STATUS REPORT ON INTEGRATED ANALYSIS METHODS FOR NUCLEAR REACTOR STRUCTURAL ANALYSIS

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SUMMARY

The purpose of this presentation is to look at the analysis of a nuclear reactor system as a total analysis task, and to examine the assumptions which are made in the separation of the analysis task into its component disciplines. The structural analysis discipline is then examined in more details to try to define a workable approach to an integrated structural analysis of the reactor system.

The presentation will start with a general discussion of the total analysis task, starting from the initial concept of the reactor plant. The total task will then be subdivided into the respective disciplines, and an attempt will be made to rationalize or criticize the division into separate disciplines.

The discipline of structural mechanics will then be examined in view of its interactions with other disciplines such as fluid flow and nuclear analysis to determine the degree of coupling which exists among these disciplines. This will be done by examining the interactions of the state variables which apply at each point of the system. The state variables considered will include fluence, temperature, displacement and pressure.

The state variables defined will then be used as the basis for the definition of an overall structural model of the reactor system. Such an overall model can be conceived in terms of the present status of analytical techniques, by use of such concepts as substructuring, constraint equations, coupled solutions for heat transfer, stress and dynamic analysis, along with fourth generation computer capabilities. A block design for an overall structural model will be discussed and the areas which require new analysis techniques will be discussed.

The last section of the presentation will present an outline of a mode of operation of a structural design/analysis activity which is established to implement a comprehensive integrated structural analysis of an entire reactor system. The concept of an evolving model of the system will be presented and the coordination required to successfully manage such a design/analysis approach will be discussed.

A brief discussion of the effects of non-linear effects such as creep, plasticity, gaps on the overall approach will be included.

INTRODUCTION

In order to give a status report on integrated analysis methods for nuclear reactor structural analysis I will begin by examining the analysis task presented by a nuclear reactor structure. With the anatomy of the task defined, we will go on to define what we mean by an integrated analysis system, including the characteristics of such a system. We will also examine the reasons such a system is necessary, or at least desireable, based on the analysis requirements for a nuclear reactor system. Then, assuming that an integrated analysis system is required, we will explain the possible ways in which such a system will be developed or will evolve. As an illustration of the evolution of an integrated analysis system, we will briefly examine the present status of the program ANSYS, which represents a start toward such an integrated analysis system. From this starting point we will examine some of the areas where questions lie and future development is required.

In Figure 1 I have represented the task of a nuclear reactor structural analysis as a rectangular region of space, with the vertical axis representing the disciplines involved in a nuclear plant structural analysis. Notice that I have included more than just the structural disciplines, since the analyses are all interrelated. The horizontal direction represents the various components in the reactor system. The goal of the analysis task is to assure a safe, economical, clean nuclear power plant.

Unfortunately, the analysis task represented by this rectangle is too large for a single analyst to accomplish, so the task must be broken down into pieces which are small enough to be handled by a single analyst. There are many ways to break up the task, two of which are shown in Figure 2. Option 1 breaks up the task by disciplines, so that a group of specialists in each discipline works on all the components. This is usually the most efficient use of analysis specialists. Option 2 breaks the task up by components, so that a team of analysts works on each component. This improves the communication between people working on the same components, but tends to isolate the specialists from others working on the same speciality. Personnel familiar with several disciplines are desirable in this approach.

Of course, a real organization is not either option, but behaves more like that shown in Figure 3. We hope that the number of missing regions is small and are sometimes puzzled at the additional pieces which are tacked onto the task but which have no bearing on the job at hand. The problem of filling in the blanks and minimizing the extra pieces we leave to management, another art outside the range of this presentation.

There are two communication networks in the analysis task, the management network mentioned before, and the data communication network. This data communication network is a portion of the integrated analysis system concept, so we will look at two different data flow possibilities.

Figure 4 shows these two data flow patterns. The first pattern I have referred to as data flow by demand. In this pattern the analysis group needing the data from another group goes to that group (directly or by memo) and requests the data required for their analysis. If the data is available, it is transmitted to the requesting group, again verbally or by memo. If the data is not available, it is generated by the proper group, or an assumption is made by the group needing the data. These assumptions should be checked by the group responsible for that set of data. After this process is repeated with all the groups having input for a given analysis, the analysis is performed. The second pattern shows another alternative for data flow. In this alternative (the data pool), all the data is obtained from a data pool and all analysis results are put into the pool. Each analysis task has the responsibility for the generating of data in the pool which results from its task. The quality of the data in this pool for each component and discipline should improve as the analysis task proceeds.

Figure 5 shows some of the characteristics of these two different data flow schemes. In data flow by demand, it is difficult to visualize the complete data requirements prior to the start of the analysis task, and it is difficult to measure the current status of the data required, both of which make the control and management of the analysis task difficult. This data flow structure makes a series analysis (each analysis discipline complete before the next starts) a natural process.

