CADD, Computer Aided Detector Design

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Abstract

Building modern particle physics detectors is "one-of-a-kind" engineering- no prototypes, no improved models. The detector must be right first time. -And yet the detectors are very complex, the teams which build themare heterogeneous and widespread and made up of people who may never meet.

1. Introduction

Mechanical CAD/CAM is, or will be, used by all the HEP detector builders in Europe. As experiments become bigger and technically more advanced, building a detector becomes a more complex project. Designing and manufacturing different sub-elements of a detector in different places in Europe - or the world - should be co-ordinated to ensure, before building anything, that the elements may be assembled and that they will function properly when together.

The engineering descriptions of elements are available in computer-readable CAD form and the designer of one element should have access to the data for neighbouring elements as his and his neighbours' designs evolve. Above all, simulations - as in the GEANT suite of programs - should be made on an assembly of three-dimensional representations of all detector elements to predict how the entire detector would behave in a hypothetical experiment. That would allow eventual drawbacks in physics performance to be found and remedied before the detector was built.

CADD aims to unite these ambitions in a design, engineering, simulation and manufacturing cycle for LHC detectors wherein the same detector descriptions would be available to physicists, engineers and, eventually, manufacturers in a corporate detector dataset.

This would allow physicists to try out design possibilities and submit these to the engineers, then monitor, by simulation, the effects which engineering implementations have on the detector's physics performance. They could thus iterate proposed equipment through from inception to simulated integration and data-taking before finalising the design and starting actual construction.

2. The Elements

2.1 Commercial Products.

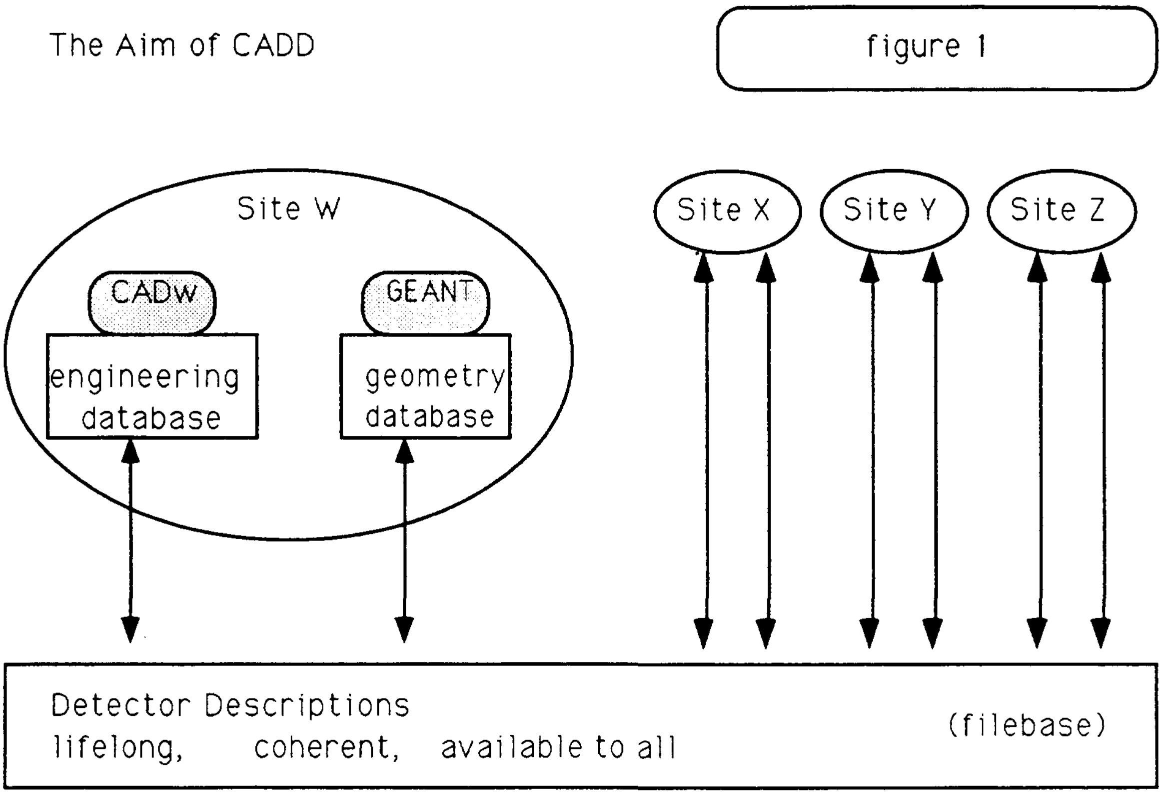
Important market products to be used by CADD are CAD packages running on workstations connected by networking facilities and all organised through database management systems. Instances of these product types are constantly evolving, ousting and being ousted. CADD aims to provide a robust "product-based" framework which satisfies the needs of HEP detector design and is well able to assimilate new products.

