COMPUTER GRAPHICS APPLICATION IN THE

ENGINEERING DESIGN INTEGRATION SYSTEM

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INTRODUCTION

The Engineering Design Integration (EDIN) System (reference 1) is a collection of computer aided design software and hardware that is being developed by the National Aeronautics and Space Administration, Johnson Space Center (JSC) on the Univac 1110 computer. A three-level system development schedule is being pursued at JSC. The Level I System, currently operational, consists of a single station, single user demand system with considerable passive graphics capability, both online and offline. The system provides a conceptual design capability useful for advanced concept studies and limited preliminary design applications.

The Level II System now under development at JSC emphasizes interactive man-in-the-loop capabilities supported by computational interactive hardware remote to the host computer. The Level II System is also expected to provide greater depth of analysis through improvement in the technology modules (i.e. structural sizing based on flight loads). The current development will provide the prototype for the Level III System, a multistation multi-user system, expected to support many projects and many design activities. To achieve the goals set for the EDIN System, considerable expansion of the technological capabilities, the interactive functions, the executive capabilities and utility programs is planned.

This paper deals with one aspect of the EDIN development, computer graphics and its application to design problems. Several conceptual design studies have been supported at JSC using the EDIN System and a variety of computer graphics technologies have been employed in the ensuing analysis.

Three basic types of computer graphics have evolved in the development of the EDIN System; offline graphics systems using vellum-inking or photographic processes, online graphics systems characterized by direct coupled low cost storage tube terminals with limited interactive capabilities, and a mini-computer based refresh terminal offering highly interactive capabilities. Each of these basic types of graphics has been employed to some extent. The results of using the graphics capability will be discussed as it relates to the application and continued development of the EDIN System.

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THE EDIN SYSTEM

The EDIN System is a computer aided design complex shown schematically in figure 1 for the evaluation of aerospace vehicle preliminary designs. The system consists of the Univac 1110 computer employing the Exec 8 operating system, a set of demand access terminals of both the alphanumeric and static graphics types, a minicomputer based interactive graphical display system and a library of independent computer programs. The program library contains technology oriented programs for estimating all major flight vehicle characteristics such as aerodynamics, propulsion, mass properties, trajectory and mission analysis, cost, steady state aeroelasticity, flutter and stability and control. There are special and general purpose utility programs in the library for generating, analyzing and controlling the flow of design data within the computer program complex.

The independent program approach to integrated design allows any of the library programs to be revised, extended or replaced without affecting the other program elements of the system in any way. External to the technology programs themselves, a data base is maintained by a series of data processors exemplified by reference 2. Each technology program may draw upon the data base for information as required. The specialists in any technology area are able to phrase the analysis of the design without regard for the other technologies involved other than the interfaces with the data base. The data base attributes are defined by the design staff and can consist of all information which is communicated between elements of the system or communicated from the system itself to the staff. The stored data represents a subset of the total amount of information generated by all of the programs within a given design sequence. When combined with the normal input data, it is sufficient to completely define the vehicles under study. When combined with the normal output, it represents the data description of the vehicle, its characteristics and mission requirements.

The total data base consists of program elements, data elements and design procedural elements stored on the Univac mass storage system. The elements are constructed in name addressable regions of online storage which can be further subdivided into user established classes of data. Each class represents an independent subset of the data recallable by the user of the system. Data manipulation is performed by several processors, some supplied with the Exec 8 System and some developed specifically for use in the construction and maintenance of the data base by the user.

The EDIN System can be operated in a batch, demand or interactive environment (figure 2). In the batch mode all logical decisions must be built In the demand mode some user interaction with the data base is available but little interaction within a technology module execution is provided. In the interactive mode, the user has the ability to interrupt the analysis process, perform alternative analysis and alter the course of the design process. Usually a combination of batch, demand and interactive modes of operation is employed in the use of the EDIN System.

The host computer selected for EDIN is the Univac 1110 computer consisting of the executive system (Exec 8), compilers, system utilities, subroutine libraries, etc. The EDIN System relies heavily on the executive functions for program control and file management. For this reason, a knowledge of the control functions of Exec 8 are essential to the user of the EDIN System.

The operating system is an outgrowth of Univac's many years of experience in multiprogramming, multiprocessing, time sharing and communication systems. It provides a flexible user environment which is essential to the operation of the EDIN System. A complete set of software, ranging from high level language compilers to basic service functions, is included in the operating system. The five major categories are:

System Processors.

Language Processors.

Utility Processors.

Subroutine Library.

Applications Programs.

The first two categories represent the base complement of software supplied with the 1100 series computer and maintained at the Univac installation. They are generally used by the EDIN System without modification. The user portion of the operating system is described in the last three categories. The EDIN System takes advantage of the software which is already available and augments the software capability in these categories with special programs dealing primarily with engineering and design integration. The EDIN interface to the Univac 1100 series computer is shown in figure 3.

The Executive System

To take full advantage of the speed and hardware capabilities of the 1100 series system, a comprehensive internal operating environment is provided in the Exec 8. This environment permits the concurrent operation of many programs and directs the computer to react immediately to the inquiries, requests and demands of many different users at local and remote stations. The Exec 8 system can store, retrieve and protect large blocks of data and makes the best use of available file space.

Only through central control of all activities of the system can this environment of combined hardware and software systems be fully established and maintained to satisfy the EDIN requirements. The responsibility for centralized control is borne by the Exec 8 system, which controls and coordinates the functions of the internal environment. A relatively simple interface to the executive, based on the run stream concept, is provided which relieves the users of concern for the internal interaction between his program and other coexistent programs.

The technical capabilities of the Executive System cover a variety of data processing activities. The executive system design offers the versatility of handling batch processing, demand processing and real time processing using multiprogramming and multiprocessing techniques. Batch jobs may be submitted from remote terminals as well as from central site equipment. The batch mode is used in EDIN applications for long running analysis and programs with high core requirements.

Complementing the batch processing capabilities are the Exec 8 demand (or time sharing) capabilities. This mode of operation accommodates inquiry terminals operating in a demand mode. All facilities available to the batch processing user are also available in a demand mode, the primary difference being that the demand mode permits the user additional flexibility in the statement and control of individual tasks. For example, when an error is made in the demand mode, the user simply corrects it online and proceeds rather than suffering the turnaround cycle inherent in batch processing. The demand user may interact with the system at various levels which include the Executive System, a conversational processor or with a user program. Many conversational EDIN programs take full advantage of the demand mode. Design analysis can be interrupted at any point to assure integrity using the demand mode.

The Exec 8 system is also designed to be used with other computers which have parallel processing and intermediate data transmission requirements. The Univac Communications Subsystems, together with the scheduling and interrupt processing features, provide an environment satisfactory for the operation of parallel processing computers. The EDIN System currently uses this capability for the interactive graphics (Adage 330) computer.

The Executive System is designed to ensure effective and efficient utilization of the mass storage devices. The consequence is an unprecedented ability to relieve users of the responsibility of maintaining cards and magnetic tape, thus eliminating many errors which heretofore have accompanied the use of large scale software systems. At the same time, the overall operating efficiency is considerably improved. Card handling is virtually eliminated in the use of the EDIN System.

Executive Control Statements

Control of the operating system for the Univac 1100 series computer is accomplished through a relatively small and easily learned set of executive control statements. These statements which are identified by a leading @,

    @statement

direct the executive system in the processing of a run. Control statements may evoke executive functions such as scheduling, assignment of facilities (files), etc. or may cause the execution of a user program or a processor. The executive control statements are designed in a

compact and descriptive manner to facilitate use and yet provide access
to all of the features of the Executive System, the EDIN program library
and Data Management System.

Run Stream Concept

The run stream concept is employed as the primary interface between the
computer operating system and the user. The run stream contains control
statements and data that describe the specification of the tasks which
will be performed by the computer. It is the largest working group read
and manipulated by the Executive System. The run stream itself is a
sequence of data images which taken as a whole constitute the total
specifications for a run. The run stream consists of an @RUN control
statement followed by other control statements and data which direct the
performance of individual tasks. Each task consists of one or more con-
trol statements which provide technology oriented or utility operations.
Tasks may also be grouped into partial run streams. The partial run
stream may be added at any point in the run stream by use of the @ADD
control statement. The run stream is terminated by an @FIN card which
directs the executive to terminate processing of the run stream. In the
batch stream of operation, the entire run stream is normally stored on
the mass storage facilities before run processing is initiated. The
Executive System schedules the run stream as an unit. Once initiated,
the executive processes the entire run stream. In a demand mode, the
run is normally initiated immediately upon acceptance of the @RUN control
statement from the demand terminal. The system continually solicits the
demand terminal for additional run stream input which generally occurs
dynamically or on a conversational basis. The demand solicitation con-
tinues until an @FIN control statement is submitted from the demand
terminal.

Once the run is opened, the executive processes the control statements
as they are encountered. A batch run terminates as the result of an
abnormal task termination. However, in the demand mode, an abnormal
task termination will not terminate the run but simply print the
diagnostic message which causes the abnormal task termination and
solicits another executive control statement.

EDIN/EXEC 8 INTERFACE

The EDIN System is interfaced with Exec 8 through a relatively simple
application of the partial run stream (@ADD element) concept. Figure 4
illustrates a typical conceptual sizing study involving a multiple stage
launch vehicle. Each block in the diagram represents a design task.
Each task is physically constructed in an @ADD element containing con-
trol statements and data for execution of one or more programs required to
perform the task. The @ADD elements are actually augmented by data base
information requests. The requests are satisfied by preprocessing the @ADD
element with the EDIN data processors. Once the data base requests are
satisfied, the modified @ADD element may be processed by the Exec 8 system.

Data base interface is illustrated in figure 5. A partial run stream is interrogated by a data processor, which modifies the @ADD element with data base information. The modified @ADD element is then processed by the Exec 8 system resulting in generation of normal output and EDIN interface data. The interface data is a subset of the normal output which can be placed in the data base by a data processor.

Any set of vehicle component matching and sizing loops can be defined by one or more partial run streams (or design tasks). There is no effective limit to the number of design sequences which can be performed using the partial run stream concept. The sequences can be repeated as often as necessary and can be terminated on criteria contained in the data base.

DATA MANAGEMENT SYSTEM

The EDIN System provides a balance of data management techniques which consider the inherent capabilities of the computer operating system, past efforts in the storage and retrieval of stratified data and the recent development of some flexible paging techniques for the transfer of information between the computer core and the mass storage of the computer. The Univac Exec 8 System provides the resources for the storage of large complex data files, for the storage and retrieval of the files and for the cataloging protection and backup of the files. The Exec 8 System has several processors with instruction sets for manipulating the data retained in mass storage. A limitation on the operating system capabilities arises in accessing the subfile level of information in the system files once the file is addressed.

