CUSTOMISED WORKSTATIONS FOR CAD AND A.I.

CONVERTED I.B.M. PC MACHINES AS AN ALTERNATIVE TO "LOW COST" PURPOSE MADE ENGINEERING WORKSTATIONS (SIMILAR PERFORMANCE FOR HALF THE COST)

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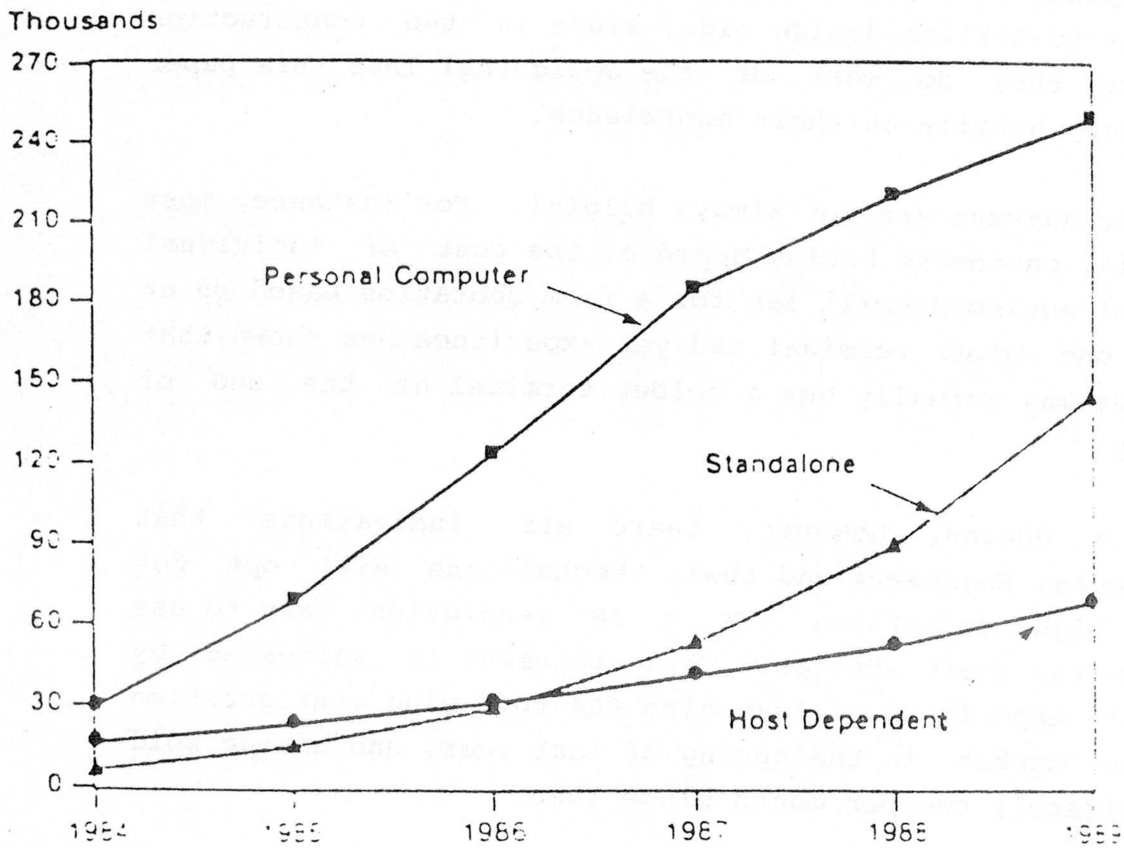
Unless they have been working on the reverse side of the moon in recent months, there can be little doubt amongst the world's construction industry leaders that the CAD war for their hearts and minds (and pockets) is beginning to warm up. And those who now control the various Profession's somewhat depleted coffers may find their hold diminishing under increased pressure from the personal computer (PC) based, desk top end of the market. These systems are adding a new dimension to the traditional field of battle which is rapidly developing into a three cornered fight.

The computer industry has long ridden into the CAD affray on the back of mighty mainframe computing engines, or more recently, on the powerful engineering type of workstation, both of which may shortly have to give way before a host of small machines. Although it is possible that the traditional "octopus" type of mainframe configuration, supporting a number of terminals, may temporarily hold on to its market share, the "stand-alone" desktop machines in the form of PC AT's and more specialist engineering workstations have recently become a major force in the CAD industry (see Figure 1). This paper attempts to explore this phenomenon and tries to investigate the likely impact of these lower cost (networked?) machines on the rapidly awakening CAD, and A.I. scene in the construction industry.

Fig .1.

CAD/CAM WORKSTATION SHIPMENTS



Source DATAQUEST

Low Cost - The Real Issue?

The purchase of many PCs especially in Construction at the present time is justified on the basis that they offer a system for a number of applications, namely word-processing, office automation, technical calculations, and some CAD capability, but the possibility still exists that the real issue is expense. Over the last 20 years, U.K. Architects for instance have seen a decline in salary in real terms of over 17% for Principals (the people making the decisions on CAD expenditure), and Architects are in the front line when it comes to selling design aids, since in the construction industry they do most of the designing! Thus this paper draws very heavily on their experience.

End user surveys are not always helpful. For instance, most potential customers having heard of the cost of individual items of equipment will ask for a firm quotation based on at least one colour terminal and yet experience has shown that only 50% may actually buy a colour terminal at the end of the day.

Given a choice, however, there are indications that Architects, Engineers and their Technicians will opt for fast, high definition (IK x IK resolution) easy to use systems for their offices. This statement is validated by Arcaid's experience of launching the following configuration on the market in the spring of last year, and having sold approximately two per month since then.

