTING
• NONDIGITAL

POSTMISSION
• POSTFLIGHT ATTITUDE &
  TRAJECTORY HISTORY
• ORBITER ANCILLARY

REAL - TIME
TIMELINE / DATA
QUALITY STATUS

SL
POCC

JSC
MCC

SLDPF INTERFACES
Figure 1

03/31/87
LB

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Additional data processing is performed by the SOPS. The data are edited, time ordered with overlapping data removed, decommutated, and quality checked before shipment to users. In a similar manner to the SIPS QA analysis, SOPS QA analysts combine information from various summary reports and processed logs to determine the quality of data and to decide the data status (release or reprocess).

2.0 CONFIGURATION OF PROTOTYPES

2.1 SIPS Knowledge System Prototype (KSP)

2.1.1 Overall Description and Function

The SIPS KSP is designed to emulate the performance of experienced SIPS QAAs in the evaluation of Spacelab Quality Control and Accounting Records (SQARs). This function is currently performed through the examination of printouts of the SQAR items.
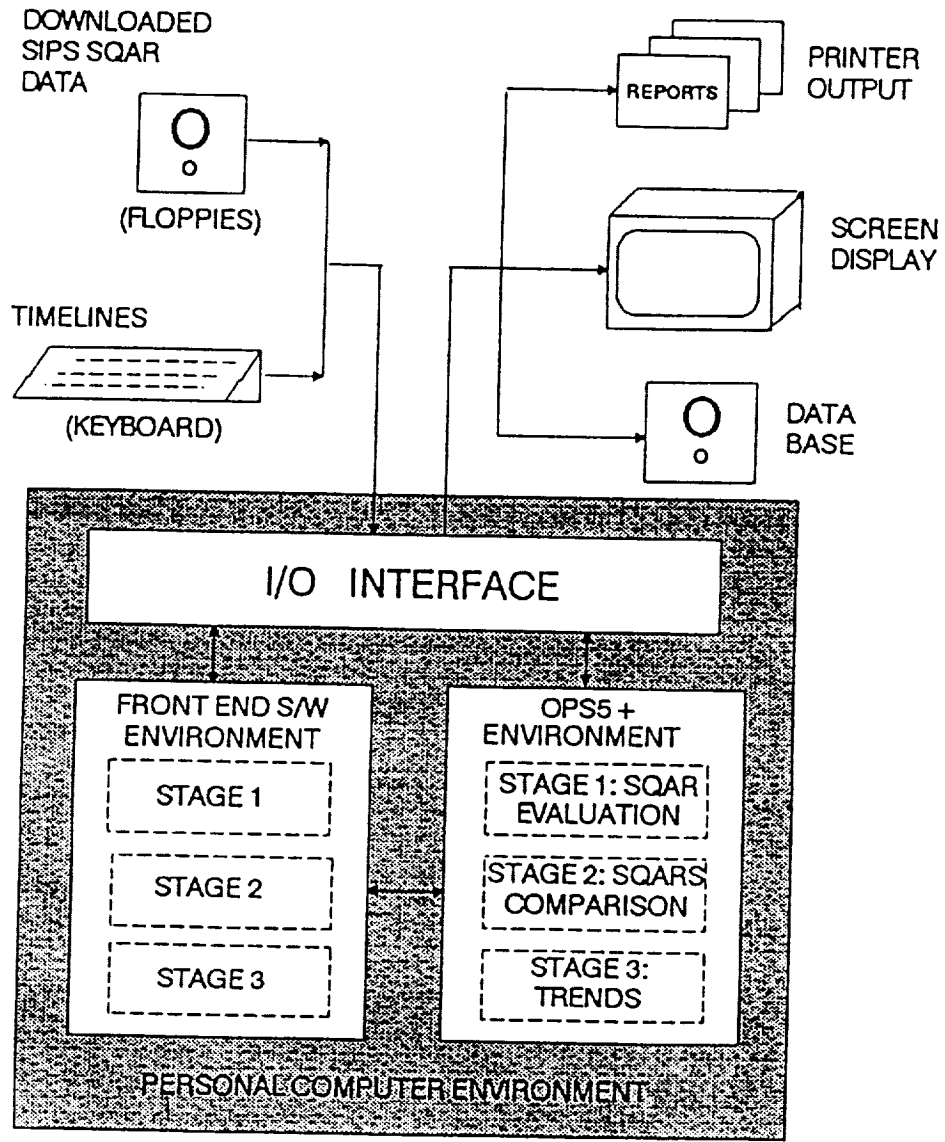
Initially, three problem areas were identified: gathering the expertise of the QAAs, accessing the data which is used in their decision making, and configuring the system on an IBM PC AT. See Figure 2 for a diagram of the KSP configuration.

The first task was the gathering of expertise of the QAAs in the area of SQAR analysis to determine if this area is a practical choice for an expert system. It became apparent that the expert system concept would work, but the scope of the initial effort would have to be restricted due to the extensiveness of the application and the limitations of the prototype hardware and software configuration. Three stages of analysis were established: initial evaluation, comparison of initial and redo runs, and data trends. Each could stand alone logically but needed access to the data and decisions of the others. This problem was addressed by the use of a database to store data as well as the decisions of each stage. The use of the database allowed the expert system to be divided into modules to run with the available memory of the prototype configuration.

The next task addressed was that of accessing the data needed for the decision making. As a test, the most used report, the Spacelab Quality Control and Accounting Record (SQAR) Report was downloaded from the Gould SEL 32/77 to an IBM PC floppy disk. Code was added to the system to read the downloaded report from the floppy and to store the data in the database. The test succeeded and dictated that the data access methods should be automated.

The code surrounding the database continued to grow to include database creation and loading, data validation, data maintenance, SQAR selection, expert system module selection, and expert system report selection. This module is known as the "Front End" because it controls access to and exit from the other expert system modules.

As previously mentioned, the expert system is divided into three parts or stages. Each stage operates independently in the expert system environment. As the expert system modules run, pertinent data and decisions are written to report files from which data base updates and printed summary reports are generated. A Spacelab Quality Assurance and Accounting Record (SQAR) must first be evaluated (Stage 1).

DOWNLOADED
SIPS SQAR
DATA

O
o

(FLOPPIES)

TIMELINES

(KEYBOARD)

REPORTS

PRINTER
OUTPUT

SCREEN
DISPLAY

O
o

DATA
BASE

I/O   INTERFACE

FRONT END S/W
ENVIRONMENT

STAGE 1

STAGE 2

STAGE 3

OPS5 +
ENVIRONMENT

STAGE 1: SQAR
EVALUATION

STAGE 2: SQARS
COMPARISON

STAGE 3:
TRENDS

PERSONAL COMPUTER ENVIRONMENT

KSP   CONFIGURATION

Figure 2

Two evaluated SQARs can be compared and the better one selected (Stage 2). Trends are investigated in Stage 3.