2.2 Simulation

HEP event simulation tools are evolving continually to meet the needs of the physics community. GEANT, the primary simulation tool considered for use in CADD, is having a new detector geometry database implemented with the aim of allowing greater freedom in the description of detector geometry. It is hoped that it will also ease communication with CAD systems. The version of GEANT with new geometry will be referred to here as GEANT4, to distinguish it where necessary from the current version, GEANT3. In GEANT the detector is described by the physicist as an assembly of volumes of material. Particles from simulated events are tracked through these volumes to examine the aptitude of the detector. As millions of tracks are followed at each examination, the tracking code must be very fast.

2.3 Detector Descriptions

To ensure the coherency of different aspects of a detector, we need a corporate dataset describing all equipment relevant to the detector. This dataset should allow complete information exchange from design time to installation time. It should be accessible to the software of the detector teams throughout Europe to allow "concurrent engineering" to take place. During the design phase the files describing a detector element will be kept in the institute which is working on that element, for it is from there that it will be most frequently accessed. Thus the dataset will be distributed. See figure 1.



For technical, financial or technical support reasons, LHC partners have different CAD tools (see appendix A). These reasons prevent CADD from imposing a unique CAD system on the partners. Besides, it is impossible to predict which, if any, of the currently available systems will exist a decade from now. Thus there is the problem of communicating CAD data from one system, with its own view of the world, data structures and techniques, to another. One might have a direct interface between each pair of systems or an interface between each CAD system and a standard "neutral" file format. Since about ten CAD systems are involved in CADD, the standard file format approach clearly involves fewer interfaces.

Expensive detectors and accelerator equipment are long-lived, their upkeep requires a far-sighted commitment and so the datasets describing them must be kept permanently for eventual use in calibration, in new CAD systems and in mid-life modifications.

3. The CADD Initiative

CADD was launched at CERN in December 1990. It was hoped it could be in operation in time for the design of LHC detectors, Indeed, the count back from installing experiments in LHC in 1997 requires that CADD have some working parts in 1992 and offer several reliable facilities in 1993.

For the reasons mentioned above, it was decided to use Neutral Format computer Files (NFF) as the medium through which CAD systems would exchange data. NFF are used on an everyday basis in large industrial concerns like AeroSpatiale and the German car manufacturers. (Nevertheless: BOEING is in the process of standardising on one CAD system - CATIA - for all operations in the Boeing 777 project, specifically to avoid the problems of transferring data between different CAD systems)

Since direct experience in this field was lacking, it was decided to begin with an investigative implementation of a CADD data transfer facility to find out what the problems might be. The French standard SET was chosen as Neutral File Format for this experiment since SET provided a means of expressing geometrical entities in Constructive Solid Geometry (CSG). CSG is close to the idiom used in the present GEANT3 geometry database to describe detector elements - and the inclusion of GEANT in the design cycle is an essential part of CADD. The ANSI standard format, IGES, also supports CSG transfers, but we knew of no IGES interface which transfers 3D solid geometry.