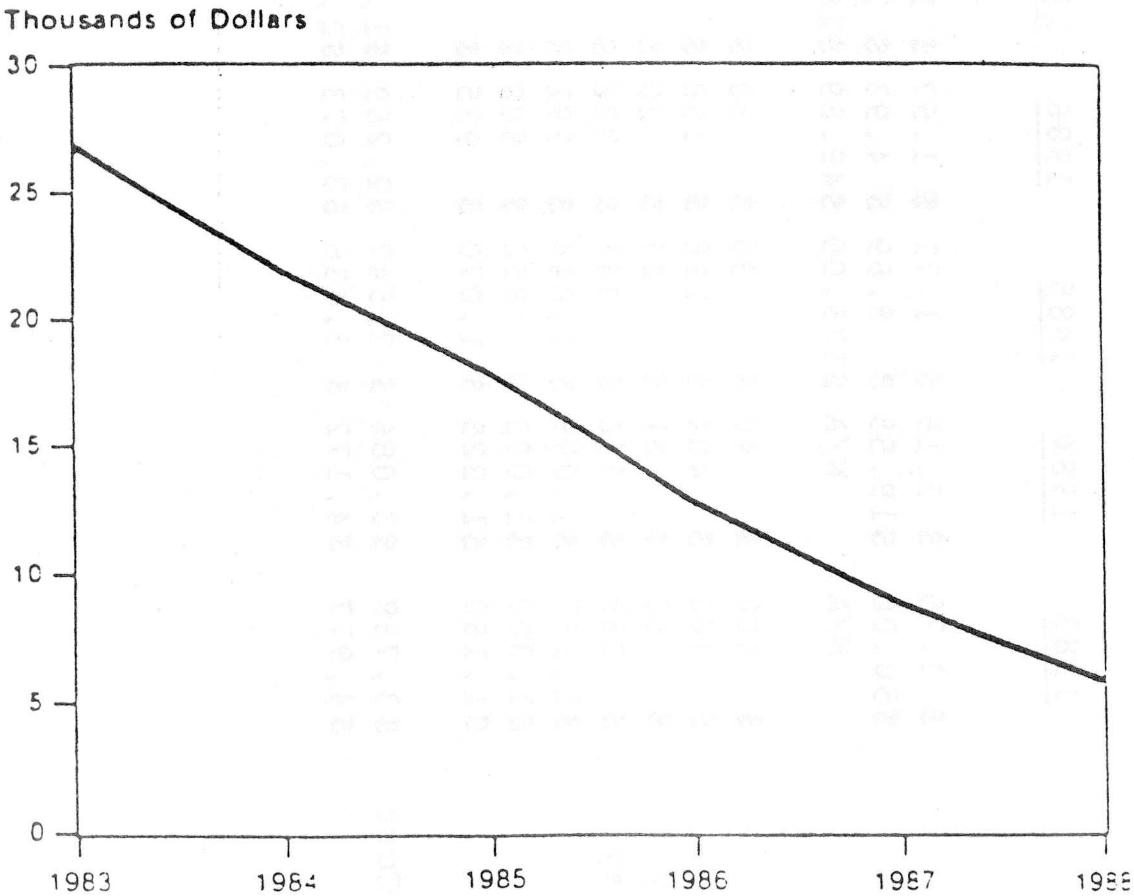
Cost	£8,000
Computer:	1 Mb min. CPU 32 bit processor based with 40 Mb disk - 30ms av. access time
Screen:	19" 1024 x 780 black-on-white Mouse driven cursor

WORKSTATION COMPONENT AVERAGE PRICES
(Estimated Prices in $US in OEM Quantities)

Component	1983	1984	1985	1986	1987	1988	1983-88 CAGR
Memory							
64K	$ 3.75	$ 3.16	$ 1.71	$ 1.57	$ 1.48	$ 1.52	(16.5%)
256K	$50.00	$19.55	$ 8.69	$ 4.93	$ 2.96	$ 2.47	(45.2%)
1M	N/A	N/A	$175.00	$48.89	$26.75	$16.13	(54.8%)
32-bit MPU	$ 400	$ 40	$ 36	$ 30	$ 25	$ 20	(45.1%)
1MB Main Memory	$ 480	$ 404	$ 218	$ 158	$ 95	$ 79	(30.3%)
128K Image Memory	$ 60	$ 51	$ 27	$ 20	$ 12	$ 10	(30.3%)
Monochrome Display	$ 388	$ 366	$ 346	$ 326	$ 308	$ 290	(5.6%)
Color Display	$1,157	$1,099	$ 1,044	$ 992	$ 952	$ 923	(4.4%)
50-MB Winchester	$1,300	$1,000	$ 850	$ 800	$ 700	$ 650	(13.0%)
LAN Connection	$1,160	$1,225	$ 1,070	$ 935	$ 840	$ 760	(8.1%)
Avg. Monochrome Cost	$3,788	$3,086	$ 2,547	$2,269	$1,980	$1,809	(13.7%)
Avg. Color Cost (256 colors)	$4,977	$4,172	$ 3,436	$3,073	$2,707	$2,511	(12.8%)

Fig 2

AVERAGE ENGINEERING WORKSTATION SELLING PRICE FOR A FIXED CONFIGURATION



*Configuration includes 1Mb main memory, 50Mb disk, 1K x 1K monochrome display, 16Mb virtual address space, LAN connection

Source: DATAQUEST

Colour offered at £2,000 extra (only 50% take this up)

While there is currently no one system manufacturer in the market that can meet these parameters at the price, since most engineering workstations cost twice as much it is entirely possible to put such a system together with help from a few existing specialist and accessory manufacturers.

