A Report on the Utilization of the MOSES Computer as a Tool in Development and Dessimination of System Dynamic Models

Hans Esmann Eriksen
Jutland Technological Institute

Erland Hejn Nielsen
The Aarhus School of Business Administration
Economics & Modern Languages

ABSTRACT

The Jutland Technological Institute (JTI), Aarhus, Denmark, has embarked a project to promote the utilization of System Dynamic models in Danish Industries. The vehicle of this projekct is a new type of hybrid computer, the MOSES (Modular Symbolic Electronic Simulator) system, developed at the Technical University of Denmark. In ongoing projects the MOSES system has demonstrated itself as an invaluable "discussion" partner. We have performed a series of seminars with managers from medium and large sized Danish companies. At these seminars some of the generic structures of growth companies have been discussed and related to Danish conditions. This report contains a brief description of the MOSES system and a description of the ongoing project.

BACKGROUND

The Jutland Technological Institute is a non-profit based technological service centre offering services to the Danish industry. The main function of the institute is to transform theoretical research results into applied technology by:

- consulting on managerial and technological issues
- running industrial training courses
- testing new products, processes and materials
- performing research and development projects

Within managerial consultancy the institute has embarked a project to promote the utilization of System Dynamic models in Danish Industries.

Most of the excisting relevant System Dynamic Generic Structures are developed in USA. The premises of these models are not always consistent with the situation in Danish industries. With the object of making it possible to evaluate and adapt the American models to Danish conditions a cooperation has been established between the Århus School of Business Administration, Economics and Modern Languages, and the Jutland Technological Institute (JTI). As part of his post graduate study on economic models and methods Mr. Erland Hejn Nielsen has joined the project to assist with the theoretical evaluation of the proposed models.

THE MOSES SYSTEM

As vehicle of the project a new type of hybrid computer has been chosen: The MOSES system (Modular Symbolic Electronic Simulator) developed at the Technical University of Denmark by Kaj Jensen, Ph.D.

MOSES comprises a series of analog, digital and hybrid pre-programmed modules, which are placed manually and immediately interconnected through an electronic baseboard, thus eliminating all software programming and 95% of the wiring experienced on hybrid system. In this way the MOSES System provide a powerful and flexible simulation machine with the following advantages:

- Simple Man Machine communication.
  The modules are corresponding directly to System Dynamic symbols and the model may be programmed based on the system dynamic flow chart. This is important when the user is unfamiliar with traditional software developing technics (managers).

  As an example fig. 1 shows a part model of an inventory and production model (Lyneis corporate planning and Policy Design p. 86).

  Fig. 2 shows the corresponding system dynamic diagram.