The EDIN Data Management System is designed to subdivide the Exec 8 files in a manner that will allow the data retained in mass storage to be accessed at any level from the single parameter level to a large matrix of data. Rather than constructing an extensive single computer program that attempts to be all things to all people, the EDIN Data Management System provides an extendable three-level data management capability. This approach permits the individual designer using the system to make his own decisions with regard to the storage method and techniques. It also permits the flexibility of using existing data sources not specifically created for EDIN.

The lowest level of the Data Management System deals with the interface between the data in mass storage and the computer operating system. This level of the Data Management System is provided by the Exec 8 software and consists of the file utility processors, the file administration processors and other system level processors. The system processors are accessed using Exec 8 control statements. Therefore, first level software may be used directly by the EDIN user for transmitting large structured blocks of data. The files may also be accessed by the programmer who seeks economy above all else. The file level constitutes the foundation for all higher level data management components.

The second level of the Data Management System provides the mechanism whereby the files can be organized into blocks of data called pages. Pages of information can be organized in a number of ways and names can be given to each page. A pointer system or directory is maintained by a Fortran callable software package developed for and maintained in the EDIN library. The second level is the programmer level. It is used to interface the technology modules directly with the data base and constitutes the primary interface for the EDIN data processors.

The third and highest level of the Data Management System is provided to make the system more usable to the designer who may not be a programmer. The capability is provided in the data processor, described in reference 2, which is designed to maintain a data base of stratified information. The stratified data can be selectively accessed and merged with the input stream of the EDIN technology programs. This level also provides the interactive language structure which allows the user to sit at a remote terminal and interact with the data base directly and generate design reports. The DLG processor also contains routines for processing the output from the technology programs for the storage of design information in the data base.

Although the user may access the data base through any of the three levels, it is the lowest level maintained by the Exec 8 System which actually stores and retrieves the data. Exec 8 handles all of the underlying data management functions including file assignments, file directory maintenance and security procedures as well as the data block transfer to and from mass storage.

THE PROGRAM LIBRARY

The EDIN library of independent computer programs provides the system user with the basic building blocks to perform integrated vehicle design analysis. Thus, to establish a given analysis, it is necessary to use only those programs required for the particular analysis. Figure 6 illustrates the types of analysis that can be performed in each technology area. The programs generally perform some engineering analysis function such as aerodynamics, performance or structural analysis. For example, the aerodynamics estimation programs provide theoretical and empirical methods spanning most aerospace vehicle shapes in common use over a complete Mach number spectrum. The performance programs provide vehicle performance methods ranging from simplified segmented mission analysis to the most complex variational optimizational techniques. Although the EDIN technology module library has extensive analysis capability, it does not permit computerized design studies much beyond the conceptual level.

Other nontechnology oriented programs, called utility programs, perform computer aided analysis function such as optimization, display graphics and report writing. During a simulation, system performance and constraint criteria are generated which are later used to evaluate the vehicle design (either automatic or manual). Special purpose utility programs are aids

in this evaluation. The utility programs generally transfer information or transform data to user formats or to meet other simulation requirements. They perform such tasks as compiling and executing interface programs, suppressing unnecessary printed information generated during design simulation and the routing of design reports to alternate user sites.

Most of the technology programs were in existence before development of EDIN. The programs are largely a result of NASA or USAF sponsored research studies. Most of the utility programs were created as part of the EDIN System to facilitate integration of the technology modules. There is no limit to the number of programs which can be incorporated into the library or to the number of programs which can be called upon in a given design situation. Integration of new technology programs into the system is a relatively simple task involving only a few hours to a few days of effort. New programs are constantly being integrated into the system as a need arises.

THE GRAPHICS SYSTEM

The use of computer graphics has been exploited for many years in industry with specific application to geometry definition for part design. This application has been termed Computer Aided Design. Now however, computer aided design is taking on a broader meaning as more effort is being expended in the development of capabilities in integrated design analysis such as the EDIN System. Integrated design analysis becomes feasible when the software and hardware are available to analyze and interact with the design process. Computer graphics in the EDIN System refers to that portion of the software system which supports the integrated design analysis using graphics output hardware available at JSC. Three types of graphics are employed, each aimed at specific hardware classes and generally toward a specific design analysis objective.

Offline Graphics

The offline graphics system uses the CALCOMP pen plotter, the SD4060 film plotter or the FR80 film plotter. While these devices have historically provided the bulk of computer graphics capability, the main use for them in the EDIN System is for engineering reports. The offline systems are characterized generally by high quality and poor turnaround. The resolution is better than .254 mm. The turnaround at JSC is one to four days. Further, the user can apply little judgment in the arrangement and annotation of the plotted information. All judgment factors must be applied without benefit of seeing the plotted information.

The EDIN offline software system (figure 7) is interfaced through a series of standard graphics routines which generate lines, symbols, etc. A lower level software package provides software windowing and clipping of the plot vectors to the specifications of the user. Both software packages are designed to generate plots on all three plot hardware devices.

Online Graphics

Two Tektronix 4012 storage tube terminals (Univac 1110 demand) have provided the bulk of the online graphical analysis capability for the EDIN System since their delivery in 1974, and for a very reasonable cost (approximately $10 000 per station). The advantage of this low cost graphics system has been the enhanced capability afforded by the "instant" visualization of the computer results. Online decisions affecting the design can be made with little interruption of the computation process. In other words, the design analysis is performed in a much smaller span of time. The major disadvantages have been the slow line speed (300 BAUD), poor hard copy and the early limitation on vector graphics input capabilities. The slow line speed severely restricts the use of menus in program control and hence the interaction of the user with the analysis program.

Early in 1975, one Tektronix terminal was adapted to a 1600 BAUD direct line to the Univac 1110 computer. This capability had an immediate and dramatic effect on the plotting capability through a five-fold increase in plotting speed, but in general, the speed remains too slow for large amounts of vector data such as total configuration geometry and the generation of menus for program control. However, the 1600 BAUD rate is quite adequate for two-dimensional plots.

Concurrent with the upgrading of the hardware capability described above, new software was made available from Tektronix which provides input graphics capability. Operating from the keyboard, a crosshair position and a one-character command can be transmitted to the computer program in execution. The program can be precoded to perform various operations based upon the information transmitted.

The EDIN online software system (figure 8) is interfaced to the Tektronix terminals much as the offline graphics system (figure 7) is linked to the CALCOMP, SD4060, etc. There is one exception, the addition of an edit feed back. This feature allows the user to edit the plotted information. The editing includes the addition and deletion of data points and text, rescaling, windowing, etc. The data can be replotted any number of times until the user is satisfied with the content. The user can then specify that the image or plot produced on the Tektronix terminal be duplicated on any of the offline devices.

The benefits to the EDIN System afforded by the online software capability are twofold. First, the user can apply the system as a monitoring device during a design simulation. In this mode, working copy is available from the Tektronix hardcopy unit. Second, the system can be used to preview and edit plotted information before investing the resources and turnaround time to generate offline plots. As a matter of practice, the online graphics system has drastically reduced the offline plotting requirements.

After several months of operation of the EDIN System using the Tektronix
terminals limited input graphics capability, it has become evident that
significant improvements in the edit capability of vector data already
stored can be offered but there are obvious inaccuracies in entering new
vector data from the terminal. For example, the accuracy of geometric
data input from the scope is generally not acceptable for engineering
applications such as aerodynamics analysis or mass properties evaluations.
One practical solution is the use of a data tablet, companion to the
scope. These devices use a stylus (or bomb site) to detect coordinates
on the tablet and can be used in conjunction with overlayed drawings
to accurately enter geometric data or to edit data which resides in the
data base.

The data tablet can also be used very effectively for program control
menus, a capability which is not otherwise practical with the line
speeds now in use. The menu can be a prepared hard copy overlay for
the data tablet. Raster positions on the tablet can be coded to
correspond with the menu overlay. Data tablets are available in two
sizes.

The smaller size is a hand-held tablet which is ideal for menus but
has limited application for geometry definition. The larger size is
practical for entering geometry but does not have the portability of
the small tablet. The addition of a large data tablet would raise
the average cost per graphics station to about $15 000.00. Plans for
future online graphics stations for the EDIN System include the use
of input data tablets.

Interactive Graphics

A truly interactive design integration system involves an intricate
relationship between the user of the system and the hardware/software
system itself. To be acceptable to the design community, the interactive
system must provide a natural extension of the designer's own capabilities.
Therefore, any system related to interactive computer aided design must be
highly user oriented. The involvement of the user during the development
period is essential to the success of the system. A significant portion
of past EDIN development effort has been the application of the system to
real engineering design problems at NASA. It is expected that the same
user community involvement will be pursued for the interactive development
program.

To date, computer graphics in the EDIN System has been used in the
definition and modification of three-dimensional geometry descriptions for
input editing, output analysis and for report preparation using two-
dimensional graphics. Highly interactive capability has been limited by
the availability of suitable hardware. The recent acquisition of the Adage

330 Graphics Display System by JSC has greatly enhanced the potential for interactive   computer aided design.

The Adage 330 Graphical Display System (GDS) consists of Adage DPR-4 (32K of 30 bit words) minicomputer and Adage 400 micro processor. The system has an interactive graphics terminal along with some peripheral equipment such as disk, light pen, input tablets, etc. The GDS is linked to a Univac 1110 computer via a 19,200 BAUD line. When the EDIN System is fully developed, the technology modules and the bulk of the data bases will reside on the Univac 1110. Graphical analysis functions will be performed on the GDS as well as the Tektronix. The split is not yet clearly defined but some functions will be available on both systems. The user will interact through the demand system on the 1110 and through the refresh terminal on the GDS. In the display mode, the available GDS core will be used largely for buffering display data. In a nondisplay mode, small technology modules may be executed.

For some classes of problems requiring the use of the GDS, data integrity between the minicomputer and the Univac 1110 must be maintained. Therefore, the transmission of data from the 1110 to the GDS will require special handling to provide the required data integrity. The file structure for the GDS will be compatible with the system data file formats on the Univac Exec 8 System. The user will be able to specify the accuracy degradation allowed in the transmission of data to and from the GDS mass storage system.