As Professor Fred Heath of Heriot-Watt University put it recently, "given the rapid decline in component pricing (listed, Figure 2), together with the increasingly competitive nature of the market, it is probable that the average price of a 32-bit system, equivalent to the above configuration, will drop about 26% per year from its current level to approximately £4,000 by 1988 (as illustrated in Figure 3). This decline has profound implications for Industry, (and is not limited to the hardware side only). For instance, making and selling components at the production end can be said to be a fairly profitless activity, utilising almost no manpower resources. The 256K memory chips developed two or three years ago were expected to sell for $100 each at launch. A few months ago they were selling in bulk at $3.50 each while the price to produce is probably near to $11. A major manufacturer lost about one thousand million dollars in 1985 year and completed a plant which at full strength could make half the world's needs in memory chips. About nine other companies did the same.

The market area which makes money is where an end-user product with plenty of scope is marketed with proper financial backing. This generates as much employment as can be expected in today's automated world, and creates plenty of profit for support of research and development (and indirectly University research). There is a paradox however. Often the idea that makes revolutionary new

The U.K. CAAD Market

The 1986 RIBA figures break down this market as follows:

Small private practices (1-5 qualified staff)	2300
Medium private practices (6 - 10 qualified staff)	670
Large private practices (11 + qualified staff)	460
Unclassified private practices	3000
Local Authorities and Government departments	660
Architects in Industry and statutory bodies	360
TOTAL	7450

FIGURE 4

systems possible, while sometimes brilliant, is not expensive to develop on its own. The difficulty and expense is in conceiving and creating the end-user product and designing the hardware and software sub-systems. (It is not unusual with a system of original hardware cost of about £25,000 in its first incarnation to end up with a final software bill of the order of 10 or 20 times greater than that!)"

Where is the Computer Aided Architectural Design Market - Small v. Large Vendors

When scrutinizing the penetration potential of low-cost systems it is important not only to consider the total market size, but also where the market may be found. In the U.S. 48% of the 2.8 million engineers and draftsmen work in large establishments with 1,000 employees or more, and only 17% work in establishments with 100 or less employees. In the Architects Offices in the U.K. almost the inverse is true, i.e. 75% work in offices with 5 of a staff or less (see Figure 4) and similar figures have been obtained for Architects in the U.S. Although CICA's information to date has indicated that the traditional incidence of installed CAAD capability is with the larger establishments, (see Figure 5) the recent advent of "cheap and cheerful" systems on the market has meant that there is now a higher incidence of installed CAAD capability in smaller practices (1986). Nevertheless the number of installed workstations per Architect/Technician is still very low (approximately one in thirty or just over 3%).

In the U.S. it does not necessarily follow that the market for low-cost systems lies with smaller companies (since networking is more advanced there). In the U.K. architectural market this is definitely the case. (N.B. Lower cost in this context does not always mean lower productivity. A PC AT with suitable enhancements benchmarks

CALCULATION OF BREAK-EVEN PRICING FOR CAAD SYSTEMS

		(1) Manual Methods	(2) Arcaid £17,500	(3) Arcaid 2stn £22,500	(4) Autre CAD £20,000	(5) A N Other £50,000	(6) A N Other £50,000	(7) A N Other £50,000	(8) A N Othe £50,000
					£'000				
Annual Costs: Depreciation		-	6	6½	6½	17	17	17	17
Wages		15	15	30	15	15	15	15	15
Overheads:									
Heat and Light	500								
Rent & Rates	2000								
Telephone	500								
Stationery	500								
Sundry	500								
		4	4	4	4	4	4	4	4
System Maintenance		-	2	5	2	5	5	5	5
Interest (Average over 3 years)		0	1	1½	1½	4	4	4	4
TOTAL ANNUAL COSTS (£'000)	(1)	19	28	47	29	45	45	45	45
Hours available per year:									
Total weeks per year		52							
Annual Holiday		(4)							
Public Holiday		(2)							
Sick Leave		(2)							
		44wks							
At 40 hours per week =		1760hrs	1760	1760	1760	1760	1760	1760	1760
At 75% "effective" =		1320hrs	1320	1320	1320	1320	1320	1320	1320
			Assume 50% better perf	x2=2640 Assume 75% better perf	Assume 25% better perf	No improvement in perf	Assume 25% better perf	Assume 50% better perf	Assume 75% better per
Divide (1) by		19000 / 1320	28000 / 1980	49000 / 4620	29000 / 1760	45000 / 1320	45000 / 1760	45000 / 1980	45000 / 2310
Hourly costs =		£14.4ph	£14.1ph	£10.2ph	£16.5ph	£34ph	£25.5ph	£22.7ph	£19.5ph

FIGURE 5

almost as fast as the super-micro equivalent, while running the Arcaid 3D software - (see also Figure 12.) But it is possible, (as always), to drop too low as Figure 5 indicates, and this is by far and away the norm for the performance of these machines).

Reflecting the understanding of where the market may exist the following key points can be made:-

1. Smaller practices can now for the first time begin to contemplate the use of CAAD.

2. They may not have sufficient time and expertise "in-house" to evaluate a system properly.

3. Because of the greater "bunching" near the bottom end of the market, there is a greater tendency to take "pot luck" and buy on cost rather than on features.

This does not always lead to proper system selection, based on adequate value for money criteria. The table of performance comparisons in Figure 5 assumes a variety of improvements in performance and attempts to clarify this issue.

