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NUMERICAL CONTROL TRAINING AND DEMONSTRATION CENTRE

Prepared for the Government of Bulgaria

by the United Nations Industrial Development Organization,

acting as executing agency for the United Nations Development Programme

Based on the work of Brian Gotti,

expert in computer-aided design

United Nations Industrial Development Organization
Vienna

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ACKNOWLEDGEMENTS

I would like to express my thanks and appreciation to the management and staff of the NC/CAM Metalworking Development Centre and to those of the IMM for their assistance, interest and support in making this mission successful.

Particular thanks are due to Mr. Lubomir Moinov, Director, IMM; Mr. Boyan Bonev Deputy Director, IMM; Mr. Nikola Todorov, Division Chief, IMM; Mr. Dimitar Penkov, NC/CAM Centre Project Manager and to all the staff members who participated so fully in our seminar discussions.

I should also like to thank Mrs. Rossitza Georgieva NC/CAM Centre interpreter for her hard work in preparing the mission report and for her dedication at a time of difficult circumstances.

Special thanks are also given to Mr. Plamen Bonev for doing so much to make my stay in Bulgaria not only effective but also enjoyable and to Mr. Boris Tzekovski for contributing also to a memorable experience.

I wish the Centre and the Institute well in their future endeavours.
INTRODUCTION

A) The primary input sources and data used in the preparation of this report were the Project Document, the Project Progress Reports and the previous Project Mission Reports as follows:


2) Project Mission Report: John A. Moorhead, dated 18.12.79

3) Project Mission Report: James C. Warner, dated 17.04.80

4) Project Mission Report: Thomas H. Spencer, dated 30.06.81

5) Project Mission Report: Dominique Laffret, dated 23.07.81

6) Project Mission Report: Mihaly Kovacs, dated 20.08.81

7) Project Progress Reports: Dimiter Penkov
   Dated December 1979
   Dated August 1980
   Dated March 1981
B) Interviews, demonstrations and discussions.

1) Project scope, accomplishments and current status.
   1.1. Boyan Bonev, Deputy Director, MTI
   1.2. Nikola Todorov, Division Chief, MTI
   1.3. Dimiter Penkov, Manager NC/CAM Metalworking Development Centre

2) Computer assisted NC part programming systems - demonstrations and discussions
   2.1. Vladimir Cheshmedjiev, NC Coordinator - NC/CAM Centre
   2.2. Ognian Petrov, Process Planner, NC/CAM Centre
   2.3. Russi Michailov, Process Planner, NC/CAM Centre

3) CNC 3-axis Coordinate Measuring Machine - demo and discussions
   3.1. Borislav Geshev, Metrologist, NC/CAM Centre

4) Noise and Vibration Measurements
   4.1. Dimiter Todorov, Laboratory Chief

5) Sony Colour Videotape Equipment Use
   5.1. Anton Todorov, NC Training and Demonstration Videomovies Organizer and Producer

6) Machine Tool Institute's Pilot Plant and Workshop Training Laboratory of the NC/CAM Centre
   6.1. Dimiter Penkov, Manager, NC/CAM Centre

7) Discussions on CAD/CAM systems, computerised systems for classification and coding of workpieces, structure and use of data bases. Recommendations concerning the second phase of the Project
7.1. Nikola Todorov, Division Chief - MTI
7.2. Dimitar Penkov, Manager NC/CAM Centre
7.3. Pencho Penchev, NC/CAM Centre staff member
7.4. Vladimir Cheshmedjiev, NC/CAM Centre staff member
7.5. Dimitar Dimitrov, NC/CAM Centre staff member
7.6. Atanas Batakliev, NC/CAM Centre staff member
7.7. Russi Michailov, NC/CAM Centre staff member
7.8. Sasho Markov, NC/CAM Centre staff member

C) The author also:

1) Delivered a lecture to 59 staff of the NC/CAM Centre and the Machine Tool Institute on the subject 'An Overview of CAD Technology'

2) Provided a selection of relevant literature (see Annex A)
OBJECTIVES

1. Advise concerning the latest CAD hardware and software applications available.

2. Advise concerning the Centre's organization to promote CAD.

3. Conduct seminars in CAD.

4. Prepare a final report of the mission including conclusions and recommendation concerning the CAD activities in the Centre.
FINDINGS AND CONCLUSIONS

Present Situation

1. Through the lengthy discussions held with the managers and staff named it is apparent that the Institute has a dedicated and enthusiastic team of people who have made themselves aware in considerable detail about the potentialities of CAD systems linked to a manufacturing and planning data base. In preparation for the next phase project the team now requires practical experience, through fellowships, of CAD/CAM systems in operation in order that they may plan correctly the acquisition of both hardware and software.