In the scheme of data flow to and from a data pool, the data requirements have to be defined at the beginning of the analysis task. The data in the pool can progress from tentative to design to final as the analysis proceeds; control and traceability procedures can be implemented; and parallel analysis (simultaneous analyses by all disciplines) is facilitated.

With these two types of data flow patterns defined, it is possible to make some comments on the ways of sub-dividing the analysis task. These comments are shown in Figure 6.

The management task is proportional to the number of subdivisions. The more the subdivisions, the greater the communication task in the demand data flow procedure, since the number of boundaries goes up as the number of subdivisions is increased. However, this is compensated for by greater visibility and traceability, since the data is (or should be) recorded as it crosses the interfaces. The larger the region the more efficient the communication, because the analyst is using his own data. This, however, results in a decrease in data checking and traceability because these intermediate results are not recorded. If a data pool exists, these results must be put into the pool, and traceability is maintained.

The progression of a multi-discipline analysis task can also be visualized as a series process or as a parallel process. Figure 7 illustrates the series approach to the design iterations, with some of the characteristics thereof. Each task has a consistent set of data (assuming that all data comes from the task before), and there is little wasted effort in a redesign, because of these consistent sets of data. However, the time per design iteration is maximum, and most of the analysis disciplines are idle while waiting for a new iteration of data. Balance of the workload is difficult for a subdivision by discipline.

Figure 8 illustrates the concept of parallel analysis. Here each discipline is working at the time time on its analysis task, using the best data available at the present time from the other disciplines. The further the discipline is from the given discipline, the less current the data will be. This approach is necessary if there are multiple interactions between analysis fields, as if the deformation (static and dynamic) affects the nuclear and thermal characteristic of the system. The parallel procedure requires the minimum time per iteration, but has the potential for the maximum amount of wasted effort if a major redesign is required. Many more iterations are possible in a given analysis time.

With these basic concepts of analysis task subdivisions, data flow paths and parallel vs. series progression through a multi-discipline analysis task, we go on to define an Integrated Analysis System (IAS).

II. CHARACTERISTICS OF AN INTEGRATED ANALYSIS SYSTEM.

We now will define an Integrated Analysis System (IAS) in terms of its characteristics. This set of characteristics is presented as a minimum which must be achieved by a system before it could be called an Integrated Analysis System. An actual system might be much more than this minimum. These minimum characteristics are shown in Figure 9.

1. Computer Program - The amount of data in a nuclear system analysis is so big that any treatment by other than digital computer is inconceivable.

2. Multi-disciplinary - The amount of data which flows between the various analysis tasks dictates that the IAS must be multi-disciplinary. Manual passage of data from one discipline to another is time consuming and error prone. Separate modeling by various analysis groups is often redundant, because the same model can be used for several types of analysis.

3. Internal Communication - The IAS must directly transfer data from one analysis discipline to another, either through specially created files or through some data pool.

4. Data Libraries - The IAS should assemble and maintain data libraries for use in the various types of analysis. Data libraries should include:

a. Nodal point location

b. Member property tables

c. Element libraries

d. Material property libraries

e. Substructure libraries

f. Loading condition libraries

g. Nodal temperature libraries

h. Nodal displacement libraries

i. Stiffness matrix libraries

These libraries form a large part of the data pool which is developed as an analysis proceeds.

5. Documentation and traceability - The data input to the IAS should be visible and it should be possible to trace the source and vintage of each data item in the data pool. An example of a computer program which provides such traceability of input data is the UPDATE program on CDC computer systems.

6. Multi-User - The IAS must be able to be used and the data maintained by several persons and disciplines simultaneously. Additions and changes by one group should not affect the operations of another group, except to provide more current data to the group using the data.

7. Large Capacity Range - A large capacity range is a broader requirement than a large capacity. A large capacity range means that very small problems must run efficiently, as well as very big problems. This eliminates the need to change from one program to another as the size of the analysis model increases.

8. Sophisticated - The IAS must be a sophisticated computer program, with current analysis capabilities. These capabilities must evolve with the evolving analysis requests. The capablities must include dynamic, inelastic, non-linear, and vasco-elastic effects, as well as the usual thermal, pressure and acceleration effects. It should not be necessary to go to special purpose programs for sections of the analysis, or to learn to use many different programs.

9. Reliable - Since the bulk of the analysis for a project will be done on one computer program, reliability of that program must be high. However, the problem of assuring reliability is improved by the fact that only one program must be verified and maintained, in contrast to the many programs now often used.

10. Usable - An IAS must be in a form that is usable by the average analyst. A system which requires weeks of training to run a single set of problems is going to be of little value, because an analytic task cannot support enough specialists to do the analyses required. Documentation and examples must be provided in sufficient quantity and variety so that an analyst can confidently set up a reasonable problem with a minimum of difficulty. As a guideline, the number of pages of documentation should be at least as many as the number of pages in the program source listing.

