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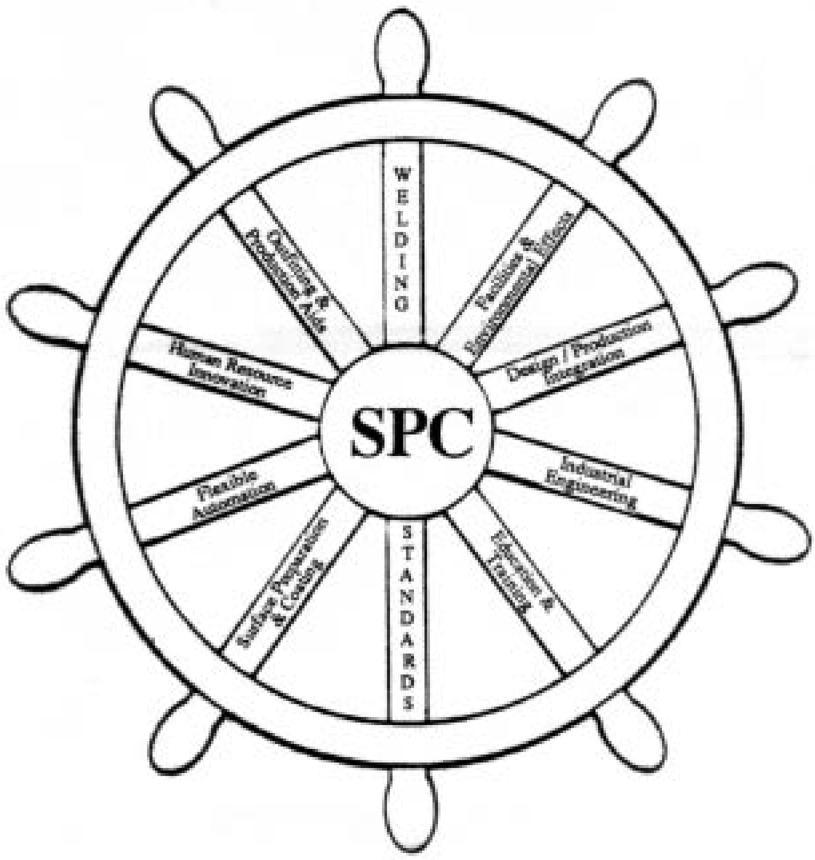

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Modeling and Transfer Of Product Model Digital Data for the DDG 51 Class Destroyer Program

5A-1

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INTRODUCTION

Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) technologies offer significant benefits in the design, construction, and life cycle support of today's complex Navy ships. CAD provides the capability to create three dimensional (3D) product models which can realistically represent geometry and associated design data of the ship prior to construction. Building of a computer model of the ship prior to construction reduces interferences and improves design accuracy and completeness. The 3D computer models consist of geometry and associated design data for components and systems, and provide a tool to design and evaluate form, fit, and function. Efforts such as interference detection and resolution, simulated walk-throughs, change-impact analysis, and improved production sequence planning can be conducted concurrently with design development. Detail design drawings, manufacturing sketches and Numerical Control (NC) instructions can be developed and extracted directly from the design database. This reduces duplication of data, saves time, and lowers costs - for both the construction of the ship and the life cycle maintenance functions that follow. The most significant benefits of 3D CAD/CAM methodologies as applied to complex Navy surface combatants are improved design and manufacturing accuracy and consistency, which in turn result in savings in production time and cost. On the U.S. Navy's ARLEIGH BURKE (DDG 51) Class AEGIS Destroyer program, CAD/CAM technology is being implemented to take full advantage of these savings.

BACKGROUND

Computer Aided Design is a rapidly developing technology in the shipbuilding industry. In 1985 Bath Iron Works (BIW) and Gibbs and Cox planned to execute detailed design for DDG 51 in 3D CAD. However, the necessary resources and capabilities did not exist to successfully complete the plan and BIW reverted to manual design. To support the transition of DDG 51 design to CAD it was necessary to create or acquire the following:

- Processes - adequately piloted and tested methods.
- Software - the necessary application computer programs and relational database management software.
- Hardware - the required distributed and integrated work stations with sufficient processing speed.
- Trained personnel

Since the beginning of the program, Bath Iron Works (lead yard) , Gibbs and Cox, and Ingalls Shipbuilding (follow yard) have built their CAD capabilities to the point that their combined resources have made it feasible to model the ship. Based on this capability the AEGIS Destroyer Program initiated a project to move DDG 51 to a CAD based design.

The project objectives are to allow construction of ships in two yards from a single design; to improve the movement of construction data between the shipyards; and to create a digital information base for life cycle support.

The project required the achievement of two tasks, transferring the existing paper design into CAD and creating the capability to transfer intelligent 3D product models.

This paper addresses the specifics of the parallel efforts in CAD modeling and Digital Data Transfer (DDT) implemented by the AEGIS Destroyer Program. The paper covers background information, task objectives, problems encountered and their resolution, current status and future plans. This project represents a significant cooperative effort between the U.S. Navy's AEGIS Destroyer Program, BIW, Ingalls, Gibbs and Cox, and General Electric/Government Electronics Services Division.

PRODUCT DATA MODELING

Approach

The Program Manager in the AEGIS Destroyer Division (PMS 400D) initiated a project to translate the paper design information into 3D CAD product models in a phased program over a 36 month period. The product model consists of all information necessary to define the detail design for manufacture. The product models will be used to generate fabrication and installation drawings, supplemental drawings, NC information and templates. The 3D CAD models will also be available for use in the contract and detail design stages of future flights of the DDG 51 Class.

The CAD modeling effort is intended to create a database to support construction. The 3D design models will be used to check and clear interferences and, after validation against the manual design control mats and issued construction paper, will replace the paper design control mats as the design basis for the class. Accomplishing the actual modeling requires the resources of both shipbuilders and the Class Combat Systems Engineering Agent, General Electric (GESD). There are seventy-seven Design Zones in the ship and a plan was laid out for concurrent work on an initial subset of twenty-six zones. These twenty-six zones were selected because they are the most complex and represent the largest initial payoff.

The AEGIS Destroyer Program tasked Bath Iron Works and Gibbs & Cox with modeling eleven Combat Systems zones including the Combat Information Center (CIC), Radio Central, and the Pilot House. General Electric was tasked to provide the combat system components as library parts to be transferred to Bath and used directly in the models. Ingalls Shipbuilding was tasked with modeling the fifteen zones comprising the auxiliary and main machinery spaces. Both modeling efforts are shown in Figure 1. Model content and library part standards were developed concurrent with this work to insure the resulting. models would meet the needs of both shipbuilders and the Navy. The overall 3D Modeling Process is shown in Figure 2. A graphical depiction of the steps involved in the replacement of manual drawings with CAD drawings is shown in Figure 3. Bath Iron Works as lead yard is tasked to process the resulting models to replace the existing paper design control mats. The approach depends on the ability to effectively transfer 3D product model information between the shipbuilders.

Needs and Capabilities

In all design and manufacturing environments, there is a pressing need to improve the quality, usability, timeliness and accessibility of engineering, design, and production data. This is especially true within the shipbuilding industry. Navy surface combatants are very complex, have long procurement cycles, incur significant design changes, and have long maintenance and overhaul life-cycle requirements.

Introduction of 3D CAD into the design and construction process as early as possible minimizes the duplication of information. For the existing DDG 51 design the appropriate point of transition to CAD is the Design Control Mat (DCM). The DCM represents the culmination of the composite design process, and marks the starting point for preparation of construction products. The DCM is also the document used to incorporate design changes.

A primary benefit of 3D CAD is the availability of accurate and consistent data for Computer Aided Manufacturing (CAM). The definition of CAM in this context is all manufacturing data used by Production, not just limited to the classical definition of Numerical Control (NC) data. Realization of the full potential that CAM offers in production requires that all construction information originate from the same 3D CAD database. This information includes: drawings and material lists; NC tapes; templates; and jigs and fixtures. CAD can also provide additional information such as improved production sequence planning graphics, which are not practical otherwise.

3D product models, within the context of CAD/CAM, include definition of:

- Object type (e.g. components, fittings, pumps, valves, cableways, etc.)
- Detail, clearance and maintenance geometry
- Location
- Orientation
- Connectivity information
- Catalog (material)

- Instance identification (specific occurrence of the part)
- Revision identification (latest change to the part)

Additional information such as zone, discipline, and system is also stored within each model. This data is sufficient to control the design configuration, and may be integrated with other material or production systems. For example, this data may be tied to a material catalog through the catalog number, and, to material management systems through the instance identifier (unique piece or part number identifier) and catalog number. The CAD product model is then the central source of material identification for quantity, type, and fabrication and installation data. Additional material data for definition of work packages, construction stage and sequence, shop floor control, and inter-trade routing (e.g. the production bill of material) should supplement the CAD engineering/design bill of material on a separate but linked Material Management System.

Utilizing well-defined processes and standards, CAD linked with engineering data management tools offers the opportunity to integrate the entire shipbuilding process. Product models, tied to a relational database which defines the material incorporated in a design, provide: the basis to drive the yard detail material ordering system: input to the Navy supply support system; and input for technical publications and training.
In like fashion, a relational database, which defines process information associated with the installation of each component, feeds the materials control system and the production planning system. A separate but integrated file tracks all the drawings associated with any model and flags them for revision when changes are made to the model.

To support engineering efforts of the shipbuilding process, the use of Computer Aided Engineering (CAE) is being developed. As engineering changes are introduced in the class and revised ship support systems are required, the use of analysis programs which operate directly with the CAD data greatly enhance the system engineering function. Controlled use of the CAD database insures the analysis matches the actual system configuration. Development of on-line engineering analysis tools offers the opportunity to improve both the quality and the efficiency of the design engineering process.

The implementation of these CAD/CAM technologies has started, but remaining work is formidable. While the use of 3D CAD may not make the individual designer more efficient, the resulting data used to drive the entire production process makes the CAD system a powerful tool.

Development of capabilities like these is critical to achieving the quality improvements and cost savings needed to make continued product improvement possible and affordable. The AEGIS Destroyer Program is advancing the development of these capabilities and their introduction into the program.

