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Three operational systems are currently in use. These systems are located at Hill AFB in Ogden, UT, Kelly AFB in San Antonio, TX, amd the Phillips Laboratory at Edwards AFB in California. Eash of these systems is configured to process X-ray computed tomography, CT, images. The Hill AFB installation supports the aging surveillance effort on Minuteman third stage motors. The Kelly AFB system supports the acceptance inspection of airframe and engine components and torpedo housing components. The installation at Edwards AFB provides technical support to the other locations.

This paper presents the development history, the system design issues, the system hardware and software architecture, and a brief description of the operational systems and their functions.

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Computer aided feature extraction, classification and acceptance processing of digital NDE data

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ABSTRACT

As part of the Advanced Launch System technology development effort begun in 1989, the Air Force initiated a program to automate, to the extent possible, the processing of NDE data from the inspection of solid rocket motors during fabrication. The computerized system, called the Automated NDE Data Evaluation System or ANDES, was developed under contract to Martin Marietta, now Lockheed Martin. The ANDES system is generic in structure and is highly tailorable. The system can be configured to process digital or digitized data from any source, to process data from a single or from multiple acquisition systems, and to function as a single stand-alone system or in a multiple workstation distributed network. The system can maintain multiple configurations from which the user can select. In large measure, a configuration is defined through the system's user interface and is stored in the system's data base to be recalled by the user at any time.

Three operational systems are currently in use. These systems are located at Hill AFB in Ogden, UT, Kelly AFB in San Antonio, TX, and the Phillips Laboratory at Edwards AFB in California. Each of these systems is configured to process X-ray computed tomography, CT, images. The Hill AFB installation supports the aging surveillance effort on Minuteman third stage rocket motors. The Kelly AFB system supports the acceptance inspection of airframe and engine components and torpedo housing components. The installation at Edwards AFB provides technical support to the other two locations.

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Keywords: automated NDE processing, NDE, aging, solid rocket motors, computed tomography

1. INTRODUCTION

The Air Force has invested significantly in inspection technology in the past 20 years. The investment supporting the rocket propulsion mission has been mainly in the implementation or development of data acquisition technology. Work sponsored by the Air Force's Titan launch system program office and the Air Force Wright Laboratories represent two examples. The Titan program developed X-ray and ultrasonics facilities to perform real time radiography, RTR, and thru-transmission and pulse echo ultrasonics inspections on the new Titan IV solid rocket booster. The Air Force Wright Laboratories developed large industrial CT system technologies for inspecting ballistic missiles. These CT based technologies have subsequently been implemented at Hill AFB, UT in the form of a nine million electron volt, Mev, facility for inspecting the Minuteman third stage motors and a fifteen Mev facility for inspecting all Peacekeeper stages and stages one and two for Minuteman. Although, some data processing technology was also implemented with all of the data acquisition technology development, the assessment of the components being inspected is still based on visual interpretation of the NDE data.

A joint R&D effort between NASA and the Air Force was undertaken in 1989 to develop a new generation of launch vehicles. This effort was called the Advanced Launch System, ALS, later renamed the National Launch System, NLS. The goal was to reduce the cost of placing a payload in low earth orbit by an order of magnitude, to $300 per pound. The Strategic Defense Initiative, SDI, was the primary driving force for reducing the launch costs, although, the commercial launch industry was also a factor. The tonnage of hardware projected to be placed in orbit to implement a spaced based defense is extremely large and the cost to put it in orbit is staggering. Thus, the country engaged in an effort to provide cheaper access to space. The Air Force managed a technology program for ALS named NDE for Solid Rocket Boosters (NDE for SRB's). This program addressed technology to reduce the fabrication costs of solid rocket boosters as a contribution to the goal for total launch costs. The goal of the program was to totally automate the NDE data processing and decision processing for the in-process and end item acceptance during the manufacture of the solid rocket boosters for the ALS effort.

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2. PROJECT HISTORY

The NDE for Solid Rocket Boosters program was conceived as a $12M effort consisting of four phases spanning five years. The program was to conclude with the delivery of a production ready system to support the fabrication of the solid rocket booster design being developed in other ALS projects. The tasks in the first phase of the program were to develop the operational requirements, develop the functional design of the automated system, to generate a hardware and software architecture to be incrementally developed in the subsequent three phases, and to define the test and validation plan to demonstrate that the system performed properly. The automated system was called the Automated NDE Data Evaluation System, or ANDES. Although it was to be developed for ALS, from the program's beginning, the plan was to build ANDES as generic and as flexible as possible.

It is not unusual for a large government program to be initiated with significant sums of money, a large amount of fanfare, and great expectations only to be significantly reduced in scope or canceled in a relatively short period of time. This is what happened with the ALS effort. Due to changes is the strategic arms arena, the SDI payload requirements were greatly reduced and consequently the need for a heavy lift launch vehicle at that time. This in turn eliminated the main thrust fueling the requirement for ALS. In the second year, the ALS funding was cut dramatically. In the third year, most of the ALS programs were ended. The NDE for SRB's effort was early in phase two, finalizing the system design and beginning to write software. The program was reorganized to deliver a functioning prototype system on the remaining contract funds. While preparing to end the effort, the Air Force searched for other benefactors to continue the development. Two were found, Kelly AFB and Hill AFB.

A new task in the NDE for SRB's contract was added in the third quarter of FY 91. This task was to deliver an operational version of ANDES to Kelly AFB to process CT images for several miscellaneous components they were fabricating or refurbishing. In the third quarter of FY 92 another task was added to develop an ANDES system to support the processing of CT images on Minuteman third stage solid rocket motors at Hill AFB. These added tasks permitted the program to extend the development of ANDES into operational systems. These two systems do not have all of the functional capabilities intended in the original ALS design and described in this paper. They do contain the fundamental operational capabilities, plus the software and hardware architecture for the original system design which can be implemented in the future.