Two types of graphics display capabilities will be required, static and dynamic. Most static graphic functions now available in the EDIN System will be required on the GDS. In addition, new graphics functions will be required to support graphical analysis programming for the GDS. The basic static graphic function (figure 9) will be equivalent to the CALCOMP subroutines PLOT, AXIS, LINE, GRID, SYMBOL, etc. The development activities will extend these basic graphic function requirements to include a basic set of interactive graphic functions. All GDS applications programs will use this "second level" software. Obvious applications of the GDS are three-dimensional geometric manipulations, separation studies, plume impingement studies, etc. Other potential applications include program control through light pen, selection from menus, tutorials, report generation, etc.

Interaction with large technology programs is an essential goal in the development of EDIN. Therefore, the user of the GDS will have demand access to the Univac 1110. Further, the access will be achievable during execution of any GDS program. This will allow the user to effectively interact with executing programs on the Univac 1110 while performing GDS display and editing functions. Fortran callable interrupt and data transfer utilities will be available for the development of effective interaction between the Exec 8 programs and the GDS programs.

Although some Adage supplied software is available, much software must be developed to make the GDS an effective system. Some preliminary display programs have been developed since the delivery of the system in June of 1975, but the interactive capabilities thus far have been relatively untapped.

APPLICATION OF GRAPHICS TO DESIGN SIMULATIONS

SRB Replacement Study

The use of a recoverable liquid rocket booster (LRB) system (figure 10) to replace the shuttle solid rocket booster (SRB) system offers the potential of reduction in cost per flight, increased payload, less environmental impact and overall reduction in energy requirements. It has been proposed that the use of the basic shuttle orbiter, a modified ET and the new LRB system could achieve the potential. The concept uses the shuttle in essentially unmodified form. An RP-1 stage using three modified F-1 engines mounted aft of the shuttle ET replaces the existing SRB's. Some modification of the ET would be required to take thrust loads longitudinally along the tank rather than laterally through the tank. The expended LRB stage is jettisoned at BECO and recovered for reuse. The mission profile, figure 11, is designed to meet the shuttle mission 3-A payload requirements with sufficient propellant to fly an AOA mission.

The study, designated EDIN04, was initiated for the purpose of assessing the proposed LRB concept. The study was performed using EDIN software and represents a joint effort between NASA and Sigma Corporation. Information available from other NASA contractors was also employed where applicable. The NASA Engineering Analysis Division and the Future Programs Division were instrumental in defining design requirements and constraints. Other NASA divisions were involved in the analysis. Sigma Corporation developed the simulation procedures and assisted with the engineering analysis which resulted in a technical assessment of the concept.

Technical Assessment Techniques

Historical weight estimating relationships were developed for the LRB using Saturn technology and modified as required to support the EDIN04 study. Based on NASA funded studies, no weight penalty for the ET redesign was assessed in the present study. Mission performance was computed using current shuttle computation ground rules to allow for reasonable comparison of the existing shuttle with the EDIN04 results. Performance analysis was based on a point design trajectory model which optimizes initial tilt rate and post BECO control history. A gravity turn was employed during the LRB boost phase rather than using the shuttle angle of attack profile. A combination of SSME throttling and one F-1 engine shutdown was used to control the dynamic pressure and the longitudinal acceleration limits.

The study was conducted in four parts. The first and basic EDIN04 assessment provides a comparison of vehicle designs with and without the RTLS/AOA trajectory constraint and one with a 10% dry weight contingency imposed on

the LRB. The second part of the study considered the possibility of a degradation in SSME thrust level. The LRB was redesigned for four levels of SSME thrust. The third part considered the possibility of off-loading ET propellant using a base line 10-meter diameter booster and SSME thrust levels degraded to 85% of currently quoted levels. The fourth and final portion of the study upgraded the weight estimating relationships resulting from modification of the interstage and aft skirt lengths, deletion of the intertank structure, modification of the LOX/RP propellant tank weight sizing coefficients, modification of aerodynamic surface sizing equations and modification of the interstage sizing coefficient. Selected study configurations from the earlier parts of the study were resized. Results of the study have been retained by NASA for internal use.

Computer Graphics Utilization

Computer graphics was employed in the EDIN04 study in two ways:

Two-Dimensional Analysis Plots.

Three-Dimensional Configuration Studies.

The two-dimensional plots illustrated in figure 12 were generated using the online Tektronix terminal for visual control and monitoring of the flight constraints such as load factors and dynamic pressure. The plots were also generated on CALCOMP for incorporation into the assessment report. A general purpose independent plot program of reference 3 has the ability to extract data from the data base and present it in user specified formats.

Plotting instructions are specified in the run stream or they can be specified conversationally by the user. The data may be presented in the usual x-y sequence or can be presented as contour plots. The user can select the segments of data to be plotted as well as scaling, annotation, titling and smoothing of the resultant plot. Options are available for grid lines, multiple access and for tabulating the data in columnar format. The data itself may be edited by repositioning data points, the addition of text, etc.

Three-dimensional configuration images were used for calculation of LRB aerodynamics, for launch and separation sequences and for the generation of mass properties data. The three-dimensional imaging program (reference 4) uses a surface definition based upon quadrilateral elements to describe a picture-like drawing of an arbitrary shape. The program can be operated in a demand or batch mode and can construct both online and offline images. The image geometry is used in the weight and balance program where each quadrilateral represents an element of mass which is summed with the other elemental masses to form the total mass properties of the geometric shape. Weight and balance calculations were emphasized in the EDIN04 study.

ADAGE GRAPHICS APPLICATIONS

Since the installation of the Adage 330 in June of 1975, there have been relatively few actual applications developed. Those which have been developed have been experimental in nature providing users with software design data for future development activities. Among those applications which have been developed are the geometry input module, an editing module and a separation module. The geometry input module is illustrated in figure 13. The sequence of four photographs preceding clockwise from the upper left shows an engineer using the data tablet for two-dimensional geometry input, the resulting section input displayed on the screen, the fuselage component, which is the result of a number of section inputs and the final configuration consisting of a number of components.

The edit module is illustrated in figure 14. Here, the picture sequence illustrates a three-view (developed by Nelson Logan of Lockheed Electronics Corporation) of the total configuration with an oblique view inset which can be rotated to any angle. The other three picture sequences illustrate plan form, inboard profile and section cuts using the hardware windowing techniques available in the Adage 330 micro-processor. The window techniques illustrated in figure 14 have been standardized into a Fortran callable subroutine package for use in any Adage 330 computer program.

The separation module is illustrated in figure 15. The geometry for a number of vehicles is stored in the EDIN data base. These geometric configurations can be loaded into the separation module as individual components. The module then uses separation data generated external to the separation module. Dynamic separation sequences can be viewed from any observer orientation. The sequences shown in figure 15 illustrate SRB and external tank separations (top) for the shuttle launch sequence and the shuttle separation (bottom) from the Boeing 747. The sequences shown are illustrative in nature and do not represent actual engineering studies.

All of the above modules are preliminary software developments and will undergo major refinements during the next several months. They are discussed here to provide illustrations of the type of EDIN related analysis which can be performed on the Adage 330 computer. Other applications are being explored which take advantage of the Adage capabilities.

CONCLUDING REMARKS

The EDIN System at JSC has provided a computer aided design environment in which conceptual and preliminary designs can be assessed in a timely manner (usually 3-6 weeks). The components of the system are the Univac 1110 computer, a flexible data management system and a library of independent technology programs. The EDIN interface to the Univac computer is formulated on the run stream concept in the language of the computer operating system and the technology module input data. Both elements of the run stream can be augmented with data base information to satisfy the interdisciplinary design requirements.

The EDIN System provides the user with the ability to formulate the computer aided design problems at the task level in the same manner as is employed in the industrial design process. However, most communication is handled by the computer. Demand interaction with the programs can be performed. Any vehicle matching and sizing loops can be constructed. A flexible data management system provides the user with the ability to construct data base elements to meet both small and large design objectives. Once constructed, the data base elements can be assessed at the user level or at the program level and the data can be secured as read only elements using the existing Exec 8 software. The resulting design simulation is a flow of program executions which are completely controlled by a man-in-the-loop.

The program library contains technology modules which permit the user to phrase most design problems at the conceptual and preliminary design levels. A large repertoire of EDIN utility routines have been created for interfacing the technology programs to provide a smooth flow of data from one to the other.

A graphics system for EDIN has been created which permits offline graphics, online graphics and interactive graphics. The offline graphics provides report quality graphical information. The online graphics provides quick-look analysis information, which drastically reduces the design cycle time. The interactive graphics capability, now in the embryo development stage, is expected to speed up the initial phases of design simulation and provide more flexibility to changes in direction. Computer graphics has brought to the EDIN System a more effective analysis capability, quicker design cycle time, rapid response to user inquiry and the potential of man-in-the-loop interactive design capability.

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3. Glatt, C. R. and Hirsch, G. N.: PLOTTR: An Independent Computer Program for the Generation of Graphical Displays. National Aeronautics and Space Administration Contractor Report. NASA CR-141593. November 1974.