<u>shin Life Cycle Support</u>

Ship configuration information in digital form offers advantages for life cycle support since the product model data can be transferred electronically to support activities such as the planning yard, the U.S Navy Supply System, and the various in-service engineering agents. Improvements can be made in: the process of overhaul and repair planning (installation sequence); maintaining a more accurate and up-to-date configuration; and providing more accurate fabrication and installation drawing and material information at time of repair or overhaul. The DDG 51 CAD modeling program provides the initial digital information, while the Digital Data Transfer program establishes the basic standards for content and format to accommodate the information transfer.

<u>Model Construction Benefits</u>

The process of building models has demonstrated many of the benefits CAD offers. Model construction is accomplished by assembling all the construction drawings and open change notices to establish a dated baseline. Pipe, ventilation, and electrical models are built for each ship work breakdown structure (SWBS) for the zone. Very large or complicated models may be subdivided into port, center, and starboard segments. In the case of Combat Systems and hull outfitting, models are segregated by overhead or deck within the zone. Both the fabrication and installation drawings are used to construct the model.

This has proven to be an excellent consistency check between the fabrication drawing and the installation drawing. Discrepancies are reported to the lead shipyard, which has responsibility for maintaining drawings. Corrections are made to manufacturing aides before manhours and material are spent on unusable fabrications. The resulting savings to the program have offset the cost of the modeling effort.

Model Processing Benefits

Once the individual distributed systems models have been constructed for a zone, they are merged for interference checking. Each interference is analyzed as being a problem interference or an acceptable interference. In certain cases, collisions (two objects or surfaces occupying the same space) are reported as interferences but may be acceptable. A watertight penetration of a pipe through a bulkhead is an example of an acceptable interference. Once the reported interference is classified as to its acceptability, a CAD generated sketch is created that reflects those considered to be a problem. If detailing for manufacturing aids is in process, the problem is reported to the detailing group for resolution prior to issuing the aids and drawing to manufacturing.

Post-Design Information

A major impact the modeling effort has on manufacturing will be the reduction of interferences. Ship construction schedules require many parts of the design to take place simultaneously. This leads to the possibility of pipes, ventilation ducts, and/or wireways being routed into the same location and interfering with equipment. While the composites or design mats worked toward the elimination of these occurrences, some undetected interferences still manage to slip into the manufacturing process. It is widely accepted that the elimination of interferences and their corresponding costs is a major benefit from 3D modeling during the design and manufacturing processes.

Another major benefit of CAD modeling is the ability to extract data to satisfy the manufacturing criteria of the specific yard. These criteria tend to be determined by the equipments in a specific yard and how these equipments are used. Extraction of Numerical Control (N/C) data can, when properly formatted, drive burning or bending machines. After being entered into the product model and checked, data is programmatically extracted.

Another feature is the ability to extract specific task-oriented drawings where the craftsman receives only that information required to perform his job. The craftsman does not have to work from a large, complicated and cluttered design drawing. Figures 4, 5, 6, and 7 are examples of the types of drawings and bills of material that can be extracted from a product model. Projected cost benefits from other uses of this data have been identified and efforts are underway to develop their capabilities. These include uses such as simulated walk-through and change impact analysis.

Planning can clearly benefit from access to this information. By testing "what-if" scenarios, size and sequence of installation can be optimized while viewing the actual data in three dimensions. Further, different views can be utilized to represent the configuration of the ship as it is being manufactured rather than the configuration it will ultimately assume. Many fabrication or installation drawings may be plotted in an inverted position that enables a craftsman to view his product as it appears to him. Drawings showing downstream work will show the product flipped to a ship orientation for final integration with other ship components.

costs

This project has required a significant investment in personnel, hardware, training and processes. While the AEGIS Destroyer Program has carried the majority of the costs, each participating organization has had to dedicate management resources and make a corporate commitment to implement new technology. The effects of this project will permeate through each organization and in some instances fundamentally change methods of operation. The challenge is to manage the changing methodology and CAD based ship construction.

Status

Actual 3D modeling and drawing development work is well underway with eighteen (18) zones completed by both shipbuilders and the majority of the library parts completed by General Electric and BIW. Model transfer from Ingalls to Bath is in process, and the AEGIS Destroyer Program has tasked both shipyards to create construction products from their models. Extensive work remains to be done to integrate models as they are built and to transition to 3D CAD-based design both within each yard and between the yards for the DDG 51 Class, but the achievements thus far leave no doubt of future success.

OUTFITTING DATA TRANSFER PLAN

Background

Transfer of the product models and use by both shipbuilders, combat systems design agent and the Navy is required to achieve the full benefit of using CAD. Each yard uses CAD systems for outfitting and structural definition which are different within and between the yards. Bath Iron Works uses Computervision for outfit and AUTOKON for structure; Ingalls Shipbuilding utilizes Calma for outfit and SPADES for structure. In order to utilize these combined resources, it was necessary to develop a means of translating digital data between their proprietary and incompatible data formats.

Objective

The AEGIS Destroyer Program's overall objective in this effort is to implement a two-way transfer of Outfit product models between the BIW Computervision (CV) System and the Ingalls calma System, as illustrated in Figure a. Both BIW and Ingalls had previously developed the capability to transfer structural models from their respective structural to outfit systems.

Overall Approach

The AEGIS Destroyer Program tasked BIW and Ingalls to develop a mutually agreed-upon plan of action. In order to implement a digital data transfer capability between dissimilar CAD/CAM systems, several steps are required:

1. Models must exist or be created
2. Data to be transferred must be defined
3. Format of the transfer medium must be defined or selected
4. Transfer computer software must exist or be created
5. Testing must be accomplished to validate the process
6. Transfer procedure must be defined and implemented

When the AEGIS Destroyer Program initiated this project in January 1988, and both BIW and Ingalls already had significant 3D modeling experience. Step 1 was completed by building models of three selected zones to use in the test phase. Steps 2 through 6 represent the basic scope of the DDT project as described below.

The management and technical approach for DDT included consideration of the following requirements and constraints:

Requirements.

- Transfer of engineering and design product model intelligence
- Achievable and verifiable transfer accuracy
- Configuration accounting
- Elective component substitution
- User friendly translator usage
- Minimized transfer file data volume
- Minimized translator processing time
- Minimized translator software maintenance

Constraints.

- Large number of components contained in 3D product models
- Complexity of the component relationships defining distributive systems
- Volume of component non-graphic (attribute) data contained within the 3D product models
- Similarities and differences between component libraries and database constructs across the two CAD/CAM systems
- Current state of the art in Initial Graphics Exchange Specification (IGES) and Product Definition Exchange Specification (PDES) development and implementation.
- Current state of the art in database management systems
- Existing manual drawing transfer between the two shipyards

Data Transferred

BIW and Ingalls completed definition of the data to be transferred for distributive systems early in the project. This definition was reviewed, modified, and approved by the AEGIS Destroyer Program, BIN and Ingalls for all disciplines. Reference 1 provides a listing of the data transferred and contained in the product models. The effort involved in the definition and concurrence which this document represents was extensive. It involved a significant review of the modeling practices of both organizations and an in-depth understanding Of the internal architecture of both CAD/CAM systems.

Neutral File

The next major step in DDT was definition and selection of the format for the transfer. The AEGIS Destroyer Program, BIW and Ingalls mutually explored the following alternatives:

1. "Flavored" Initial Graphic Exchange Specification (IGES) or Standard IGES. "Flavoring" is the term used to define the process of augmenting the shortcomings of the implemented standard in order to adapt it to the required task.
2. Defer until the completion of Product Definition Exchange Standard (PDES) and its commercial implementation.
3. Development of direct translators by a software developer specializing in CAD direct translators.
4. Use of a neutral file that defines object data.

Option 1, the IGES approach was not selected because both shipyards were using and developing CAD applications that were object oriented instead of entity oriented. PDES is still in its definition phase and selection of Option 2 would have required several years delay in implementation of a production translator. Option 3 would have required the development of direct translators. They were not available for 3D product model information and would not have met the Navy's need for flexibility in future use or expansion. Option 4 was selected by the AEGIS Destroyer Program for capability, flexibility for future expansion, and ability to create within the time available.

Object Transfer

The use of an object oriented neutral file (Option 4) offered significant advantages in reducing the size of the transfer files. More importantly, the object transfer approach retained the intelligence contained in the original model. In this context, object (or component) is an BVAC shape, a piping valve, a piping fitting, an electrical cableway hanger, etc. Figure 9 illustrates the object approach versus the IGES approach. As defined by IGES the desired object would have been geometrically constructed on the receiving system as a series of separate lines, arc, etc., rather than an object with associated properties and intelligence.

Bath Iron Works was tasked to outline the translator specification. BIW and Ingalls divided responsibility for writing the specifications - each wrote different sections and exchanged work. The end result was the "DDG 51 Class Digital Data Transfer Project Functional Specifications" Reference 2. After the final specifications were agreed to by both shipbuilders and approved by the Navy program office, each shipbuilder developed or subcontracted the computer programs specific to his system.

BIW and Ingalls both use an object modeling approach on their CAD systems and each has the capability to attach design attributes to objects, as well as a property file capability. Attributes consist of information such as catalog number, piece/part number, fitting type, etc. Property files contain geometric data that allow an object to be graphically displayed, and non-geometric data such as catalog number (link to model), description, weight, and a specification number that describes the object. A means was developed to correlate objects between systems. In the case of pipe and purchased parts for BVAC and electrical, it was determined that catalog numbers could define the object. For manufactured items (HVAC shapes, flanges and gaskets; penetrations; hangers; cable paths, etc.) a shape table was developed that defines the object. Each component was assigned a classification that defines the discipline and either the catalog number or the shape table to define the object. To complete the process a catalog cross reference file was developed which correlates the Ingalls and BIW catalogs and provides orientation normalization between the CV and CALMA systems.

Class Librarian and Parts Transfer

The testing of the translator was based on the transfer of a common test zone modeled at both yards. Use of the object oriented approach requires the existence of: (a) equal part libraries at both shipyards, or, (b) development of the capability to digitally transfer library parts. Early in the project, it was determined that while the libraries for such items as piping were similar, certain DDG 51 specific equipment items existed only on the BIW system.