2. Three computer aided part programming systems were seen in operation and they appear adequate for the majority of 2,5 dimensional parts. Two NC part programming languages developed by staff of the Centre, one for turning machines and the other for drilling, boring and milling machines, are particularly suitable for dissemination throughout Bulgarian metalworking industry. The ELAN software on the Hewllet Packard 984ST desktop computer and the associated fellowships contributed substantially to this successful outcome. Extension of the Centre's capability into computer aided part programming for complex 3-dimensional parts and sculptured surfaces will await the arrival of the proposed turnkey CAD/CAM system and until that time there will be a significant gap. Fortunately only 15% of parts are classed as complex and, even for these, a measure of aid could be obtained from the present systems. Three dimensional software does not appear to be required as a matter of first priority.
3. Questions arose about the advisability of using CNC controllers for part programming. The writer feels that this would be a bad policy in general, although it may have to be permitted through lack of other facilities. CAD/CAM brings most of its benefits through greater management control of data, so that the trends in all large manufacturing organizations are to centralize the preparation of operations plans, including N/C programmes, using CNC controllers only for communication, programme storage and, when necessary, local programme editing. As a policy guideline this approach should also be adopted for Bulgarian industry and the Centre should take the lead in resisting the temptations to do otherwise.

4. The coordinate measuring machine was seen in action and is clearly a valuable tool. The associated PDP 11/34 will be of much greater use to the Centre when the multitasking operating system RSX 11M is available, even through more disc store will be required. The proposal to add an LSI 11/23 processor, with DECNET to link both processors with disc memory, is a sound one since the PDP 11/34 will be freed to provide a full time resource to other engineering functions. Using a PDP 11/34 to drive the CMM is a wasteful use of a powerful machine. It should also be noted that the LSI 11/23 is a relatively powerful processor for which NC part programming software is also available.

5. The organization of Production Services Units in the UK was discussed. These are units, some of which are commercial companies and one of which is operated by CAD Centre, which provide a part programming service to industry, allowing new or potential users of NC to assess costs, learn the techniques and deal with overload situations. Such a service could be a useful addition to the NC Centre's methods of disseminating the NC technology.
6. The HP desk top computer is being used as a word processor in the preparation of reports and other documents, adding significantly to the general efficiency of the Centre. It should be noted that a large part of the value of a future CAD/CAM turnkey system will be derived from document processing of various kinds.

CAD Hardware and Software

7. Most of the turnkey CAD/CAM systems commercially available were discussed. The writer had brought a specification of the recently advertised Ferranti Cetec CAM-X system (VAX) and the Cambridge Interactive Systems MEDUSA (PRIME). The team had carried out considerable literature research and some members had seen (for example) Applicon systems in operation. There was lively discussion of the relative merits of storage tube displays, refresh vector displays, raster displays and colour.

8. As with all technically strong organizations there is some preoccupation with technical features of systems and this needs to be matched by an equally developed understanding of the managerial aspects of CAD/CAM. It is a common experience that many different CAD/CAM systems have been used effectively but that success depends mainly on the extent to which management understands the purpose for which the system has been installed and is dedicated in carrying out all the organizational tasks needed to make such systems effective. In the Bulgarian situation the availability of support from the vendor is the most important factor and special attention may have to be given to the problem of developing home-grown support.
9. Discussion also brought out the point that a CAD/CAM system when delivered will require further work, over and above the normal training of design office staff. Some additional software development may be required and, more importantly, creating a manufacturing data base will require a lot of work over a period of months or even years. This observation has organizational implications that will be discussed below.

10. More thought also need to be given to the question of whether a CAD/CAM system is to be used to aid existing skilled staff or to try to produce drawings or plans automatically because skilled staff are scarce. The system will be used in quite different ways depending on the answer to the question. As the NC Centre is leading the way for Bulgarian industry it is important that this question be answered eventually, when more understanding has been gained.

11. The proposed programme for Phase 2 envisaged installation of a CAD system followed by work on part classification and process planning. The writer feels that this is the wrong way round. Most U.S. and Western European companies adopting CAD have existing computer aided manufacturing planning and production control systems of some sort, based on material and parts classification systems. Indeed, it is difficult to envisage a substantial benefit from a CAD system without such a prerequisite. Otherwise the benefit is simply in speed of drawing production which is generally accepted as a marginal gain. The real benefit of CAD always arises from better control of manufacturing information and this can only be done if the basis of manufacturing information system exists. Major recommendations are made in this area (see below)
12. The proposed CAD/CAM system will have to serve the needs of machine designers and manufacturing planners and provide some level of development resource for the engineers of the NC/CAM Centre. Within the available budget it is clear that the system must be viewed as a pilot project, used mainly for developing expertise, developing any software not available by purchase and developing awareness of the techniques pending acquisition of more systems in the future. The project will need to concentrate attention on certain applications in order to avoid the temptation to diffuse the available effort.