4 Standards

The question of standards is non-trivial

a) Engineering standards are large, formal and complex (Version 4.0 of the IGES standard contains 500 pages of detailed specifications) thus expensive to implement. So a CAD vendor tends to implement only that part of a standard which is required by his most important customers. Hence the exchange of data with another system is restricted.

b) There has been a growing awareness that it is not enough to define entities which may be exchanged in a standard, but there also must be rules for their use. In other words there must exist a grammar, syntax, usage and all the other elements which allow people to communicate clearly and precisely. In present standards such rules do not exist.

c) The nature of a CAD system may be such that it simply cannot cope with certain kinds of geometry. Indeed vendors try to produce - and users to buy - a system with a distinctive quality which gives it an edge over other systems. This diversity is a wealth: we have to learn to deal clearly with the resulting diversity.

It is intended that the forthcoming ISO CAD data exchange standard, STEP, be adopted in the future, though we do not expect that STEP implementations will be common enough to be useful to CADD before, say, 1994 - too late for early work on LHC.

With the STEP standard the exchange problem should diminish and several tools and methods have evolved during its gestation period. These methods and concepts which are being developed for STEP should be kept in mind in all of current CAD/CAM and simulation developments. STEP will embody, notably, Application Protocols which define exactly what entities will be expressed in a given field of work, and how the CAD system should express them. STEP entity definitions are written in a formal data description language called EXPRESS. Meanwhile CADD faces the problem of making different CAD systems communicate in the currently defined standards.

4.1 Inside GEANT

At present GEANT3 uses sixteen basic geometrical solid forms, combinations of these forms, and only these forms, describe the detector volumes . Highly optimised tracking code calculates in which volume particle is, how far it is from the volume surface etc. as the particle is followed. The sixteen forms accumulated because they were needed in describing detectors and because they were amenable to fast tracking code. Such a description of a detector may be mapped onto the Constructive Solid Geometry, or CSG, description used in some CAD solid modellers. In principle GEANT should be able to exchange data with these CAD systems. This is desirable, not only to preserve the accuracy which may be lost in manual transcriptions but because the amount of data can be very large - there are around 1,000,000 volumes in the GEANT model of L3.

Work on GEANT4 continues and the new geometry - this time based on a surface description of the detector volumes - with corresponding tracking code may be in production by the end of 1992. (A prototype tracking implementation has a speed competitive with the traditional tracking through the L3 detector). These new volume descriptions would free the physicist - or the engineer or the CAD system which wants to communicate with GEANT - from the tyranny of the sixteen canonical forms, while keeping them available as "surface-macros" where convenient. It will also free the GEANT team from the upkeep of some very specialised pieces of tracking code. The surface descriptions of volumes are close to another style of CAD model representation, Boundary Representation or B-rep. We hope that the

GEANT4 geometry can be implemented in such a way that it may be simply mapped to B-rep. and thus communicate freely with several CAD systems.

4.2 The use of the SET standard.

The Euclid interface with SET is fairly complete and can read most of the design data from GEANT3. However the SET interfaces of other CAD tools such as I-DEAS and Pro/Engineer do not cover enough of the SET standard to read this data. Given that the CAD world is waiting for the imminent STEP standard, it is most unlikely that the CAD vendors can be persuaded to devote resources to further development of their interfaces to obsolescent standards.

Faced with CAD systems which produce, and consume, partially matching subsets of the data exchange standards, CADD can only try to make the maximum use of these incomplete facilities. Thus data will be produced from each CAD system in any of the formats which we find to be of any use to our partners. There are at least five commonly implemented data exchange standards, IGES (ANSI), SET (AFNOR), DXF (AutoCAD proprietary format), VDA/FS and VDA/IS (DIN).