3. DESIGN ISSUES

Prior to describing the architecture of the ANDES system, it is necessary to develop some background information about the configuration of a typical solid rocket motor (SRM) and the fabrication process used to construct a motor. This information in necessary to understand why the software and hardware are organized as they are. Figure 1 is a drawing of a
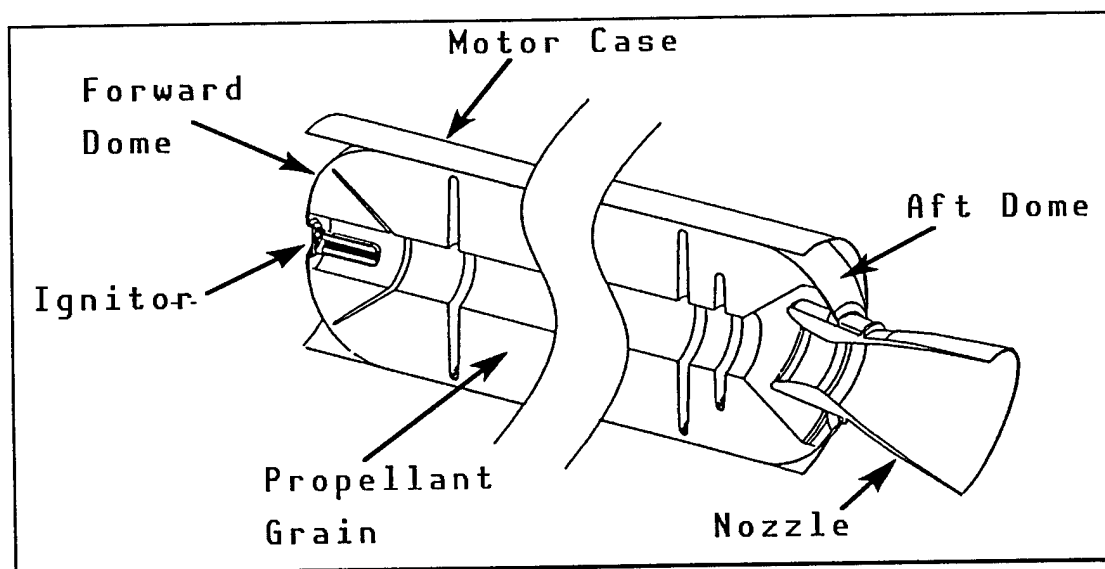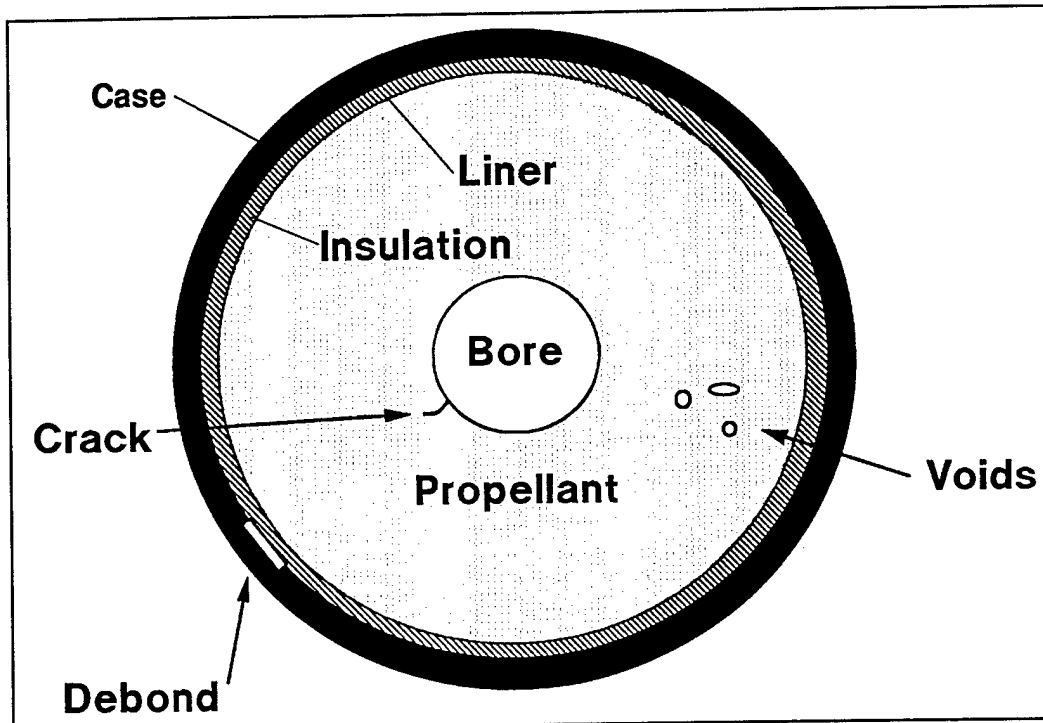

Figure 1. Basic Solid Rocket Motor.

basic solid rocket motor. The prominent features of a typical SRM are the motor case, propellant grain, nozzle, and ignitor. The motor case may be a welded metal construction or a filament wound composite. The case consists of a cylindrical barrel section closed at each end with curved domes. The ignitor and nozzle are attached to the forward dome and aft dome respectively. In the case of a composite wound case, the attachments are circular metal bosses. On the inside surface of the motor case are two other components, the insulator and liner, see figure 2. The thicknesses of these two components and the

Figure 2. Cross Section of Typical Solid Rocket Motor.

case are exaggerated in the figure. The insulation is a rubberized material which protects the case from the heat of the burning propellant. The liner is an adhesive interface to bond the rubber based propellant to the insulation. The size of a solid rocket motor varies greatly. The diameter of SRM's can range from a few inches to several feet. For ALS, the case diameter was to be about ten feet with a length exceeding 80 feet. Figure 2 also indicates the three major categories of defects which are critical in SRM's.