11. Available - An IAS must be available. The most sophisticated analysis system developed by the largest nuclear power firm is going to be of little value to anyone except the developing firm unless it is made available and maintained for use by anyone desiring to use the system. Several analysis groups working in the same reactor system but located at different parts of the country should be able to use the same analysis system, and freely exchange data and results.

III. NEED FOR AN INTEGRATED ANALYSIS SYSTEM

Having outlined some of the characteristics of an integrated analysis system, it is of value to review some of the factors which make such a system desireable at this point in time. Figure 10 is a summary of some of the factors which are leading toward an integrated analysis procedure.

1. Increased Analysis Requirements - The amount of analysis required for a nuclear power plant is increasing rapidly. Included in these increased requirements are additional seismic analyses, both by modal techniques and by time history analyses; increased safety analysis to provide assurance of safe operation over all conceivable conditions; in-elastic analyses, both plasticity and creep, especially for the breeder reactor projects; more interaction of the various components of the reactor system, as in the floating power plants with their elastic supports for all components, and more interactions between various disciplines, as on thermal distortions affecting flow patterns; increased requirements for reliability assessment; conflicting design requirements, as between safety and cost, thermal vs. pressure stresses and analysis vs. test costs; and the problem of analysis with a range of uncertainty in the materials data.

2. Increased Manpower Costs - The cost of engineering manpower is increasing, especially the cost of analysis specialists. The cost of an analysis task can be minimized in several ways:

a. Maximize productivity of Analysts by reducing repetition and duplication (as in modeling of structures), facilitating the interpretation of results (as by graphic presentation of results), minimize the use of analysts in manual transmission of data across interfaces (as in report writing), and minimize errors and re-analyses.

b. Minimize the training time and costs, so that a capable analyst can be trained without a heavy investment in time. Minimize the amount of specialized knowledge required to do his or her job.

c. Minimize the reliance on experts. Develop tasks which allow a qualified engineer to obtain reliable results without the assistance of an expert. Utilize experts for analysis planning and review.

3. Higher Human Expectations - A trend which is becoming evident and which can be expected to continue is a higher expectation on the part of engineering and analysis personnel.

a. Analysts are human, and have the human needs for a sense of achievement, a need to feel creative, a need to interact in groups with other humans, a need to feel responsibility, and a need to feel a part of a significant activity.

b. Analysts and engineers often are a special type of person, in that they feel that there is a right answer and that they must reach it, they must ask questions and obtain the answers, and they like to work with well-defined tasks and interfaces.

c. An analysis system must support the analyst's desires in that it should not limit the range of questions that may be asked, or deprive the analyst of the answers he needs. It should facilitate the communication of results, a skill that sometimes eludes the analyst, and it should respond rapidly so that he has the answer to his question before he has forgotten the question or why he asked it.

4. Evolving Computer Systems - The fourth generation computer systems are now appearing, and these systems will further increase the amount of analysis which can be done and decrease the ratio of computer cost to program cost, making an integrated analysis system more economical. These new computer systems have larger capacities, faster calculation speeds and more sophisticated data handling and storage capabilities.

5. Increasing Number of Organizations Involved in an Analysis Project - With the increasing size and complexity of an analysis task, more and more organizations are involved in an analysis of a nuclear reactor system. The problem of communication of models, data, and results between organizations becomes more difficult

as the number of analysis organizations involved increases. Use of the IAS would reduce the difficulties in these interfaces.

IV. DEVELOPMENT OF AN INTEGRATED ANALYSIS SYSTEM

If it is concluded that some sort of an integrated analysis system is desireable for a nuclear system analysis, where does one go to obtain such a system? To provide an answer to this question it is of interest to review the ways in which computer programs are created, the types of organization which create computer programs, and the incentives for creation of computer programs.

There are two distinct forms of program creation, as illustrated in Figure 11.

1. Project - The first form is the project, in which the goal is to generate a computor program. In this approach the goals, requirements, and capabilities of the program are specified in detail before the task is started. The project usually proceeds on a fixed schedule and is based on a fixed price. There is little incentive to exceed the original specifications, so the resulting program usually reflects the state-of-the-art as it existed (or was visualized) at the time the project was started. The resulting program may be several years out of date as soon as it is completed. Additional projects are required to bring the program up to the current state-of-the-art, if that is possible.