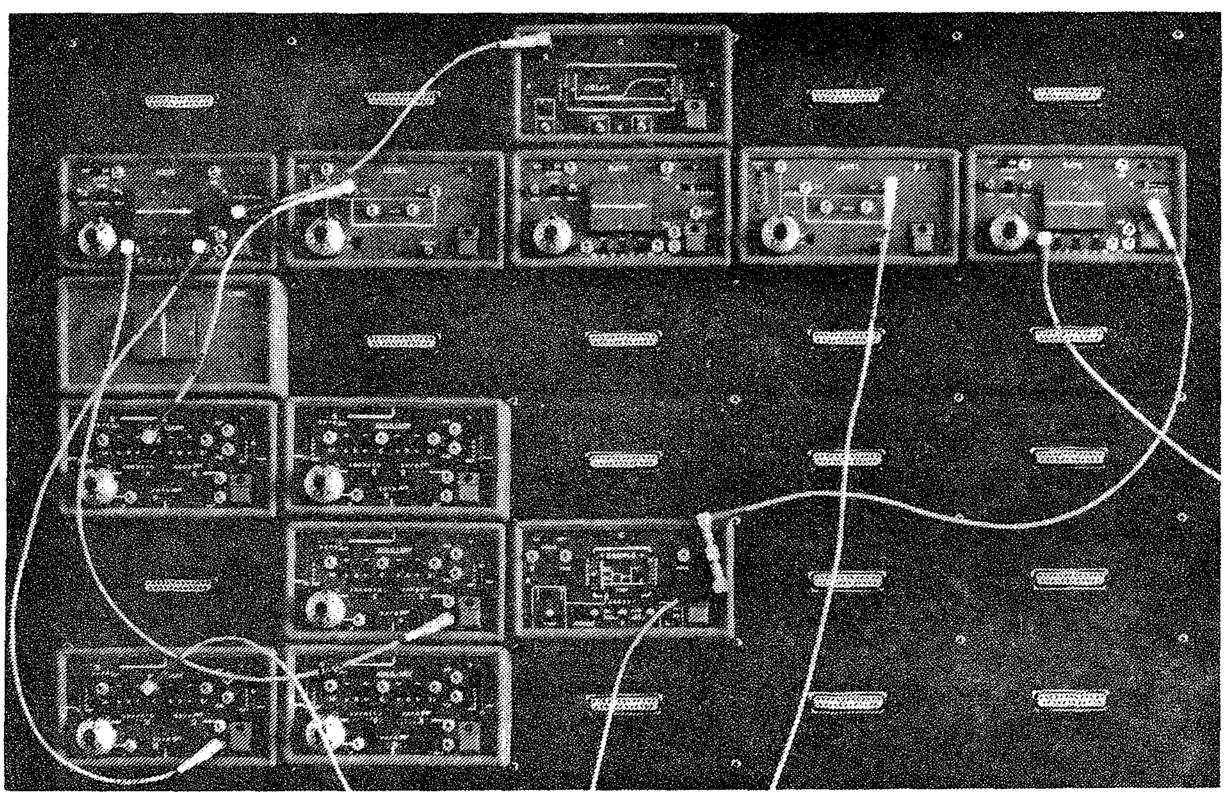

Fig. 1: Part of Dynamic Inventory and Production model on the MOSES system corresponding to the SD diagram in fig. 2.

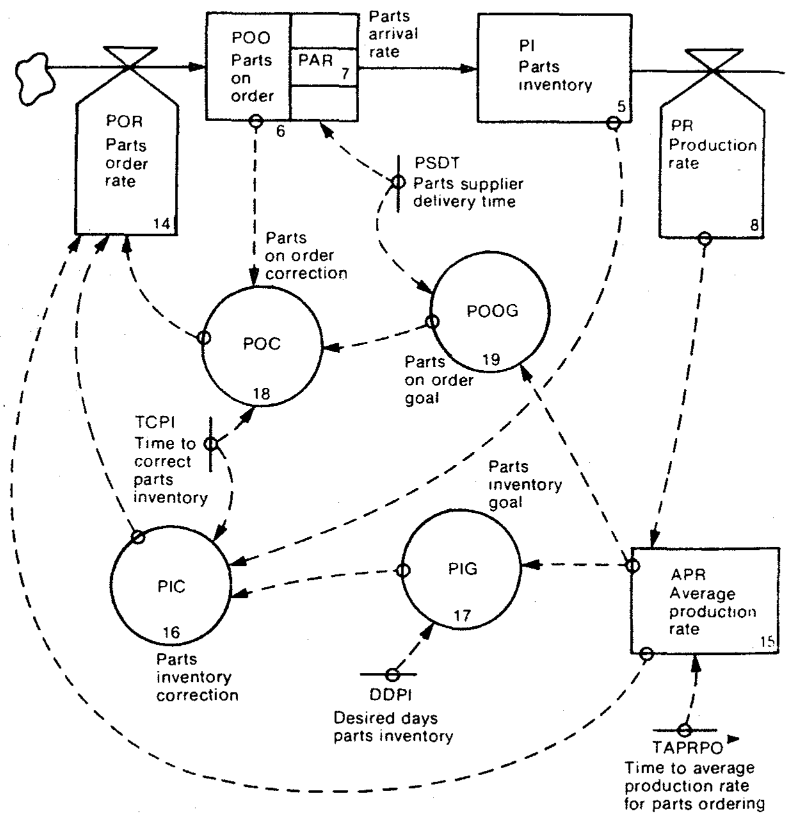

Fig. 2: Part of Inventory and Production model corresponding to the MOSES model in fig. 1.

- Processing Speed.
  Because of the pipeline structure of the calculation the system performs 25 simulations/1 sec. independent of the size of the model. The speed makes it possible to perform monte carlo simulation on the system enabling the user to evaluate parameter sensitivity quickly.