4. Glatt, C. R.: IMAGE: A Computer Code for Generating Picture-Like Images of Aerospace Vehicles. National Aeronautics and Space Administration Contractor Report. NASA CR-2430. September 1974.
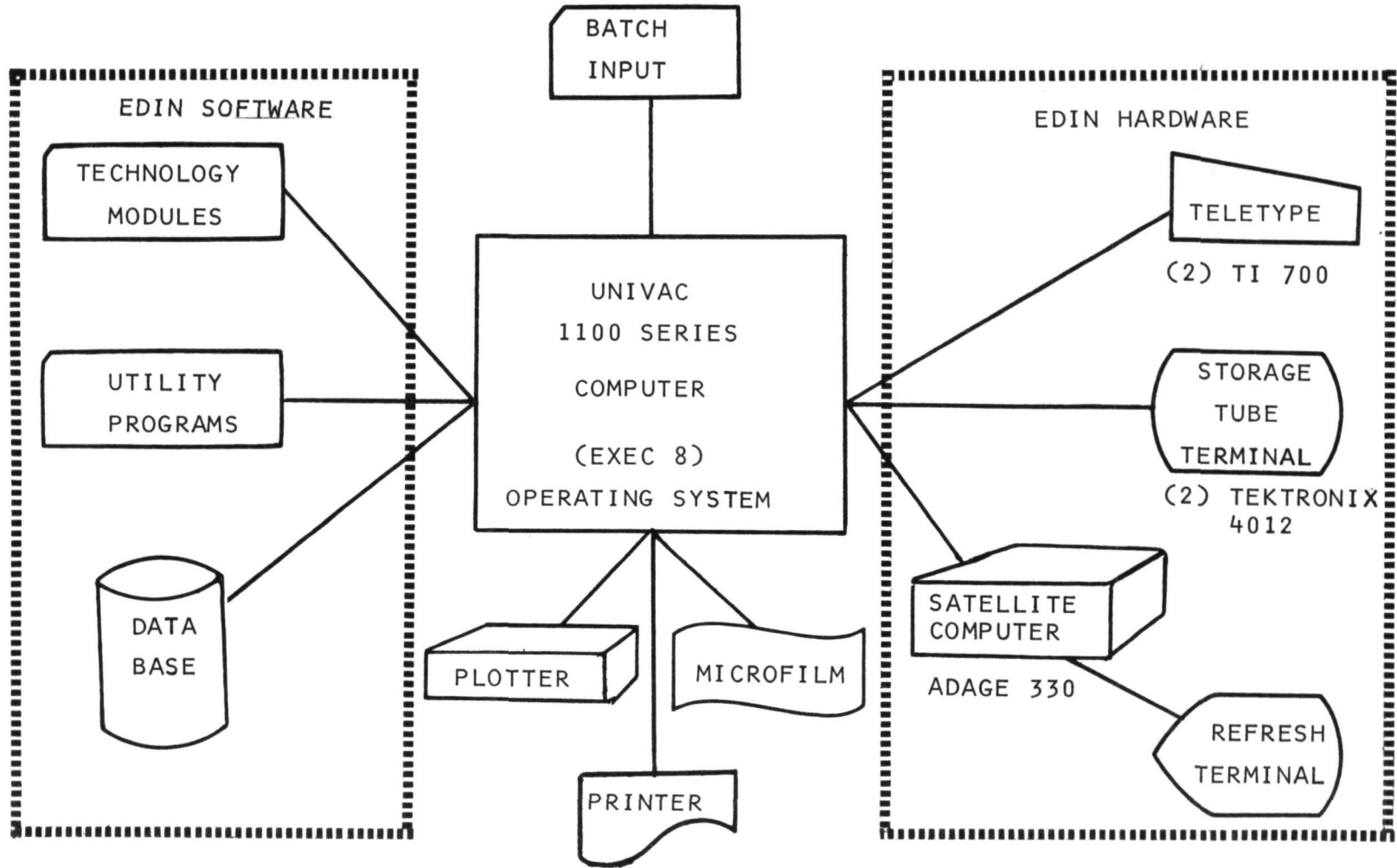
BATCH
INPUT

EDIN SOFTWARE

TECHNOLOGY
MODULES

UTILITY
PROGRAMS

DATA
BASE

UNIVAC
1100 SERIES
COMPUTER

(EXEC 8)
OPERATING SYSTEM

EDIN HARDWARE

TELETYPE

(2) TI 700

STORAGE
TUBE
TERMINAL

(2) TEKTRONIX
4012

SATELLITE
COMPUTER

ADAGE 330

REFRESH
TERMINAL

PLOTTER

MICROFILM

PRINTER

FIGURE 1   COMPONENTS OF THE EDIN SYSTEM.

OPERATING MODES

BATCH OPERATION

    PREPARED SIMULATION STREAM
    NO INTERRUPT
    ALL CONTROL LOGIC BUILTIN
    ONSITE OR REMOTE SUBMITTAL
    OFFLINE GRAPHICAL ANALYSIS

DEMAND OPERATION

    PREPARED SIMULATION STREAM
    INTERRUPT AND RESTART CAPABILITY
    DATA BASE INTERROGATION AND EDIT
    AUXILIARY CALCULATIONS CAN BE PERFORMED
    ONLINE GRAPHICAL ANALYSIS AND EDITING

INTERACTIVE OPERATION

    PREPARED OR UNPREPARED SIMULATION STREAM
    INTERIM ANALYSIS OF RESULTS ONLINE
    ALTERATION OF SIMULATION STREAM ONLINE
    EXECUTION OF PARTIAL SIMULATION STREAMS TO SUPPORT ANALYSIS
    REPORT PREPARATION AND MODIFICATION
    DATA BASE INTERROGATION AND EDIT
    INTERACTION GRAPHICS CAPABILITY

FIGURE 2   EDIN OPERATING MODES.
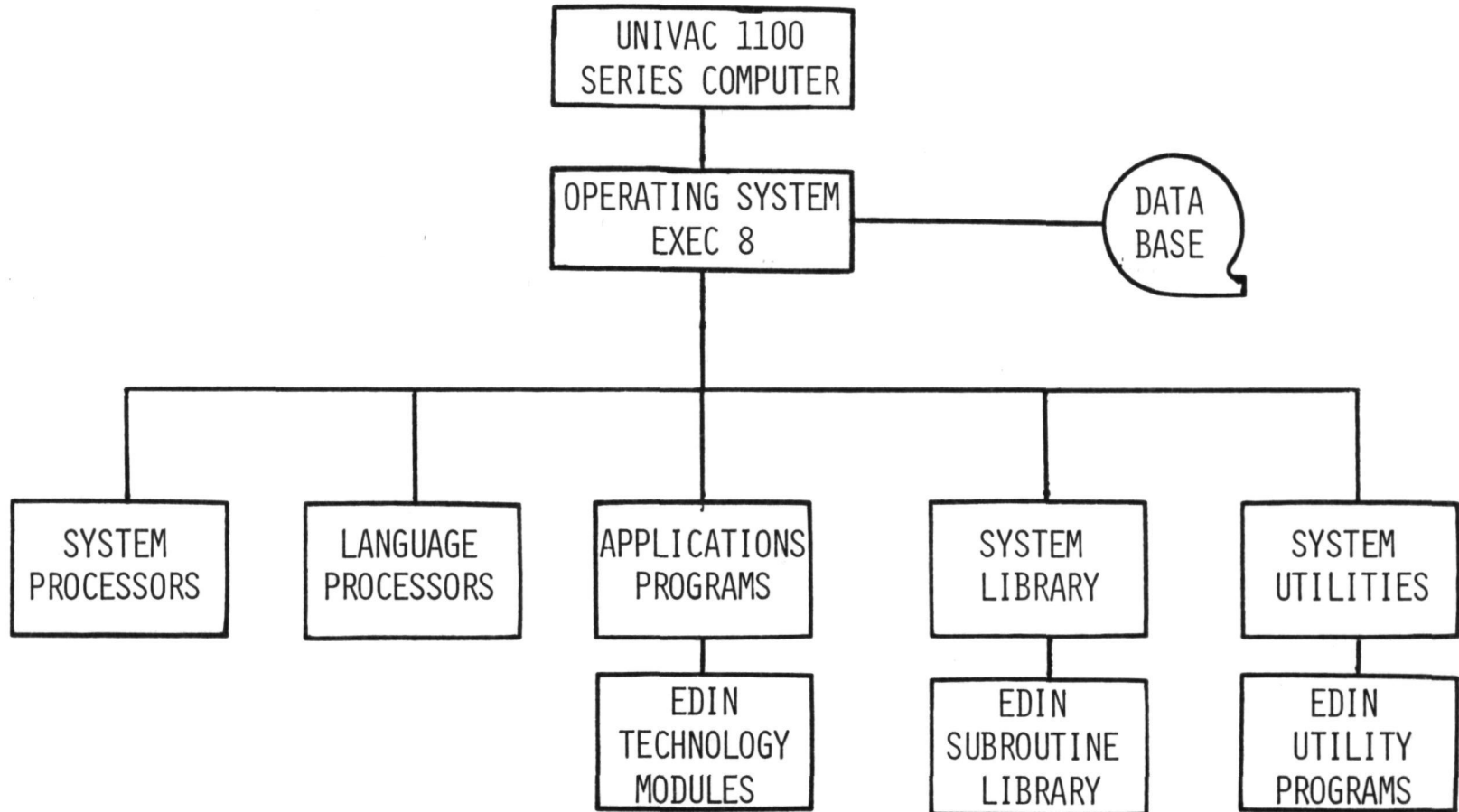
FIGURE 3   EDIN INTERFACE TO THE UNIVAC 1100 SERIES COMPUTER.

```
                    START              ● CREATES A TEMPORARY INTER-
                                         PROGRAM DATA BASE.

                                  ● USER INTERACTION.

                    SIZER                ● PRELIMINARY SIZING BASED ON
                                           ESTIMATED MASS FRACTION AND
                                           IDEAL VELOCITY.

                 SET/STAGING             ● ESTABLISHES LOOP CRITERIA.

                    TANK                 ● COMPUTES TANK VOLUMES
                                           AREAS AND MASS PROPERTIES

                    WAATS                ● COMPUTES STAGE WEIGHT AND
                                           MASS FRACTION.

                    ROBOT                ● MAXIMIZES LAUNCH PERFORMANCE
                                           AND COMPUTES IDEAL
                                           VELOCITY DISTRIBUTION.

                    VIDEAL               ● COMPUTES IDEAL VELOCITY AND
                                           UPDATE DATA BASE.

                                  ● USER INTERACTION

                    REPORT               ● WEIGHT STATEMENT AND
                                           PERFORMANCE SUMMARY
```

FIGURE 4   LAUNCH PERFORMANCE AND SIZING STUDY.