13. The restrictions on computers available are a major constraint on the Centre's ability to carry out its objectives. Most turnkey CAD systems are developing towards the use of quite powerful machines (VAX 780 or equivalent) in order to handle the data base requirements which arise in practice. The Institute will obviously need a data base of some magnitude.

14. The difficulty of dealing with vendors of complex systems at a distance was discussed and the writer emphasised the importance of:

a) a well written Requirement Specification accompanying the initial enquiry and the invitation to quote;

b) conducting tests on short listed vendor's systems before final choice.

There was much discussion of the appropriate size of processors and disc storage. The CAD Centre uses relatively large PRIME and DEC processors, ranging up to 1MB, with disc storage between 80MB and 300MB, supporting 6-8 terminals. This may not be typical of the NC Centre's needs which will probably feature larger data base with less programme development and fewer computer terminals. Sizing the system will be an important aspect of the Requirement Specification.
Organization

15. The NC/CAM Centre will find itself at the heart of a technology transfer process for the Bulgarian industry, in much the same way as CAD Centre has done in the UK. The CAD Centre's organization is therefore relevant. The following observations are made.

a) Graduate engineers, although they should be able to programme, are better employed to define functional specifications and to train industrial users.

b) Graduate engineers should be backed up by "professional" software system designers and programmers.

c) Part programming, with or without computer aids, should eventually be the responsibility of technicians.

d) Graduate engineers should be developed as consultants as they mature.

e) If a widespread industry is to be served fully, then intermediate organizations should be set up to take on part of the technology transfer role. In the Bulgarian situation these intermediaries would presumably be units located at the various machine tool factories and trained by the NC/CAM Centre.

16. Being dependent on bought in hardware and software systems clearly limits the rate of development. Moreover, in the field of manufacturing planning the software has to be developed to suit the organization concerned, even though based on existing packages. The Centre should be strengthening its software capability in order to address both these problems.
17. The CAD system will create its own operational demands and new staff functions. In particular the need is foreseen for:

a) an operator (junior grade)

b) an administrator to control operating standards and data base management

c) system programmers to provide local software maintenance and to enable interfacing of new applications software.

18. Without wishing to overemphasise programming it may be useful to arrange formal training, or at least to obtain appropriate literature and books on structured methods of analysis and program design methodology assuming that these subjects are not taught in engineering courses.

19. Training in the use of English (and presumably other European languages) is going ahead well and a number of staff are quite proficient. It is essential that this effort be maintained strongly if fellowships are to be of most value.
RECOMMENDATIONS

The following recommendations are mainly concerned with the preparations for a Phase 2 project and with organizational matters aimed at increasing the NC/CAM Centre's effectiveness during Phase 2.

1. During 1982 the Centre should concentrate on two new activities:

   a) preparing to specify and order a suitable turnkey system;

   b) beginning the analysis of parts classification and work flow in the Machine Tool Institute's work of design, planning and prototype machine tool production.

   The use of experts, arrangements of fellowships and study tours should be organized towards these two primary purposes.

2. The process of ordering a turnkey system should be based on a formal Requirement Specification which is developed for the initial enquiry and refined for the invitation to tender. This specification should detail the Centre's requirements both in terms of applications and in terms of the equipment details. Use of an expert in drafting such a specification document should be considered (see below).

3. Bearing in mind the wide range of requirements which the first CAD system must fulfill (see Finding 12) and also bearing in mind the limited budget, it is recommended that vendors be asked to supply several different work stations, for instance:
a) high resolution visual display unit (vdu) for general arrangement drawings and complex parts programming;

b) low cost, raster graphics vdu for simpler parts drawings and part programming;

c) alpha-numeric vdu for software development, process planning and operations planning.

4. The possibility of implementing the MICLASS and MIPLAN software on the existing PDP 11/34 at an early date should be seriously considered. A short assignment by an expert from TNO in Holland should be arranged to discuss whether such an implementation is feasible and what size disc store is likely to be required. The question of re-implementing the MICLASS and MIPLAN software on a future turnkey CAD system should also be raised with TNO.

5. Analysing parts classification and work flow in the Machine Tool Institute should begin during 1982 in parallel with obtaining software. A great deal will be learned from such analysis and it will be necessary in any case. The manual system resulting from such an analysis may be useful in its own right. The staff involved will be much better prepared for using classification and planning software and the CAD system when they arrive.