- Programming Productivity.
  The seven different processor modules corresponding to system dynamic symbols are easy to utilize, and the debugging of the programme is performed visually while simulating. Small changes of the model may be done quickly and the result of the change is seen immediately. This speed of change and calculation give a great advantage during model development.

  As illustrated in fig. 3 the system developer is working in a loop consisting of

  1) comparing information from a model and the model object
  2) analysing
  3) changing model and parameter
  4) running the model etc.etc. the circle is continued until an acceptable model behaviour has been found. The total developing time depends on the slowest of these activities.

Further fig. 3 illustrates how dessimination of your model may improve the understanding of the model. A dessimination method like MOSES simulation gives an immediate possibility of transferring new ideas from the audience back to the model developer.

- Dessimination Capability.
  During model development the system may be utilized in cooperation with the client. Variation of the model structure, parameters and content of the tables may be tested and the result can directly be seen. The MOSES system now acts as a discussion partner and creates a common basis of understanding.

  The fact that you may push a button, representing a system parameter, and simultaneously observe the result of the change on output has a significant impact on your capability of perceiving the internal structure of the model. This point may be illustrated with the following Chinese proverb freely translated:

  I hear - I forget
  I see - I remember
  I do - I understand

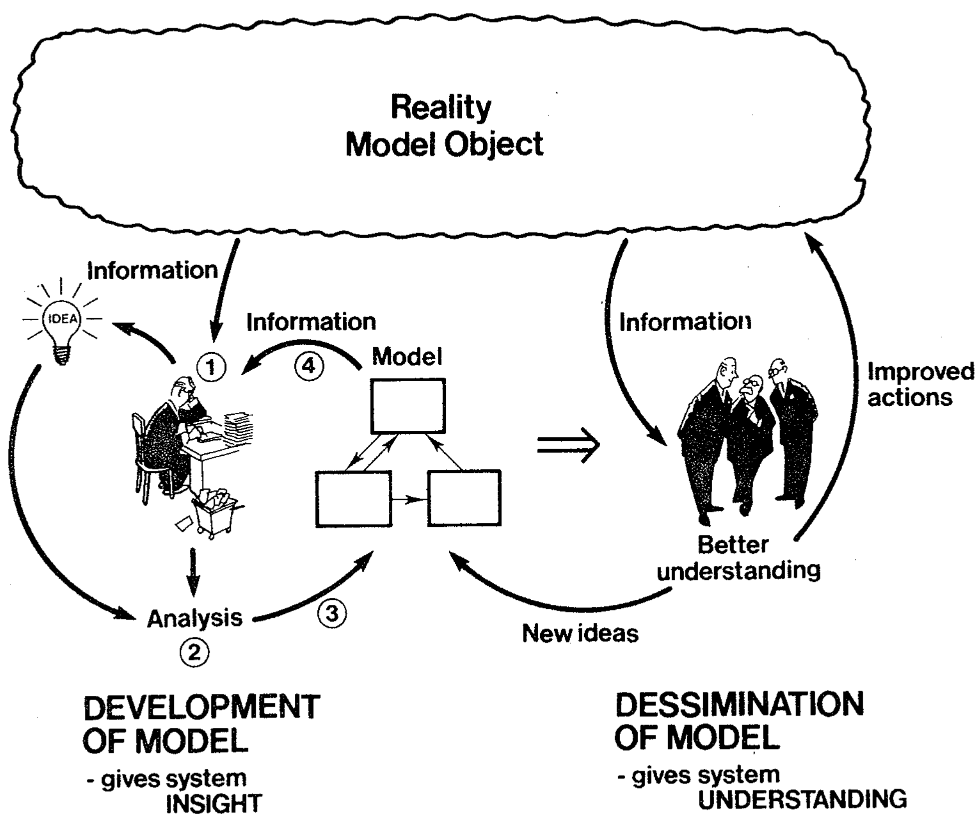

Fig. 3: Illustration of working process of system analysis during model development and model dessimination.

THE PURPOSE OF THE SEMINAR RUNNING:

Whenever we have more than one person dealing with the same thing, the outcome is highly dependent upon the insight in the interconnectedness in the group. This is also valid to a firm where the interconnectedness is very complex and not very easy to communicate to a broader audience.