2.1.2 KSP Knowledge Base

The rule-based expert system tool OPS5+ is being used to develop the knowledge base for the KSP. The knowledge elements (rules) are in the following form: "IF <condition(s)> THEN <action(s)>." The KSP knowledge base rules are organized in 3 groups or stages: SQAR evaluation, SQAR comparison, and trends divided (Figure 2).

2.1.2.1 SQAR Evaluation (Stage 1)

In the SQAR evaluation phase (Stage 1) of the KSP (Figure 3) there are 201 rules. The SQAR record produced by the Gould SEL 32/77 is examined and evaluated. The result is a recommendation to accept or reprocess the file in question. The initial SQAR record is placed by the SIPS software automatically in one of four categories: above criteria, abort, hold, or null. The KSP performs further examination to determine how good the data is and if the data can be improved. Analysis occurs for each of the four categories and actions are recommended to the analyst. A summary file is created during the expert system session and is available to be printed at the end of the Stage 1 expert system session.

CATEGORIES:

Above Criteria. SQARs marked "above criteria" are examined for coverage and recovery. Missing intervals are identified and pursued. The KSP can recommend one of three choices: "release (above criteria):, "reprocess (source of improved data identified)", or "release (below criteria, best available)".

Abort. SQARs marked "abort" are examined for coverage, cause of the abort, recovery, data quality, and timing. The KSP can recommend one of two results: "release (above criteria)", "reprocess (abort)".

Hold. SQARs marked "hold" are a mixture of various types of failures. These SQARs are examined for coverage, missing intervals, bad records, and duplicate file components. The evaluation proceeds depending on the problems of the various file components. Recovery, partial (channel) abort, data quality, timing, scheduling, and receipt are examined. Several different types of failure can and do occur simultaneously. The KSP examines each situation and can recommend "release (above criteria)", "reprocess (abort)", "reprocess (source of improved data identified)", or "release (below criteria)".

Null. SQARs marked "null" are one of two types. Either no data was scheduled thus creating a deliberate pause, or data was scheduled and not received. The KSP examines the timeline for scheduling information and various operators' logs to verify data receipt/non-receipt. The KSP can then recommend "release (valid null)", or "reprocess (data expected)".

2.1.2.2 SQAR Comparison (Stage 2)

In the SQAR comparison phase (Stage 2) of the KSP there are 130 rules. This stage allows SQAR records evaluated from Stage 1 to be compared and evaluated
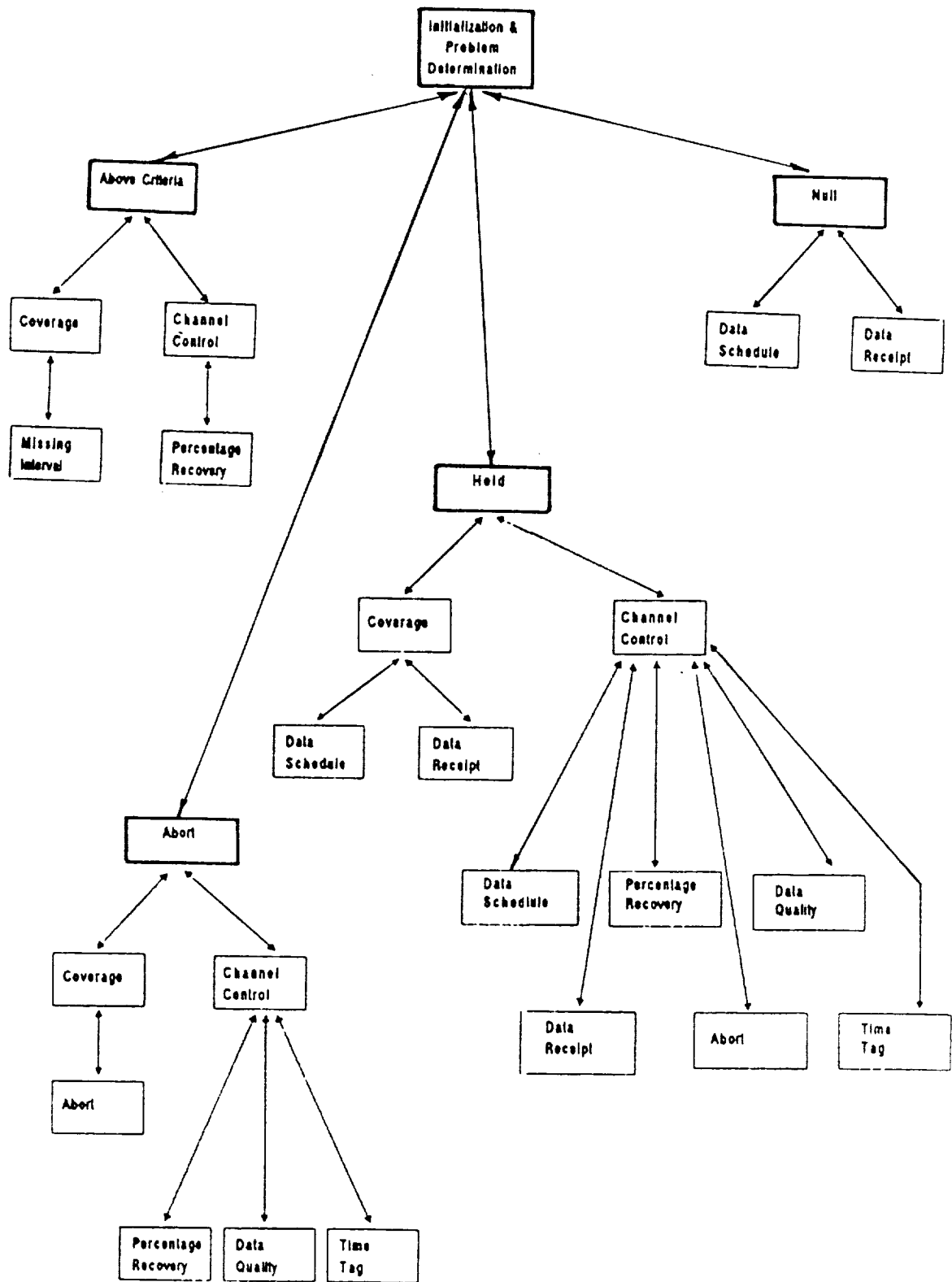
Figure 3. KSP SQAR Evaluation (Stage 1)

(Figure 4). The result is the recommendation of the better of the two SQARs. The comparisons fall into three categories; two null files, one null file and one non-null file, and two non-null files. Extensive analysis is performed on two non-null files. A summary report, a detailed report, and a final status report are available to be printed at the end of the Stage 2 expert system sessions.