2. Evolution - The second form of computer program creation is by the process of evolution. In this process a "final" program is not a goal, but a current program which solves the currently defined problems is desired. This evolution process has many of the characteristics of a normal life cycle. A base capability is developed or obtained and a new program is born. This base capability is applied to real projects, with generalized enhancements added as required for the problems defined, giving the growth phase of the program. If the program is applied to only a limited class of problems, the growth is limited and a specialist develops. Once the program has shown the capability of solving a large variety of problems and satisfying the needs of most of its users, it is a mature program. It is maintained for some period of time to keep up with the changing of computer systems. Occasionally a copy of the program will be made and used as a base point for a new computer program. This is the process of reproduction. Finally, the effort of converting to yet another generation of computer systems becomes more effort than is justified and the offspring or other computer programs with greater capabilities are available and the computer program finally dies, its life perhaps prolonged for a few months by a process of emulation.

Possible organizations for the development of an Integrated Analysis System are shown in Figure 12. We will examine the incentives available for each of these organizations to see which, if any, is likely to develop such a system.

1. Government - the first place people turn, when a major project is to be approached, is to the government. However, nuclear power generation is a world-wide problem, so which government should be responsible? A cooperative venture is just too much to consider. A government would have the funding resources, but a government system would be developed on a project basis. Sharing of the resulting system would be unpredictable.

2. Private Industry - If an integrated analysis system looks desireable, corporations which dominate the nuclear power field will generate such systems, one per corporation. Each one will be better than all the others and, of course, each one will be company property. Only the large corporations will develop these systems and they will not be available to the general public. Most of the large computer analysis systems will follow the evolution path, with the development being guided by the needs of that corporation.

3. University - Several universities have the technical capability to develop an integrated analysis system but funding would be required, with the corresponding strings attached. The university developers tend to suffer from a lack of continuity of personnel, and there is also a tendency to be remote from the actual analysis problems and pressures. Development tends to be on a project basis.

4. Technical Software Supplier - A fourth possible source for an integrated analysis system is the technical software supplier. This is a new phenomenon which has appeared within the last few years. These organizations develop computer programs, usually at their own expense, and make these programs available to users for a fee. The motivation of the software supplier is very straightforward - he is trying to make a profit, ideally as much as possible. Once this fact is accepted, we can see that several desireable results develop from the presence of a healthy set of technical software suppliers. Competition between suppliers is sharp, keeping the cost to the user very low and the service high. Development is in direct response to demonstrated needs. Competition requires that the supplier must maximize the productivity of his program. He also supplies system maintainenance and assures machine independence. A program which is not operating will generate no revenue for the supplier. The supplier tries to anticipate new requirements so that his program is used when the requirements materialize. The fact that the program must be used to develop revenue to the supplier means that the supplier must be able to provide training for users, must insure communication between the user and the developer, and must assure simplicity, reliability and usability of his product. He must be sure that his program is available when and where it is needed. The program development cost is spread over many users, each one according to the amount of use. The software supplier can attract and utilize creative personnel, both by adequate compensation and by challenging and creative work.

Because such technical software suppliers are now in existence, and want to remain so, what is now required is a clear statement of the requirements for an integrated analysis system for nuclear power analyses, and a clear indication that such a system would be used. If these requirements are met, one can expect to see at least five different integrated analysis systems competing for usage within the next five years.

V. STATUS OF AN EVOLVING COMPUTER PROGRAM - ANSYS

The ANSYS computer program is an example of a computer program which is evolving to meet the needs of the users of the program. It is being developed and maintained by a technical software supplier (SWANSON ANALYSIS SYSTEMS, INC.). It is one of the programs which is likely to evolve into an integrated analysis system, if the desire for such a system is demonstrated.

Figure 13 illustrates some of the characteristics of the current ANSYS program which indicates that it is evolving toward a system which could be called an integrated analysis system.

1. Disciplines - The major disciplines included are Heat Transfer, static structural analysis and dynamic analysis. The heat transfer capability includes conduction, radiation and free and forced convection; the static analysis includes elastic, in-elastic (plasticity, creep and swelling), and large deflection capabilities; and the dynamic analysis includes modal, seismic, harmonic response, and linear and non-linear time history analysis.

2. Internal Communications - Include direct interfaces between the heat transfer and the static structural analysis, and between the static and dynamic analysis.

3. Libraries - The ANSYS program currently accepts libraries of nodal points, member properties, elements and material properties. These libraries are maintained by existing system routines, such as UPDATE. It creates and accepts libraries of substructures, displacements, and temperatures. It has a limited capability for generating and using stress distribution libraries.

4. Graphics - Extensive graphics capabilities are available for input checking to assure reliability and for the display of the structural displacements calculated in the analysis.

5. General Features - The ANSYS program features multi-level substructuring, multi-level nodal point and element generation capabilities, data checking options, displacement coupling and equations of constraint, in-elastic convergance criteria, and dynamic storage allocation.

6. Capacity Range - Problems have been economically solved in the range from 2 to more than 20,000 degrees of freedom, from 0 to more than 10,000 elements, and from 0 to more than 100 substructures.