The fabrication of a SRM is a multi-step process, see figure 3. The significant features in this diagram of the process are that there are a number of intermediate process completion points, that NDE may be performed at any or all of these points, and the locations of the various process steps and NDE data acquisition are likely to be separated by significant distances (miles). The NDE data collected at the intermediate process steps are used to accept the part for further processing. This data can also be used to extract process control information, single part fabrication history information, and system production history information. Typically, this information data base is in the form of a logbook which follows each motor through the process. In addition to the process steps described in figure 3, there are other functions which are typical to the fabrication process. These functions include program administration, scheduling of the flow of the components through the fabrication and inspection processes, planned engineering reviews of each component, and material review board (MRB) actions on components which experience difficulties or develop anomalies during processing.

4. ANDES DESIGN AND DEVELOPMENT

The challenge for the NDE for SRB's program was to design and develop an automated system which would service all of the fabrication processes and functions and to capture the knowledge base of the inspector to accurately evaluate the NDE data and to render the correct judgements on the acceptability of the component. It was also desired to make the
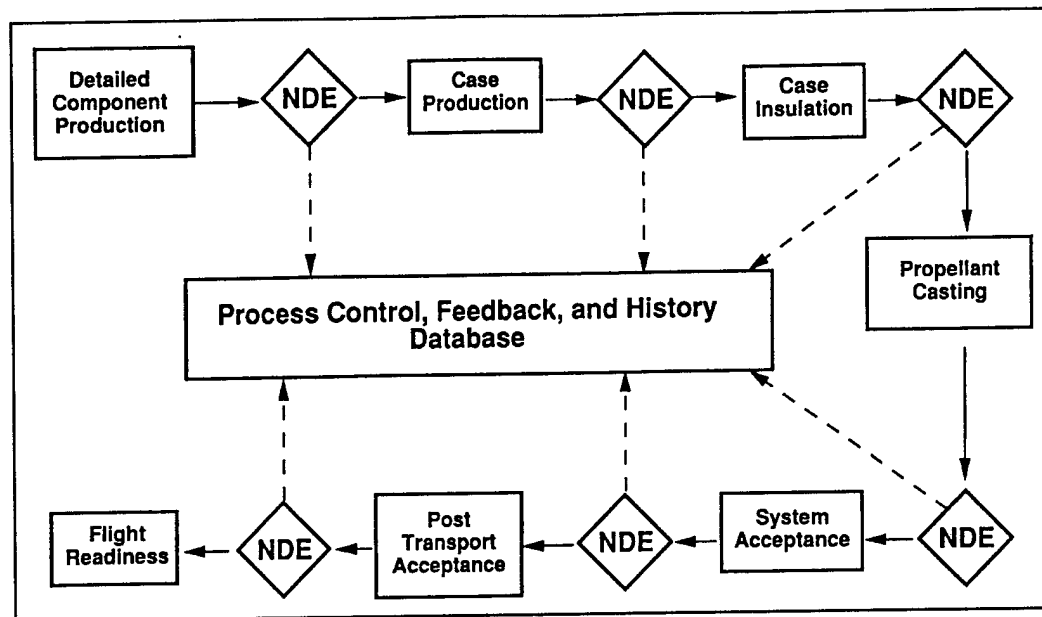
Figure 3. Process Steps for Fabrication of Solid Rocket Motors.

resulting system as paperless as possible. This would reduce cost and reduce the risk of losing program documentation. One of the most formidable tasks was to define what the various production and inspection personnel did, how they did it, what information they needed, where the information came from, what information they generated, and to whom or where they reported it.

4.1 System functional description

Figure 4 shows a top level functional diagram of the ANDES system as it was designed for ALS. The two ovals represent the two major software modules, the seven cylinders represent various classes of information to be stored in the
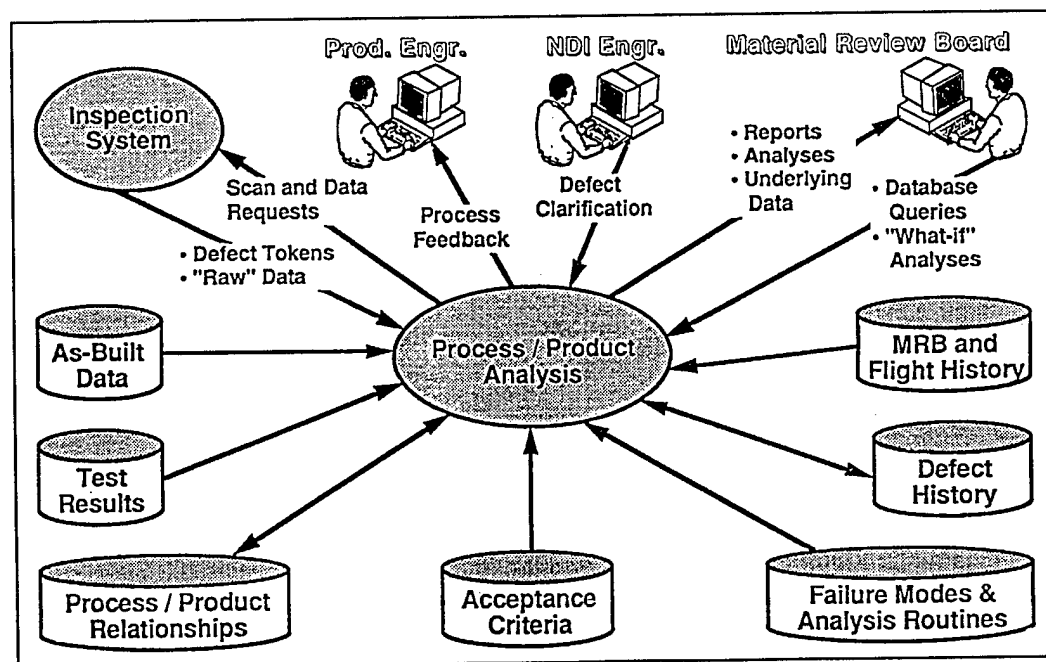

Figure 4. Functional Diagram of ANDES Software.

system data base, and the computer terminals represent three of the user interfaces with the system. The arrows depict the directions of information flow. The Inspection System module is the interface to a NDE data acquisition system. This figure shows only one of these modules, however, ANDES is designed to service multiple acquisition systems. The actual system would have a tailored Inspection System module for each acquisition system that is connected. What is not apparent from this figure is how the software system is configured and managed from a global standpoint. The main user interface for setup, maintenance, and overall system management is implemented as part of the Process / Product Analysis module. The software architecture and functionality will be discussed in more detail later in the paper.