The Educational Market

In common with many educational establishments in the U.K., Departments of Architecture have been starved of capital investment recently. In fact the Government has singled out one or two for closure. That, together with the perceived wisdom in the Professions that CAAD does not really work (see the poorer results from Figure 5), has meant that little consideration has been given to this type of training in the recent past. However, the advent of PC based systems and the realisation that a student embarking upon an undergraduate course today will not start fulltime gainful employment until the 1990s has given added impetus to a re-think of this attitude. But as hardware suppliers know, it is software which still sells the bulk of hardware and many give the software free to education establishments in order to (a) sell their machines, and (b) put their name in front of the students as potential future customers. (This would profit Arcaid very little at a crucial time and therefore our policy has been to offer to supply software at 50% of its main selling price). At present there is one partial Arcaid installation at the Department of Architecture in Heriot-Watt University, and a full micro main-frame installation in the Department of Building.

The majority of other schools of Architecture and Building in the U.K. meantime do have some embryonic CAAD system based mostly on 8 or 16 bit micros but not always for general undergraduate use.

By virtue of their lower cost and "stand alone" nature, desktop PC systems are a natural fit for the educational market. Sales of CAD/CAM systems to educational establishments could represent a significant proportion of the future CAD market especially in the light of the U.S. experience.

1. Research (by Dataquest) as shown that by the end of 1984 the first year in which IBM PC's were sold approximately 1 million PC computers had been shipped to the U.S. school environment. This is expected to increase to 7.8 million by 1989.

2. In 1984, 44% of all worldwide shipments of personal computers went to schools there.

3. The educational environment also purchased $209m worth of PC software in 1984. Nearly half of the PC software

revenue went for scientific and technical applications including CAD/CAM.

Market Value and Potential for Growth

The Frost & Sullivan 1986 study of CAD shows that the total W. European market was worth some £200m last year for both large and small CAD systems in all applications: architecture, construction, engineering, chemical and industrial plant and offshore construction and mapping.

A calculation based on the Sixth Annual CAD Systems Survey (Sales) produced by C.I.C.A. suggests that U.K. sales represent some 50% of the total U.K. and Europe figures for CAD systems although the GNP is only some 15%.

This would suggest a U.K. total market for CAD of £100m.

If the proportion of the construction industry figures to total U.K. sales is then extracted, a figure of 13.5% emerges representing construction applications. This gives a U.K. market figure for the construction industry of £13.5m which is in line with notional value figures for major and low cost system sales extrapolated from the aforementioned C.I.C.A. report.

Thus U.K. potential current outlets might appear as follows:-

Private architectural practices	4,900
Local Authority and Government	2,500
Consulting engineers (estimate)	400
Major private housebuilders	700
Architects within industry & commerce	100
	8,600

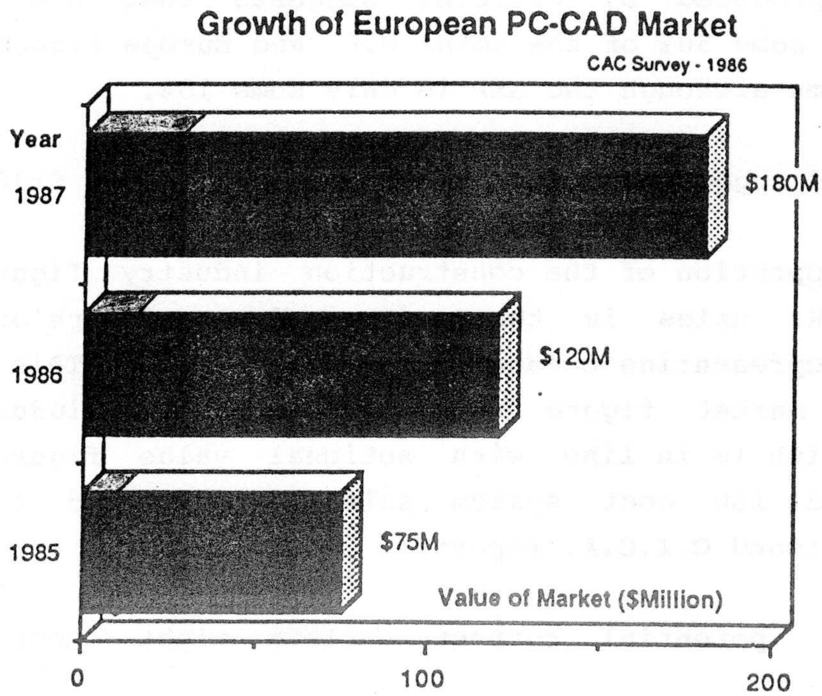

Growth of European PC-CAD Market
CAC Survey - 1986
Year
1987
$180M
1986
$120M
1985
$75M
Value of Market ($Million)
0
100
200

FIGURE 6

A number, possibly 12%, of these outlets will have some form of CAD system which may or may not be up to date and regularly used.

Frost & Sullivan give a growth picture for CAD of 26% for 1987 and 18% to 1990. On a straight projection:-

£m	£m	£m	£m	£m
1986	1987	1988	1989	1990
13.5	17.0	20.0	23.6	27.8

The total PC share of this now is shown in Figure 6, and if Frost & Sullivans % figures for the Construction Industries share are put against these, the Construction Industries percentage of PCs is shown by the solid hatching.

From a recent market survey commissioned from the Scottish Development Agency, by Arcaid, the following points also emerged:-

There was a high proportion of respondents interested in some form of CAAD system and who could see the wide variety of benefits that computerisation might bring them.