Two Non-Null Files. The most meaningful comparison is between two files which both contain data. These files must have the same number of channels, and the channel IDs must correspond. A system of weights assigns values to the data evaluation criteria items: total frames, elapsed time, recovery, data quality, timing, frames without synchronization errors, and frames without timing errors. Evaluations are made on a channel by channel basis followed by a file level recommendation at the end.

One Null File and One Non-Null File. An attempt to compare a null file with a non-null file will be decided in favor of the non-null file. The null file is then marked as redundant.

Two Null Files. An attempt to compare two null files is virtually a draw. The file with the longer elapsed time is selected for retention, and the file with the shorter elapsed time is marked as redundant.

2.1.2.3 Trends (Stage 3)

Trends. Stage 3 of KSP is designed to identify trends from the evaluated SQARs. Indication of trends allows for identifying troubleshooting problem areas. For example, "Do the majority of data failures occur at a certain transmission rate or from a certain piece of equipment?";"Are certain channels failing more than others?"; "Are most aborts located in the same channel or within the same user group?". As a diagnostic tool, this will be beneficial in solving processing problems.

2.1.3 KSP User Interface

The KSP Front End interfaces with the user in the form of selection and input screens. Required responses are limited to one key-stroke if default values are selected (Figure 5). Page forward and page backward options are provided. Data input/viewing screens are provided to allow input and data maintenance (Figure 6).

The KSP expert system Stage 1 interfaces with the user in the form of a running dialog. It is initiated by loading and initializing the evaluation program after entering the OPS5+ environment (Figure 7). Data not directly downloaded is obtained by querying the user. Response requirements are limited to one character. During the Stage 1 expert system operation, a summary report is created that is printed on request (Figure 8). The Stage 2 program is loaded and initialized to perform the comparison analysis (Figure 9). This stage operates without intervention from the user as the SQAR comparison is executed. During Stage 2 operation, both a summary report and a detailed report are created and may be printed on request (Figure 10 and 11).
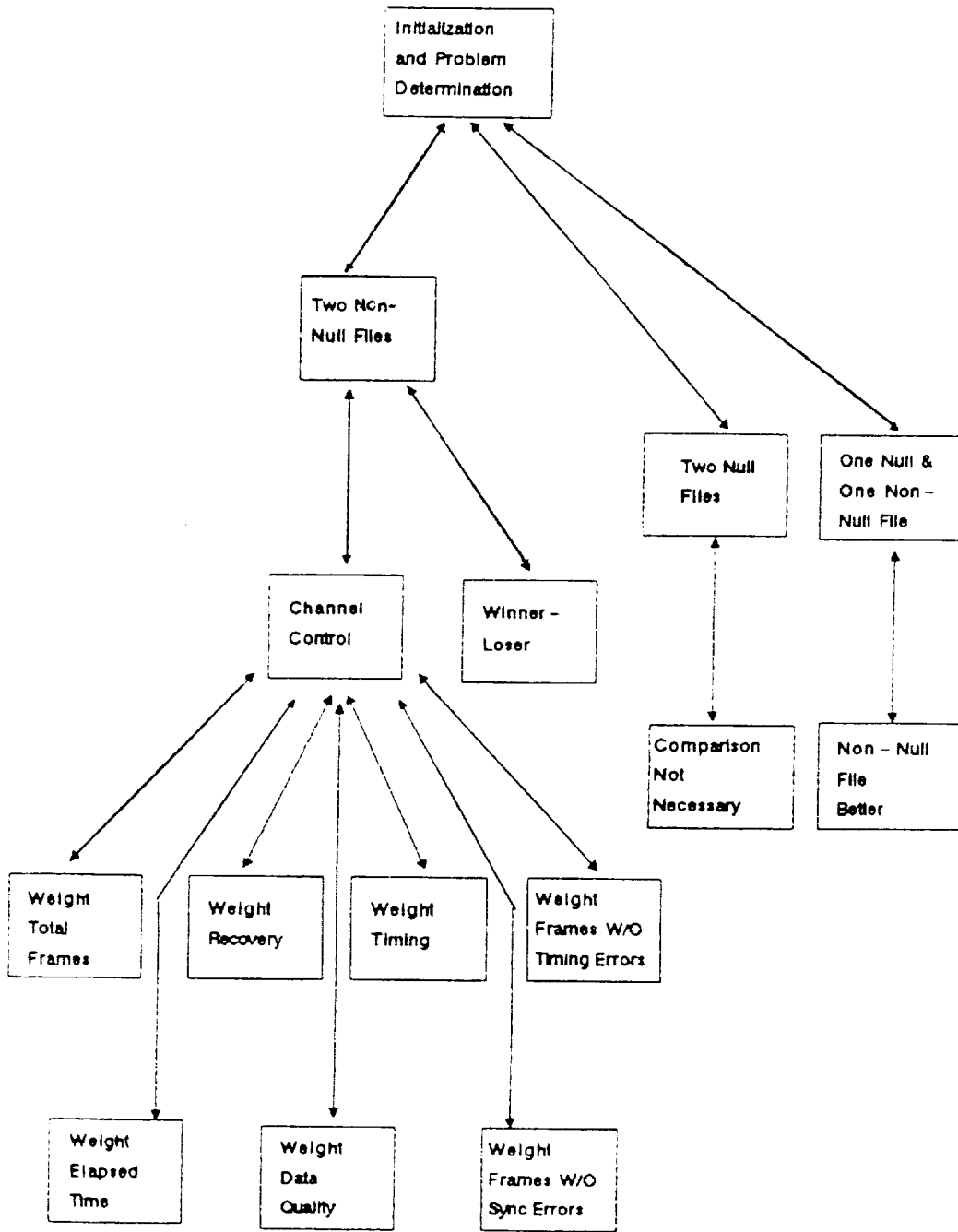
Figure 4. KSP SQAR Comparison (Stage 2)

```
********SPACELAB INPUT PROCESSING KNOWLEDGE SYSTEM PROTOTYPE*************
***********************STARTUP SCREEN***********************************
*                                                                       *
*                                                                       *
*                      TYPE  U, S, C, E, P, OR X                        *
*                      -------------------------                        *
*                                                                       *
*             U (DATA BASE UPDATE PROGRAM)                              *
*                                                                       *
*             S (SCREENS PROGRAM)                                       *
*                                                                       *
*             C (COMPARE PROGRAM)                                       *
*                                                                       *
*             E (EXPERT SYSTEMS PROGRAM)                                *
*                                                                       *
*             P (PRINT EXPERT SYSTEM SUMMARY REPORT)                    *
*                                                                       *
*             X (EXIT TO OPERATING SYSTEM)                              *
*                                                                       *
************************************************************************
```