In figure 4, the arrow from the Inspection System oval to the Process / Product Analysis oval is labeled with two types of data, defect tokens and raw data. Raw data is the NDE data generated by the acquisition system and defect tokens are small packets of text information which describe the characteristics of a detected feature, see figure 5. The approach of "tokenizing" the information about a detected feature was chosen to minimize the amount of data being permanently stored and shared between processes.

```
Token:                              Typed Anomaly:
  {
    class: propellant                2: gouge - accept.  PSC Script used: 3RDG.gouge.any (New)
    radial_center: 151.019318        angle center:      153.07 deg.;   major extent:      9.61 mm;
    angular_center: 153.066589       radial center:     151.02 mm;   radial extent:      4.27 mm;
    major_extent_mm: 9.614274        minor extent:       6.34 mm;   major extent:      3.17 deg.;
    major_extent_deg: 3.167152       area:            36.94 sq. mm;   relative amplitude:    0.87 %;
    minor_extent_mm: 6.342917        min. distance to bore:  0.15 mm;   max. distance to bore:  4.42 mm;
    radial_extent: 4.267532          min. distance to ins.: 128.18 mm;   max. distance to ins.:  133.87
    orientation: 85.215927          mm;
    area: 36.944504                   axial start:       57.15 mm;   axial extent:        6.35 mm;
    rel_amplitude: 0.874997
    min_dist_to_bore: 0.154984
    max_dist_to_bore: 4.422516
    min_dist_to_ins: 128.180756
    max_dist_to_ins: 133.870804
  },
```

Figure 5. Example Token (left) and Corresponding Typed Anomaly (right).

4.2 Hardware architecture

The hardware architecture used for the ANDES system was chosen primarily due to the operational requirements dictated by the fabrication process layout, several locations widely separated in distance. The architecture is shown in figure 6. The existence of several stations in the process flow which can be widely separated required a system with several workstations connected on a local area network. The figure depicts two inspection facilities and, consequently, two inspection system modules. The figure also shows one workstation for the rest of the activities, but this would most probably be several stations. For example, a work station would be located at the program office to initiate and monitor the progress of component fabrication. Another workstation would be located in each of the engineering areas, process control, NDE, and analysis. The data storage and data processing would be distributed between the various workstations.

4.3 IS software architecture

Now that an overview of the hardware and software architectures has been presented, a more detailed discussion about how ANDES works and what it does is in order. Let us turn our attention to the inspection system (IS) module first. Figure 7 shows a detailed functional diagram of the interior processes of this module as it was originally designed. The top three boxes in the figure represent the software features which would handle the internal functions for communicating with the
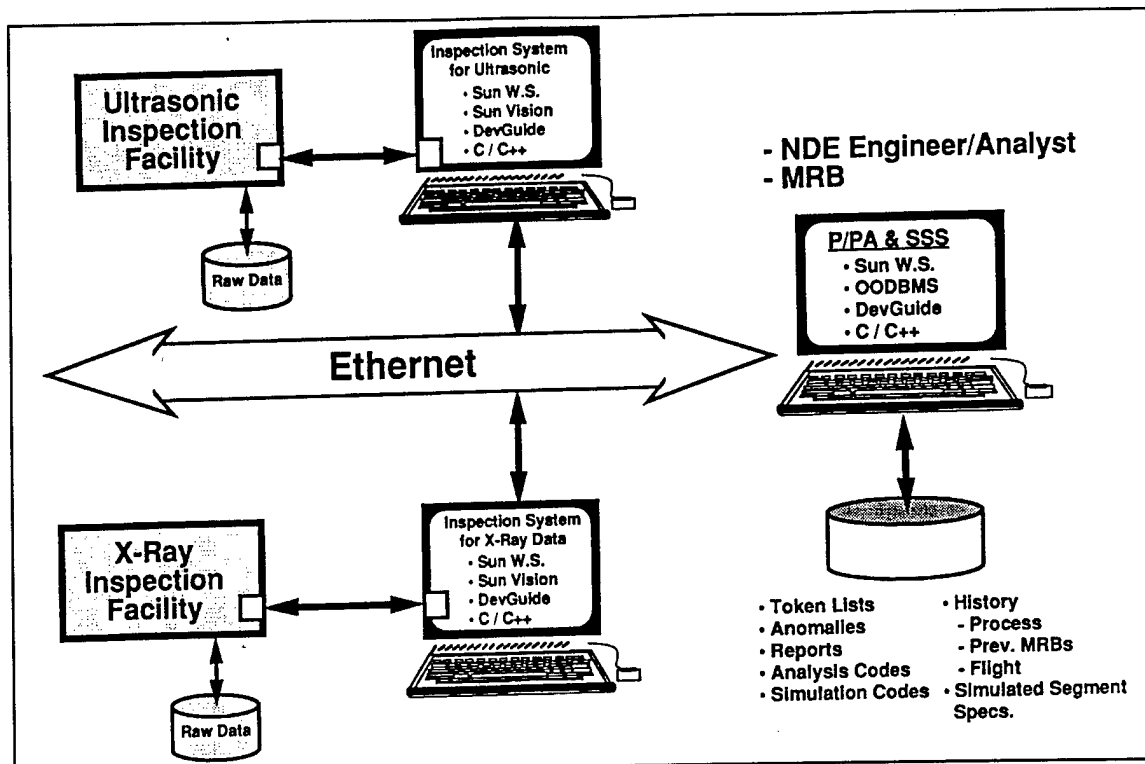
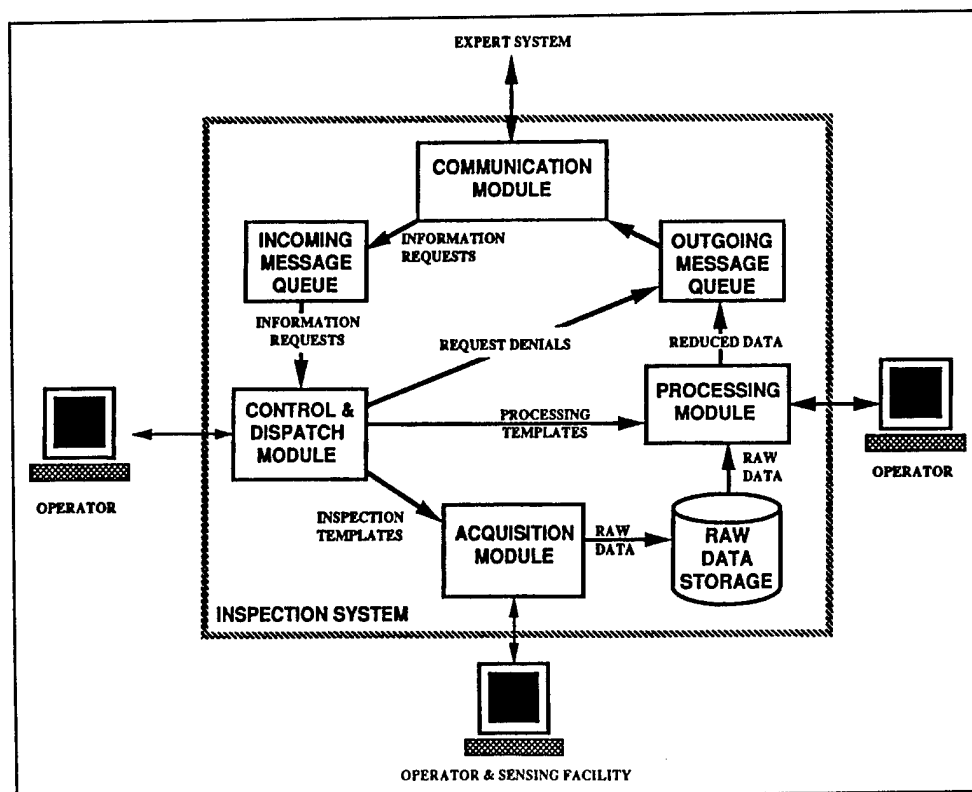**Figure 6.** ANDES Hardware Architecture.