Where library parts did not exist at Ingalls, the yards were tasked to create the necessary computer programs and procedures to transfer the parts from BIW. The approach chosen was to create a procedure file defining the component at BIW, and to create software to read the file at Ingalls and automatically rebuild the library part in the CALMA system. The capability was based upon the use of seven basic graphic primitives that were common to both CAD systems. Figure 10 represents a sample transferred part. With the capability to transfer parts came the opportunity to establish a standard library for the DDG 51 Class. BIW was tasked to act as the Class Librarian. The library parts transfer capability is in use between BIW and Ingalls. Full two-way part transfer by means of the procedure file is under development.

Life Cycle Support

The DDT project is concentrating on three aspects of CAD information to insure its ability to support future class logistics: standards for zone model content, library part content and the transfer process. These efforts are intended to be consistent with the developing Product Definition Exchange Standard. The content standards will ensure that the information contained in the models and libraries will support design, construction and life cycle support needs. By working with the PDES group, the transfer products are being developed to support data transfer both now and in the future.

Testing and Results

The translator software was developed and extensively tested by both shipyards. The overall process is illustrated in Figure 11. Both shipyards created a test model for each of three disciplines (piping, HVAC and electrical) for a common zone. First, each model of each discipline was given an internal loop test. Then, these models were transferred from their source yard to the receiving shipyard, processed both in and out of the receiving shipyard's translator, sent back to the source and reprocessed to create a model. This full-loop test was sufficient to determine any deficiencies in the software.

Functional software was developed and tested for intelligent 3D model bi-directional transfer between CV and Calma for piping, HVAC and electrical objects. The results are illustrated in Figures 12, 13, 14, and 15. These isometrics are representative of the translator capability and were created during the testing phase.

Status

The translator software is operational and in use between the shipyards. An additional phase of translator development is ongoing to add capability for piping and vent hangars, waveguide, holes, certain foundations, and outfit and furnishings. When complete in late 1990 the translators will be capable of moving complete product models.

STRUCTURAL DATA TRANSFER

Approach

The objective of this effort was digital transfer of 3D structural design models generated on AUTOKON or SPADES from one system to the other while retaining their topology, intelligence, and lofting capability. Ingalls Shipbuilding, Inc., a SPADES user, and Bath Iron Works, an AUTOKON user, were tasked by the AEGIS Destroyer Program to produce a joint plan of action to develop software to accomplish this transfer. A system specification was written entitled "Autokon <--> SPADES Model Communication System" Reference 3.

Cali and Associates (developers and marketers of SPADES) and Autokon CIM, Inc. (developers of Autokon and part of Kockums Computer Systems A/S) were the two firms subcontracted through Ingalls to develop the software. The approach taken was to create a neutral file containing the data elements necessary to define all required structural objects. The software programs which generate and use the neutral files were called translators. An overview of the links between the two systems is depicted in Figures 16 and 17.

NEUTRAL FILE

The translator/neutral file approach was selected for structure for the same basic reasons that it was selected for the outfit system. The goal was to transfer recognizable objects complete with intelligence and attributes. Commercially available implementations of IGES would have limited the transfer to a collection of points, lines, and arcs comprising the graphic representation of the objects and would not have fulfilled the requirements of the transfer. By utilizing the translator/neutral file approach, the intelligence of the original model was captured and lofting capabilities were retained. Further, it was felt that an IGES file based on simple entities. (lines, arcs, points, etc.) would have been prohibitively large to store and/or process in a timely fashion when applied to models the size of those being considered for transfer.

Partial Transfers

A requirement of DDT is to be able to transfer only a portion of a given design zone, as opposed to the practice of transferring an entire zone with each exchange. To support this requirement, the concept of the "design window" was implemented in each CAD vendors' system. This feature did not exist on either system and it provided a means of specifying boundaries for the design zone to be transferred.

The design window is a 3D subset of the design zone whose contents are to be transferred. It allows the user to send/receive only the desired portion of a zone, for example, a space where additional structure has been inserted after the entire zone has already been sent or received at the other installation. This concept prevents having to re-send an entire zone in order to pick up only a small area of change.

configuration Management

Closely related of partial transfers is Configuration Management. The partial transfer capability highlighted the need to track the status of previous transmittals of the structural model of the design zone. Partial transfers must address what data has already been sent, what has not, and what has changed between transfers.

By means of a catalog, the translator keeps track of the structural objects being transferred, bypassing objects that have already been translated and passing only those items which are new or changed. A report is generated by the translator with each transfer, thereby documenting the zone's transfer status.

Status

The translator software is operational. There are two translator programs; one installed and running on the Prime computer at BIW and the other installed and running on the IBM 3090 at Ingalls. Translator capability is planned for inclusion into the next formal release of the two CAD systems by their respective vendors.

TRANSLATOR COSTS

Outfit

The outfit translators are custom software packages owned by the AEGIS Destroyer Program. The full cost of development and the cost of maintaining the translators is the responsibility the AEGIS Program. Unlike translators based on national standards the CAD system vendors do not have any responsibility for ensuring compatibility with their new software releases. This was the cost of acquiring a transfer capability sufficient to the needs of the program.

Structural

The structural translators were developed under AEGIS Destroyer Program funding but are the responsibility of the CAD vendors to maintain. Because of their unique structure and the lack of IGES translators in this area the vendors found it to their advantage to assume maintenance responsibility and offer the capability in their respective CAD programs.

ISSUES

The transition to 3D CAD design and electronic data exchange has introduced technical and management challenges. The Project has anticipated many of the issues solved them by the basic approach. Others have been solved in concept but remain to be proven in production. Four of the open issues are configuration management, model completeness, yard practices, and on-line inter-yard CAD access.

Configuration management is both a technical and management issue. Technically the challenge is to establish and maintain positive control of product models and their derived products as they are modified during design development and engineering changes. For management the challenge is to efficiently transition the configuration management organizations from paper to electronic data. The AEGIS Destroyer Program is using information modeling as a basic tool in attacking this issue.

The AEGIS Destroyer Program established zone model content and library part content standards as the tools to solve model completeness issues. The information incorporated in a model determines it's usefulness for design, engineering analysis, construction and future logistics support. The DDG 51 Program defined the standards on the basis of current practices and projected class support needs. As the models are placed in use the need for more or different information will surface and the standards will be modified as needed.

Each yard has construction practices as well as CAD modeling practices which are different than the other. The differences in modeling are often the result of construction process differences. Shipyard management and the DDG 51 Program standards are the basic tools used in resolving the impact of these differences on the data exchange process. The effectiveness of management in dealing with problems in this area will have a significant impact on the benefits realized from this program.

On-line inter-yard data access is a capability which is important to efficient use of the DDT Project now and will become more important as more of the ship is placed in CAD. The ability to access the latest data immediately prior to releasing work packages could provide significant savings to the construction program. The principle issue is security. Each yard is concerned with the security of their computer data for yard management and performance. While access to CAD would not necessarily require access to shipyard management systems, it is feared that internal networking could allow the competing shipyard to acquire critical business sensitive information. This issue is a management problem currently under review by the shipbuilders.

These issues all contribute to Engineering Data Management. Integrating the many separate data systems which have been created within the shipyards over the years and transitioning to the full use of electronic data for all design and construction support functions are significant management challenges. While tools to attack the problems are available in the form of local area networks, wide area networks, and Engineering Data Management Software Systems implementation will require time and innovation.

These and other issues will be dealt with and solved by the DDG 51 Program. The solutions instituted will consider both the current and projected needs of the AEGIS Destroyer Program.

SUMMARY

The U.S. Navy's AEGIS Destroyer Program established this project to take advantage CAD/CAM in ship construction. Accomplishments and benefits have been significant. Twenty-six zones of the ship have been divided between the shipbuilders for modeling and a plan is being pursued to complete modeling for the remainder of the ship. The combat systems engineering agent has been tasked to provide contract level 3D models of the combat system spaces and library parts for all combat system components. These products are being used within the shipyards to support construction.

The end result of the modeling effort will be interference-free digital design product models. These will replace the traditional design control mats. The product models will also be transferred to each shipbuilder where manufacturing information will be extracted.

The DDG 51 Digital Data Transfer project has put in place a basic translator that supports the exchange of product models. It provides the required path to allow full use of the product models for all program participants.

Actions taken to improve the long term use of the product models and the DDG 51 Digital Data Translator include:

- Establishing Library Part and Zone Model content standards.
- Establishing configuration accounting requirements and procedures.
- Completing Library of Parts for DDG 51 Class (i.e. all valves, combat system components, pumps, motors, etc.)
- Interfacing the data transfer efforts with groups involved with the establishment of national standards for IGES and PDES.

The U.S. Navy's AEGIS Destroyer Program has established long term goals for further development and exploitation of the technology implemented on this project. The DDG 51 DDT translators require further refinement and the use of product model information is just beginning to be developed. The work remaining is significant and the goals have been time phased over several years. The work done to date positions the AEGIS Destroyer Program to take full advantage of CAD and CAM during

construction and to realize many of the benefits of Computer Aided Acquisition and Logistics Support (CALS) over the life of the Class.

ACKNOWLEDGMENTS

The U.S. Navy's AEGIS Destroyer Program could not have successfully completed this project without the help of these key contributors:

Bath Iron Works Corporation
Ingalls Shipbuilding
Gibbs and Cox
General Electric, Government Electronics Systems Division
Cali and Associates
Kockums Computer Services
Calma Corporation
Prime/Computervision Corporation

REFERENCES

1. Naval Sea Systems command "3D CAD Model Content Standard", DDT Document #188, March 1990.
2. DDG 51 Class "Digital Data Transfer Project Functional Specification", DDT Document #57, Revision C (Phase II), March 1990.
3. "Autokon <--> SPADES Model Communication System", Rev 8, November 1989.