7. Training Requirements - A capable analyst can work with the User's Manual and the Examples Manual and learn to use the ANSYS program. However, attendance at a two-day seminar is recommended for static, heat transfer, and modal analysis training. An additional two days of training is recommended for dynamic analysis, and an additional day for familiarization with the in-elastic analysis capabilities. These training times assume a familiarity with finite element computer techniques.

8. Reliability - The ANSYS program is used more than two hundred hours of computer time each month, involving several thousand analyses by several hundred analysts. Most features have achieved a high reliability under this diverse set of requirements. New features are verified at several locations before general release to achieve a reasonable reliability.

9. Availability - The program is available at computer centers in the USA, Canada, Europe, Japan and Australia. It is also available on in-house computers at several locations. All systems are as identical as possible considering the different computers and operating systems, and all are maintained from one central site.

VI. THE FUTURE

We can look at a chart like Figure 13 and ask "What should be the next steps in the development of an Integrated Analysis System?" However, if we review the concept of an evolving computer program, we see that such a question does not have a direct answer. What is next depends on the needs, and the needs are also evolving.

Figure 14 shows some of the areas where the future needs seem to be and the directions in which the development may proceed.

1. General Purpose vs. Special Purpose Elements - Will special elements to characterize specific nuclear components evolve, or will more general elements with large numbers of nodal points be used to represent the component? What (if anything) will replace the line elements?

2. Fluid Flow - A general fluid flow - heat transfer capability is needed, so the fluid-cooled solids can be analyzed with the fluid temperature and pressure being determined.

3. Neutron transport - Finite elements can be used to solve the neutron diffusion equation. Should these be included in the integrated analysis system?

4. Control circuits and functions - When should these be added to an overall system model?

5. Buckling Analysis - Is structural instability a common enough problem to expedite a linear buckling analysis, and how about plastic or creep buckling?

6. Data Pool Maintenance Problems - Are special routines needed to maintain the data pool or are the existing program and/or system routines sufficient? The system routines vary from system to system.

7. Probability and Reliability Evaluations - Should the system be modified so that randomly distributed data can be supplied and so that statistical analyses can be performed on the results?

8. Graphical Presentation of Results - How can the results be better displayed to minimize the effort required to interpret the results?

9. Material Characterization - What new material characterizations are required, especially in the in-elastic analysis formulation?

10. Failure Evaluation - Should the program compare its results against some failure criteria to predict failure or calculate reliability? What criteria are applicable?

As a final question, should we try to reach the point of generating a model of a reactor and then keeping this model throughout the life of the reactor, imposing on this model the external environment experienced by the reactor? Would such a model predict component failures before they occured and allow the evaluation of alternate operating procedures to maximize system reliability? Or is such a procedure outside the range of present technology?

VII. SUMMARY

It has been the intent of this paper to explore the topic of an Integrated Analysis System for Nuclear Reactor System analysis. It was not the intent of the paper to answer any questions, but rather to raise as many as possible in a limited amount of space.

It is felt that an integrated analysis system will evolve in the next few years and that its form is going to be generated by the desires and needs of the analysis groups. The more dialogue that develops between the program developers and the program users, the more the resulting systems will meet the needs of the users.