Peter Senge states that

> "In particular almost all organizations lack the conceptual tools to integrate this sense of common purpose and shared responsibility with the "mental models" upon which decisions are based".

The participants in our course could agree on this lack of such a conceptual tool which could capture the complex interrelatedness of a modern firm, but they were also aware of the problem that if we had a way to formulate relevant "mental models", how do we easily communicate them to non-modelers.

So the seminar running has two main purposes - first to give an introduction to the value of system dynamics insight in practical management problems - second to demonstrate the ability of the MOSES system to communicate system dynamic models.

THE PARTICIPANTS

The participants of the first seminar have been selected among some of the large Danish production companies, because these companies in their ongoing strategic planning have been involved in several of the areas covered by the presented models, and because of this they have a good background to evaluate the content of the models. When the models through this initial process have been tested and adapted to European conditions, a broader set of seminars will be started to introduce the working method for small and medium-sized companies.

THE PROGRAMME

The content of the programme is based upon James M. Lyneis: Corporate Planning and Policy Design - A System Dynamics Approach, Forrester's INDUSTRIAL DYNAMICS and a report (D-3586-1) on the pilot phase of the project on "System Thinking and The New Management Style", by Peter Senge.

The programme covers six sessions of approximately five hours, with 3-4 weeks between each session. Each session has a specific theme - a generic structure - that will be discussed.

The six generic structures we intend to use are

1) A basic production and inventory model with no limitations in factor availability.
2) Two variations over theme 1) - first with limitations coming from the part suppliers - second with limitations coming from the stability problem connected to the labor market.
3) Delayed delivery dynamics
4) A capital equipment ordering model - the dynamics arising from "self-ordering".
5) A dynamic financial model.
6) A dynamic organizational model.

The first session is different from the following sessions in two ways:

- because the audience at this moment has never seen a system dynamics model, and we have to be careful not to lose them.
- because we, besides getting a model running on MOSES, have to present the System Dynamic tools - causal diagramming, loop analysis and the dynamo notation.

So the first session is equally devoted to a discussion of technique and model implications.

We are able to cover all this field in the first session, because the first generic structure describes a well-known situation to the audience. It should also be noted that there is a one-to-one correspondence between MOSES-modules and DYNAMO-notation.

The following sessions are fully devoted to discussions of the generic structures. Each model will be treated in two sessions. Starting with a presentation and discussion one afternoon - continuing the following session with a repetition and experimentation with the model on MOSES carried out partly by the audience themselves, based on reflections on the model since the last presentaion.

REPORT ON THE RESULTS FROM THE SEMINARS

Though it is a course running over six sessions, it certainly is the first session that is of most interest from a pedagogical viewpoint. If you are able to captivate your audience the first time you may be able to create just the kind of enthusiasm which opens the mind for new ideas.

Let us give a brief description of the first session.

a) Pedagogical strategy:
Our intention was to generate a planned "two-way-communication". The resulting model was built up in a step-by-step fashion. This gives a natural way to introduce the elements of system dynamics. Every step is "validated" by MOSES computations both generated by us and surprisingly soon by the audience. It seems as if the MOSES computer asks for experimentation.

b) Reaction by the audience:
The introduction of such concepts as rates and levels as elements of a physical flow was accepted as natural model elements. Also delays in the physical flow did not give any discussion. By introducing the first feedback mechanism with the claim that "output = input" we were able to start simulations.

Almost immediately all questions and answers were made through the MOSES computer.

We certainly have realized that WHAT-IF analysis, especially when the WHAT-IF's are generated by the audience, is a most persuading way of doing teaching, if you can get the answers right away.

In a two hours' time we got the final model of this session (half of the model is shown in fig. 1).

The following discussion of some of the implications of this model revealed a general opinion that this model as a base structure was close to reality. Of special interest was a set of simulation runs where the objective was to tune the system to stay stable irrespective the kind of demand fluctuations. This interest did arise because of the severe consequences to the part suppliers' situation.

Problėms connected to the part suppliers' situation turned out to be of great interest, because the wanted flexibility in a firm's production process that can easily adapt to a rapidly changing environment only works if all part suppliers are able to cooperate.

There was a great interest in problems about the flows of information in the firm and its consequenses.