Figure 5. KSP Main Menu

```
******** SPACELAB INPUT PROCESSING KNOWLEDGE SYSTEM PROTOTYPE ***********
*************************** FILE MENU **********************************
*                                                                       *
*    FILE TIMELINE START TIME:                                          *
*    YEAR (YY)    DAY (DDD)    HOUR (HH)    MINUTE (MM)    SECOND (SS)   *
*        NN          NNN          NN           NN             NN         *
*    FILE SUTC START TIME:                                              *
*    YEAR (YY)    DAY (DDD)    HOUR (HH)    MINUTE (MM)    SECOND (SS)   *
*        NN          NNN          NN           NN             NN         *
*                                                                       *
*    FILE TIMELINE STOP TIME:                                           *
*    YEAR (YY)    DAY (DDD)    HOUR (HH)    MINUTE (MM)    SECOND (SS)   *
*        NN          NNN          NN           NN             NN         *
*    FILE SUTC STOP TIME:                                               *
*    YEAR (YY)    DAY (DDD)    HOUR (HH)    MINUTE (MM)    SECOND (SS)   *
*        NN          NNN          NN           NN             NN         *
*                                                                       *
*    NUMBER OF CHANNELS (1-8): N                                        *
*                                                                       *
***NEXT PAGE**PREVIOUS PAGE**EXIT***************************************
```

Figure 6. KSP File Menu

```
*************************************************************************
* Copyright (c) Computer * Thought Corp., 1985, 1986.                   *
* Welcome to OPS5+                                                      *
* : (load "eval.ops")                                                   *
* ****|****|****|****|****|****|****|****|****|****|****|****|****|****= *
* ****|****|****|****|****|****|****|****|****|****|****|****|****|****= *
* ****|****|****|****|****|****|****|                                    *
* : (watch 0)                                                           *
* : (make start)                                                        *
* : (run)                                                               *
*                                                                       *
*                 THEN THE KSP STAGE 1 EXPERT SYSTEM RUNS               *
*                       UNTIL ALL THE PRODUCTIONS                       *
*                            HAVE FIRED.                                *
*         .                          .                        .         *
*         .                          .                        .         *
*         .                          .                        .         *
*                 WHEN IT IS DONE, THE SYSTEM RESPONDS WITH             *
*                            THE MESSAGE:                               *
*                                                                       *
* No production true                                                    *
* : (exit)                                                              *
* Goodbye                                                               *
*                                                                       *
*************************************************************************
```

Figure 7. Load KSP Stage 1

```
========================================================================
SQAR EVALUATION                                              A0001A/01
========================================================================
FQC = H
File expected = 1001 seconds.  File actual = 716 seconds.  File MI = 285 seconds
ACTION:   Process HRM file when received from DACON.
========================================================================
------------------------------------------------------------------------
Channel = 1    CQC = A
Computed frames = 238607            Recovery = 83.52814 percent.
FAILURE:  Recovery/external.
ACTION:   Set CQC to F.  ** REPROCESS **
------------------------------------------------------------------------
Channel = 14   CQC = T
ACTION:   Set CQC to F.  ** REPROCESS **
========================================================================
ACTION:   Set PSC to REQ.
ACTION:   Set FQC to F.  ** REPROCESS **
========================================================================
```

Figure 8. KSP Stage 1 Summary Report

```
****************************************************************************
* Copyright (c) Computer * Thought Corp., 1985, 1986.                      *
* Welcome to OPS5+                                                         *
* : (load "comp.ops")                                                      *
* ****#****#****#****#****#****#****#****#****#****#****#****#****#****#****= *
* ****#****#****#****#****#****#****#****#****#****#****#****#****#****#****= *
* ****#****#****#****#****#****#****#                                       *
* : (watch 0)                                                              *
* : (make start)                                                           *
* : (run)                                                                  *
*                                                                          *
*                 THEN THE KSP STAGE 2 EXPERT SYSTEM RUNS                  *
*                       UNTIL ALL THE PRODUCTIONS                          *
*                              HAVE FIRED.                                 *
*        .                          .                          .          *
*        .                          .                          .          *
*        .                          .                          .          *
*                 WHEN IT IS DONE, THE SYSTEM RESPONDS WITH                *
*                            THE MESSAGE:                                  *
*                                                                          *
* No production true                                                       *
* : (exit)                                                                 *
* Goodbye                                                                  *
*                                                                          *
****************************************************************************
```

Figure 9.   Load KSP Stage 2

```
===============================================================
                   SQAR COMPARISON SUMMARY
CHANNEL ID           A0003A/01              B0004B/08
===============================================================
      3              839.389800            1355.610000
                                           * GREATER *

      4             1331.000000             865.000000
                    * GREATER *

      5             1103.000000            1093.000000
                    * GREATER *

---------------------------------------------------------------
   Total            3273.389800            3313.610000
                                           * GREATER *

===============================================================
```

Figure 10.   KSP Stage 2 Summary Report

```
================================================================================
                       DETAILED CHANNEL COMPARISON
================================================================================
CHANNEL ID 3                        A0003A/ 1                 B0004B/ 8
                                 Value   Weight            Value   Weight
Total Frames                     142804    266             71402    .133
Delta Time                         1348    266               674     133
Percent Recovery                     77    200                77     200
QP1                              99.015000 150.000000    99.644000 150.000000
QP4                              99.644000  50.000000    99.644000  50.000000
F3                                  703    ---               703    ---
Frames Without Sync Errors       142101    333             70699     166
F5                                  254    ---               254    ---
Frames Without Timing Errors     142550     66             71148      33
FINAL CHANNEL GRADE               1331.000000              865.000000
                                 **** GREATER ***
--------------------------------------------------------------------------------
CHANNEL ID 13                       A0003A/ 1                 B0004B/ 8
                                 Value   Weight            Value   Weight
Total Frames                       9573    199              9600     200
Delta Time                          715    199               716     200
Percent Recovery                     83    200                83     200
QP1                              94.463000 149.574800    99.850000 150.425200
QP4                              99.822000  49.992990    99.850000  50.007010
F3                                   530    ---               520    ---
Frames Without Sync Errors         9043    249              9080     250
F5                                    17    ---                15    ---
Frames Without Timing Errors       9556     49              9585      50
FINAL CHANNEL GRADE               1095.568000             1100.432000
                                                          *** GREATER ***
================================================================================
FINAL GRADE FILE                  2426.568000             1965.432000
                                 *** GREATER ***
OPTIONS:   (1)   OVERRIDE GRADE
           (2)   ACCEPT GRADE
================================================================================
```

Figure 11.   KSP Stage 2 Detailed Report

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2.2 SOPS EXPERT SYSTEM (ES)

2.2.1 Overall Description and Function

Code 522 developed the knowledge base for the prototype using the rule-based expert system language CLIPS. In a rule based ES all knowledge elements are represented and processed in the form of If... then... rules. The if is followed by a set of conditions and then by a set of actions that will only take place when all the conditions following the if are met.