6. The CAD system, when it is obtained, should be applied initially in one area of machine tool design and manufacture - say tooling, or gearboxes - in order to demonstrate the value of CAD and manufacturing planning, integrated through a data base, in a manageable application.
Use of Experts

7. During Phase 2, experts should be used to train Centre staff, not to act as programmers. Otherwise the level of the staff skills will not be increased.

8. Experts should be selected carefully with a specific objective in mind in each case, linked to the primary purposes identified above. The following tasks have been identified as requiring expert assistance:

   a) advising on the application of MICLASS and MIPLAN to the Institute's work and determining whether the PDP 11/34 would be a suitable machine for operating the classification and planning systems; determining the size of disc store required;

   b) preparing the detailed Requirement Specification document; the person chosen should have been responsible for the preparation of such a document previously and have played a project managing role in purchasing a CAD system, preferably in the mechanical engineering industry; also specifying suitable tests.

   c) carrying out systems analysis to identify the data quantities and flows implied by the Institute's prototype machine design activities generally and the chosen application in particular (see para 6 above);

   d) setting up the CAD system and data base administrative control procedures and operating standards; training the Centre's System Administrator; and setting up user training arrangements;

9. Consideration should also be given to the use of non-visiting experts in various countries to monitor the progress of fellowships in order to ensure that the objectives
are being met and that full benefit is being obtained from each assignment. Only two or three days per assignment should be necessary.

Staff Deployment, Training and Fellowships

10. During Phase 2 more specialisation should be developed in the staff structure. Programming support should be established in order to allow graduate engineers to concentrate on applications.

   Technicians should take over part programming from graduate engineers.

11. Nevertheless, in order to make staff attractive to organizations being asked to accommodate fellowships the most useful skill is FORTRAN programming. Formal training and practice in FORTRAN should be given to anyone being considered for a fellowship, so that he can be rapidly integrated into the receiving organization’s work.

12. The following organizations are recommended in the UK to be investigated as possible fellowship sites:

   Organization          Topic

   CAD Centre - Cambridge a) CAD/CAM system design
                         b) graphical NC part programming
                         c) sculptured surfaces

   Delta Technical Services Tool and die making
   Birmingham

   PERA
   Melton Mowbray

Generative Process Planning
13. A fellowship should be arranged as early as possible during 1982 to prepare someone for the task of writing the requirement Specification for the CAD system. A suitable site in UK would be University of Manchester Institute of Science and Technology, Manchester which has Computervision and Applicon turnkey systems used also by industrial companies. This site could also provide suitable preparation for a System Administrator.

14. Formal training in systems analysis techniques (structured analysis) and programming methodology should be obtained. Such courses are given in Western Europe, usually by American consultants and the use of fellowship funds for this purpose should be considered by UNIDO.

Study Tours

15. Further study tours for the Centre's management and senior staff should be organized as early as possible in Phase 2 in order to influence the process of specifying a suitable CAD system and, in particular, to gain knowledge about linked design and manufacturing planning systems. The following companies in the UK are recommended if visits can be arranged.

Baker Perkins Ltd., Peterborough
Dowty Mining & Supplies Ltd.,
Normalair Garrett Ltd., Yeovil
White - BSA Tools Ltd., Coventry
ANNEX A

TRADE BROCHURES

Cambridge Interactive Systems Ltd.,
MEDUSA work station and software

Ferranti Cetec Ltd.,
CAM X System

Kongsberg Ltd.,
PC 200/125 interactive part programming centre

Shape Data Ltd.,
ROMULUS solid geometric modeller

Lucas Logic Ltd.,
DIAD intelligent work station

Computer Aided Design Centre
a) GINO user's reference card
b) GINO 2-D technical information
c) GEMS image processing system
d) PDMS technical information booklet
e) COMPASS, Computer Oriented Manufacturing Production and Scheduling System

TECHNICAL PAPERS

Computer Simulation of Automatic Lathe Machining Methods - Malcom A Bird, 1981

The Role of the Computer in Machine Tool Design, F.M. Stansfield, 1974


Starting CAD at a Lower Entry Fee - Magazine Article (Euclid), 1981

The Factory of the Future - Technological Aspects - M.E. Merchant, 1980


Computer Aided Engineering for Manufacturing Industries, 1980:
   a) A Surface Modeller for the Turbine Blade Industry - R.S. Davies and A. Clarke
   b) The Computer as a Production Tool - P. Simkins
   c) Computer Aided Integrated Systems - P.J. Gibbs

CAD Centre Services for Tool and Die Making - B. Gott, 1980

Flexible Manufacturing System Development in the UK - K. Rathmill, 1981

The Problems and Benefits of Installing a Turnkey Draughting System - R. Philpot, 1981

Scope of Computer Aided Engineering - J. Black, 1981


Graphical Numerical Control - R.G. Francis, 1978