Further it was the general view that the most important factor of competition is the delivery time.

c) The MOSES computer:
We did approximately 40 different simulation runs in two hours and without disturbing the presentation at all. This would not have been possible to do with a digital computer. If we count 3 min. to each simulation run, we would have used 120 min. in all.

A plot of the result of the first model is shown in fig. 4: The Production Rate, Finished Inventory and Work in Progress is shown as a function of a temporaty increase in demand.

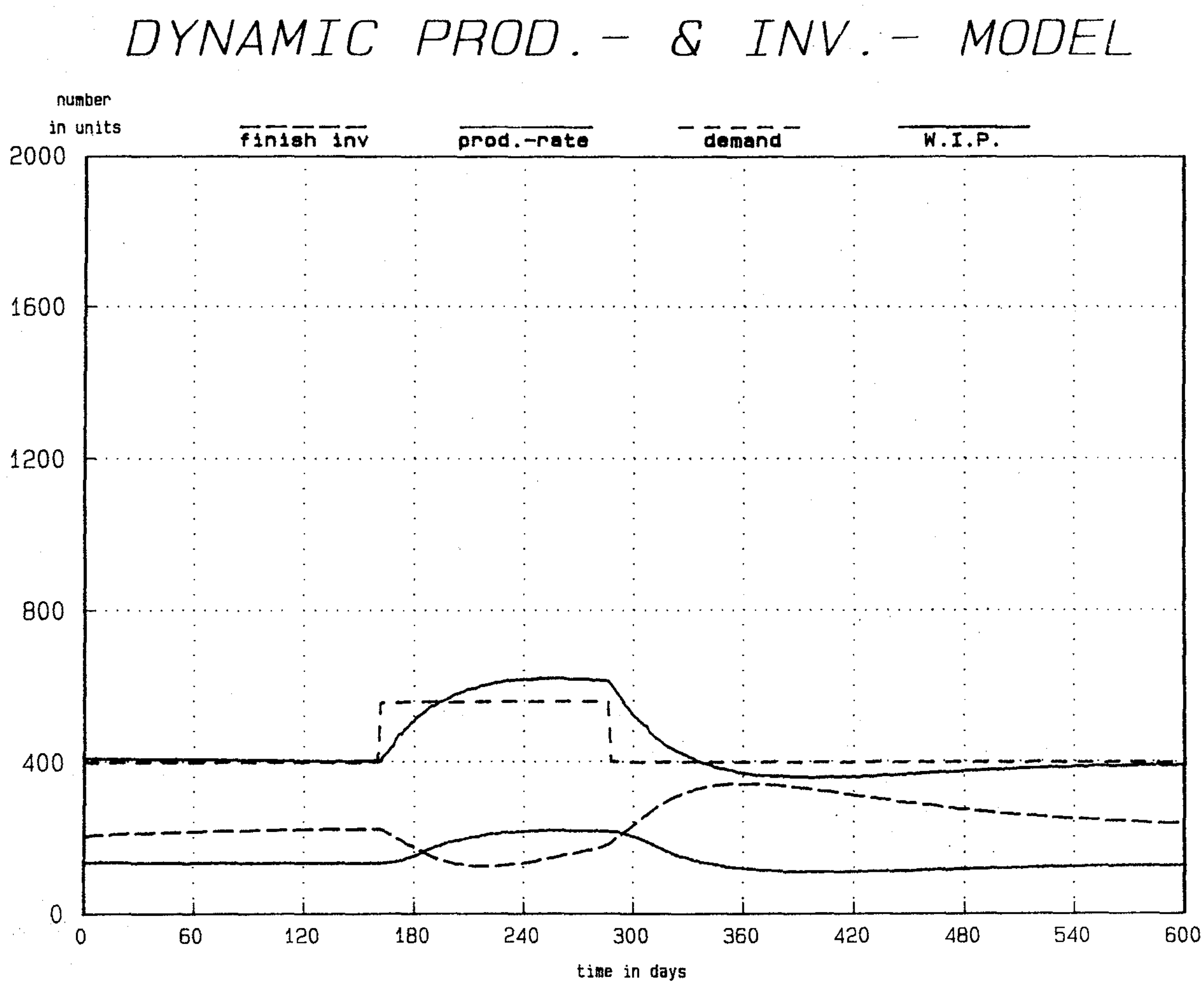

Fig. 4: Example of plot of Dynamic production and Inventory model.