IGES is the most commonly implemented neutral format so it is considered, with SET, as a primary means of communication between CAD systems for CADD. Euclid is the only CAD system we have now which is able to read the SET solids from GEANT3, so it will have to fulfil the office of "gateway" from GEANT3 to the CAD world. (CATIA should also be able to read the solid data from GEANT3 in its SET interface but we have no CATIA-SET interface in the community.) CAD vendors normally market interfaces to data exchange standards as additional options and prices so far observed vary between 5 and 50 kCHF depending on the system and the discount offered.

4.3 The GEANT3 to SET Interface

The interface from GEANT3 to the SET standard is finished in its first form. GEANT3 shapes written in SET can be read by Euclid. Thus GEANT3 is able to communicate its data to one of CADD's principal CAD systems. At present (AUG92) 15 of the 16 solid shapes with which GEANT3 works can be written to SET and read by Euclid.

The interface runs where GEANT runs; VM/CMS, VAX/VMS, UNIX. etc. and has been fairly thoroughly tested by Michel Maire and Vincent Boninchi of IN2P3. It allows the operator to select nodes from the GEANT3 tree diagram and to have these nodes displayed on the screen. When he is satisfied with what he can see he writes the data displayed to a SET file.

The amount of data which could be sent in a single SET file is restricted by array sizes in Euclid, for instance the number of points in the active data space is limited to 65000. "Divided Volumes" which are a GEANT feature, may generate a very large SET file if all the divisions are instantiated, so a subset of the result of the divisions may be selected.

The Eagle GEANT3 model has been transmitted to Euclid as has data from L3, OPAL and ALEPH.

From Euclid, data may be transmitted to other CAD systems such as I-DEAS or AutoCAD, via IGES. This is Wire Frame and 2-D data, not the original 3-D solid model. The wire frames which Euclid derives from CSG models as polyhedral approximations lose some information in the process. Work has to be done to reconstitute the volumes of interest but it does mean that the GEANT3 model can be brought into the engineering CAD context, serving as a reference representation when associated engineering work is done in preparation for manufacture.

4.4 "Flavouring" Standard Files

A CAD system can map a subset of its own view of the world onto a standard file format but this standard data may have to be adjusted before it can be read successfully by another CAD system. There is a program, CONVIGES, written at CERN to transform 2-D data written in the IGES standard by Euclid into data in the IGES standard which can be read by AutoCAD, and vice versa. This program can make formal changes such as changing file sizes or styles of text; it has already been found useful for engineering data exchange between these two programs has been used to help exchanges with I-DEAS, Pro/Engineer, etc. Since CONVIGES was developed, NFAS, produced by BMW in Munich for their enormous in-house data-exchange problem has come onto the market. NFAS appears to be a serious piece of software of industrial strength and is being tried out at CERN at the moment.

It seems clear that is it strategically correct for us to foresee the use of NFAS for IGES exchanges rather than continue the indefinite development and upkeep of CONVIGES. We expect that our experience with IGES will grow considerably in the coming months and that our knowhow, incorporated in NFAS command files, can be shared more easily with our collaborators than if it were hidden in a FORTRAN program. We will, of course, continue to use CONVIGES for any task to which it is better suited than NFAS.

We have not had a great deal of experience in the wholesale exchange of design data through IGES, and even through SET, since work so far has been confined to entities which emanate from GEANT3. Recent contacts with the Eagle protocollaboration gave some hands-on experience of IGES, initially in making their "parameter diagram" available to all members. The parameter diagram, which shows the principal dimensions of Eagle detector elements, is produced in Euclid and thus easily available to Euclid users. It has also been read by I-DEAS at NIKHEF from an IGES file produced by Euclid with very little effort.