The prototype SOPS Knowledge base can be logically divided into sets called knowledge island. Each knowledge island consists of rules to diagnose a problem, drive the user interface, and to retrieve data specific to that knowledge island. This knowledge base structure simplifies the process of modifying the ES. A knowledge island can be modified or replaced to reflect a procedural change in SOPS without affecting the other knowledge islands.

The SOPS prototype ES consists of four knowledge islands: Run Stopped Early, Data Gap Between files, Coverage, and Data Quality. The following sections present a simplified graph depicting the internal structure of each knowledge island along with a brief description. The knowledge islands were implemented in the prototype ES only to the detail required to realistically demonstrate an operational SOPS ES. The project team will expand each knowledge island for future implementation to include particulars uncovered by this prototype ES.

2.2.2 SOPS ES Knowledge Base

Run Stopped Early. This knowledge island determines if the run stopped early and attempts to determine why (see Figure 12a). The prototype ES will determine if the run stopped early by comparing the processed stop time on the SIDT report with the run stop time on the MIDT report. The QA is required to account for the missing data if the time difference is greater than five seconds. If the two stop times are within five seconds then the ES can continue to the next knowledge island; if not, the ES will attempt to determine the cause for the missing data. The ES will first check if the time from the last major frame used in the file is the same as the run stop time on the MIDT report for an indication of a possible run abort during processing. This condition is typically caused by a hardware problem such as a bad tape drive. If the times are the same, the ES will prompt the QA to look in the SIDT database and the card deck to check if the correct files were used for this run.

Data Gap Between Files. This knowledge island determines if there is missing data between two files in the run (see Figure 12b). The prototype ES accomplishes this by comparing the stop time of the first file in the run with the start time of the next file of the same type. The two types of files, high data rate and low data rate, are not compared to each other. The ES will continue to compare the stop and start time for each successive file of the same type. If no gaps greater than five seconds are found between the files, the ES can continue to the next knowledge island.
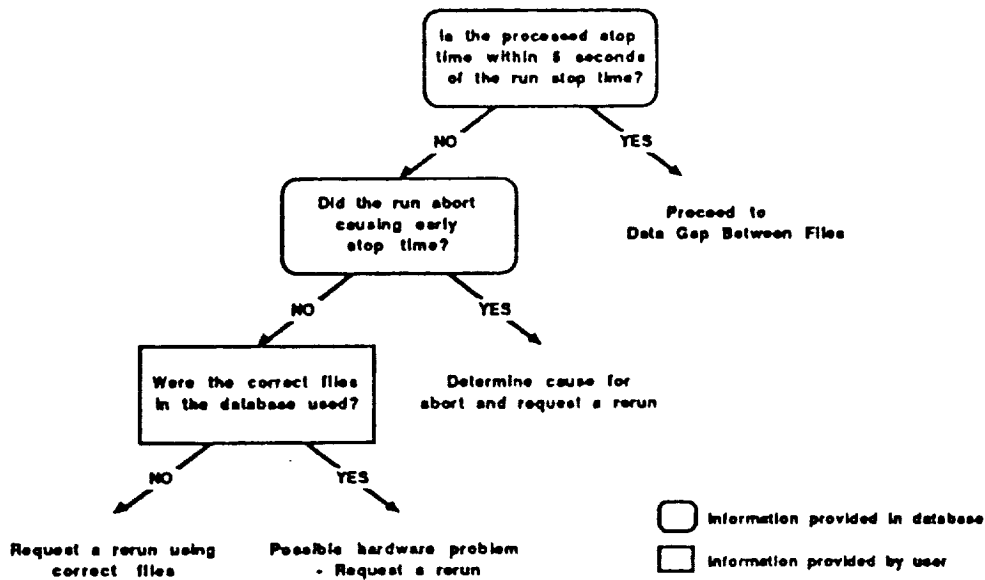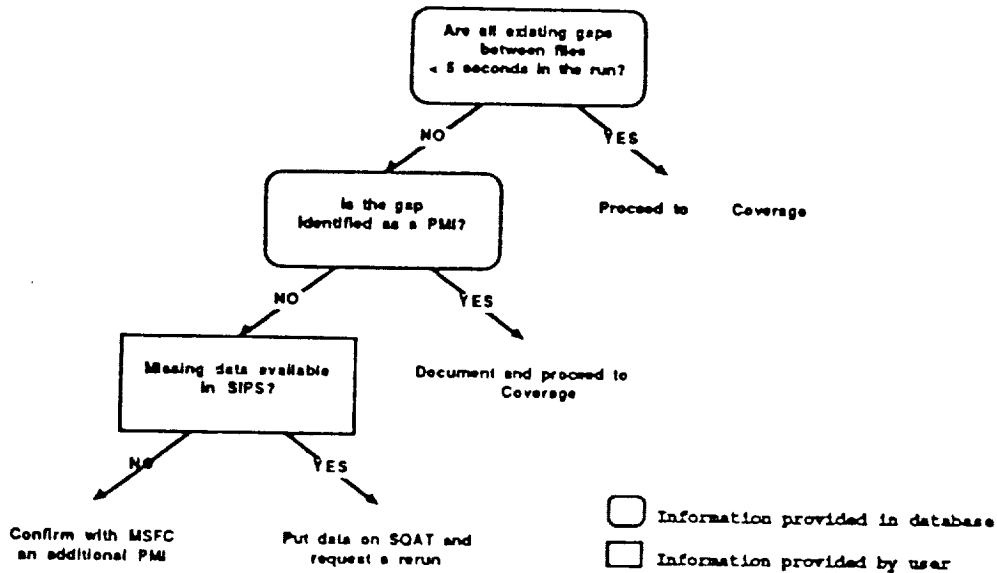
Is the processed stop
time within 5 seconds
of the run stop time?

NO   YES

Did the run abort
causing early
stop time?   Proceed to
                              Data Gap Between Files

NO   YES

Were the correct files   Determine cause for
in the database used?   abort and request a rerun

NO   YES

Request a rerun using   Possible hardware problem
correct files   - Request a rerun

Information provided in database
Information provided by user

Figure 12a.   Run Stopped Early

Are all existing gaps
between files
< 5 seconds in the run?

NO   YES

Is the gap   Proceed to   Coverage
identified as a PMI?