When asked as to how they would assess the impact of a computer's contribution to drawing the top responses were:-

Improved productivity	47	62%
Financial	29	38%
Improved staff skills	22	29%

(N.B. more than one response per respondent).

It is of note that 61% of respondents did not mention a financial qualification.

(a) Large Systems

McDonnell Douglas GDS	93	FEAL Gipsys	21
GMW RUCAPS	61	Carrier E2000	17
Intergraph	54	Computervision CADS4x	15
Peac	35	Konsberg	10
Gable 4D	31	Summadraft	9
Calcomp System 25	25	Design Computing Gintran	8
CIS Medusa	25	IBM CADAM	5
Oasys CADRAW	24	Diamond	1
CSC CEADS-CADD	24	Pafec DOGS	?
BDP	22		

Figure 7a

(b) Low Cost Systems

Autodesk Autocad (+150 in universities)	400	Ginga	12
		Easydraft	11
Robocom (Apple)	346	Stag	8
Cadvance	70	Amazon ARC+	5
Ormus 11	45	Dart	3
Robocad PC	40	Zeta 2000	1
Arcaid Board	13		

Figure 7b

The respondents (55%) or the respondents and their staffs (90%) would investigate the systems available but presumably the partners alone would make the purchase decision.

The system should be capable of being used broadly from partner level to technical assistant level, 47 (74%) thought that the system should cost up to £20,000.

It is of some passing interest to note that reliance and apparent authority that the respondents accredited to the architectural press as an information source. Out of 171 total responses 55% were related to this particular form of media compared to 21% who mentioned exhibitions and conferences. The heaviest proportion (46%) was related purely to articles i.e. editorial.

The Protagonists

Currently the low cost CAAD market in the U.K. is serviced by a number of companies who for the most part do not have any Architectural or design experience or expertise. Many may have some experience of Computer Aided Engineering or even the electronics field, but this is a far cry from knowing the needs and workings of the Building Industry. Figures 7 a & b reflects the 1986 market share ranking of the better established system houses in the U.K. In addition, CICA estimates that there are well over 450 small companies who offer some type of CAD/CAE software, and many more are also invading the CAAD market just now.

Another recent development has been the larger traditional turnkey CAD/CAM companies' assault on the low cost CAAD field. Computervision, McDonnell Douglas (ARC), Calcomp and RuCaps have advertised single workstation systems during the last few months, although it is doubtful whether (a) they

Top 20 fee earners (from those that provided figures)

		1985 turnover	Percentage increase on previous year
1	Building Design Partnership	£23m	13
2	Robert Matthew Johnson-Marshall	£8.4m	15
3	Y R M Partnership	£7m	10
4	Fitch & Co	£6.92m*	—
5	Percy Thomas Partnership	£6.54m	11
6	Stewart McColl Associates plc	£5.6m	28
7	Covell Matthews Wheatley Partnership	£5.5m	55
8	GMW Partnership	£5m	25
9	MWT Architects	£4.56m	30
10	D Y Davies Associates	£4m	60
11	Michael Aukett Partnership	£3.5m	40
12	T P Bennett Partnership	£3.3m	—
13	Watkins Gray International (UK)	£3.17m	
14	Atkins Sheppard Fidler & Associates	£3.1m	15
15	John Brunton Partnership	£3m	30
16	Barton Willmore Partnership	£3m	20
17	DEGW	£2.2m	120
18	Mason Richards Partnership	£2.2m	15
19	Richard Rogers Partnership	£2.1m	45
20	Austin-Smith: Lord	£2.05m	17

*1984 figure)

FIGURE 8 SOURCE BUILDING DESIGN

have installed very many and (b) that their Architectural customers are totally convinced about the result. The Calcomp strategy has been to buy up a smaller company with a suitable PC based product. They now find their large system sales eroded by their own low cost product, and prefer not to demonstrate System 25 alongside CADVANCE!

When considering that the larger and most prestigious Architectural Practices still offer the greatest potential market for CAAD systems (see list, Figure 8) the customising turnkey vendors are likely to be the major benefactors here provided they can equip themselves with a large direct sales force of experienced Architects or Engineers who are able to speak on equal terms with the Principals, (they after all hold the purse strings of the Practice).

Surprisingly Computervision in the U.S. shipped nearly 200 units of its IBM PC based Personal Design Systems during the last eight weeks of 1984 without any formal announcement of the product. This clearly demonstrates the tremendous need for their type of system in the U.S. even within the installed base of companies that also have larger, mainframe based CAD/CAM systems, and the same has begun to happen in the U.K. But clearly CV have a different strategy for coping with the large versus small machine problem to that of Calcomp!

The other major marketing issue has been the availability of a suitable engine for the low cost market place. Part of the reason for this last being slow to develop has been the lack of a suitable "industry standard" machine in the low cost bracket. That has now appeared in the form of the IBM PC/AT and "clones" which entered the U.K. market in the autumn of 1985. In the United States the question of a brand name market leader may be important. Of the people who buy an IBM PC type of machine, 75% actually buy IBM. Whereas in Europe the brand image is treated with much