PEDAGOGICAL PITFALL USING THE MOSES COMPUTER

During the seminars we have made some observations and reflections of the pedagogical process. The following conceptual causal loop diagram tries to illustrate the point.

A messy blackboard can spoil a lecture. So can too many overheads. The pitfall in connection with the MOSES computer is its ability to generate new information quicker than the mind is able to absorb it.

Like working with a blackboard or overheads, working with MOSES demands selfcontrol.

The basic process working with MOSES is ... think → generate an experiment → MOSES answers immediately → new information is created → (delay) → transform it to new knowledge = (think)

An experiment can be either good (controlled) or bad (diffuse). A good experiment is generated based on processed information = knowledge. It is generated in a marginal diminishing rate as knowledge increase. A bad experiment is generated, let us say linearly based on new information (not yet processed) over some critical amount of information. The basic difference between a good and a bad experiment is that the bad experiments increase confusion which slows down your ability to process information to knowledge. The critical amount of information is time dependent on factors such as tiredness.

This system runs optimally on a knife-edge. As tiredness increases or if you lose selfcontrol, the system can exceed its tresshold value and colaps (go and drink a cup of coffee!).

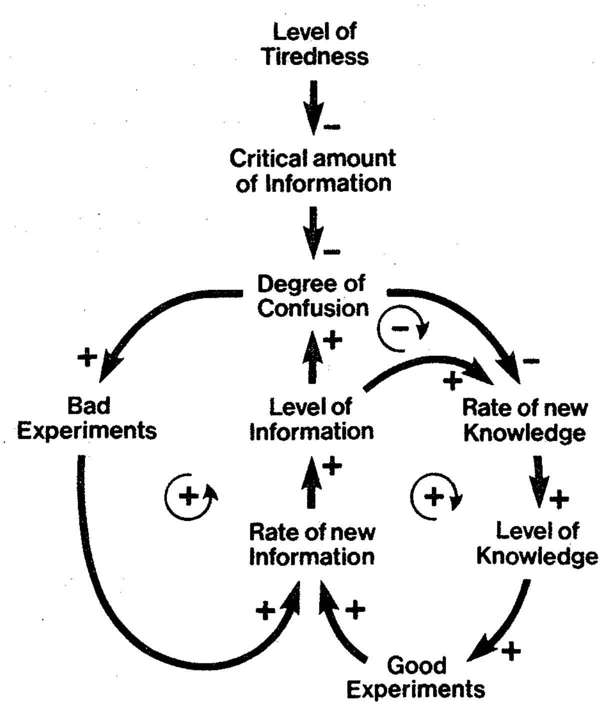

Fig. 5: An illustration of how development of knowledge is connected with good and bad experiments during analysis of a problem.

Contrary to a modelling process where you use a normal digital computer and where you have a significant delay between input and output, a modelling process based on MOSES can colaps so suddenly that you first realize the colaps after having made a hole series of nonsense-simulations. Anyhow, all this just has to be taken in consideration when you are doing work with MOSES:

You can by use of tight self-control push the accumulation of knowledge per time unit far above what is possible by traditional means.

AN IMPLEMENTATION STRATEGY OF SYSTEM DYNAMIC MODELS

MOSES simulation has many advantages during model development and as additional tool in the dessimination of model insight. When a model is to be utilized as a part of daily operations, digital simulation tools are better, because of lower price of equiptment, simplicity of rerun model, higher precision and better capability to handle large models.

For that reason we will propose a combined utilization of the two types of systems, when a System Dynamic model is to be used in a company. A typical implementation plan will consist of the following phases:

Phase 1. Model Development.
During this phase the analysis and key personnel from the company select an appropriate set of basic generic models describing the problem. Adaptations to the model are made describing unique features of the company and parameters are estimated.

In this phase the MOSES system gives an effective tool to develop submodels and to introduce the key personnel to the working method.

Phase 2. Model Acceptance.
When the basic models are selected and developed the results are to be presented to a large fora. The main object is to create acceptance of the model and understanding of the dynamics combined with the creation of user-enthusiasm.