PARTIAL RUN STREAM

● DATA PRE-PROCESSING

DLG PROCESSOR

DATA BASE

MODIFIED RUN STREAM

NORMAL OUTPUT

TECHNOLOGY PROGRAM EXECUTION

EDIN INTERFACE DATA

DLG PROCESSOR

DATA BASE

● DATA POST-PROCESSING
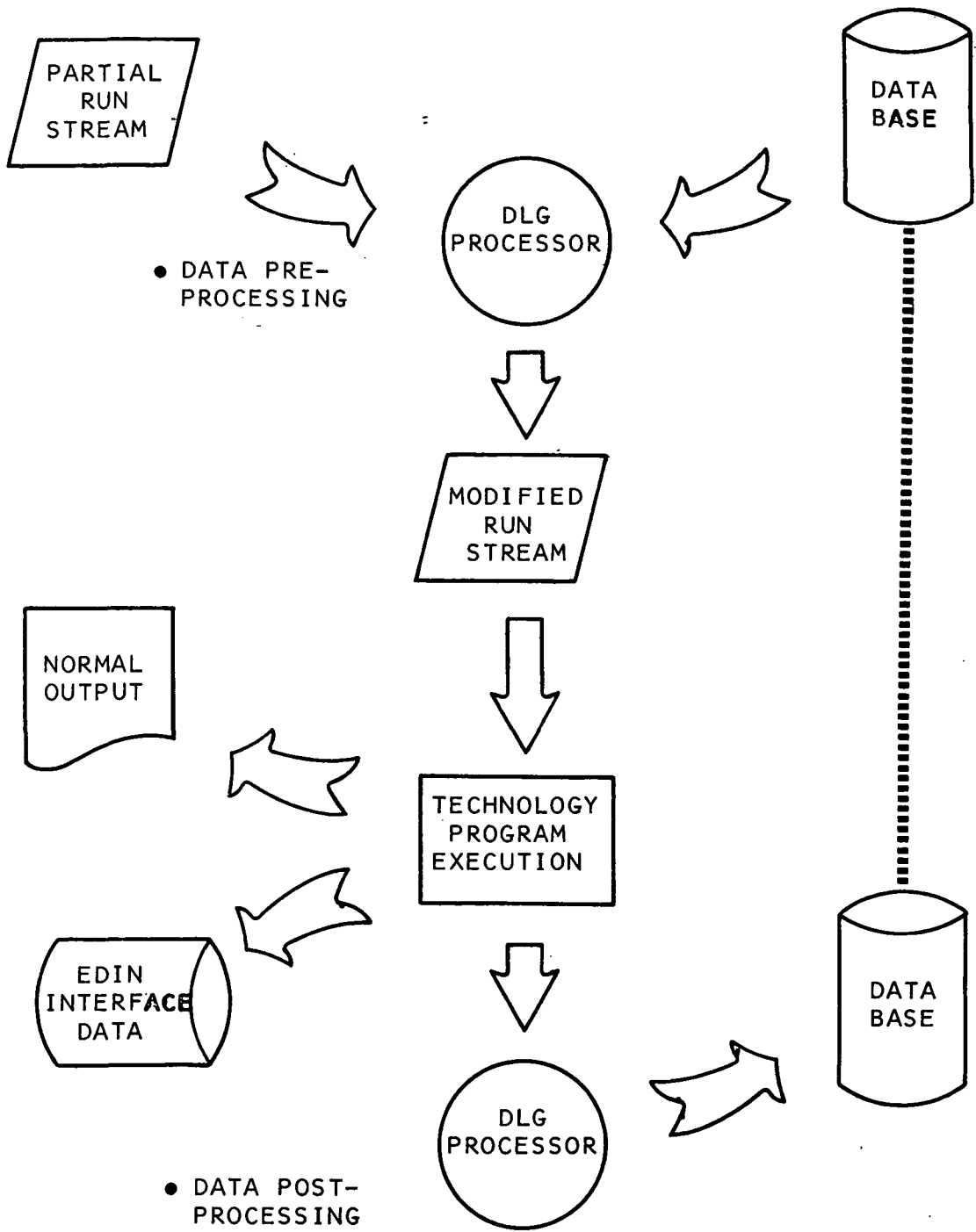
FIGURE 5   DATA PROCESSOR FUNCTIONS.

GEOMETRY	COLLECTION OF SPECIALIZED GEOMETRY GENERATORS.
AERODYNAMICS	EMPIRICAL SUBSONIC, TRANSONIC AND SUPERSONIC METHODS. LINEAR THEORY SUPERSONIC ESTIMATES. NEWTONIAN AND COMBINATION HYPERSONIC METHODS.
PROPULSION	ROCKET ENGINE SIZING AND THRUST CHAMBER DESIGN. TURBO/RAMJET ENGINE CYCLE AND INLET DESIGN.
PERFORMANCE	EIGHTEEN DEGREE-OF-FREEDOM MULTIPLE VEHICLE SIMULATION. GUIDANCE LAWS AND OPTIMAL STEERING/ TARGETING. THREE DEGREE-OF-FREEDOM OPTIMIZATION BY PARAMETER OPTIMIZATION, FIRST AND SECOND ORDER VARIATIONAL TECHNIQUES.
WEIGHTS	HISTORICAL METHODS, PSEUDO STRUCTURAL ANALYSIS OF FUSELAGE STRUCTURES FOR SHUTTLE RELATED BOOSTER AND ORBITER CONCEPTS.
STRUCTURES	SIMPLIFIED AEROELASTIC LOADS AND FLUTTER. STRUCTURAL SIZING AND FINITE ELEMENT ANALYSIS.
COST	HISTORICAL METHODS BASED ON FIRST UNIT WEIGHT, DESIGN PHILOSOPHY AND OPERATIONAL PHILOSOPHY.
BALANCE	PREDICTIONS BASED ON CLOSED SHELL STRUCTURES AUGMENTED BY POINT MASS ANALYSIS.
OPTIMIZATION	PARAMETER OPTIMIZATION BY FIRST AND SECOND ORDER AND RANDOM PERTURBATION TECHNIQUES.
GRAPHICS	TWO AND THREE DIMENSIONAL DISPLAY GRAPHICS FOR ONLINE AND OFFLINE DEVICES. LIMITED INTERACTIVE PROGRAMS ON THE ADAGE 330.

FIGURE 6   EDIN SYSTEM SOFTWARE.
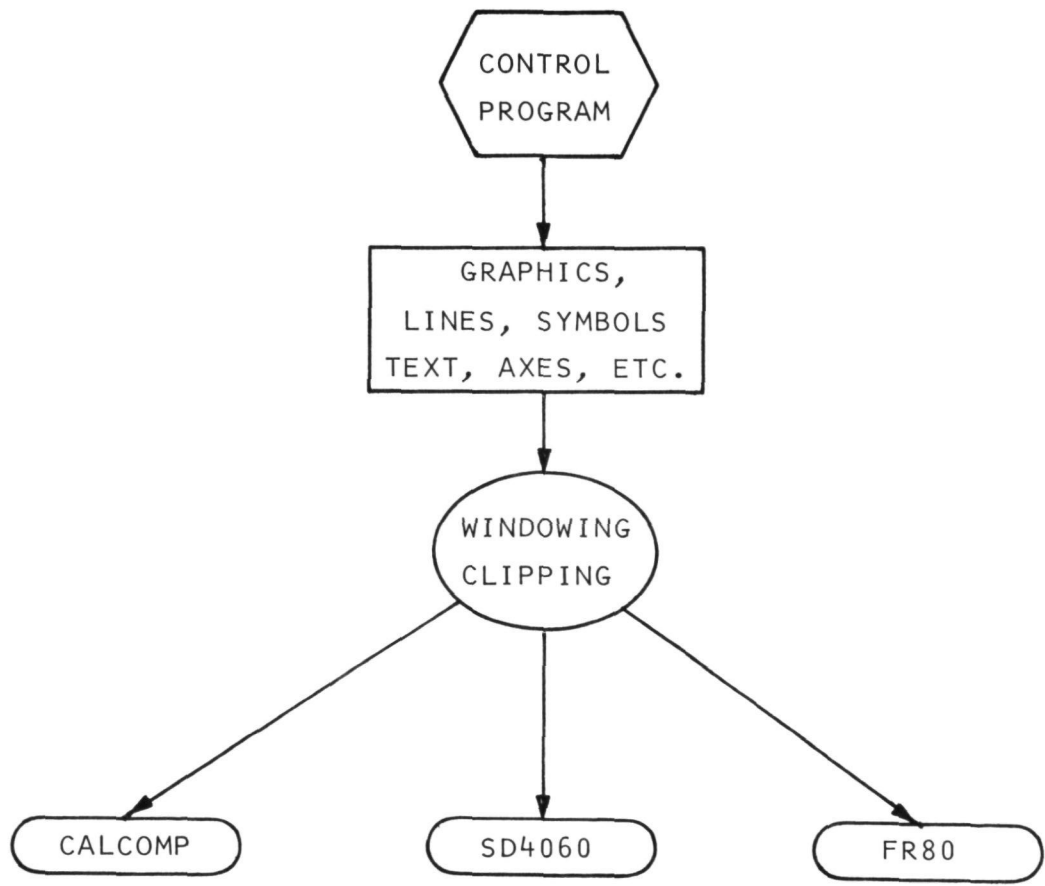
FIGURE 7   OFFLINE GRAPHICS.
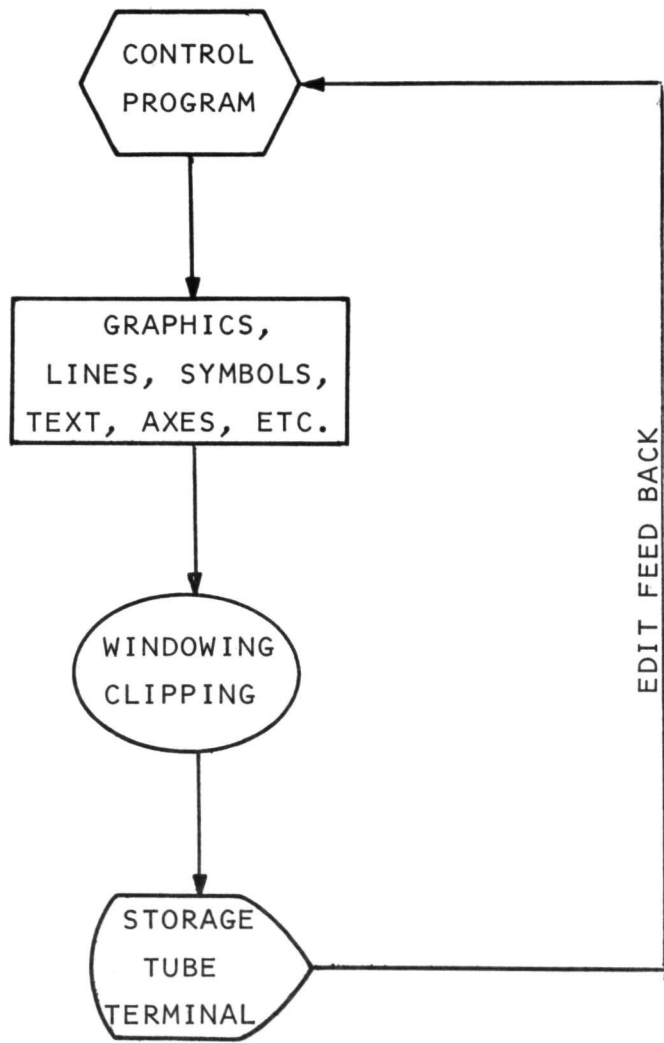
FIGURE 8   ONLINE GRAPHICS.
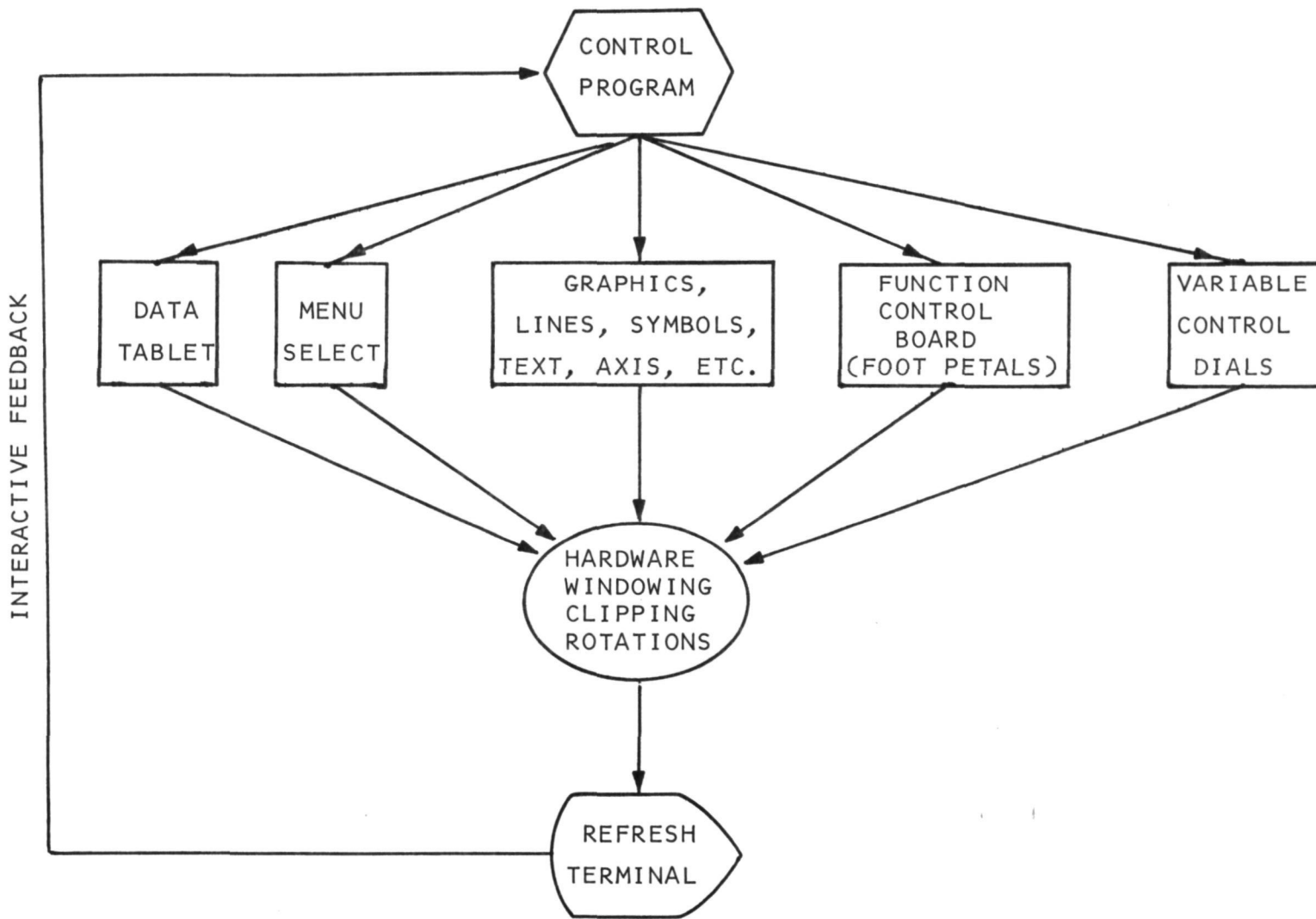
FIGURE 9   INTERACTIVE GRAPHICS.