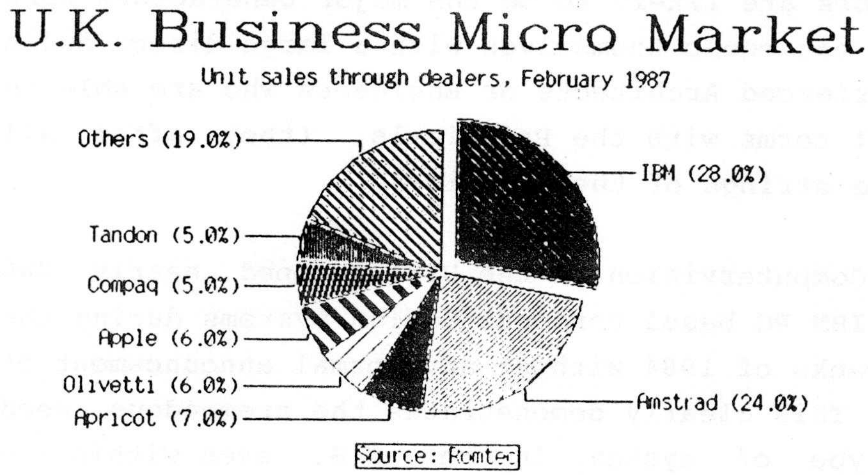

U.K. Business Micro Market
Unit sales through dealers, February 1987
Others (19.0%)
IBM (28.0%)
Tandon (5.0%)
Compaq (5.0%)
Apple (6.0%)
Olivetti (6.0%)
Apricot (7.0%)
Amstrad (24.0%)
Source: Romtec

FIGURE 9

greater pragmatism and customers tend to buy on performance rather than on the manufacturer's label. Thus 50% more European based customers looking at IBM PC type machines do not buy IBM and would rather go for the clones which are mostly cheaper and better performers (see Fig. 9). The so called low-cost engineering workstations such as the Whitechapel or the Apollo or the Perq are under very heavy pressure (ref. Apollo sales figures for 1985), as hardware prices continue to fall and customising the PC becomes a more attractive solution. That is in preference to choosing a specially engineered solution, custom made by a manufacturer.

From a software standpoint there are two battle lines forming, based on systems of marketing or distribution. The U.K. dealer channel is currently dominated by established suppliers such as Autocad and Robocom, see Figure 7 etc., while the direct sales channels appears to the territory of the turnkey vendors who specialise in customising systems to individual office requirements.

These two types of outlet require completely different approaches to the sales and marketing and therefore the likelihood of one technique and possibly one vendor taking over the total market is slight. However, it would seem reasonable to assume that customising companies will continue to carve out a large slice of the market for themselves with highly motivated, knowledgeable and experienced workforces, while the "cheap and cheerful" non-construction industry vendors will continue to sell because of their greater coverage of the market place, through a larger number of dealer outlets.

CAD is no longer new but from the early 1980's the rate of growth of the industry and the products to meet the demand have escalated substantially.

CADCAM International magazine (September 1986) lists 72 companies offering stand alone CADCAM systems of which only 14 specifically mention building or architecture. The others break down as follows:

2D drafting	20
2D drafting and 3D modelling	18
PCB design, etc	12
Others (CIM, CAE, etc)	8

CICA predict a growth rate of only 15% for large systems next year but, if Autocad, the current best seller, is taken as the barometer, it can be predicted that sales of low cost systems will more than double in the same period.

Immediate Problems

Despite the tremendous promise the low cost CAAD market holds at present there are a number of other technical obstacles which need to be surmounted in order to capitalise on the full market potential. These problems include:-

1. Poor graphics performance

2. Low speed c.p.u.'s

3. Inadequate storage

4. Ill Considered software

Taking these in their correct order and incidentally in order of importance:

1. Poor Graphics Capability

   Either through a basic lack of understanding or downright obtuseness on the part of manufacturers there is still a serious shortfall in the quality of the graphics devices offered as part of the original equipment. It is not unusual to read of high resolution graphics on a 540 x 380 pixel screen, "large" size (15" diagonal) tube in advertisements. This is not only inadequate but insulting to the Construction Industry Professionals who are being cultivated as potential customers. A minimum size of screen is 17", (19" preferred) with at least 1024 x 780 pixel points displayed. Anything else will seriously limit the productivity of PC based systems. Architects and Engineers usually create the most dense and most complex drawings of all CAD users and therefore have the greatest difficulty in achieving acceptable levels of productivity from such equipment. The ability of the system to pan and zoom in to a crucial part of the drawing is especially critical because Designers in the Construction Industry are used to scanning a manually created drawing in microseconds. Whereas the standard PC offerings can often take minutes to generate new views of a model, this artificial constraint can be the cause of a great deal of frustration and frequently results in total abandonment of CAAD by an operator. This problem must be resolved by any serious CAAD vendor before offering his system on the market.

2. Slow c.p.u. performance

In the main this is due to the use of 8 or 16 bit processors or lack of arithmetic co-processors. There is no real excuse for non-performance in this area. A drawing on a computer screen is made up of a large number of vectors. To create these with any semblance of accuracy, the computer requires an arithmetic chip. To misunderstand that is to misunderstand one of the basic tenets of computer drawing. Another fundamental point is that drawing is very hard on the processor.

For not only is it necessary to process all the detailed instructions normally required of a business or financial machine but a technical machine also has to process co-ordinates of the point at which the operator requires these instructions to be carried out. This consequently doubles the amount of work which has to be done at each stage and with a 16 bit processor makes each operation an exercise in tedium. Thus the fast 32 bit processor (32 bit in - 16 bit or 32 bit out) is the only immediate solution to this problem and very few vendors offer that sort of power from a PC type of machine today. Yet offer it they must. In any event it does not appear very likely that many CAAD vendors will be able to shoe-horn their software into a PC. That either requires the dropping of facilities, or a high level of additional skill, well above that of the average software "hacker". (It may also require going back to a clean sheet of paper!)