Figure 7. Functional Diagram of Inspection System Module.

rest of the ANDES system. The Control and Dispatch Module in the IS is the inspection system operator's interface for managing and scheduling the IS processes and for responding to system messages and requests. The Acquisition Module is the interface with the data acquisition system for the IS. The Processing Module is responsible for performing the image analysis and feature extraction from the NDE data. The Raw Data Storage is the location of the NDE data files generated by the acquisition system.

Looking at an operational scenario is the best way to clarify the functioning of the IS module. The production manager issues a message to the ANDES system requesting the normal thru-transmission ultrasonic inspection on motor serial number A-005 which is being transported to the ultrasonic facility. This motor has completed the case insulation processing step (see figure 3) and needs to be checked for unbonds between the insulation and case. The ANDES system relays the message to the appropriate Inspection System Module which places the request in the request queue, informing the operator of an inspection request. When the motor arrives, the operator mounts it in the inspection system and initiates thru-transmission data acquisition. When data acquisition is completed the data is stored in Raw Data Storage. The operator then issues a command to the IS to initiate data processing using the normal thru-transmission processing template. This template controls the actions of the Processing Module for retrieval of the raw data, feature extraction, token generation, and transmission of any token information generated to the ANDES data base. The IS module also issues two messages of its own. One goes to the originator of the data request informing him that the action is complete and the other goes to the decision system module of ANDES informing it that there is a set of anomaly tokens to be processed.

It was envisioned that a fully functional ANDES system would be integrated closely enough with the data acquisition systems, through the respective IS, that adaptive scan features would be available. This would mean that if the decision system modules of ANDES detected problems with the data or if there were difficulty processing anomalies from the token information, a request for a non-standard inspection could be issued automatically to the IS. This inspection request would contain the specifics of the inspection procedure to gather the additional data needed in order to properly assess the part. This request would be examined by the inspection system operator and he could either perform the requested operation or consult with the production manager to deny the request and instruct ANDES to use the existing data.

4.4 PPA software architecture

The largest module of the ANDES system is the Process / Product Analysis (PPA) module. This module controls the main user interface for the system. The system management functions and much of the system setup and tailoring are performed through this module. In addition, the PPA module performs the analysis and decision rendering functions on the tokens passed from the IS module. The functional diagram of the analysis and decision processes is shown in figure 8.

The PPA module periodically polls the message area of the ANDES data base for a message that a list of tokens has been generated by an IS module. When this message is detected, PPA retrieves the list of tokens and proceeds to process them using a template which has been designated by the operator. As shown in the figure, the image and token data are received from the IS module. The image data would then be checked to verify the quality of the data. If the quality was sufficiently low, the PPA could issue a message to the IS requesting the data be replaced or permission to proceed with substandard quality. The token data describing each anomaly or feature in the NDE data would proceed to the Typer. In this step the token data is classified by type, size, orientation and location, see the example in figure 5. Once typed, the tokens are passed to the specification comparator which checks each anomaly against the appropriate product specification criteria. In this step each anomaly is categorized as being within or outside of tolerances. No further processing would be done on those anomalies that are within tolerances. They would simply be stored and reported. Anomalies exceeding the tolerances would be tagged as rejectable defects and would then be subjected to engineering analysis procedures built into the PPA module to estimate the remaining margin of safety and the projected impact on performance of the part. All of this information would then be passed to the final decision module to issue the recommended disposition of the part, accept or reject. If required, the system would then assemble a material review board report to support the MRB process that would decide if the part could still be used with the lower margin of safety, if the part can be repaired, or if the part must be scrapped.