4.5 A CAD to GEANT3 Interface?

There are a number of difficulties in going from a CAD system to GEANT which do not exist in going from GEANT to a CAD system.

a) The interface from GEANT3 to SET was designed to be as simple as possible; this involved unravelling the GEANT data structure, transferring the forms to the SET format and writing out the small number of entities onto which the GEANT3 shapes were mapped . The commercial Euclid-SET interface can read this data easily. Writing an interface for GEANT which can read a SET file written by a commercial CAD system is more difficult. It is not possible to constrain the CAD system to restrict itself to writing only certain entities and so we must be prepared to deal with the full standard. This means writing a lot of software.

b) Even if a complete interface were to exist so that GEANT3 could read everything written by Euclid, say, there is still a problem. Only those objects whose morphologies correspond to the 16 shapes can be understood by GEANT3 and used by its tracking routines. Furthermore the shapes need to be identified as BOX, Tube etc. One way around this difficulty is to constrain the CAD systems, when preparing models for GEANT3, to use only GEANT3 shapes: this is discussed below.

So no code has been written to allow GEANT3 to read SET data. One-way transfer already promotes coherency between GEANT3 and CAD and we feel that it is the wrong time to invest effort in trying to provide a general input capability for GEANT3. But there is a clear need for a general interface from CAD to GEANT. Even when a physicist-friendly input interface exists for GEANT4, the right place to do the engineering work will be in the engineering CAD system. We should have facilities to transfer that work into GEANT4 rather than having to enter it over again by hand.

5 Current directions, Current Work

Data can now be moved from GEANT to Euclid.

To allow Euclid to act as a gateway from GEANT to the other CAD systems we must establish IGES data transfer skills; we will use NFAS for this. An important aim of CADD is to help exchange design data between engineers using different CAD systems, independently of the GEANT connection. NFAS will be used for this also. A framework (CIFAS) has been built up incorporating NFAS and CONVIGES to provide easy transfer mechanisms between different CAD systems for an engineer or draughtsman. At present CIFAS is limited to those systems running at CERN (Euclid, AutoCAD and Pro/Engineer) but as soon as user feedback and experience have sufficiently hardened it, other CAD systems will be catered for.

It seems clear that no general interface can be made from all CAD systems to GEANT3 in a reasonable time and budget. However GEANT4 will use surface descriptions rather than a fixed set of shapes. It will certainly be easier to map any object made in a CAD system onto a set of surfaces which can be understood by GEANT4 than to express that object in terms which GEANT3 could understand - but GEANT4 is still being developed and the details of its interface with CAD can not yet be fixed.

It is planned that GEANT4 will be running at the end of 1992. Before that, we hope that the CADD team will have gained enough experience in IGES exchange to have some understanding of the different natures of the CAD systems used by our collaborators. This experience should make the team better qualified to write a general interface for GEANT4.

It may be that much of the design of detectors for LHC must be done before GEANT4 is working. Work is going on, or planned, in Aachen, Helsinki, INFN and IN2P3, to implement solutions specially for the CAD systems which they use and which will allow GEANT3 shapes to be produced in the CAD system and input to GEANT. These solutions are described below.

Appendix B shows some target dates.

5.1 An ItalCAD-GEANT3 Interface (INFN)

INFN uses the ItalCAD CAD systems (S7OOO, 3D-PSM) and no SET interface is foreseen for these. Indeed ItalCAD's development effort has been devoted to early implementations of a STEP interface.

Rather than wait for the general availability of STEP, INFN have asked ItalCAD to write a direct interface between GEANT3 and the ItalCAD products; work began in June 92. Data will be sent to GEANT3 in a form which it understands by implementing a special menu which allows the CAD user to select GEANT3 forms with which to build his model.

This gives ItalCAD users a facility for entering models into GEANT which is more user-friendly than the traditional FORTRAN code which has to be written for GEANT3. The fact that 3D-PSM will soon have a STEP interface brings GEANT closer to STEP and it is hoped that ItalCAD personnel working in GEANT will help to transfer some of the STEP-appropriate technology to the GEANT world. In particular the architecture of the ItalCAD STEP implementation uses an Internal Data Structure - essentially a set of subroutines which may be called from FORTRAN or C - to store and retrieve geometric data; any future development of GEANT would certainly benefit from including lessons from this structure.