The first requirement means running against the tide of events, while the second needs talent so rare that it is little wonder 9 out of 10 PC based drawing systems are very crude indeed. (And that includes some very big names in the business).

3. Inadequate storage

The lack of speedy access to the great bulk of the Designer's data is still a major flaw in the architecture of many CAAD workstations. Typically, building models are made up of millions of components and assemblies. Holding this in core is extremely onerous but the de facto technical operating system for desk tops is Unix and Unix based systems being disk orientated anyway normally hold the bulk of the Designer's information on a Winchester of one sort or another. Thus, the speed of accessing these devices is

TABLE OF CAAD SYSTEM COSTS

B & W (without plotter)

SYSTEM	STANDALONE ("networked?")	UPGRADEABLE ("octopus")
1. Station	£12,000	£21,000
2. Station	£20,000	£28,000
3. Station	£30,000	£34,000
4. Station	£37,000	£37,000
5. Station	£42,000	£41,000
6. Station	£48,000	£45,000

FIGURE 10

a test of both the mechanics and the electronics. Typically even a "fast" access disk (average access time 20-25ms) requires a fast controller to go with it. Most of these latter devices are still only 8 bit, so causing frequent bottlenecks in the system. This has stimulated the creation of a host of fast interface devices of the S.C.S.I. variety or ESMD and even cache memory. Any supplier not offering one of these solutions should be avoided.

4. Poor software

It takes typically 6 to 8 years to train an Architect or Building Designer. An average person, it is said, obtains 80% of his information about the world by visual means. For a graphics designer this percentage is probably very much higher.

So any software writer attempting to encapsulate or "bottle" this skill has a tremendous job on his hands. 99% of program writers are just not up to it. They do not have one tenth of the insight required hence, the most successful creators of graphics software are usually from one of the graphics based Professions themselves. This extremely rare combination of talent, that of Designer and software writer, is almost unheard of, which explains why so many existing CAAD systems are so unsuccessful; they simply do not have what it takes. Even to start off on the right foot and recruit the correct balance of skills initially does not mean that the right decisions will be made all along the development way and that the Company will come out with a viable (or any) product at the end of it.

Alternative Offerings

While it may be true to say that the straight PC type of system will unquestionably play a major role in the development of the CAD market in the near future, these may not be without competition. This will come from the following sources:-

1. The aforementioned mainframe machines.

2. Powerful "Off the Shelf" engineering workstations.

3. Converted PC type machines, customised to provide enhanced graphics capability.

1. Mainframe Micros

   This is still perhaps the best option for an office requiring to automate its design processes on a grand scale. The price per workstation equipped is still lower by this means when purchasing in bulk than networking a number of PCs together (see Fig 10). It also provides the additional facility of centrally shared data which is of incalculable value to a large office, since about the only justification for being large, is a large pool of knowledge or intelligence to go with it. Here we enter the realms expert systems and A.I., and as these concepts advance the larger offices will be better able to justify their raison d'ete. Sadly very few Vendors of these systems offer real value for money. If an office is going to the trouble and expense of installing a computer (and a powerful one if it is to cope with drawing and modelling) it is not unreasonable to expect it to do a lot else. But how many of them are geared up for that?

2. Engineering workstations

It would appear that while these are relatively easy to create they are not easy to create and manufacture at an affordable price and thereby offer good value for money. This may be partly because the approach does not lead to so many economies of scale with a much smaller market for the product. (Technical computers still do not achieve as a high market penetration as office automation machines). But there are a number of these offerings available now in the £25,000 to £35,000 bracket, - although they may not be so attractive to the vast majority of purely Architectural Practices. This is because of the long number of hours needed to work at them, in order to obtain a decent return on the high level of initial capital invested (see Figure 5 again).

3. Customising an existing machine

Here is the concept which comes closest to being the "best of both worlds". Firstly, choosing to build upon an existing manufacturers range immediately offers economies of scale in manufacturing and purchase especially since it taps a far wider market than the merely technical one. Next, finding the necessary customising parts is a relatively easy task by comparison to that (mentioned previously), of creating the software. And customising is well within the capacity of people equiped with the skills to do the first part.

For instance Opus systems, a start-up in Los Altos, California, has developed a board set that plugs into the IBM PC (and clones) or look-a-likes and allows users to run full 32 bit Unix applications using standard AT&T System V on national semiconductors 32032 processor. The act of running large CAAD programs in the PC

BYTE BENCHMARKS ON OPUS SYSTEMS

	VAX-11/780	VAX-11/750	SUN-2/120	OPUS 32.32	OPUS 32.16
1. PIPES	3.2 100%	4.6 70%	7.6 42%	3.5 91%	5.3 60%
2. SCALL	4.8 100%	7.0 69%	6.8 71%	6.9 70%	9.6 50%
3. FCALL	1.0 100%	1.7 59%	.8 125%	.8 125%	1.2 83%
4. SIEVE	1.7 100%	2.4 71%	5.1 33%	2.3 74%	3.0 56%
5a. DISK WRITE	2.0 100%	3.0 66%	1.8 111%	1.5 133%	1.7 117%
5b. DISK READ	8.0 100%	8.0 100%	4.9 163%	4.2 190%	4.6 170%
6a. SHELL	3.3 100%	3.8 86%	3.5 94%	3.0 110%	4.8 68%
6b. 1 SHELL	4.3 100%	4.3 100%	3.6 119%	3.3 130%	3.9 110%
6b. 2 MULTIPLE SHELLS	5.5 100%	5.5 100%	6.2 88%	4.8 114%	6.0 91%
6b. 3 MULTIPLE SHELLS	7.8 100%	8.8 89%	8.7 90%	6.2 126%	8.3 93%
6b. 4 MULTIPLE SHELLS	9.0 100%	10.3 87%	11.8 76%	8.0 112%	10.5 85%
6b. 5 MULTIPLE SHELLS	11.0 100%	13.3 82%	14.4 76%	9.2 119%	12.8 85%
6b. 6 MULTIPLE SHELLS	13.8 100%	15.0 92%	18.0 77%	11.1 124%	15.4 89%
7. LOOP	2.6 100%	5.1 50%	7.4 35%	5.8 44%	9.2 28%