The MOSES system gives good possibilities to make a good presentation where the audience has possibility to pertubate the created model with new ideas.

Phase 3. Operational Utilization.
When the user of the model has achieved a good know-how about the model and understands, how it reacts in several situations the model may be transformed to a digital form. Now the user may utilize the digital version to perform ad hoch part analysis.

As there exists a one-way correspondence between the MOSES model and a DYNAMO model the implementation of the operationel form of the model is a question of a few days work.

Phase 4. Extensions of the model.
During operational utilization of the model new problems may be identified, and the user may want further investigation. The MOSES system is now a good tool to test new extensions of the model.

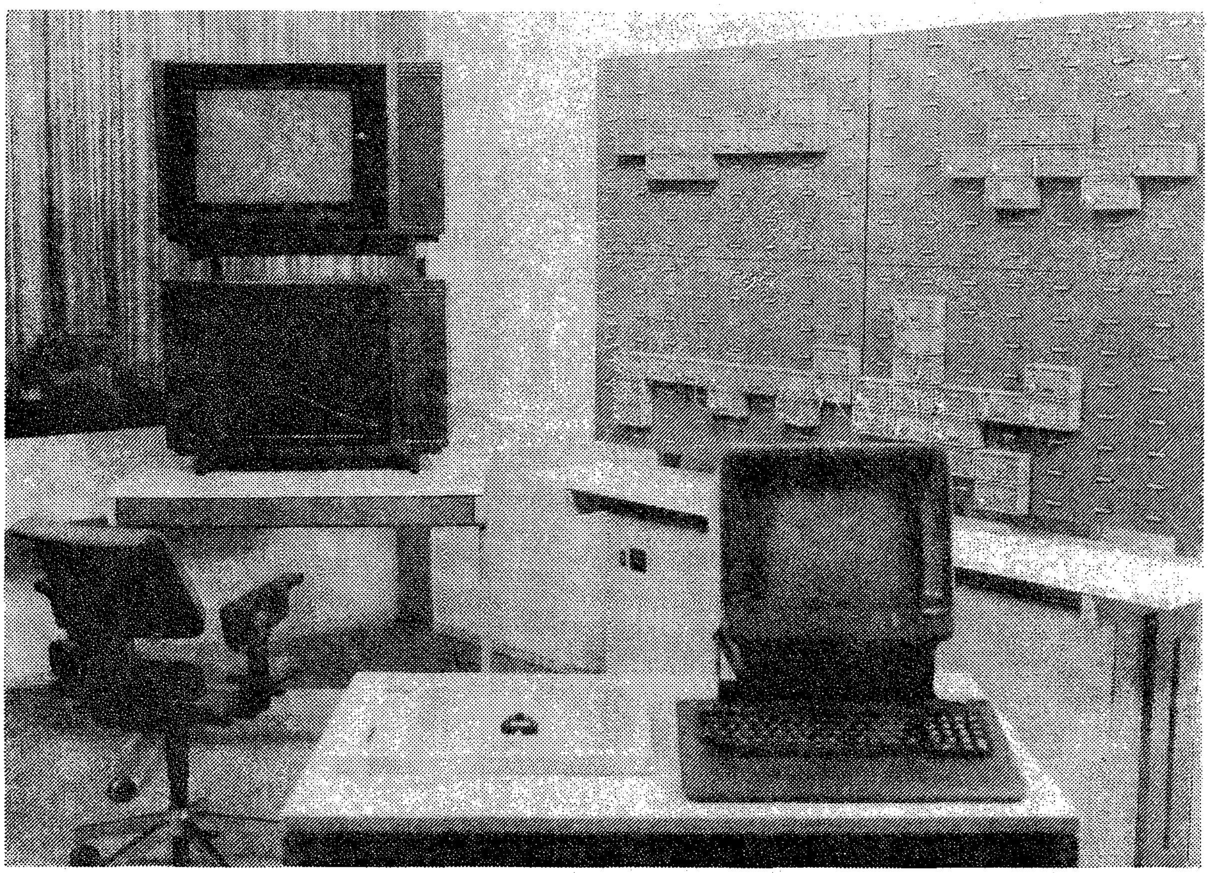

Fig. 6 The MOSES Work Station

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