NO   YES

Missing data available   Document and proceed to
in SIPS?   Coverage

NO   YES

Confirm with MSFC   Put data on SOAT and
an additional PMI   request a rerun

Information provided in database
Information provided by user

Figure 12b.   Data Gap Between Files

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In the event a gap is found, the ES will check if the gap is listed on the Permanently Missing Interval (PMI) List; if not, the ES will prompt the QA to determine if the data is available in SIPS by checking the Event Summary Report (ESR), Configuration Controller (CFC) log, Playback Summary log, and Data Processing Summary Report (DPSUM). The QA will request the missing data records, if available, to be placed on a Spacelab quality control and accounting tape (SQAT), the tape loaded into the SOPS database, and the run reprocessed.

If the data is not available, the ES will prompt the QA to determine if the gap is an undocumented PMI. If the QA confirms an undocumented PMI, the ES will insert the PMI on the PMI List and continue.

Coverage. This knowledge island determines if there is missing data within a file in the run (see Figure 12c). The first step the ES takes is to calculate the minor frame coverage for the time between the channel start and stop times for each file. If the minor frame coverage for each file is greater than 98 precent, the ES can continue to the next knowledge island.

If the minor frame coverage is less than 98 percent, the ES will prompt the QA to check the ESR and CFC log for comments about gaps and dropouts in data. In the case where gaps, including PMIs, are noted in the logs, the ES will recalculate the minor frame coverage over the file times containing the gap. If the minor frame coverage is still below 98 percent, the ES will prompt the QA to check on the High Data Rate Recorder (HDRR) for the missing data.

Data Quality. This knowledge island is concerned with the quality of the data and if it can be improved (see Figure 12d). The ES determines the quality of the data by calculating the percentage of error flags set. If the percentage of error flags is greater than two percent, the ES will attempt to check the file quality codes. If SIPS did not release the data below criteria as the best available, the ES will prompt the QA to check the ESR and CFC log for comments about dropouts or poor data. Where no explanation for the poor quality is found in the logs, the ES will prompt the QA to determine if the data can be cleaned up before proceeding.

2.2.3 ES User Interface

The SOPS ES prototype uses many of the features that are standard for applications running on the Apple Macintosh . The features include the use of multiple windows, pull-down menus, and dialog boxes. Figure 13 is an example of the default screen layout used in the prototype.

Dialog boxes and windows may contain buttons, scroll bars, or space for the analyst to type in additional information called a text field. Whenever possible, the ES will set a default value for the text fields. If the analyst changes the value of a text field, the ES should perform consistency checks and prevent the analyst from entering invalid values. For example, if a text field requires a number, the prototype will only allow digits to be typed in. The consistency checking on the operational ES should be expanded to confirm that the value, as it is being typed in, is within the correct range and notify the analyst if it is not.

2.2.3.1 Windows

The primary windows that will be viewed by the QA analyst are the Transcript, Time Line, and Conclusion windows. The Transcript window maintains a log of the ES
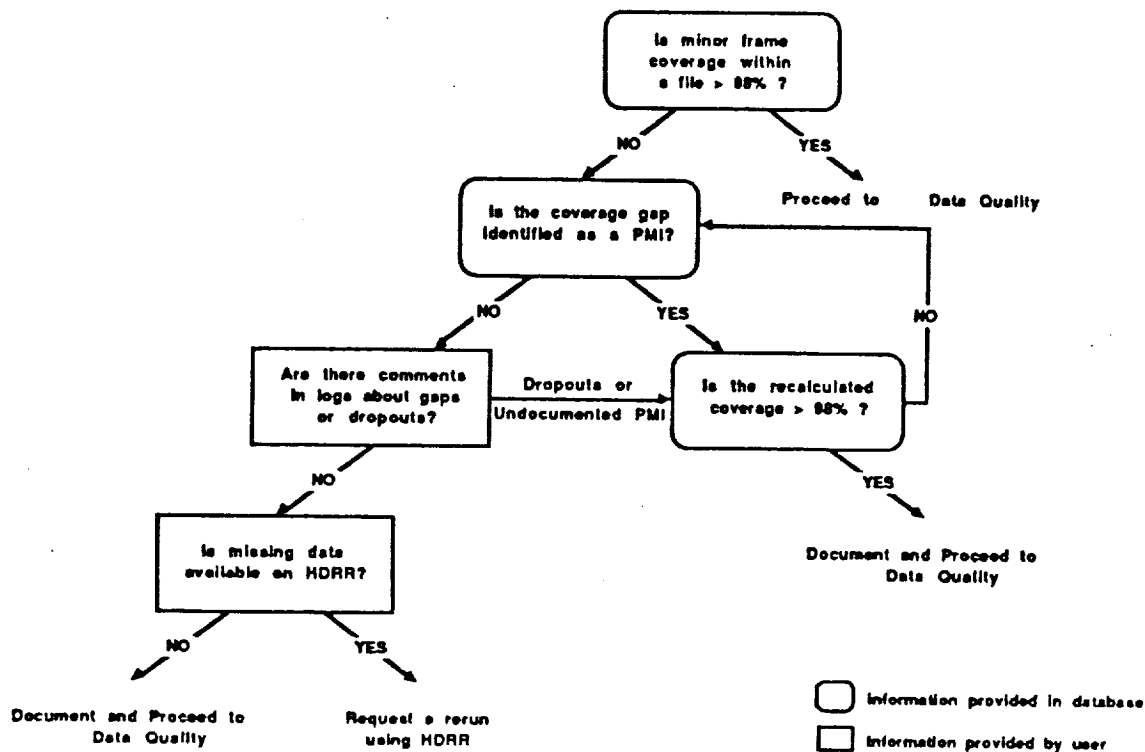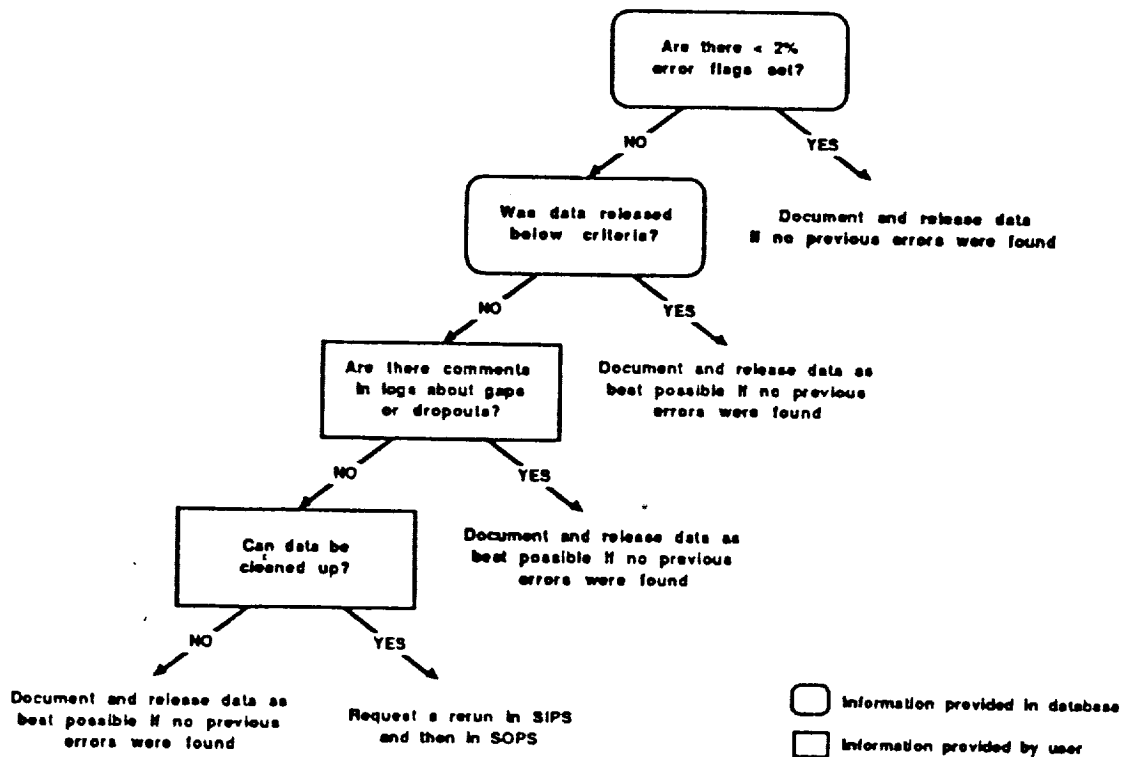
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Is minor frame coverage within a file > 98% ?