3D CAD MODELING
(INITIAL ZONES FOR MANUAL TO CAD CONVERSIONS)

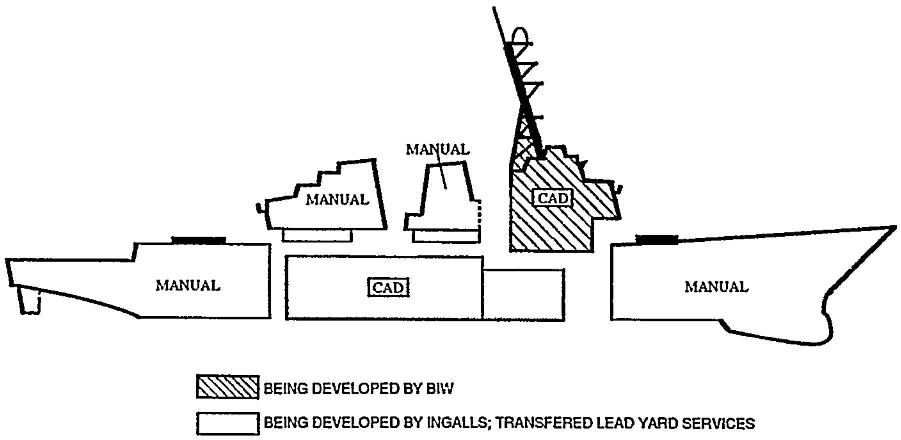


FIGURE 1

3D CAD PROCESS

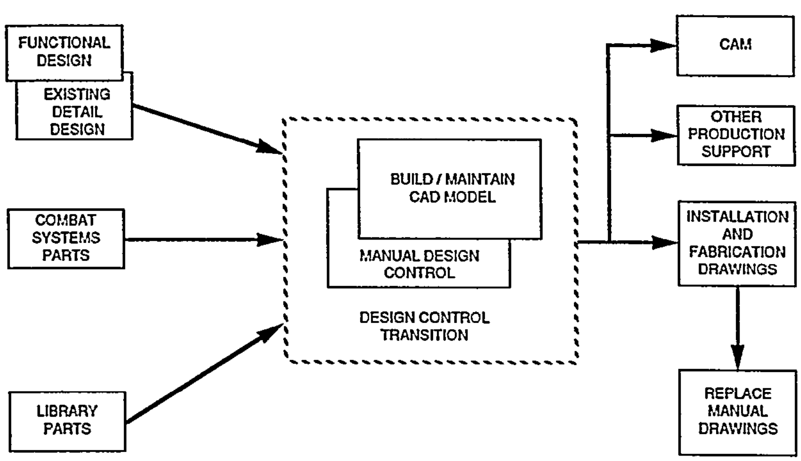


FIGURE 2

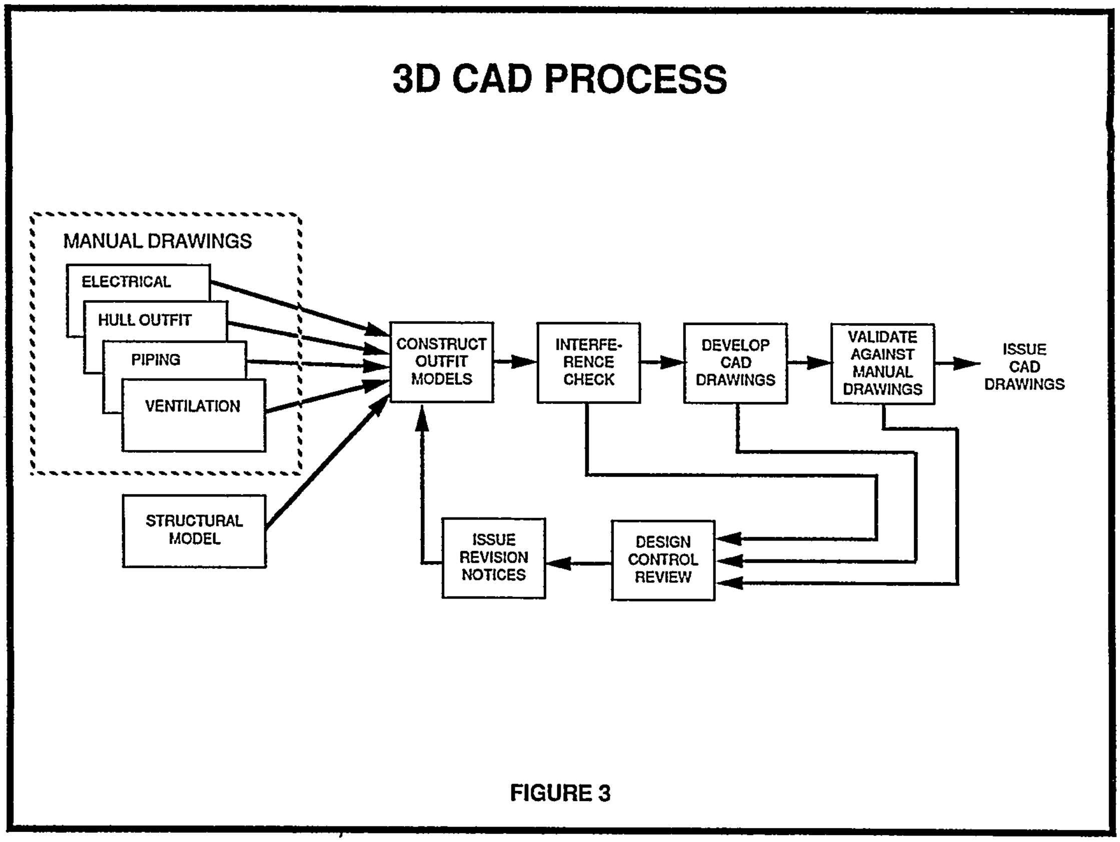


FIGURE 3

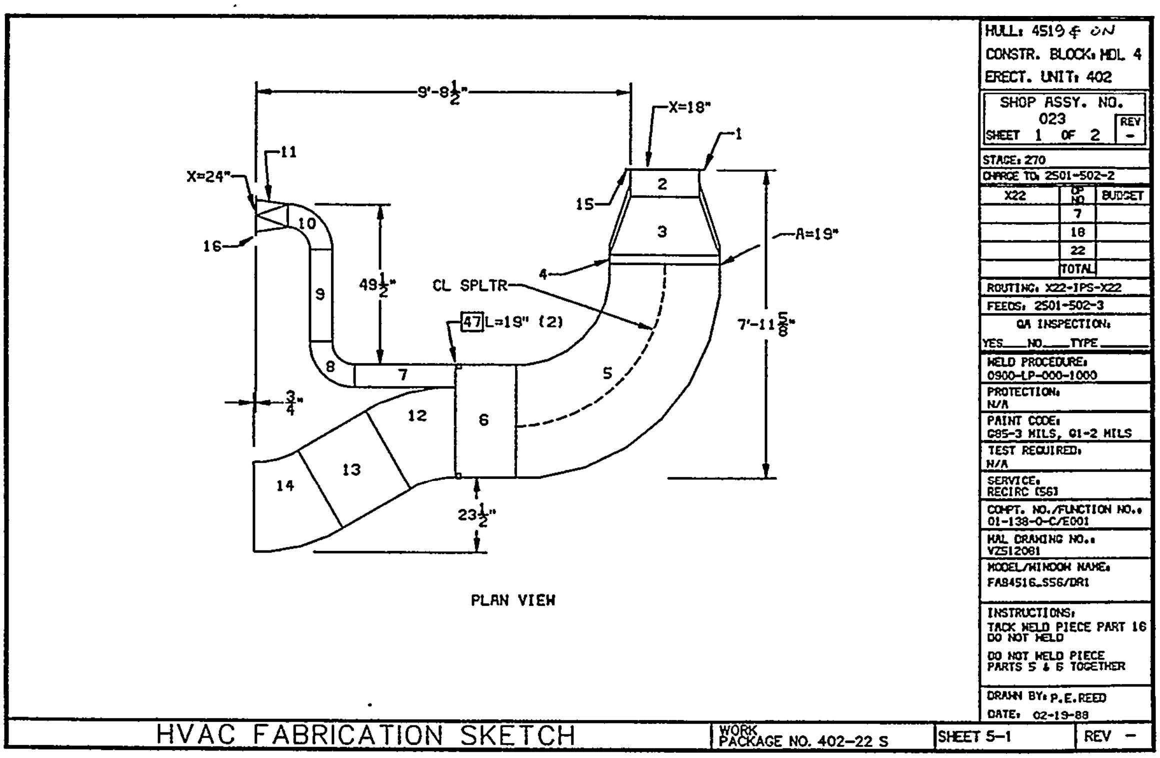


FIGURE 4

HULL: 4519 & ON
CONSTR. BLOCK: MDL 4
ERECT. UNIT: 402

SHOP ASSY. NO. 023
SHEET 2 OF 2 REV -

MODEL/WINDOW NAME: FAB4516_S56/DR1

NOTES:

FN/MAL NUMBER	QTY	DESCRIPTION	SOURCE NUMBER	MATERIAL	MAT REQ NO	STORE RM LOCATION	STATUS
27/7-11	22 SF	.050"THK SHEET (AA)ALY 5052 TEN H-32 QQ-A-250/8 FOR NHT AL DUCT UP TO 18"	9535-DA0-621354 (VLD512081)	AL ALY			
28/2,12-14	41 SF	.060"THK SHEET (AA)ALY 5052 TEN H-32 QQ-A-250/8 FOR NHT AL DUCT 18-1/2"-30"	9535-DA0-621355 (VLD512081)	AL ALY			
29/3-6	101 SF	.080"THK SHEET (AA)ALY 5052 TEN H-32 QQ-A-250/8 FOR NHT AL DUCT ABOVE 30"	9535-DA0-621357 (VLD512081)	AL ALY			
57/1,15	1 EA	28"X14" FLANGE ASSY SP000030-7126 AL NHT TO AL SPOOL	0000-SP0-307126 (VLD512081)	AL ALY			
87/16	1 EA	10"DIA FLANGE ASSY SP685022-1715 AL NHT TO AL NHT	6850-SP0-221715 (VLD512081)	AL ALY			
47	1 EA	HANGER ASSY LIGHTWEIGHT SP685035-0011 AL NHT DUCT TO AL STRUCTURE	6850-SP0-350011 (VLD512081)	VARIOUS			