8.25 METER
(27 FT) DIA
EXTERNAL
TANK (ET)

10.06 METER
(33 FT) DIA
BOOSTER

X

Z

SHUTTLE ORBITER

LIQUID ROCKET BOOSTER

FIGURE 10   EDIN04 CONFIGURATION.

ET SEPARATION

STAGING

REENTRY

ASCENT

29545 KG PAYLOAD
(65000 LB)

104 DEG INCL (WTR)

50 X 100 NM ORBIT

76.2 MPS (250 FPS) OMS

30.5 MPS (100 FPS) RCS

RECOVERY

LIFTOFF
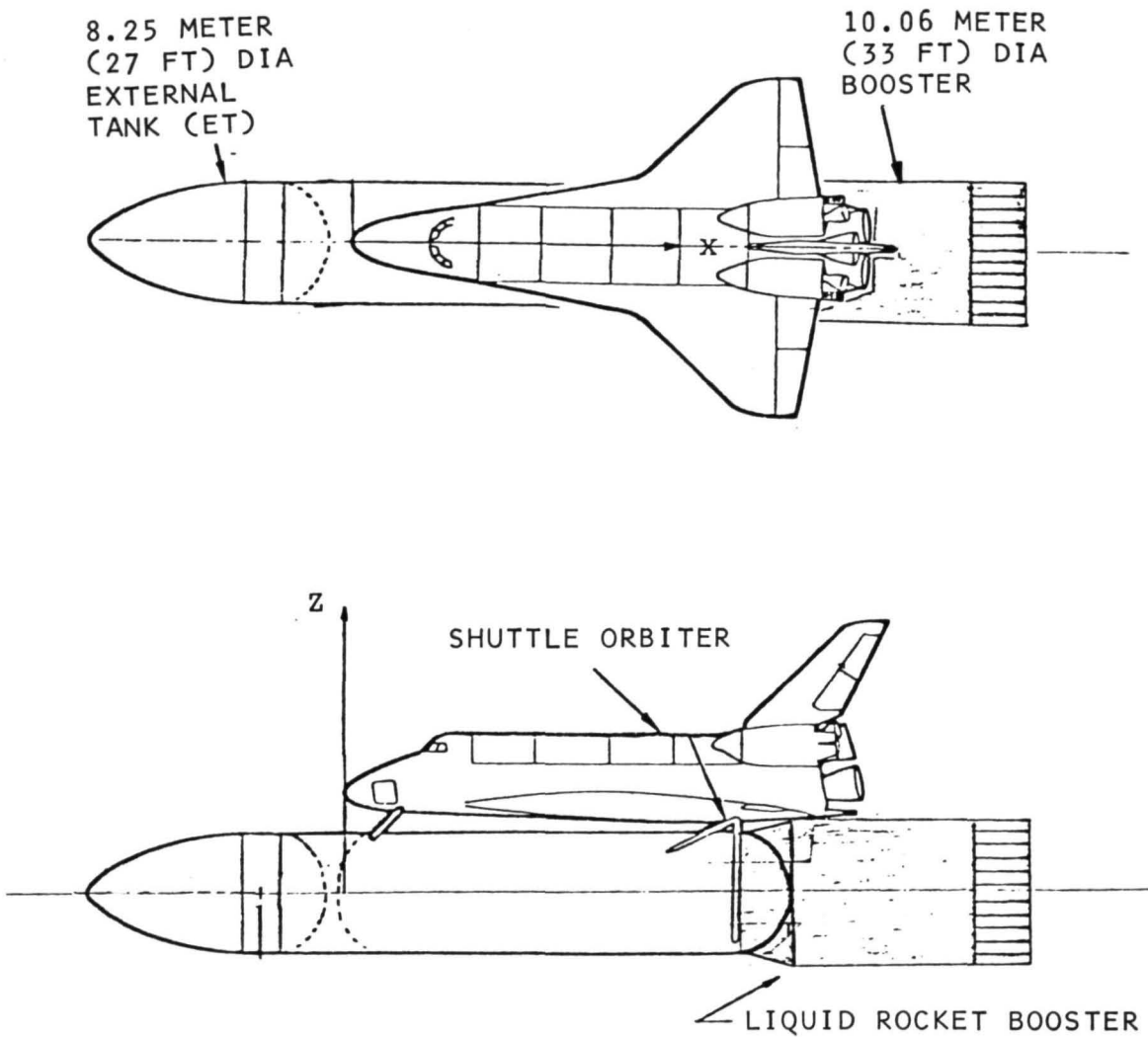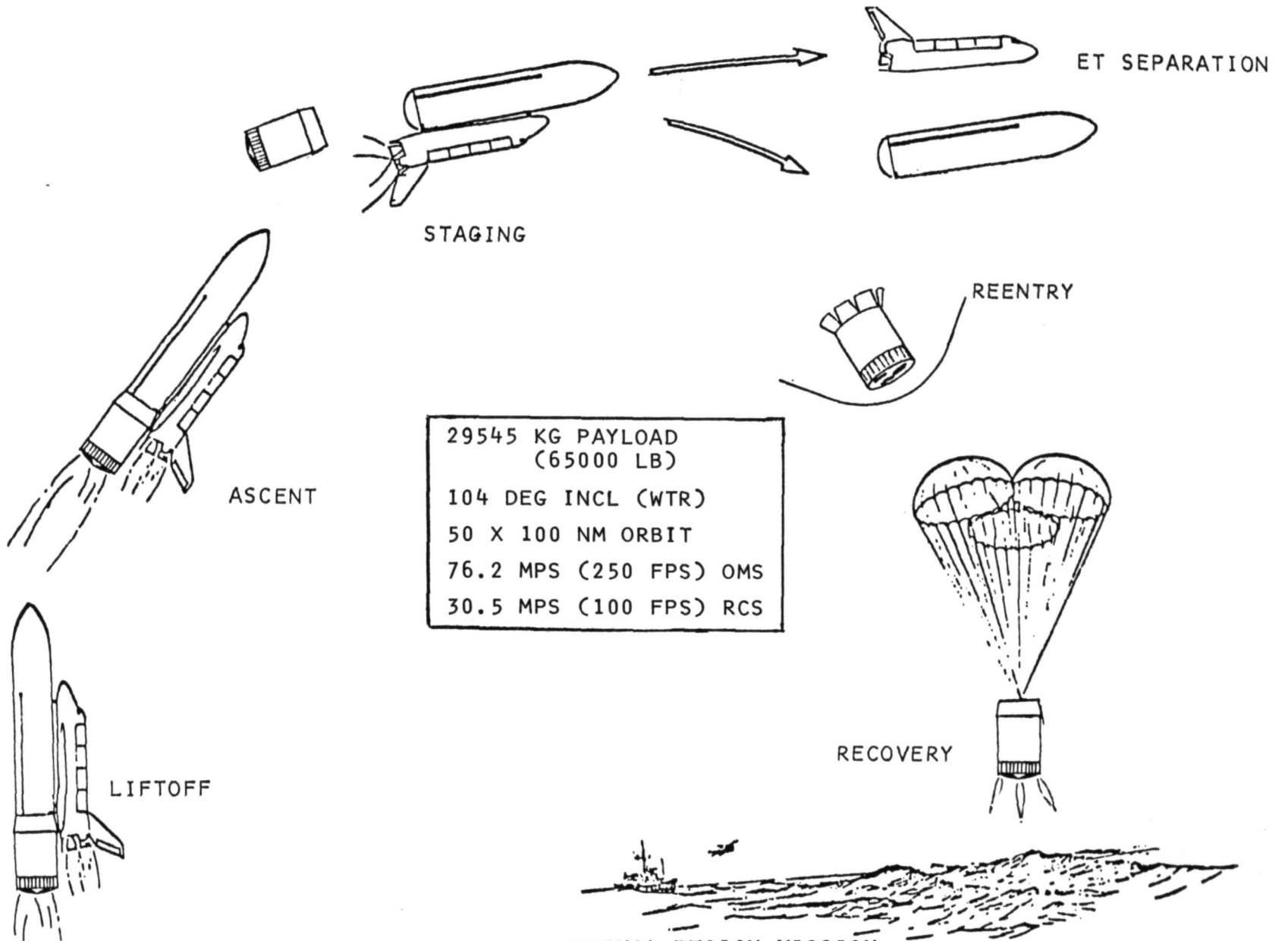
FIGURE 11   EDIN04 DESIGN MISSION