NO

YES

Proceed to Data Quality

Is the coverage gap identified as a PMI?

NO

YES

NO

Are there comments in logs about gaps or dropouts?

Dropouts or Undocumented PMI

Is the recalculated coverage > 98% ?

NO

YES

Is missing data available on HDRR?

Document and Proceed to Data Quality

NO

YES

Document and Proceed to Data Quality

Request a rerun using HDRR

⬭ Information provided in database

▭ Information provided by user

Figure 12c. Coverage

Are there < 2% error flags set?

NO

YES

Was data released below criteria?

Document and release data if no previous errors were found

NO

YES

Are there comments in logs about gaps or dropouts?

Document and release data as best possible if no previous errors were found

NO

YES

Can data be cleaned up?

Document and release data as best possible if no previous errors were found

NO

YES

Document and release data as best possible if no previous errors were found

Request a rerun in SIPS and then in SOPS

⬭ Information provided in database

▭ Information provided by user

Figure 12d. Data Quality

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Figure 13 - Default Screen Layout
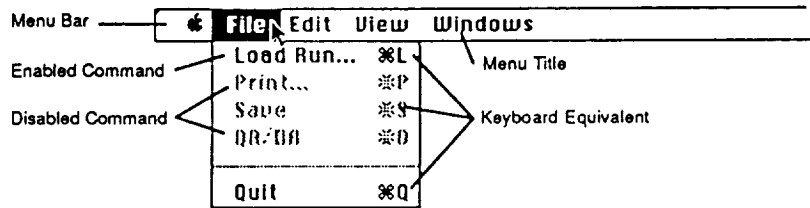
Figure 14 - Example Pull-Down Menu
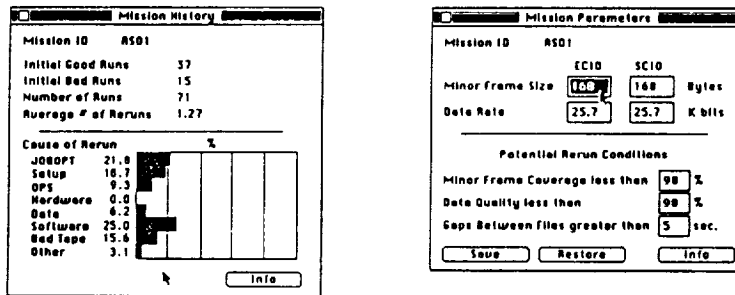
a) Mission History

b) Mission Parameters

Figure 15 - Mission Windows
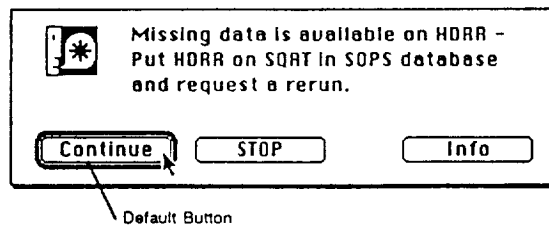
Figure 16 - Recommendation Dialog Box

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session that can be printed upon completion. This log will contain all questions asked by the prototype ES and the analyst's responses, all recommendations from the ES, and any comments the analyst wishes to add. The Time Line window displays the run in a graphical format with the expert system's current focus of attention flagged. The Conclusion window displays the conclusions reached (rules fired) by the ES.

The screen also has the SIDT Report, SIDT/MIDT Report, MIDT Report, and preview windows. The report windows contain detailed data about the run being evaluated. The preview line is a special window that displays help information related to the current position of the mouse.

The QA analyst can customize the window arrangement on the screen with the mouse by positioning the cursor on the title bar of a window, pressing and holding the mouse button down, moving the mouse to a new position (the window will follow), and releasing the button (this is referred to as "dragging" an object).

Many of the windows used in the prototype have scroll bars that the analyst can use to change the current view of the contents in the window. Scrolling can only be accomplished in an active window with the scroll bars visible. To make an inactive window active, the analyst positions the cursor in the window and presses and releases the mouse button (referred to as "clicking" on an object). In addition, some of the windows contain a size box and a zoom box for resizing an active window. The analyst simply drags the size box with the mouse to reshape the window, or clicks in the zoom box to expand the window to the full size of the screen. Clicking in the zoom box again will return the window to its original size and position. The QA analyst can use this feature to get a more comprehensive view of a window and then return without disrupting the layout of the screen.

2.2.3.2 Menus

Displayed at the top of the prototype screen is the menu bar (see Figure 14). It contains the titles of the menus available. To choose a command from the menu, the analyst positions the cursor over the menu title and holds the mouse button down. While holding down the mouse button, the analyst moves the cursor down the displayed menu. As the cursor moves to each enabled command, the command is highlighted. When the analyst releases the button on a highlighted command, that command is selected. A shortcut for selecting some commands is holding down the Command key in combination with another key called the keyboard equivalent. Commands that have keyboard equivalents list them in the menu.

The (Apple) menu contains up to 15 desk accessories such as a calculator or a clock that the analyst can use during an evaluation run. Choosing any of the desk accessories causes that acceessory to appear on the screen. The analyst can use the Edit menu to cut, copy, and paste the information in most desk accesories.