HVAC FABRICATION SKETCH (B.O.M.) | WORK PACKAGE NO. 402-22 S | SHEET 5-2 | REV -

FIGURE 5

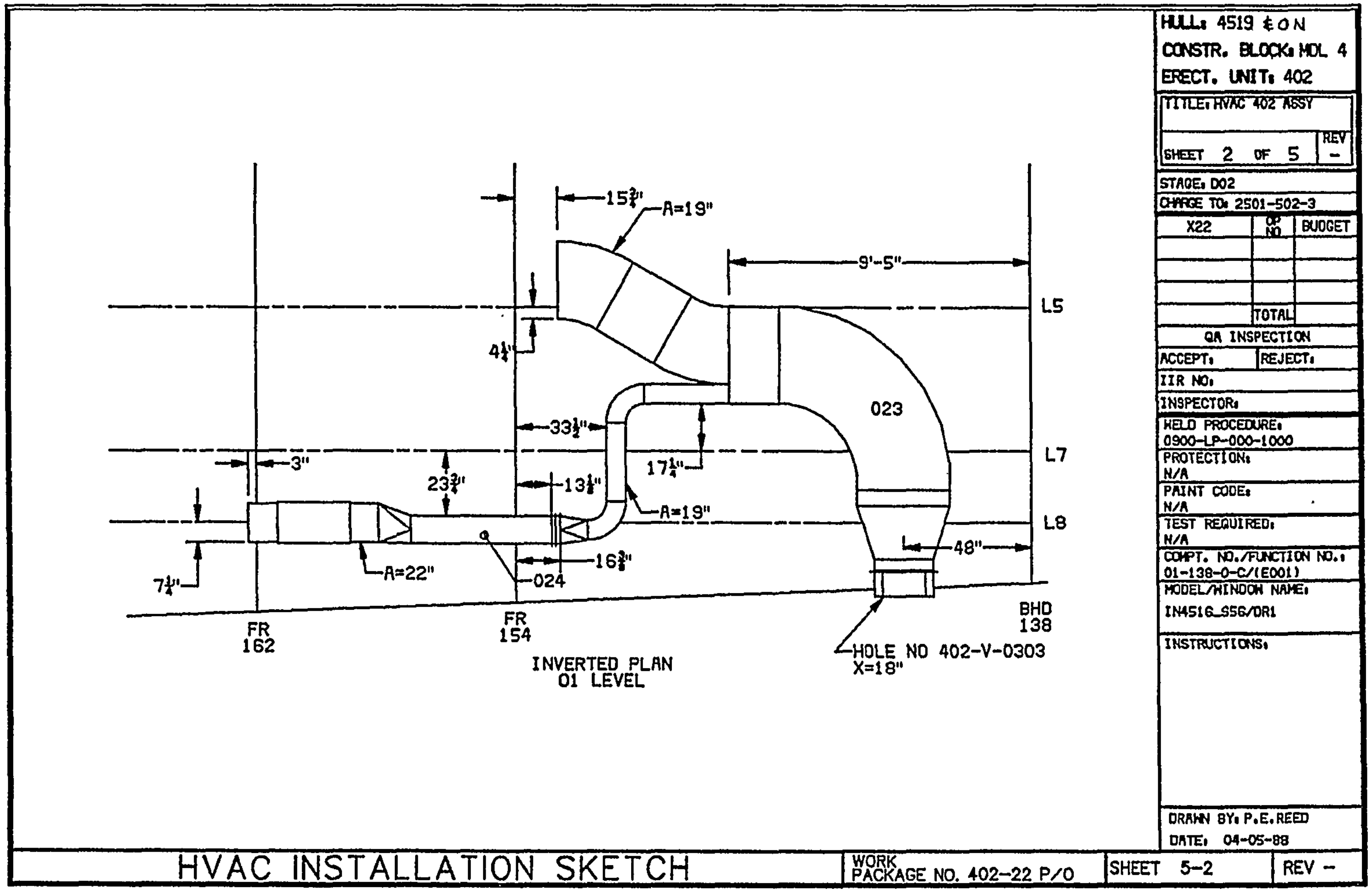

HULL: 4519 ⊄ON
CONSTR. BLOCK: MOL 4
ERECT. UNIT: 402
TITLE: HVAC 402 ASSY
SHEET 2 OF 5
REV -
STAGE: D02
CHARGE TO: 2501-502-3
X22
OP NO
BUDGET
TOTAL
QA INSPECTION
ACCEPT:
REJECT:
IIR NO:
INSPECTOR:
WELD PROCEDURE:
0900-LP-000-1000
PROTECTION:
N/A
PAINT CODE:
N/A
TEST REQUIRED:
N/A
COMPT. NO./FUNCTION NO.:
01-138-0-C/(E001)
MODEL/WINDOW NAME:
IN4516_S56/DR1
INSTRUCTIONS:
DRAWN BY: P.E.REED
DATE: 04-05-88
15¾"
A=19"
9'-5"
L5
4¼"
023
33½"
L7
3"
23¾"
13¼"
17¼"
A=19"
L8
48"
7¼"
A=22"
16⅜"
024
FR 162
FR 154
BHD 138
INVERTED PLAN
01 LEVEL
HOLE NO 402-V-0303
X=18"
HVAC INSTALLATION SKETCH
WORK PACKAGE NO. 402-22 P/O
SHEET 5-2
REV -

FIGURE 6

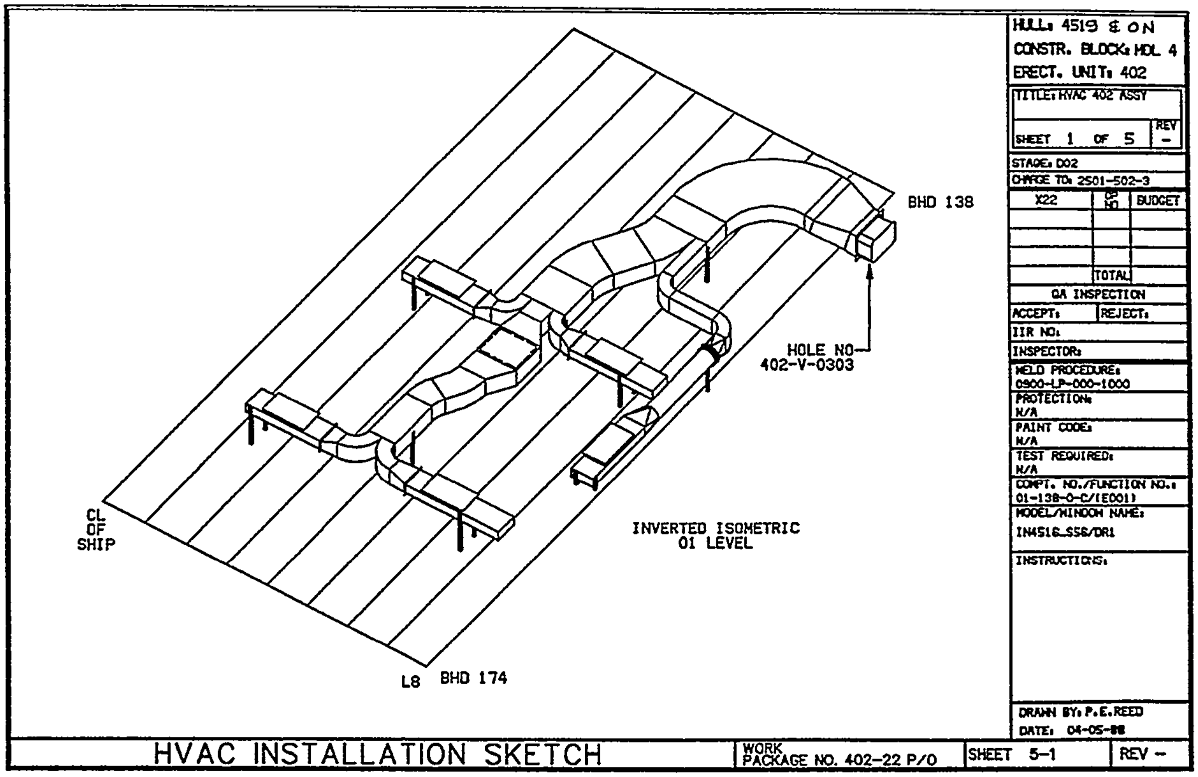


FIGURE 7

DDG 51 DIGITAL DATA TRANSFER

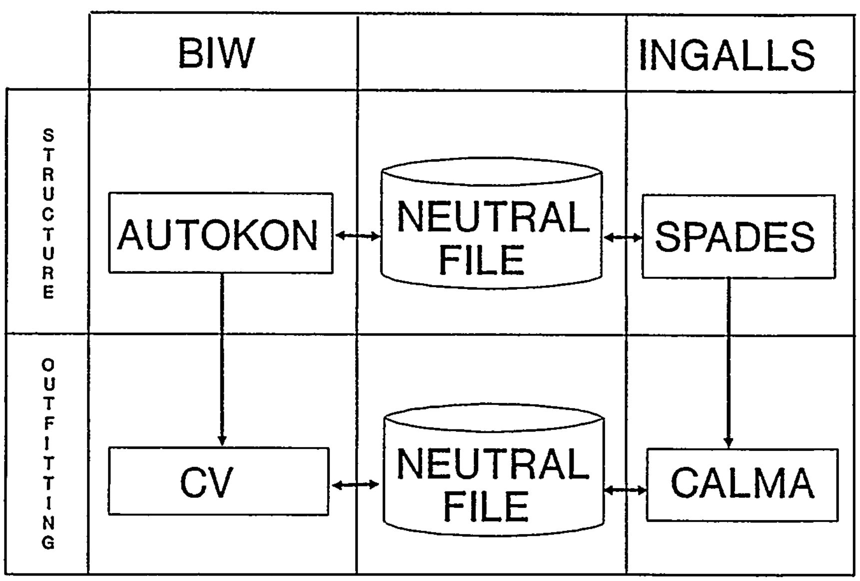
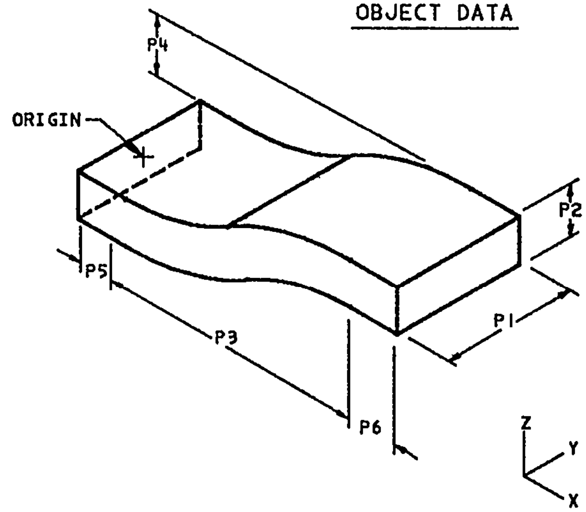