The data processing step which compares the typed anomaly information to product specifications is performed at three different levels. The first level is the single anomaly check. At this level each reported anomaly is checked against specifications for a single anomaly of the appropriate type. For example, if a void less than one half inch in diameter is acceptable, then any single void smaller than this is marked acceptable and the system proceeds to the next anomaly. Once all
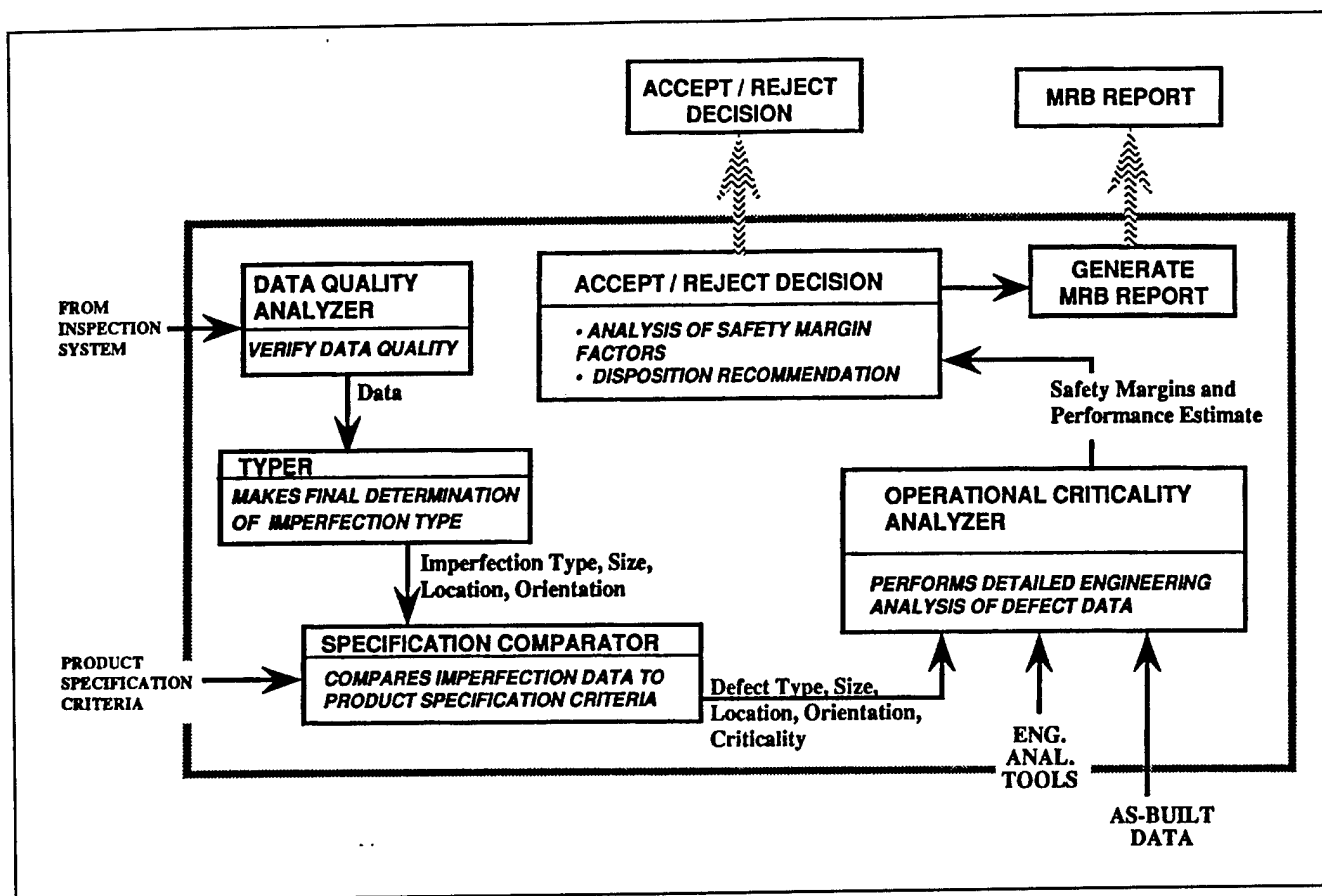
Figure 8. Analysis and Decision System Functional Diagram.

individual anomalies have been checked, the system then uses a nearest neighbor criteria to consider combined anomaly effects. In this check, the system is instructed that anomalies of similar type which fall within some threshold distance of one another are to be considered as a combined, larger anomaly. This combined anomaly condition is then checked against the established criteria. If the inspection data is two dimensional in form, such as an ultrasonics C-scan, the anomaly processing is now complete. If the data is three dimensional in nature, such as contiguous CT images, a third level of processing is used. For the case of CT images, the first two processing levels are performed on each CT image or slice. Once all slices have been processed individually, the system checks each anomaly in a slice for an adjoining anomaly in the next contiguous slice. In this manner anomalies which span several slices are identified and treated as a single anomaly. The slice spanning anomaly is then compared to the appropriate criteria to test for acceptability.