The File menu contains the following commands for processing a run file:

Load Run... - prompts the analyst for a run number and load the run into the ES;
Print... - prints the results of the ES run evaluation (not implemented in the prototype);
Save - saves the results (not implemented in the prototype);
QA/DA - starts or resumes the evaluation of a run; if the analyst has stopped the evaluation before completion, this command in the menu will be Resume QA/DA; and
Quit - quits the SOPS ES.

The Edit menu allows the analyst to perform the standard Macintosh cut, copy, paste, and clear commands on text windows and desk accessories. The analyst can copy and paste data from the Report windows or conclusions from the Conclusion window into the Transcript window.

The View menu contains the following commands:

PMI List - displays the PMI List window and allows the analyst to add a PMI;
Run History - displays the processing history of a run (not implemented in the prototype); This might take the form of the last Transcript file or a summary of previous ES evaluations;
Mission History - displays a summary window of statistics such as the number of good and bad runs over the length of the mission (see Figure 15a), and
Mission Parameters - displays the Mission Parameters window that allows the analyst to change mission specific parameters or evaluation criteria before starting the ES evaluation (see Figure 15b).

The Windows menu contains a list of all the windows on the screen. A window can be selected from this list to make it active and redrawn as the front window. The Windows menu also contains a Clean Up command which will restore the default layout of the windows on the screen.

2.2.3.3 Dialog Boxes

The prototype ES uses dialog boxes to prompt the QA analyst for more information or to display a recommendation. In the prototype ES, dialog boxes are used in two forms: modal and modeless. A modal dialog box is one that the analyst must acknowledge before doing anything else. Since modal dialog boxes restrict the analyst's options, the prototype only uses them for messages requiring the attention of the analyst. Figure 16 is an example of a modal recommendation dialog box. A modeless dialog box allows the analyst to perform other operations before responding to the dialog box.

The information in a dialog box is designed to be as concise as possible so an experienced QA analyst is not burdened with lengthy messages and explanations. For this reason, an Info button is available for less experienced analysts. The analyst can click on the Info button to get an additional page or pages of information if needed. The additional information might include a more detailed

explanation, or in the case of a question dialog box, the information might specify where to get the data to complete the dialog box.

Many of the dialog boxes in the prototype have a bold outlined default button. The default button is always selected if the analyst presses the Return or Enter key on the keyboard. The advantage of a default button is that the analyst does not have to move his hands off the keyboard to respond to the dialog box. If a dialog box does not have a default button (bold outlined button), pressing the Return or Enter key does not have any effect.

3.0 BENEFITS OF PROTOTYPES

The Spacelab expert system prototypes offer many benefits. They are fast. They are consistent. They make the expertise of the most experienced staff members available to all. The prototypes can act as training tools when refined to a detailed level. As they are developed, they identify ways in which current procedures could be further automated to increase accessibility to information and improve processing speed as well as to decrease the monotony of repetitious tasks. They also identify areas in their own operation that should be streamlined to make the expert system concept not only workable but practical.
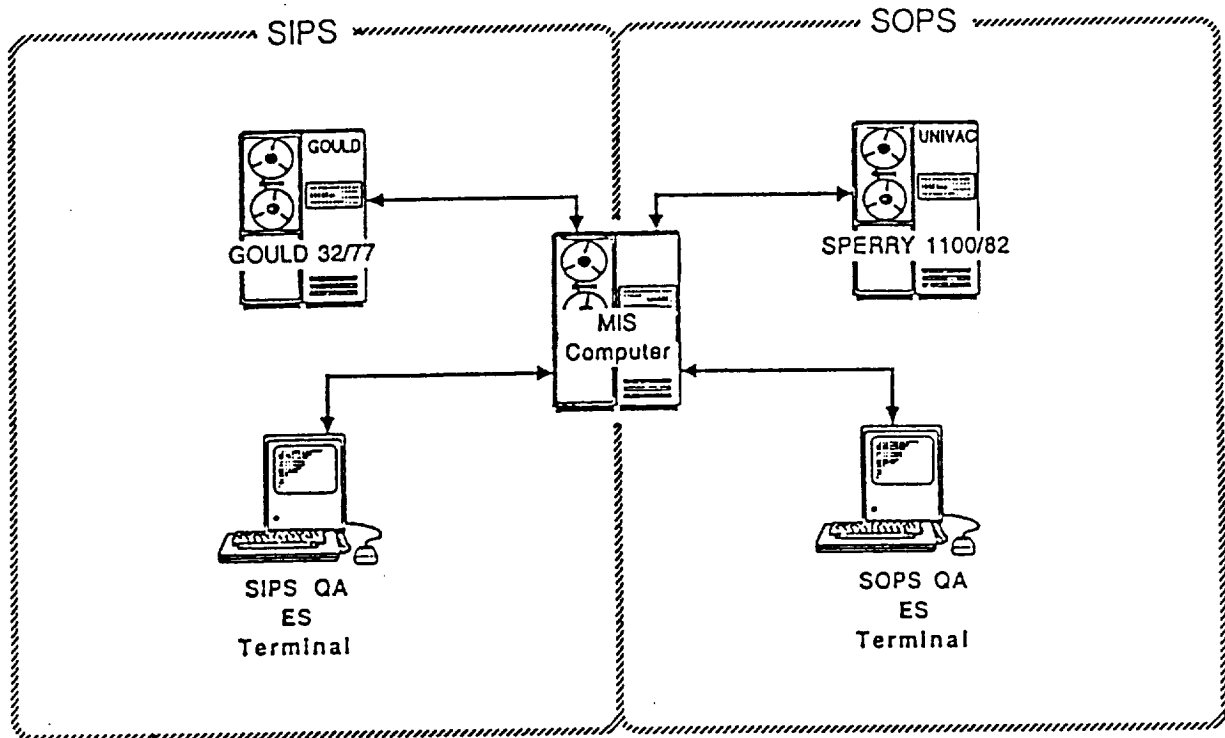
4.0 OPERATIONAL CONFIGURATION

The goal of the Spacelab prototype expert systems is to define the design and the configuration for expert systems in the mission environment. These new operational expert systems will be larger, more efficient, and more automatic, incorporating the capabilities indicated by but not present in the prototypes. Both the SIPS and the SOPS operational expert system configurations will make use of the same hardware and software for consistency (see Figure 17). It is planned that the initial configuration will be operational by July 1988, in time to support ASTRO-1, the first of several scheduled SLDPF missions in the post-Challenger period.

FINAL EXPERT SYSTEM CONFIGURATION

SIPS   SOPS

GOULD
GOULD 32/77

UNIVAC
SPERRY 1100/82

MIS
Computer

SIPS QA
ES
Terminal

SOPS QA
ES
Terminal

QA - Quality Assurance
ES - Expert System
MIS - Management Information System

Figure 17. Operational Configuration