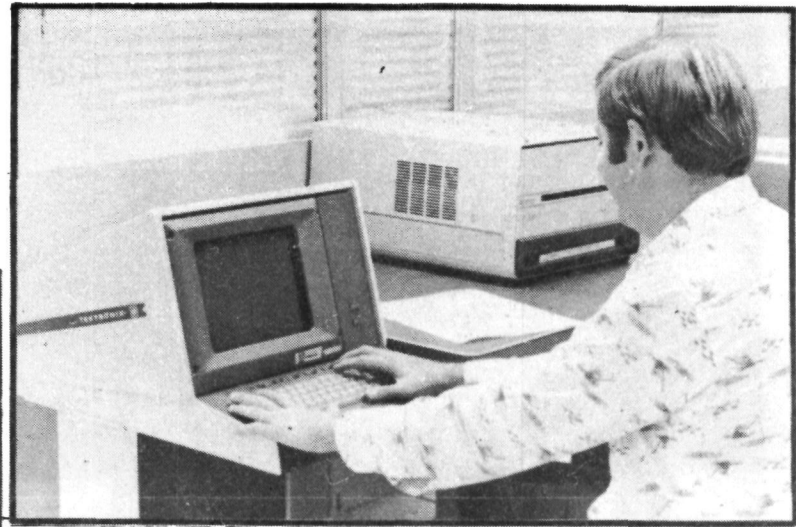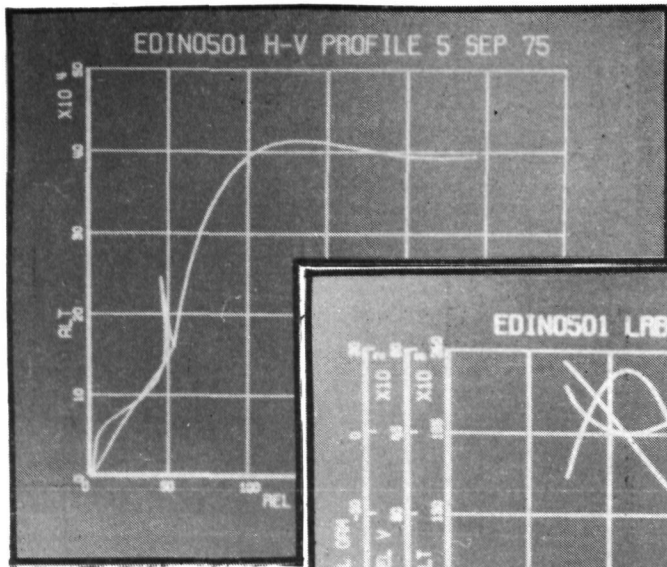
MISSION
ANALYSIS
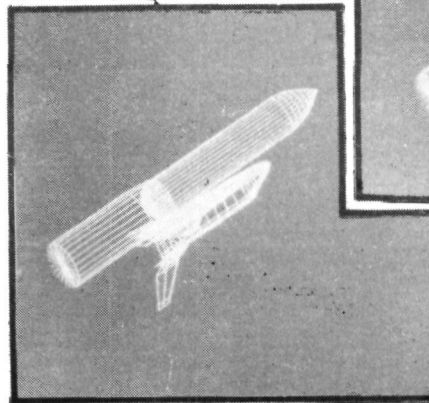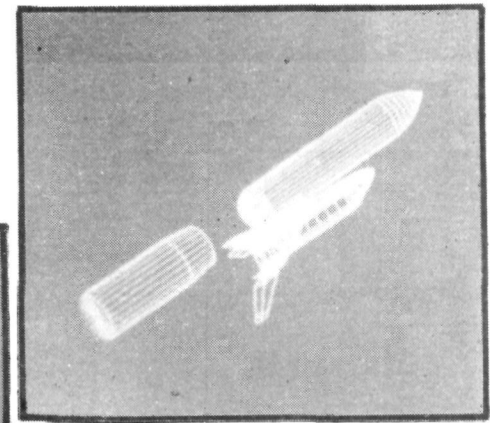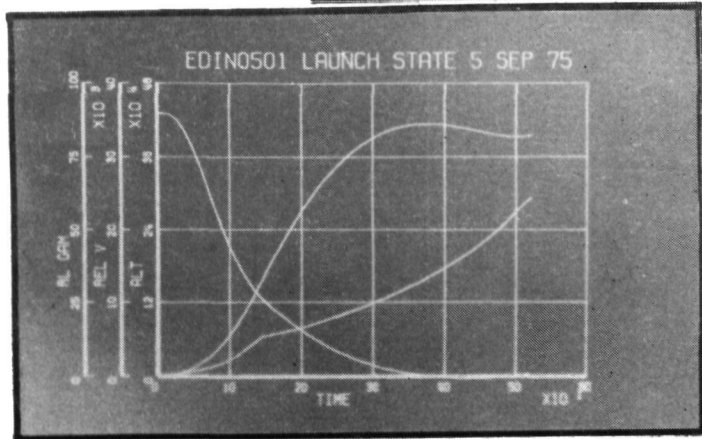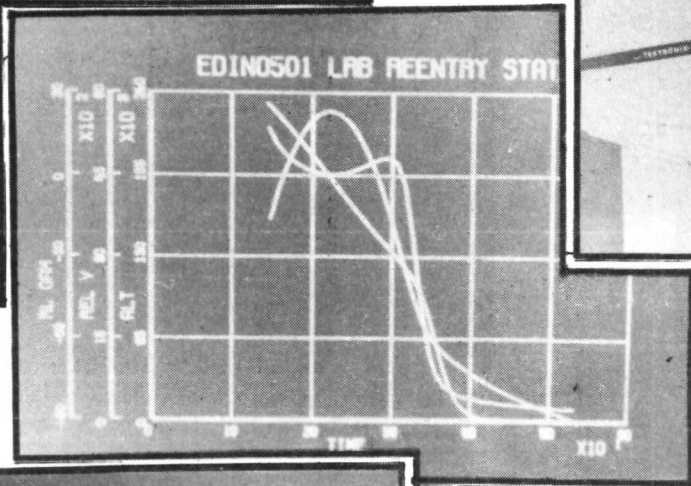
LRB
SEPARATION

FIGURE 12   LOW COST GRAPHICS
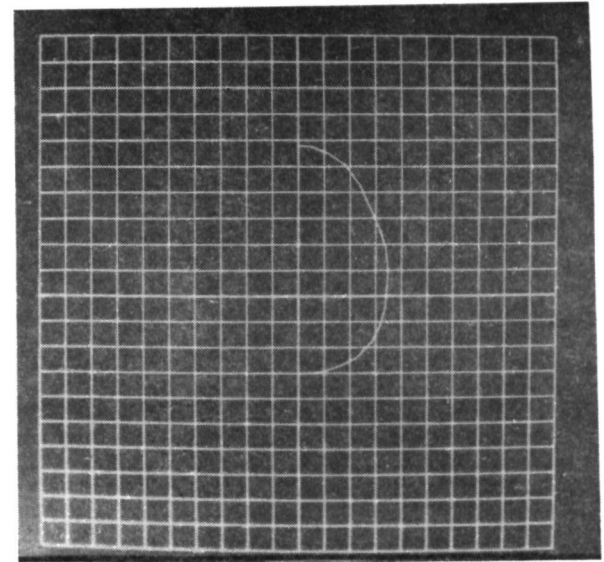
FUSELAGE SECTION
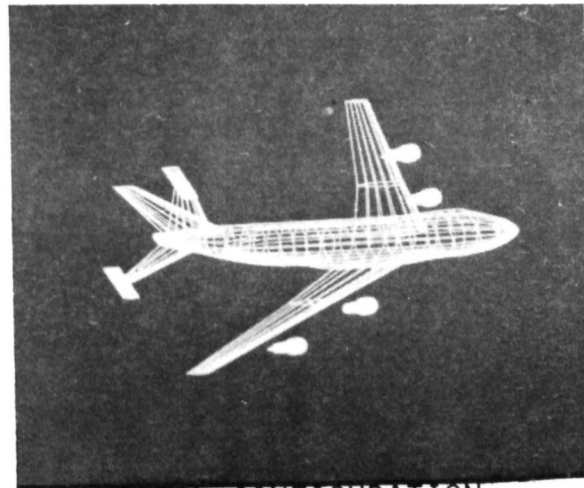
TOTAL CONFIGURATION
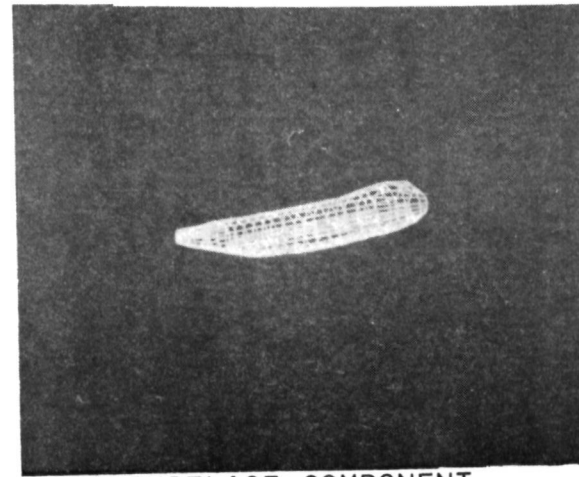
FUSELAGE COMPONENT