FIGURE 8 - Application Transfer Paths

OVERALL TRANSFER APPROACH (OBJECTS VS. ENTITIES)

PROPOSED APPROACH:

OBJECT DATA



DATA TRANSFERRED:

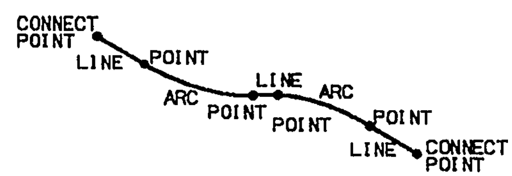
- ORIGIN
- ORIENTATION
- SHAPE DIMENSIONS

FEATURES :

- RECUCTICN IN TIME/SCHEDULE
- DESIGN TRANSFER CAPABILITY

IGES APPROACH

ENTITY (LINES/ARCS) DATA



DATA TRANSFERRED:

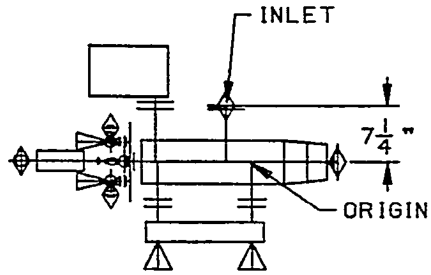
- COMPOSITE CURVE (LINES, ARCS, .POINTS)
  - EACH LINE
    START . END POINTS
  - EACH ARC
    LOCATION
    ORIENTATION
  - EACH POINT
    LOCATION
    DEFINITION OF CROSS-SECTION

FEATURES :

- REQUIRED FOR IGES - BUT NM SUPPORTED
- LIMITED DESIGN TRANSFER CAPABILITIES
- ADEED TIM AND SCHEDULE

FIGURE 9

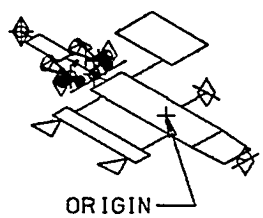
FIGURE TOP



PROPERTY

FITTYPE: 80
COMPNAME: "AIRRMVL *E"
STOCK NO: "........."
CONNECTOR (INLET CNODE)
ENDTYPE "FOFF" (INLET/OUTLET CNODE)
INTERNAL (INLINE)

FIGURE ISO (2D)



CLEARANCE ISO

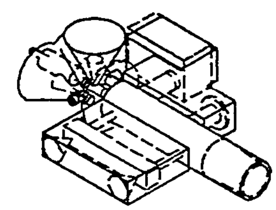
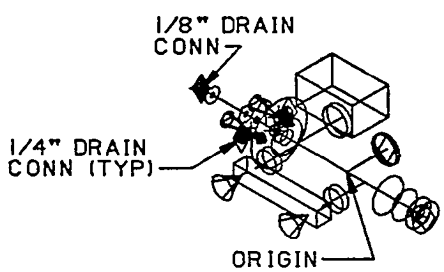
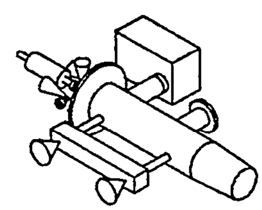


FIGURE ISO (3D)



DETAIL ISO



PREPARED BY:	MODEL SCALE	DESCRIPTION	REV
DLB	VARIOUS	AIR REMOVAL ASSEMBLY	E
AUTHORIZED BY:	DATE	LIBRARY SYMBOL FILE NAME	
HTB	4-11-87	P.3.N.ASSY.AIRRMV-01	

FIGURE 10

SH. 1 OF 3

DDT
PROCESS TESTING FLOW CHART

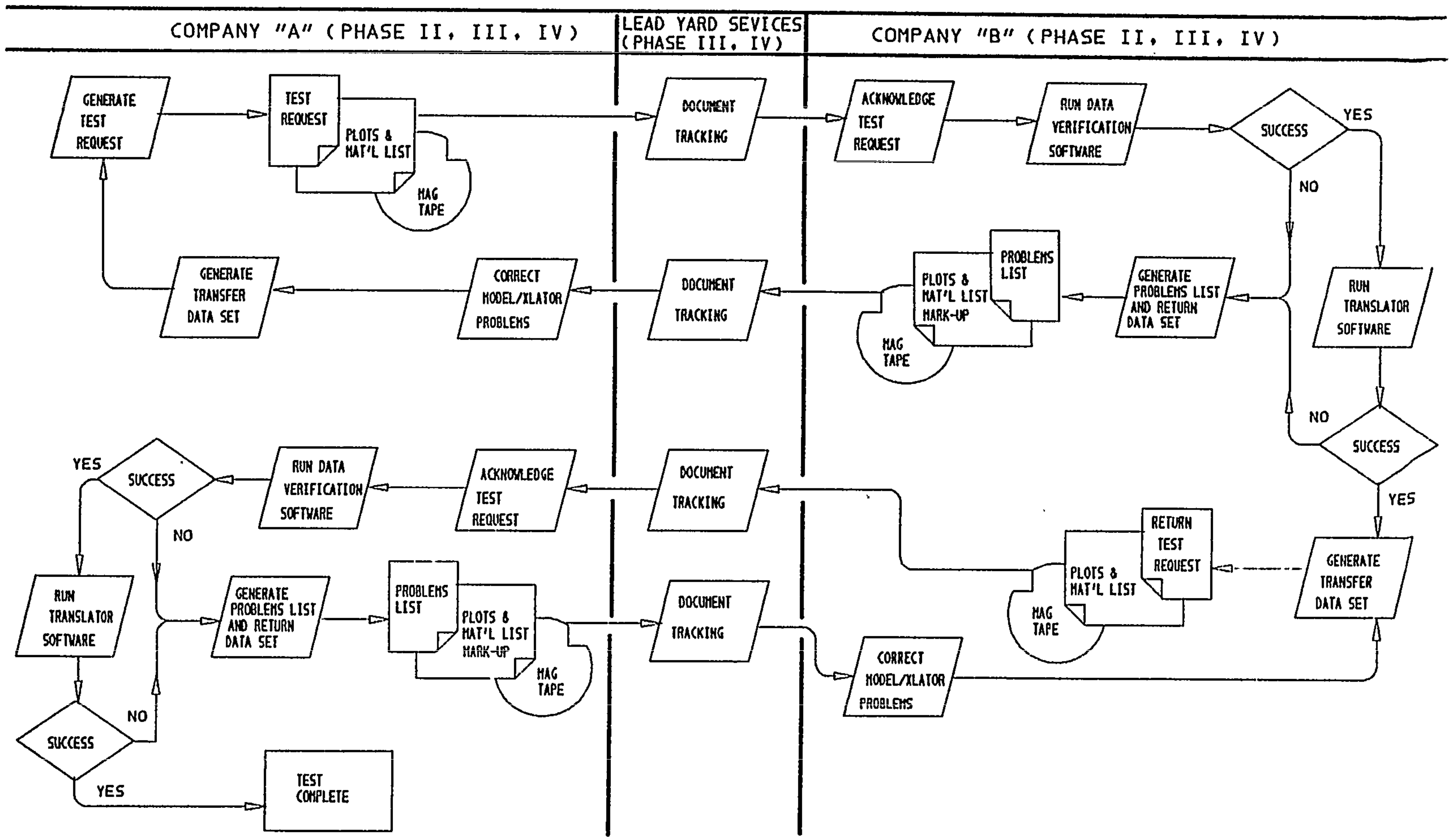
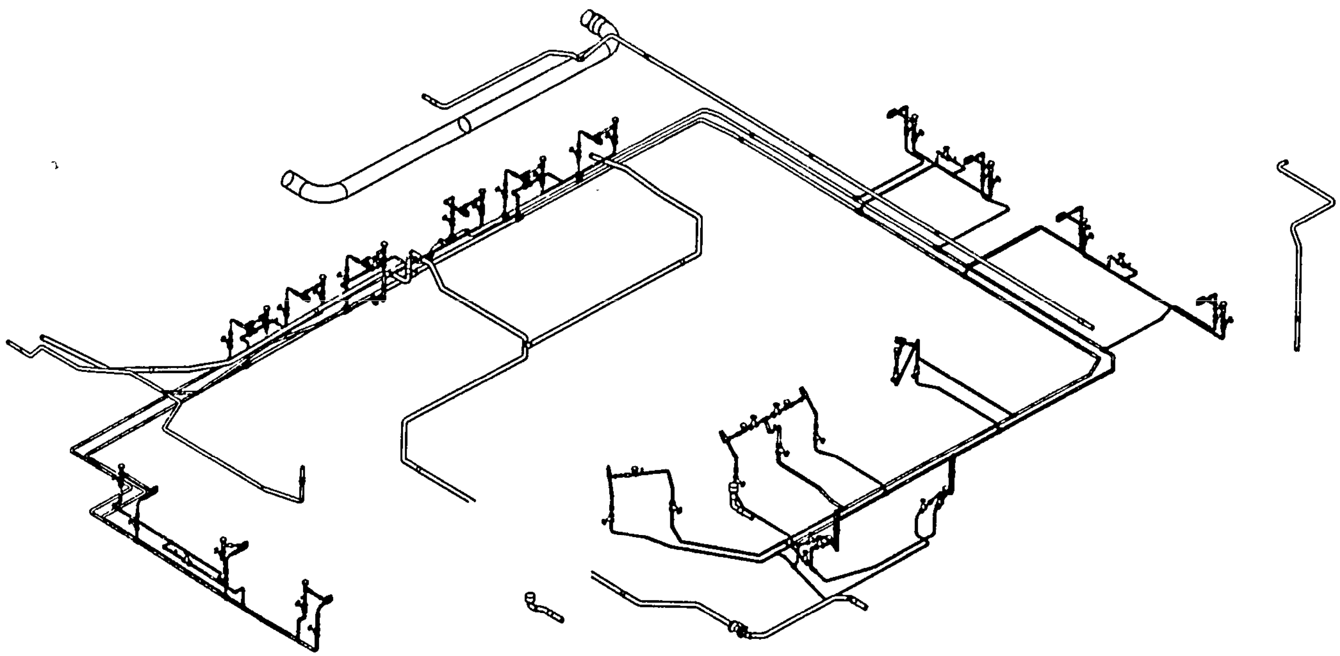