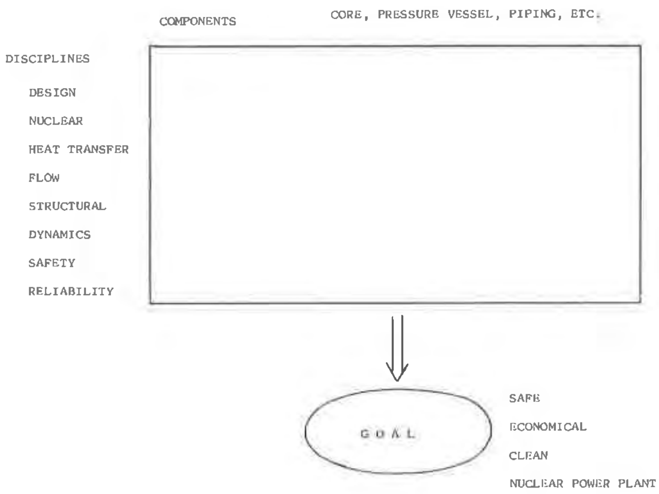


Figure 1 THE ANALYSIS TASK

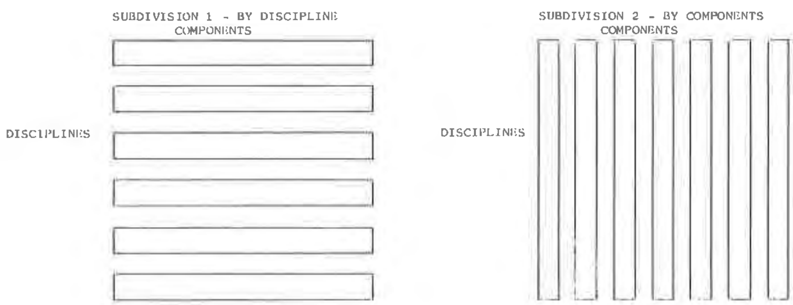


Figure 2 ANALYSIS TASK SUBDIVISIONS

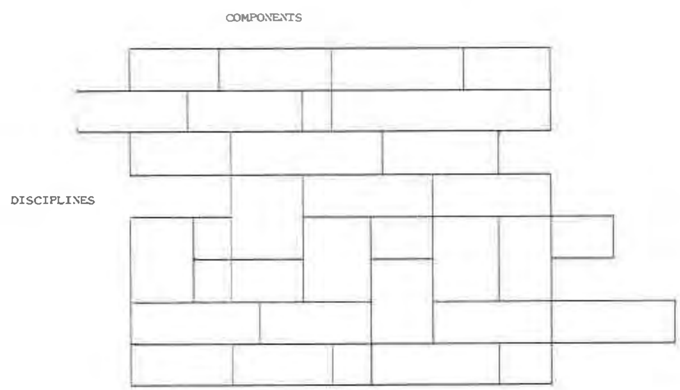


Figure 3 ACTUAL ANALYSIS TASK SUBDIVISION

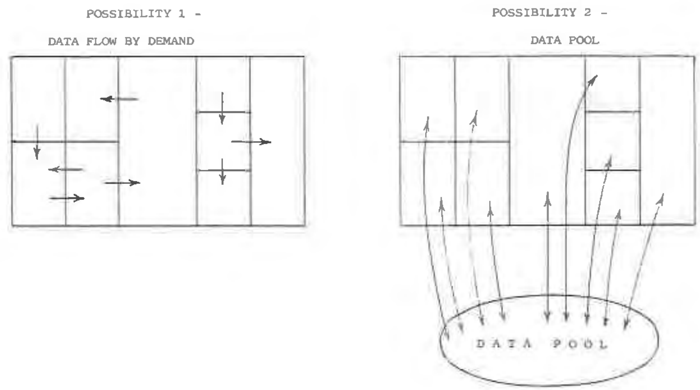


Figure 4 THE DATA HANDLING TASK

1. DATA FLOW BY DEMAND

   DIFFICULT TO VISUALIZE THE COMPLETE DATA REQUIREMENTS

   DIFFICULT TO ESTABLISH A CURRENT STATUS

   CONTROL IS DIFFICULT

   SERIES ANALYSIS BECOMES NATURAL

2. DATA POOL

   DATA REQUIREMENTS CAN BE PLANNED AND UPDATED

   DATA CAN PROGRESS FROM TENTATIVE TO DESIGN TO FINAL

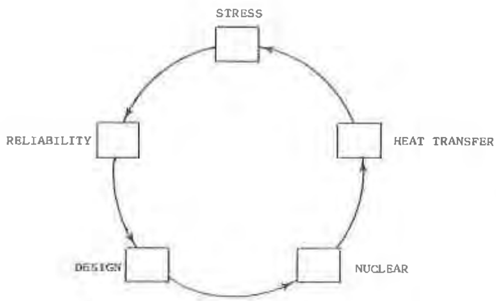
   CONTROL AND TRACEABILITY PROCEDURES CAN BE IMPLEMENTED

   PARALLEL ANALYSIS FACILITATED

Figure 5 CHARACTERISTICS OF DATA HANDLING POSSIBILITIES

1. THE MORE SUBDIVISIONS, THE LARGER THE MANAGEMENT TASK
2. THE MORE SUBDIVISIONS, THE GREATER THE COMMUNICATION TASK IN A DEMAND DATA FLOW PROCEDURE.
3. THE MORE SUBDIVISIONS, THE GREATER THE DATA VISIBILITY IN A DEMAND PROCEDURE, SINCE DATA IS USUALLY VISIBLE AS IT CROSSES BOUNDARIES.
4. THE LARGER THE REGION, THE MORE EFFICIENT THE COMMUNICATION, BECAUSE IT IS EASY FOR THE ANALYST TO COMMUNICATE RESULTS TO HIMSELF
5. THE LARGER THE REGION, THE MORE DIFFICULT THE CHECKS AND TRACEABILITY, UNLESS INTERMEDIATE RESULTS ARE COMMUNICATED TO SOME DATA POOL.