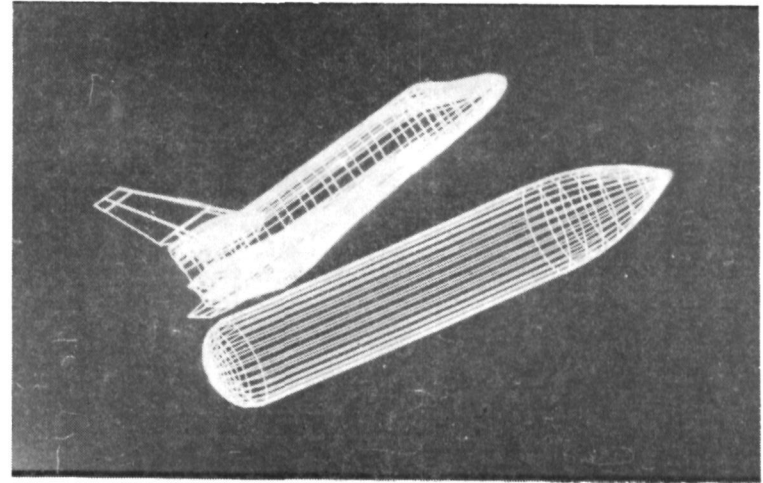FIGURE 13   GEOMETRY INPUT MODULE
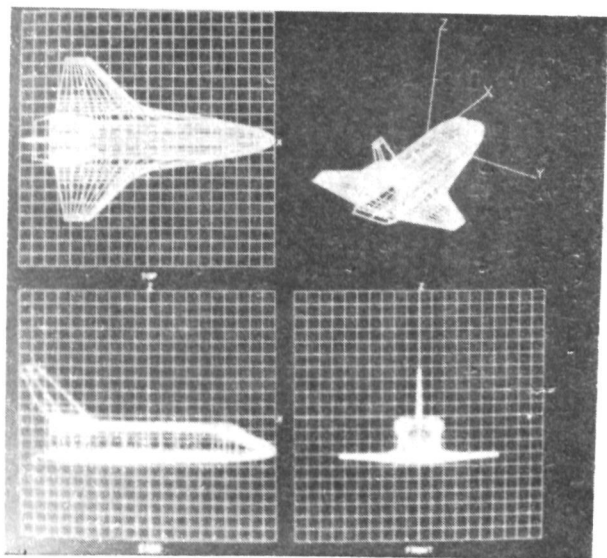
THREE-VIEW
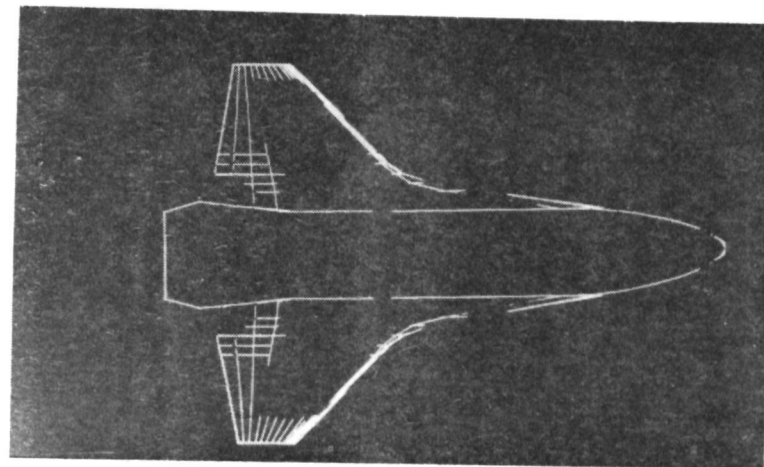
PLANFORM
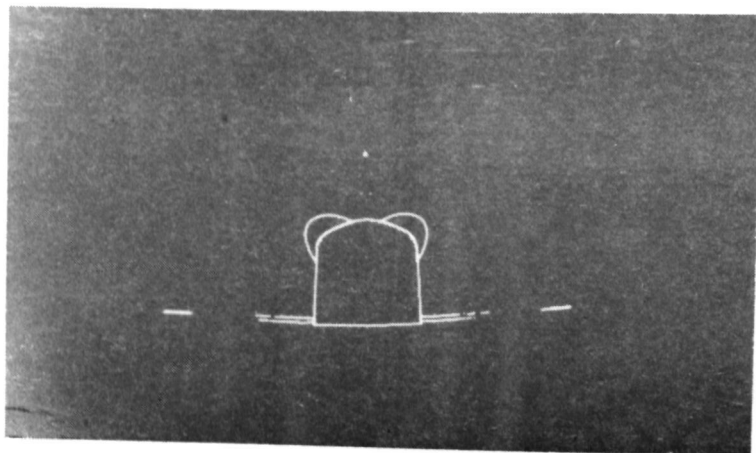
SECTION CUT
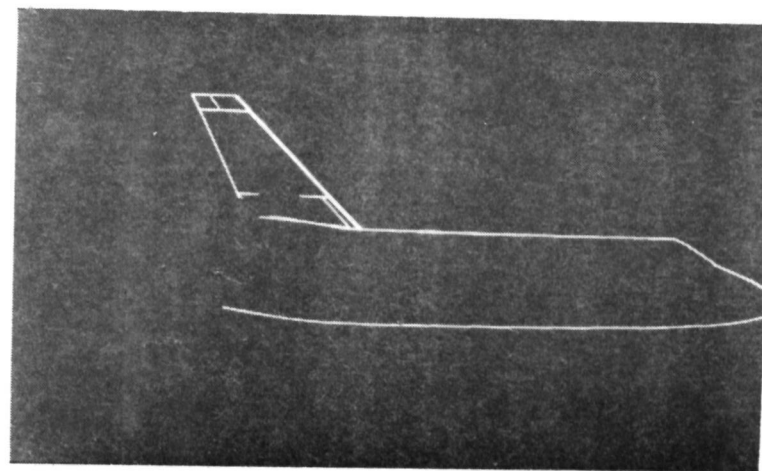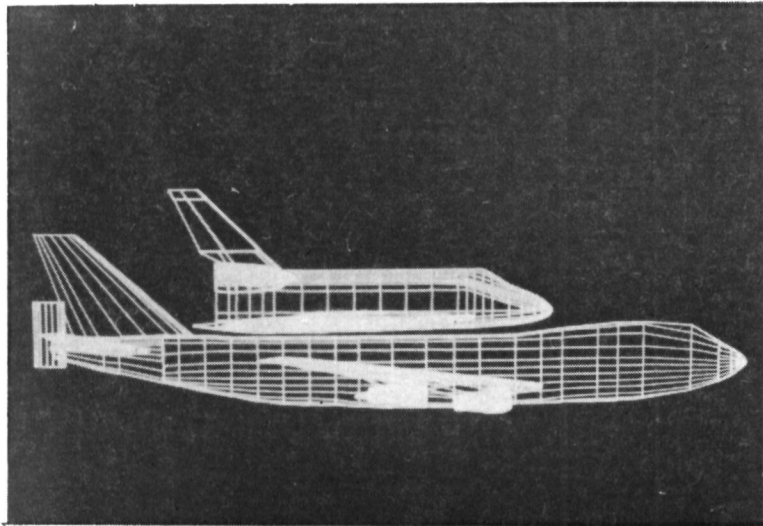

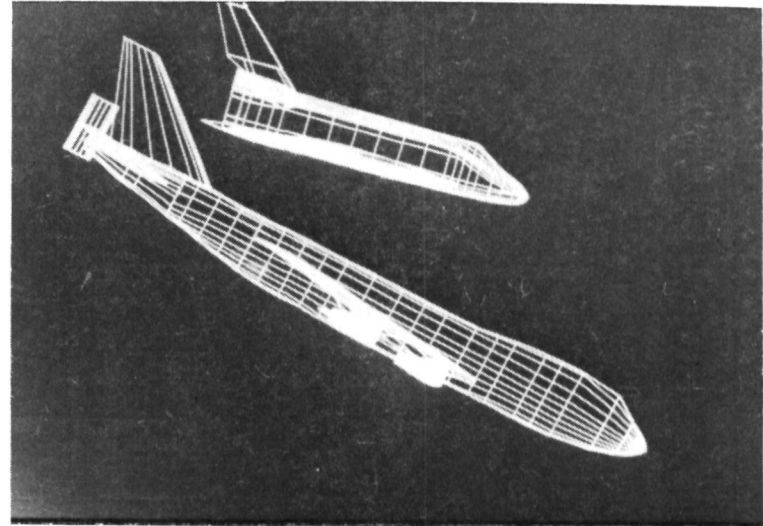INBOARD PROFILE

FIGURE 14   GEOMETRY EDITING MODULE
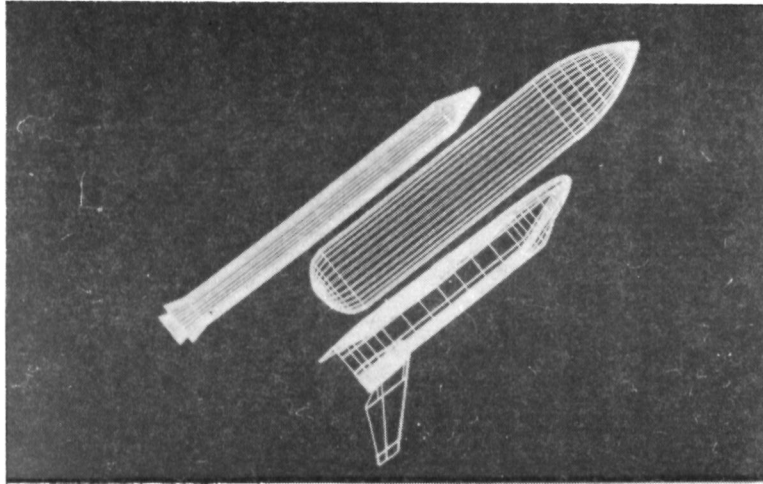
SRB BOOSTER SEPARATION

EXTERNAL TANK SEPARATION

SHUTTLE MATED TO BOEING 747

SHUTTLE SEPARATION

FIGURE 15   SEPARATION MODULE