While the ANDES system was being designed, it was recognized that the decisions rendered by this automated system would be significant in terms of affects on production schedules and funds, especially if the system recommended that a fully processed solid rocket booster be rejected. Therefore, it was very important that the decisions the system made could be traced and verified. Two methods were designed to provide this verification process. The first method was the institution of an audit trail of the anomaly processing. The user can display the acceptance criteria for any of the reported anomalies and the system will insert the corresponding values from the anomaly. In this way the user can determine which criteria controlled the accept / reject decision for the anomaly and what the actual value was of the anomaly characteristic which generated the decision. The second method, which was designed but not fully developed, is a data simulation module. This module would allow the operator to develop a realistic set of data containing anomalies using segments of actual data. In this way, the simulated data contained the characteristics of real data. The synthesized data sets with the user prescribed anomalies would then be fed to the ANDES system and processed. The results could then be compared to the known characteristics of the data to determine how the ANDES system was functioning.

5. TAILORABILITY

It has been stated that the ANDES system was designed to be as generic and flexible as possible. The purpose was to create a system which could be applied to as broad a scope of products and processes as possible and to minimize the cost of tailoring the system to a specific application. The advantages of doing this are rather obvious, being the reduction of time and cost to reconfigure the system for a new project at an existing site or the establishment of an ANDES system at a new site. The system was also designed to maintain several different processing configurations and allow the operator to select the configuration to be used from a menu. This capability would allow a single ANDES installation to service multiple production programs which use the same facilities for fabrication and inspection.

The core processes of the ANDES system are totally generic. These processes include the data base management system, the communication and messaging system, and the data analysis and decision processing engine. It is the peripheral processes and data handling which are unique to each application. The parts of the system which are unique include the interface to the individual data acquisition systems, the image analysis process which extracts the features from the NDE data, the specific anomalies and defects which are applicable to the inspected object, the specifications for the appropriate anomalies, and the contents of displayed or printed reports from ANDES.

Earlier, it was stated that the IS module was the least generic. This is because this module must interface with the data acquisition system. Even so, a substantial part of the IS is common code. In figure 7, the communication module and message queues would not change. The control and dispatch module may or may not require modification. However, the acquisition module and the processing module perform unique processes depending upon the data acquisition system and the type of image data being processed. They would need to be modified to incorporate the specifics for the acquisition system and the data. The acquisition module is the interface between ANDES and the data acquisition system. The primary function of this module is to retrieve the inspection data file or files from the acquisition system, convert the format to the internal format that ANDES uses, and store the data in raw data storage. The processing module in figure 7, performs the image processing and extracts features which could be anomalies from the image data. The image processing steps are unique to the type of data being processed, ultrasonics versus CT, or the modality of the data, amplitude versus time of flight. The feature extraction processing is also unique since it depends not only on the type of data to be processed, but also on the features of interest which, themselves, depend upon the component being inspected.

The image processing function was somewhat generalized by using an image processing system which executes user definable networks of standard and custom data processing modules. The overall ANDES configuration file contains the name of the image processing procedure to be used and the PPA passes this name to the IS when the request for data is issued. When the NDE data from the acquisition system is available, the IS issues the command to the image processing system to execute the procedure name received from the PPA. The image processing procedure contains the details about which image processing modules to use, in what order, what the input parameters are for the modules, and any other unique data that is required. This arrangement eliminates the need to make hard code changes in the main execution stream of the IS module to implement changes in the image processing. Any image processing code which must be written and compiled is limited to writing custom modules for networks executed by the image processing system. The networks themselves are generated using an interactive interface in the image processing system. Using this interface, assemblages of standard and custom modules can be hooked together to perform the necessary functions without modifying the IS or other ANDES system software.

Very few modifications to compiled code would be required in the analysis and decision system (see figure 8) to tailor the operation for a new application. The data quality analyzer module would require code modification since the data from the inspection system will change with the application. The typer, specification comparator, and operational criticality analyzer are all script driven. Once the processing has reached the accept / reject decision processor, the data has evolved into a standard content so this module would not require modification. The reports for an individual application are likely to be somewhat unique. The modifications to the report generation function could be either hard coded or generated through the report interface of the data base management system, depending on the specific requirements. ANDES employs a script language interpreter to control and execute most of the processes in the analysis and decision system loop. The scripting language is patterned after the method described in the ADA Language Reference Manual, ANSI/MIL-STD-1815A-1983. This approach is very much like an interpreted BASIC language for desk top computers. Using the ANDES script editor window, the user writes text files which define the processing to be done. Parameter values describing the detected anomalies are retrieved from the anomaly tokens and processed by the script. The script then exports the results in the form of parameter values which are stored in the data base for use by subsequent processes. The script can also initiate the execution

of external programs, if needed, and retrieve results from the program when it is finished.

An example of a script is shown in figure 9. This script would be executed by the typer function to determine the type of a detected anomaly. The characteristics used by the typer script are stored in the token information for the anomaly. In the script shown in figure 9 there are ten input parameters which are retrieved from the token. These parameters are defined between the statements "external_variables:" and "end_external_variables;". These parameters consist of one text string and nine numbers. The purpose of the script is to establish the type of the anomaly so the only output value is a text string called "type". The main part of the script is a series of if-then-else logic statements which lead to various value for the anomaly type depending on the values of the input parameters. Similar scripts are used by the specification comparator and the operational criticality analyzer.

The remainder of the tailoring functions is accomplished through various user dialog windows in the main ANDES user interface. These function include some which are rather mundane, such as establishing labels to identify various aspects of the configuration to the user. Other functions are used to establish parameters required for the operation of the system and to define proceedures to be followed. The allowable names for the anomaly types and the allowable names for characteristics used to describe an anomaly are defined from the main user interface. These names become the only valid names recognized by ANDES and are used in all data processing procedures. This enforces consistancy in terminology. The token correlation and nearest neighbor processing for anomalies may be either script driven or handled by built in parameterized procedures. The method of choice for these functions is selected from the user interface. Finally, the product specification criteria for all anomalies may be specified as a function of geometry zones in the component. These zones are defined through the user interface. All of these definitions are saved in the system data base under a unique configuration name and can be used or modified by the user at any time. ANDES can operate only one configuration at a time, but a number of different configurations can be stored in the data base and the user can select the one he wishes to use from the list.