5.2 AutoCAD to GEANT3 (Helsinki)

The principle of creating GEANT3 shapes in the CAD system and expressing a design n terms of those shapes was seen as the only way to move data from the system into GEANT3. Helsinki decided to use this approach in the AutoCAD 11.0 system for the design of their Silicon Tracker. There are two stages in the Helsinki plan.

5.2.1 Phase 1

A model of the Silicon Tracker is implemented in AutoCAD using AutoLISP. While the morphology of this model is fixed, the dimensions of the shapes are considered as variables. The user may vary for instance the radius of an array of silicon pads or the pad size; the values which he chooses are written to a file which may be read by a special GEANT3 routine.

This "parameter file" contains enough information, shape type, position, material, dimensional parameter values etc., to generate calls to the appropriate GEANT routines to create all of the shapes in GEANT. Thus the GEANT3 version of the model is created with the same shapes, of the same dimensions, in the same positions, as were used in AutoCAD.

5.2.2 Phase 2

This is a more general addition of the above scheme. In a special AutoCAD menu, the designer may choose any of the GEANT3 shapes. An AutoLISP program written at Helsinki will ask for all the dimension and position information required to implement the chosen shape in AutoCAD - and also in GEANT3. Thus an AutoCAD model is built up and a parameter file prepared for GEANT3 which contains the identity, dimensions, material and positions of all of the constituent shapes.

This second scheme is foreseen to allow the engineers to add support structures to the Silicon Tracker. The particle detecting part of the Silicon Tracker is entirely modelled in Phase 1 but this does not need to be finished for piecemeal development to be done on Phase 2

Indeed several GEANT3 shapes have been created in AutoCAD (BOX, TUBE, TUBS, TRD1) and passed to GEANT in parameter files. The shapes have been created and positioned in GEANT. Work continues.

5.3 GEANT3 and Euclid (IN2P3)

5.3.1 Reading GEANT3 data into Euclid

Files in the SET format containing the endcaps of L3 were produced in GEANT3 and transferred to Lyon. There they were read into Euclid for comparison with the original manufacturing data for the endcaps. During this exercise IN2P3 was able to give invaluable feedback to the GEANT3-SET interface team.

The data transferred to Euclid [EREG] was precise and complete. It was clear that the model data in Euclid faithfully represents the assembly as it had been defined in GEANT3. Very precise data could be found on all items - in particular the reference points around the central detector to line up the BGO crystals were present and correct. The elements could be manipulated with ease in Euclid and their GEANT3 names had also been correctly transmitted.

It was quite clear that the GEANT3-SET interface brought together the two representations of the data which had previously been distinct: - GEANT3's overview of an assembly of volumes and Euclid's mass of detailed descriptions of the individual elements.

The obvious complementarity of the two models when viewed together in Euclid shows the value of the interface for ensuring the coherence of work done in GEANT3 and work done in Euclid (and any CAD system with which Euclid can communicate effectively).

5.3.2 Preparing input for GEANT3 using Euclid

Encouraged by the success of the GEANT3 to Euclid transfers, IN2P3 are investigating the Euclid to GEANT direction. The IN2P3 scheme is similar to Phase 2 of the Helsinki plan, but is implemented in Euclid.

At present (AUG92) work has started to set up a first, simple implementation for one GEANT3 shape as a feasibility test. In a special "user application" one basic shape will be modelled in Euclid and the identity, dimensions, position, mother/daughter relationships and material of the shape passed to GEANT3 in a parameter file - using the same format as in the Helsinki/AutoCAD plan. The parameters will also be saved in the Euclid database as "attributes".

The aim is to show that certain basic techniques work. These include dealing with mother volume-daughter volume relationships and manipulating the transformation matrices which bind them. Division in the GEANT sense will be implemented right from the start. To avoid the rather heavy calculation which would be needed to instance every single division of a divided object, division may be represented inside Euclid as the first instance of the result of division of the element - for each level of division. The division characteristics would also be stored as Euclid attributes and passed to GEANT3 in a parameter file.