Figure 6 OBSERVATIONS ON ANALYSIS TASK SUBDIVISIONS



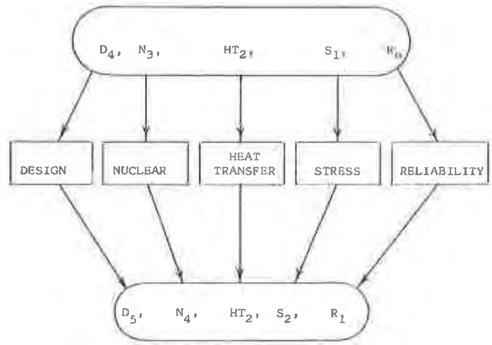
a. EACH TASK HAS CONSISTENT DATA

b. LITTLE WASTE IN A REDESIGN

c. MAXIMUM TIME PER ITERATION

d. ANALYSIS DISCIPLINES ARE IDLE, POOR WORKLOAD DISTRIBUTION IN ORGANIZATION BY DISCIPLINE.

Figure 7 SERIES ANALYSIS



a. EACH TASK USES THE THEN MOST CURRENT DATA

b. MINIMUM TIME PROCEDURE

c. POTENTIAL FOR MUCH WASTE EFFORT IF REVISION REQUIRED

Figure 8 PARALLEL ANALYSIS

1. COMPUTER PROGRAM(S)
2. MULTI-DISCIPLINARY
3. INTERNAL COMMUNICATION
4. DATA STORAGE, MAINTENANCE, RETRIEVAL (LIBRARIES)
5. DOCUMENTATION AND TRACEABILITY
6. MULTI-USER
7. LARGE CAPACITY RANGE
8. SOPHISTICATED
9. RELIABLE
10. USEABLE
11. AVAILABLE

Figure 9 CHARACTERISTICS OF AN INTEGRATED ANALYSIS SYSTEM

1. INCREASED ANALYSIS REQUIREMENTS

SEISMIC
SAFETY
IN-ELASTIC
INTERACTING SYSTEMS
RELIABILITY
CONFLICTING REQUIREMENTS
- Safety vs. Cost
- Thermal vs. Pressure Stresses
- Analysis Cost vs. Test Cost

UNCERTAINTY OF MATERIALS DATA

2. INCREASED MANPOWER COSTS

MAXIMIZE PRODUCTIVITY
- Minimize Repetition and Duplication (Models)
- Facilitate Interpretation of Results (Graphics)
- Minimize Manual Interfaces (Reports)
- Minimize Errors and Re-analyses

MINIMIZE TRAINING COSTS AND TIME
MINIMIZE RELIANCE ON EXPERTS

3. HIGHER HUMAN EXPECTATIONS

ENGINEERS/ANALYSTS ARE HUMAN
- Need sense of achievement
- Need to feel creative
- Need to interact in groups
- Need responsibility
- Need to feel a part of a significant activity

ENGINEERS/ANALYSTS HAVE SPECIAL REQUIREMENTS
- Must reach the right answer
- Must ask questions
- Need well-defined tasks and interfaces

ANALYSIS SYSTEM
- Must not limit the range of questions/answers
- Must facilitate communication of results
- Must respond rapidly

4. EVOLVING COMPUTER SYSTEMS

LARGER CAPACITIES
FASTER SPEEDS
SOPHISTICATED DATA HANDLING

5. INCREASED NUMBER OF ORGANIZATIONS INVOLVED IN A PROJECT

Figure 10 REASONS FOR AN INTEGRATED ANALYSIS SYSTEM

1. PROJECT

a. PRE-SPECIFIED GOALS, REQUIREMENTS, CAPABILITIES

b. FIXED COMPLETION SCHEDULE

c. FIXED PRICE

d. LITTLE INCENTIVE TO EXCEED SPECIFICATIONS

e. INCORPORATES STATE-OF-ART AT BEGINNING OF PROJECT

2. EVOLUTION

a. BASE CAPABILITY DEVELOPED OR OBTAINED (BIRTH)

b. PROGRAM APPLIED TO PROJECTS, WITH GENERALIZED ENHANCEMENTS (GROWTH)

c. SPECIALIZED vs. GENERALIZED GROWTH (RANGE OF EDUCATION)

d. PRODUCTION AND MAINTENANCE (MATURITY)

e. PERIODIC RE-WRITES (REPRODUCTION)

f. OBSOLESCENCE OR REPLACEMENT (DEATH)

Figure 11 FORMS OF PROGRAM CREATION

1. GOVERNMENT

a. NUCLEAR POWER IS A WORLD-WIDE PROBLEM
b. GOVERNMENT HAS FUNDING RESOURCES
c. GOVERNMENT WORKS ON PROJECT BASIS
d. SHARING BETWEEN GOVERNMENTS UNLIKELY

2. PRIVATE INDUSTRY

a. ONLY A LARGE INDUSTRY WOULD HAVE THE RESOURCES
b. PRIVATE INDUSTRY TENDS TO HOLD INTERNAL DEVELOPMENTS FOR COMPETITIVE ADVANTAGE
c. LACK OF COORDINATION PRODUCES MUCH DUPLICATION OF EFFORT
d. PRIVATE INDUSTRY PROGRAMS EVOLVE RATHER THAN BEING PROJECTS