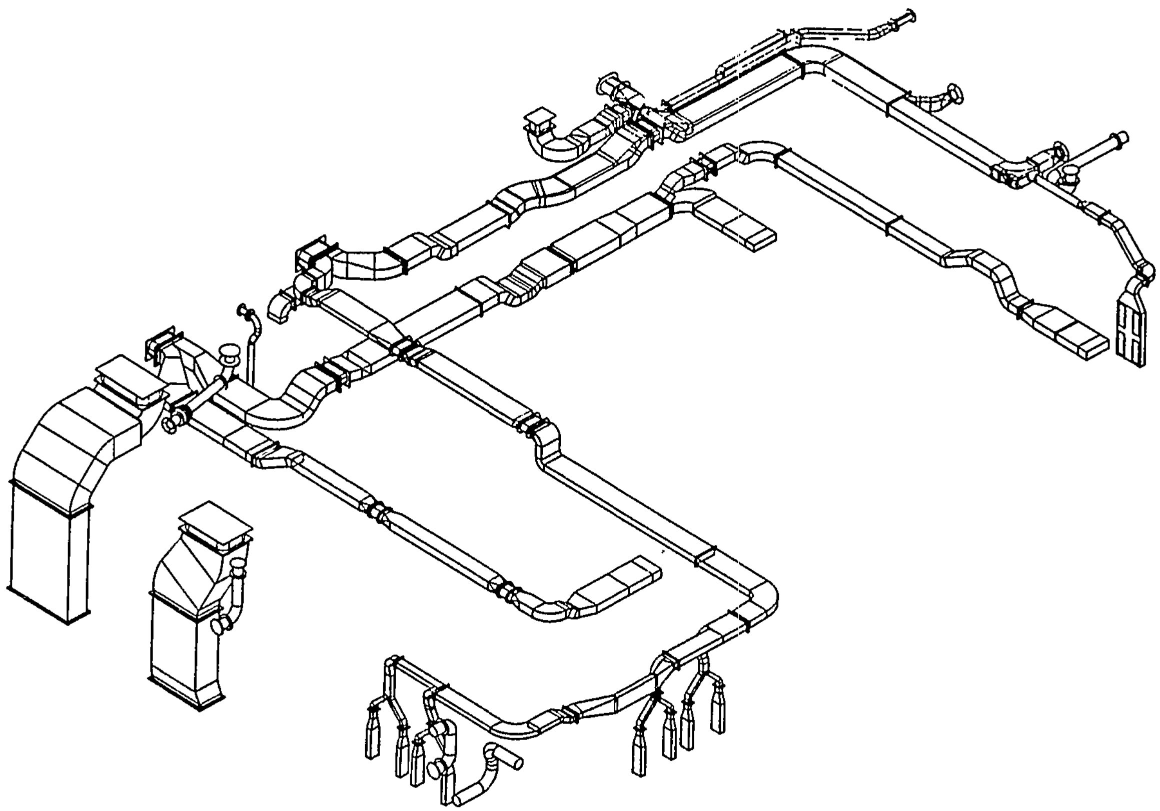
FIGURE 11

5A-1-18



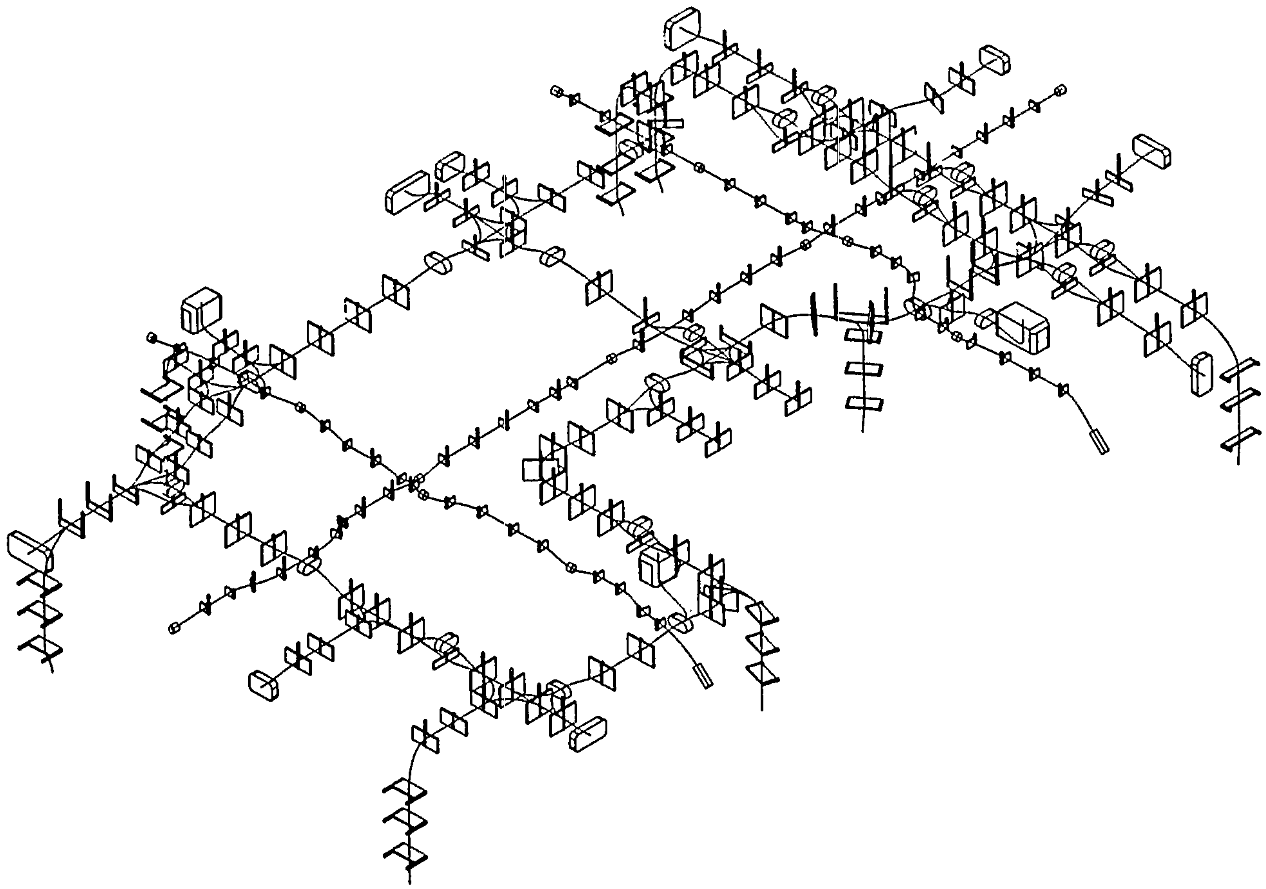
PIPING ZONE 2150 C.I.C

FIGURE 12



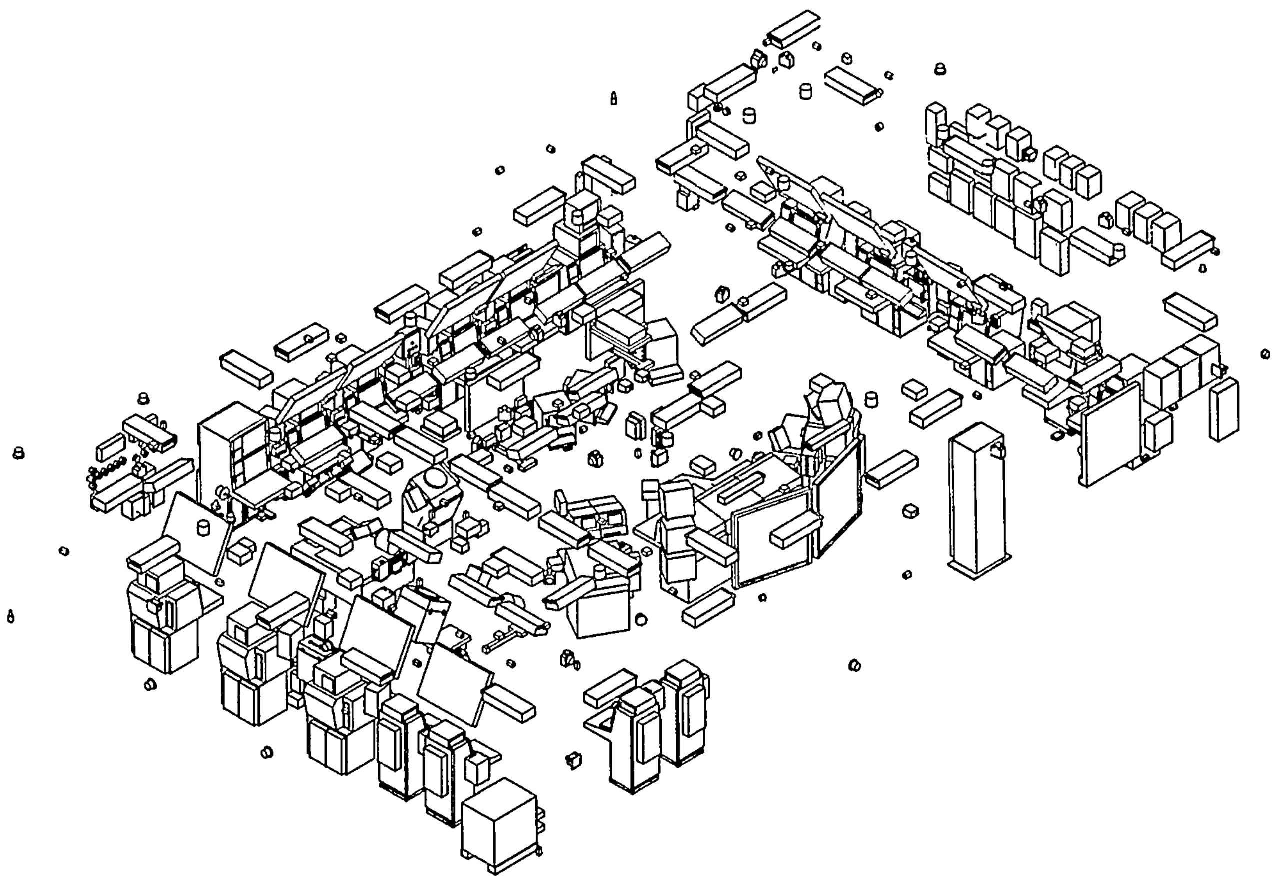
HVAC ZONE 2150

FIGURE 13



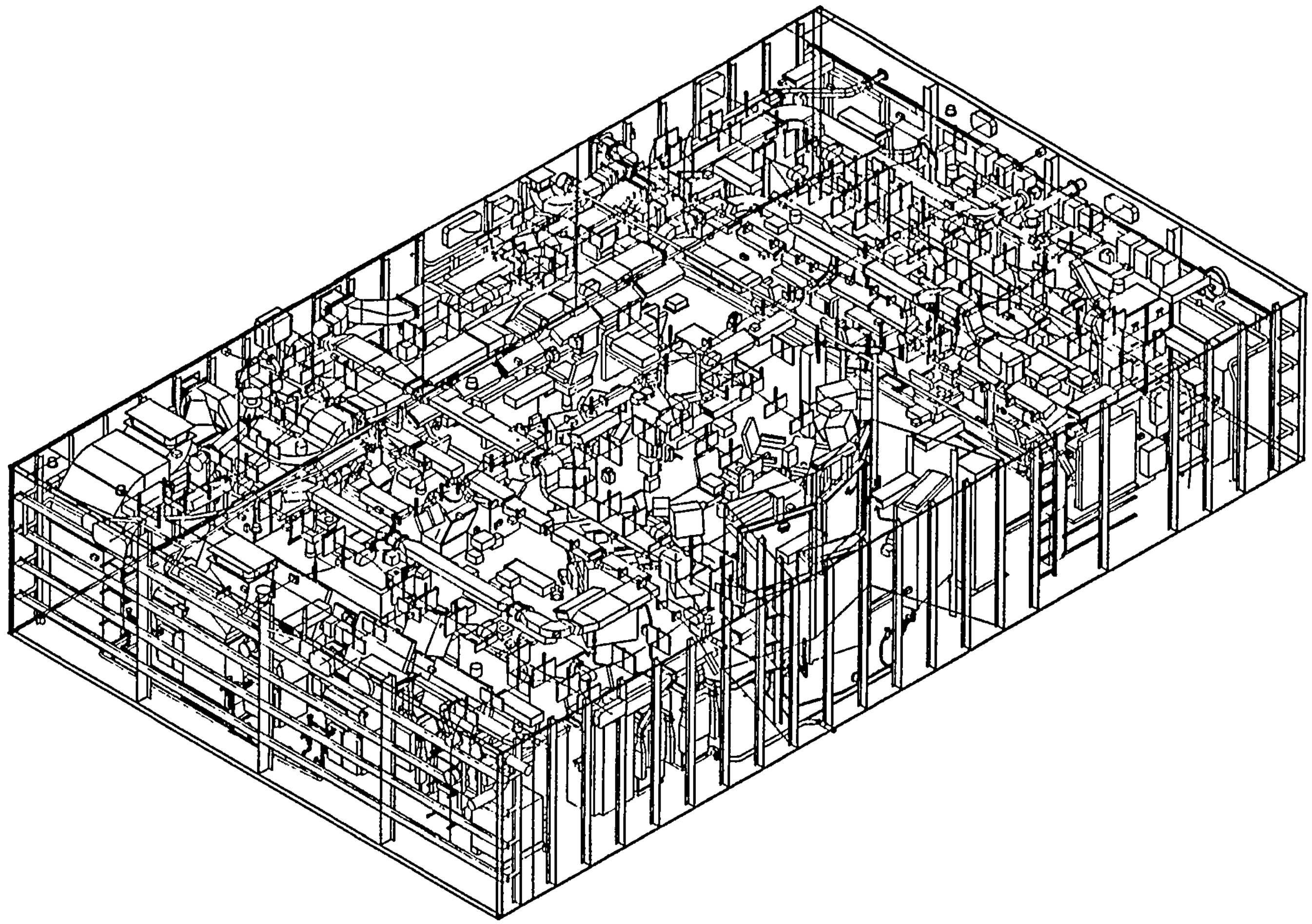
ELECTRICAL WIREWAY ZONE

FIGURE 14A



ELECTRICAL EQUIPMENT ZONE 2150 C.I.C