FIGURE 11

environment comes of age with this system and they have been bench marked faster on this than on a VAX 750 or a Sun -2/120 (see Figures 11 & 12) and may represent better VFM than the recently announced Reduced Instruction Set IBM PC RT. (The advent of the 80386 based machines in quantity in the U.K. is eagerly awaited and so is the correct software to accompany them).

The Opus board is marketed in Great Britain and Ireland by Arcaid (Hardware) Limited who see a tremendous future for this, both installed in their own equipment and also selling to O.E.Ms.

In order to obtain the necessary quality from the graphics screen Arcaid have employed a Methens graphics board from Pericom inserted into the p.c. back-plane and driving direct a 1024 x 1024, 20" colour screen, by Hitachi all running under V.D.I.

In Conclusion

It is believed that the advent of the advanced PC type of equipment in a number of guises will have the following effect on the CAD market just now.

Traditional Turnkey Components

Since these have evolved from the era of £100,000 installations they will not be overly successful in selling against PC/AT based systems.

Likewise the manufacturers have not been, and are not likely in the future to be, successful in repackaging their product for the PC/AT machine age. The picture for them, therefore, looks bleak with the possible exception of the very

AIM BENCHMARK MEASUREMENTS

AIM TECHNOLOGY SUITE II

OPUS SYSTEMS 532

Values are presented in triples—first for a VAX 750, then the Opus32.32, and finally the VAX 780.

ARITHMETIC INSTRUCTION TIMES (microseconds per op)

	short	*long*	*float*	*double*
+ add	4,1,2	1,794ns,601ns	14,12,5	11,10,3
* multiply	13,10,3	10,9,2	45,13,7	47,11,5
/ divide	37,24,21	10,13,10	78,17,11	81,15,10

MEMORY LOOP ACCESS TIMES (microseconds per byte)

	read	*write*	*copy*
CHAR type	3,3,2	3,1,2	3,3,2
SHORT type	2,1,786ns	1,587ns,793ns	1,2,783ns
LONG type	489ns,539ns,297ns	656ns,306ns,402ns	793ns,773ns,402ns

INPUT/OUTPUT RATES (bytes/sec)

	read	*write*	*copy*
DISK	408k,60k,202k	321k,48k,142k	139k,38k,74k
PIPE			155k,211k,243k
TTY 1		n/a,959,n/a	
TTY 1+2		n/a,2k,n/a	
RAM 1-byte			346k,314k,647k
RAM 4-byte			1261k,1294k,2486k

ARRAY SUBSCRIPT REFERENCES (microseconds)

short[]	long[]
3,3,2	3,2,2

FUNCTION REFERENCES (microseconds/ref)

0-parameters	1-parameter	2-parameters
funct()	funct(i)	funct(i,i)
28,10,17	39,17,22	50,24,26

PROCESS FORKS

11,38,28 per second

SYSTEM KERNEL CALLS
(calls-per-second and microseconds percall)

getpid() calls:	3,4,5 kcalls/sec or	310,272,183 μsec/call
sbrk(0) calls:	1,2,2 kcalls/sec or	887,517,505 μsec/call
create/close calls:	28,217,30 pairs/sec or	35714,4608,33333 μsec/pair
umask(0) calls:	3,3,5 kcalls/sec or	364,382,204 μsec/call

FIGURE 12

sophisticated systems which offer full 3D visualisations with lighting and shade, and real time walk through views, etc. (However, these still have to earn their keep).

The aggressively price PC/AT based offerings with well thought out software, (provided they can attack the market on a broad front) will be able to take over a large area of the traditional turnkey vendors ground and corner a very large share of the new market stimulated by the lower cost hardware threshold. The future of these companies therefore looks very bright indeed.

The major challenges for them will be:-

1. Reaching their market in time to take advantage of the lead they undoubtedly have at the moment.

2. Finding and training sufficient outlets in the dealer nexus to shake the doubtful credentials of the cheap and cheerful systems which are selling in quantity, and which may be able to turn the revenue thus obtained to advantage in rapidly improving their product.

3. Providing interfaces to and from other CAAD systems such that they can appear to be a credible alternative to large system vendors, for customers buying the second time around, (and for customers buying new hardware only).

4. Continuing to hold off the challenge from the purpose made Engineering workstation suppliers by undercutting their prices while sustaining the quality, speed and accuracy of the alternatives they offer.

The PC CAAD issue adds a whole new level of complexity to a market place that already suffers from an over-abundance of confusion and super-abundance of choice.

With literally hundreds of CAD companies and products all vying for a place on Construction Industry Designers' desks it is not surprising that purchasers have great difficulty in charting a route through the maze and coming up with a useable system which will genuinely improve the Offices performance. One result <u>is</u> certain however, and that is that the days of the £100,000 or £50,000 CAAD (single seat) workstations are well and truly numbered, which in view of the difficulties they have created for their customers in obtaining a return on their hard-earned capital, is perhaps no bad thing.