3. UNIVERSITY

a. FUNDING WOULD BE REQUIRED
b. CONTINUITY OF PERSONNEL MAY BE DIFFICULT
c. TENDENCY TO BE REMOTE FROM THE ACTUAL ANALYSIS PROBLEMS AND PRESSURES

4. TECHNICAL SOFTWARE SUPPLIERS

a. NEW PHENOMENON
b. PRODUCTS ARE MADE AVAILABLE FOR A CHARGE
c. COMPETITION IS ALIVE AND FUNCTIONING
d. DEVELOPMENT IS IN DIRECT RESPONSE TO NEEDS
e. SOFTWARE SUPPLIER MUST MAXIMIZE PRODUCTIVITY OF HIS PRODUCT
f. SOFTWARE SUPPLIER PROVIDES SYSTEM MAINTENANCE AND MACHINE INDEPENDENCE
g. MUST ANTICIPATE NEW REQUIREMENTS
h. USER HAS READY ACCESS TO PROGRAM DEVELOPER
i. SUPPLIER HAS INCENTIVE TO ASSURE SIMPLICITY, RELIABILITY, AND USABILITY
j. PROGRAM AVAILABILITY IS ASSURED
k. DEVELOPMENT COST IS SPREAD ACROSS MANY USERS
l. SOFTWARE SUPPLIER CAN ATTRACT CREATIVE PERSONNEL
m. IF INTEGRATED ANALYSIS SYSTEMS ARE NEEDED, THE TECHNICAL SOFTWARE SUPPLIER WILL CREATE THEM, PROVIDED THEY WILL BE USED

Figure 12 ORGANIZATIONS WHICH MIGHT DEVELOP AN INTEGRATED ANALYSIS SYSTEM

1. DISCIPLINES
   a. HEAT TRANSFER
      CONDUCTION
      RADIATION
      FREE AND FORCED CONVECTION
   b. STATIC ANALYSIS
      ELASTIC
      IN-ELASTIC
      LARGE DEFLECTION
   c. DYNAMIC ANALYSIS
      MODAL
      SEISMIC
      HARMONIC RESPONSE
      TIME HISTORY (LINEAR AND NON-LINEAR)
2. INTERNAL COMMUNICATION
   a. HEAT TRANSFER - STRESS
   b. STATIC - DYNAMIC
3. LIBRARIES
   a. NODAL POINTS
   b. MEMBER PROPERTIES
   c. ELEMENTS
   d. MATERIALS
   e. SUBSTRUCTURES
   f. DISPLACEMENTS
   g. TEMPERATURES
   h. STRESSES
4. GRAPHICS
   a. INPUT (RELIABILITY)
   b. OUTPUT (INTERPRETATION)
5. FEATURES
   a. MULTI-LEVEL SUBSTRUCTURING
   b. MULTI-LEVEL NODE AND ELEMENT GENERATION
   c. DATA CHECKING
   d. DISPLACEMENT COUPLING
   e. EQUATIONS OF CONSTRAINT
   f. IN-ELASTIC CONVERGENCE CRITERIA
   g. DYNAMIC STORAGE ALLOCATION
6. CAPACITY RANGE
   a. 2 TO 20,000$^+$ DEGREES OF FREEDOM
   b. 0 TO 10,000$^+$ ELEMENTS
   c. 0 TO 100 SUBSTRUCTURES
7. TRAINING REQUIREMENTS (TYPICAL)
   a. STATIC, HEAT TRANSFER, MODAL - 2 DAYS
   b. DYNAMIC - 2 DAYS
8. RELIABILITY
9. AVAILABILITY

Figure 13 CHARACTERISTICS OF THE CURRENT ANSYS PROGRAM

A. UNANSWERABLE

   THE NEEDS ARE ALSO EVOLVING

B. AREAS OF EFFORT
   1. GENERAL PURPOSE vs. SPECIAL PURPOSE ELEMENTS
   2. FLUID FLOW
   3. NEUTRON TRANSPORT (CRITICALITY AND POWER DISTRIBUTION)
   4. CONTROL CIRCUITS AND FUNCTIONS
   5. BUCKLING ANALYSIS
   6. DATA POOL MAINTENANCE ROUTINES
   7. PROBABILITY AND RELIABILITY EVALUATIONS
   8. GRAPHICAL PRESENTATION OF RESULTS
   9. MATERIALS CHARACTERISTICS
   10. FAILURE CRITERIA

C. SHOULD A MODEL OF THE REACTOR FOLLOW IT THROUGH ITS LIFE?

Figure 14 WHAT OF THE FUTURE?