Once the feasibility in Euclid is established and the effort required to make a more complete system can be reckoned more accurately, the task of implementing more shapes will be considered.

5.4 An AutoCAD Workbench (RWTH/Aachen)

Christoph Kukulies set out to make his own SET-AutoCAD interface after finding that the commercial alternatives did not handle solids. Chris has written some tools to analyse SET files and aims to make this part of a SET workbench with a bi-directional interface to AutoCAD and a 3D viewing tool based on public domain software.

AutoCAD is a cheap and widespread CAD system running in many labs, Some labs have it as their main system, others like CERN which has around 200 seats uses it as a cheap and convenient complement to Euclid. An interface between AutoCAD and SET would be a particularly attractive boon to the CADD community.

5.5 Communication with Medusa and I-DEAS (Rutherford Appleton Laboratory)

RAL has two CAD systems, Medusa, which is their normal engineering tool and I-DEAS, a 3D modelling system for which they have a single licence. It was hoped to set up a 3D link between Euclid and I-DEAS with a view to transferring derived 2D data on to Medusa. This failed because of the incomplete I-DEAS/SET interface - I-DEAS could not read the SET files written by GEANT.

RAL had some CAD data for OPAL in Medusa and we tried to out how it compared with the GEANT3 model of OPAL, Part of the OPAL model was transferred from GEANT to Euclid where 2D and wireframe data was derived from the solid model and written on an GES file. But Medusa could not read correctly enough information to make the transfer useful. We will retry this exercise when more IGES transfer expertise is built up in the CADD community.

5.6 OCTAGON Absorbs CAD Geometries into GEANT (Florida State Uni)

Schemes in Europe (above) aim to constrain the user and his CAD system to produce only GEANT3-appropriate shapes. Even where these constraints are only applied to volumes destined for GEANT some feel that the designer's style would be so cramped that he would refuse to use such a system. Time will tell if these feelings are well-founded.

At FSU, Womersley and colleagues [references 1] allow the designer to use whatever morphology he likes. The object is then decomposed in an "octree" manner into the set of boxes which will fit most closely into the envelope of the object. A box is an object which is recognised by GEANT and in which there is efficient tracking, but the number of boxes required to fill out the envelope of the designed object can be extremely large. Specifically the OCTAGON package absorbs DXF files produced by AutoCAD or VersaCAD or other CAD system. reconstructs a 3D object, and then represents this 3D object as a tree of boxes. This tree can then be positioned in a standard GEANT volume and installed as a part of any GEANT geometry. The user must be careful not to leave redundant lines in his drawings as these can confuse the OCTAGON package. OCTAGON is running at CERN but none of us is expert in its use.

A company called Quantum Research Services is interested in the CAD to GEANT problem and, with the encouragement of Womersley & Co, has produced a CAD Or GEANT Entity Translator (COGENT). Here again DXF files are scanned and this time up to six basic GEANT shapes can be recognised and reconstituted from the 2D views. This also runs at CERN as a demonstration package but while it is clear that the principle has been proved it is not yet an off-the-shelf tool. Q.R.S. hope to get a grant from the DoE to improve their product.

6 The Data Management Problem.

Design data files should be widely and quickly available and so CADD needs a directory to identify files and locations in its distributed filebase. The existing FATMEN (File And Tape Management Experimental Needs) system, written for physics data access, is adapted for CADD needs. FATMEN provides a directory and file transfer capability. The central directory records the location, etc. of the files and the file transfer mechanisms insulate CADD from evolutions in the networking world. The hierarchical naming scheme used in FATMEN helps the user to identify the contents of a file. A FATMEN directory for the management and transfer of CADD design files has been set up.

At present CADD files are stored in an anonymous FTP account at CERN which is accessible to the CADD community. These files include SET files from GEANT3 and Euclid, IGES files from Euclid and AutoCAD and PostScript files which correspond to the CAD files. The PostScript files can be read independently of the CAD system and help the designer see if the data reconstituted by his CAD system is the same as that seen in the sender system.