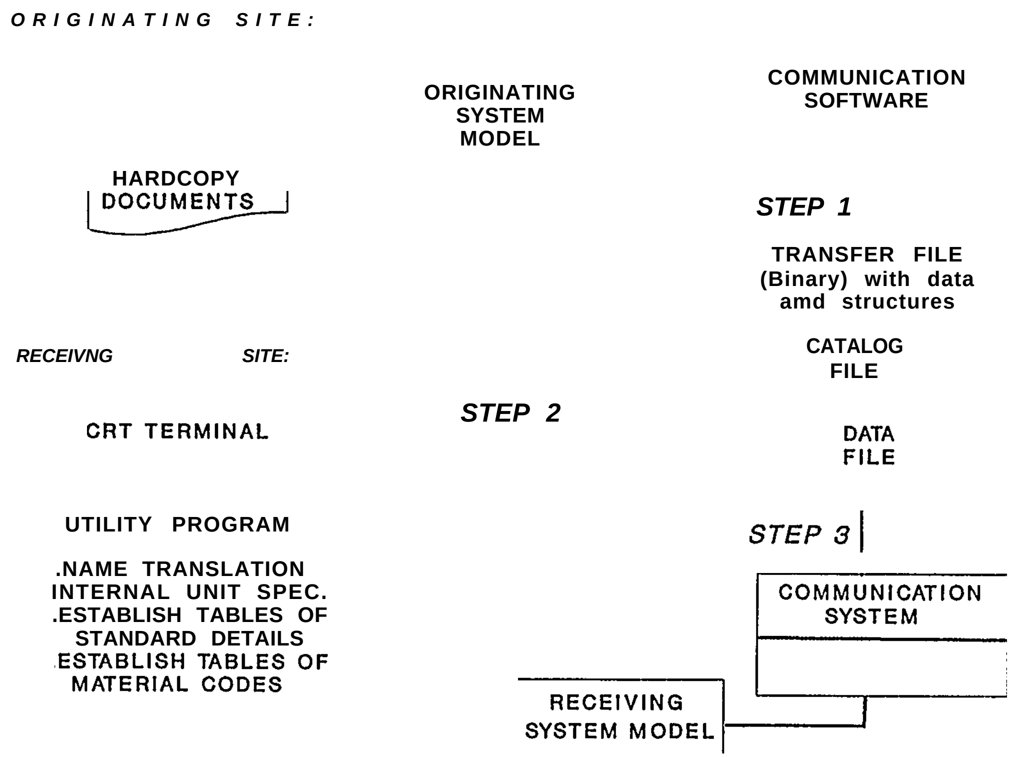
FIGURE 14B



ZONE 2150 C.I.C.
COMPOSITE MODEL ISOMETRIC VIEW

FIGURE 15

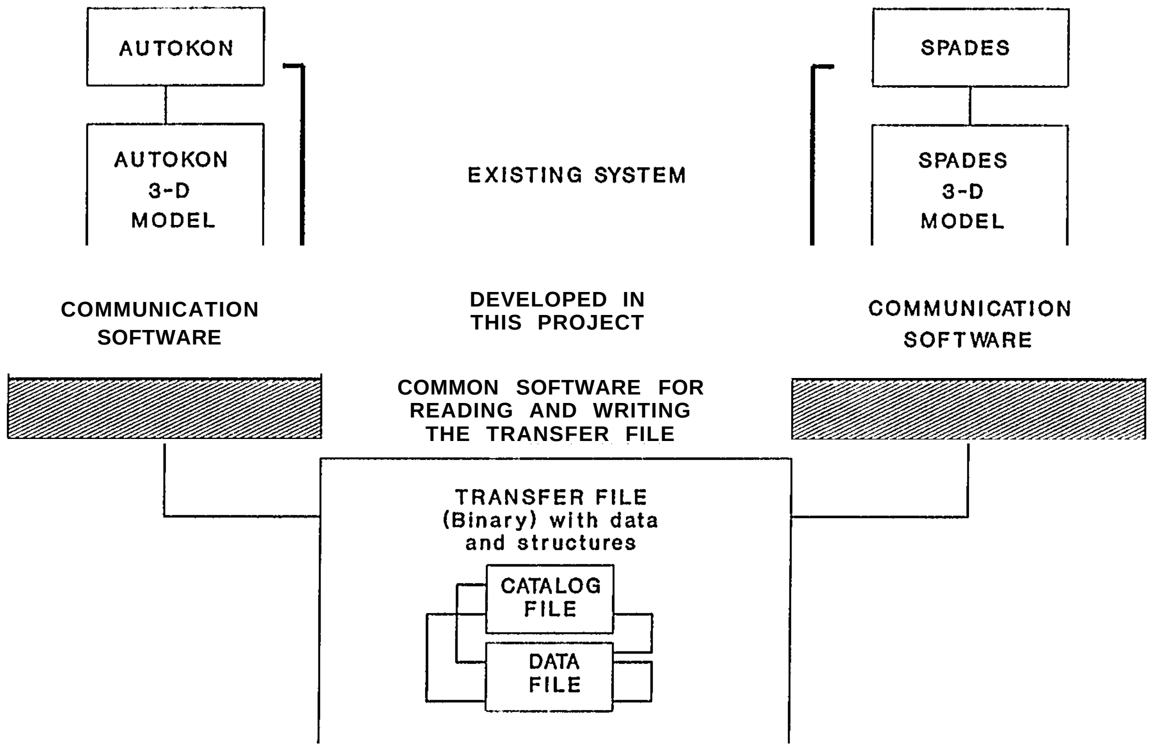
AUTOKON <--> SPADES
COMMUNICATION SYSTEM



Steps of Operation

FIGURE 16

AUTOKON <--> SPADES
MODEL COMMUNICATION SYSTEM



AUTOKON <--> SPADES LINK
FIGURE 17

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