6. OPERATIONAL INSTALLATIONS

There are three functional ANDES sites. Two of these are operational sites, one at Kelly AFB, San Antonio, TX and the other at Hill AFB, Ogden, UT. The third site is located at the Air Force Phillips Laboratory facility at Edwards AFB, Edwards, CA. The Phillips Lab is responsible for the user support of the operational systems, so the system at Edwards is used for system support and development. Both operational sites have performed very well. The system installed at Kelly AFB has been operational since 15 June, 1993 and there have been no problems reported. The system at Hill AFB has been on-line since 15 December, 1994. One minor software problem was discovered and has been eliminated. Several other problems have been reported, but all have been traced to inconsistences or problems with the data files from the data acquisition system.

The Kelly AFB system was tailored to process three different components, see figure 10. The yoke and torpedo housing were metal castings which had to be inspected for anomalies such as void content, cracks, and inclusions. The scavenge tube was inspected for leak paths and total brazed area between the end of the tube and the fitting. The Hill AFB system provides supporting data and documentation to the official film X-ray acceptance procedures for new third stage motors. The system is also used to assess motors which are cycled back through Hill AFB for maintenance after deployment. The motors are inspected for cracks, voids, and debonds.

7. SUMMARY

The work begun on the ALS project has resulted in the development of an operational system (ANDES) which can automatically process digital NDE data and provide a recommended disposition to either accept or reject the component. Two operational systems have been in service for over a year and the performance to date has been very good. The ANDES system is generic in that it can process literally any inspection data on any component with very few constraints.

```
external variables:
in_text: class;
    in_number: rel_amplitude, major_extent_mm, major_extent_deg,
minor_extent_mm, axial_start, min_dist_to_bore, min_dist_to_ins,
orientation;
  out_text: type;
end_external_variables;

if (rel_amplitude >= 1.0) then
  type :="inclusion";

else_if (class = "rubber_case") then
  if ((axial_start >= 1725) and (axial_start <= 1743)) then
    type:= "bossIns/case unbond"; // boss insulation/case unbond
  else
    type := "ins/case unbond"; // insulation/case unbond
  end_if;

else_if (class = "propellant") then
   if ((major_extent_mm > 3) and
      ((major_extent_mm / minor_extent_mm) >= 2.0)) then
     if (rel_amplitude >= 0.65) then
       type := "liner wipe";

       else_if (((orientation > 80) or (orientation < -80)) and // parallel
         (min_dist_to_ins <=  5)) then
       type := "tear";
     else
       type := "crack";
     end_if
   else
     if (min_dist_to_bore < 1) then
       type := "gouge";    // or surface void, treated the same.
     else
       type := "void";
     end_if'
   end_if;

 else
     type:= "undetermined";
 end_if'
```

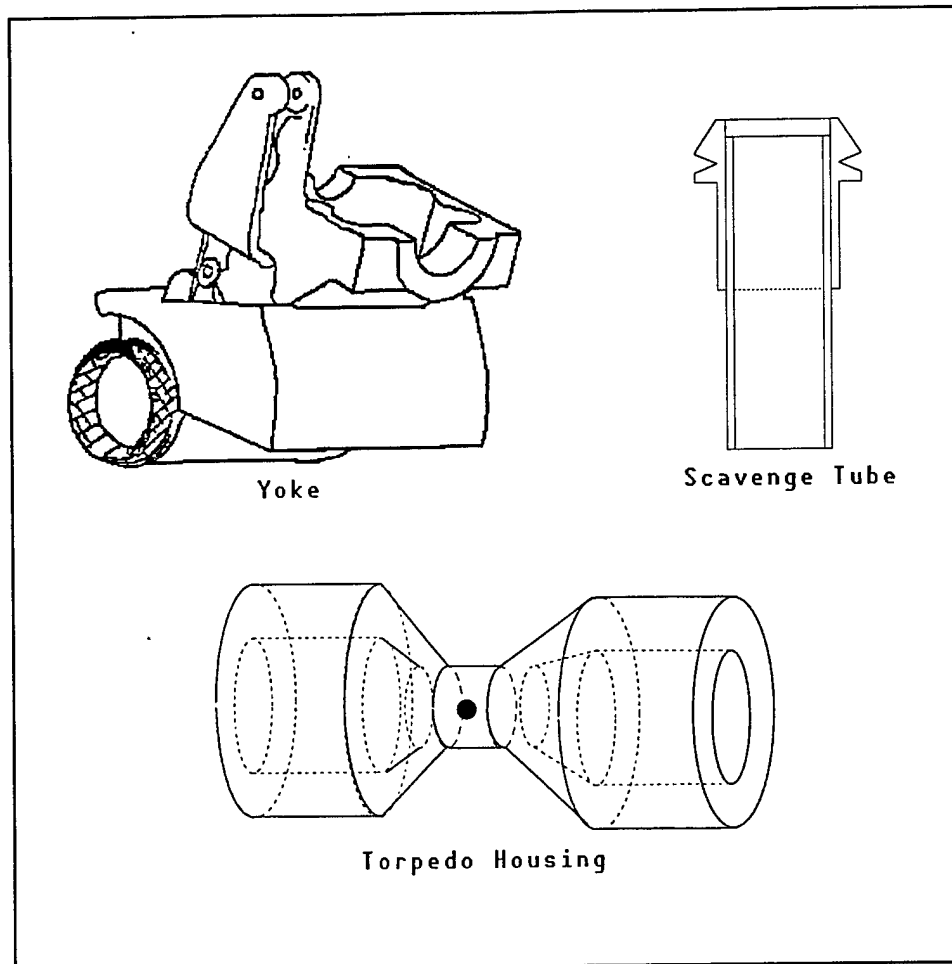**Figure 9.** Excerpt from ANDES Typer Script.

Yoke

Scavenge Tube

Torpedo Housing

Figure 10. ANDES Processed Components for Kelly AFB.