CAD design files will constitute the first, basic information to exist for a detector. These distributed design files will be related (often implicitly) in more ways than can be expressed in a hierarchical filename scheme such as can be provided by FATMEN. A relational database would allow the expression of all relationships of equipment in the CADD filebase and would be the natural starting point on which to found a complete Detector Database. (For detector elements, information such as position, detector parentage, data channel number, manufacturing history, material, calibration data etc. would eventually be needed).

No database has yet been implemented. So far we have had a small amount of data to handle so have not needed a database. This will change soon and a database facility is becoming an urgent need.

ORACLE, the DBMS used at CERN, is the obvious choice in which to implement the CADD db. This poses the problem that ORACLE is an expensive product which would not be bought by many Institutes. However any member of the HEP community has the right to execute Oracle remotely at CERN under the site licence agreement. Now a user in, say, Helsinki, might have a rather slow response if he were to execute Oracle at CERN but should not need this access more than a few times per day since he could access files he already knew via FATMEN without recourse to Oracle.

At CERN a High Level Product Model is being defined [reference 2] to formalise work previously done by the Parameter Group together with whatever methodologies and data are found to be necessary to arrive at and maintain a common understanding in the collaborations.

Conclusions

There are many elements in the CADD initiative. Some, like networks and workstations, will evolve independently and improve. The state of exchange interfaces is clearly unsatisfactory in general, they certainly do not constitute a tool which HEP designers can simply pick up and use. It is up to CADD to avoid the difficulties in this field and make use of whatever channels are found to work for its benefit. This requires detailed work. The aim to set up a framework for the concurrent engineering of detectors must, as far as possible, take into account the development work being done for STEP. When it comes, STEP should improve the situation, but it is not expected to be a panacea and our work using the current standards will help to understand better the different natures of CAD systems and how they, and the different engineering traditions of Europe, may best cooperate. It seems unlikely that all of the elements of a full CADD system will be ready in time for early work on LHC detectors, but those parts of CADD which are working will help to make better detectors.

Acknowledgements

CADD set out to provide communication paths between different Institutes, software systems, professions and traditions. This involves many people hitherto unknown to one another but, because of the active goodwill of so many to contribute, share and discuss, I feel that the area has become much clearer over the past year and a half. The work I have reported on was largely done by the small CADD team at CERN, Nils Hoimyr and Ulf Hordvik and Jouko Vuoskoski of the GEANT team. I would like to join with them in taking this opportunity to thank all of those who contribute to CADD. The encouragement we received from the CERN management has been particularly generous and we would like to thank Federico Carminati, responsible for the development of GEANT and Roland Messerli, leader of CERN's Mechanical Computer Aided Design Project for their indispensable help.

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Appendix A

CAD systems and their users

Euclid	CERN, IN2P3 (14 sites), Saclay, Geneva Uni. Serpukhov
I-DEAS	DESY, NIKHEF, RAL (1 seat)
CATIA	ETH, Zurich
3D-PSM	INFN (15 sites)
AutoCAD	CERN, Aachen, MPI Munich, Zeuthen, Oxford Uni, Krakow, LIP-Coimbra, CIEMAT Madrid, SEFT Helsinki
Unigraphics,	Los Alamos
ND TechnoVision	DESY
S7000	INFN (15 sites)
Medusa	RAL
PAFEC	Imperial College London.

Appendix B

Some Target Times

1992

September	IN2P3's Euclid to GEANT3 limited prototype working.
October	LHC experiments ready for approval, much design work finished
October	Helsinki's Silicon Tracker Designer working in AutoCAD for GEANT3
October	CERN offers IGES exchange service.
December	IN2P3's Euclid to GEANT3 full prototype working.

1993

January	GEANT4 starts to work
May	INFN has an interface between 3D-PSM and GEANT