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SCOPING STUDY FOR A REALISTIC DRIVING SIMULATOR

FINAL REPORT

O.M.J. Carsten

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1. INTRODUCTION

This report documents the results of a study carried out between December 1989 and March 1990 to determine the most suitable equipment to be purchased for building a driving simulator at the Institute for Transport Studies at the University of Leeds. This "scoping study" was intended to accomplish three main tasks:

1. A review of existing facilities both in the UK and elsewhere in Europe to ascertain what has already been achieved and what is the current state of the art.

2. Initial discussions with potential users on desired features to be built in to the simulator.

3. Discussions with equipment suppliers in the light of what was found out in Tasks 1 and 2, so that the appropriate equipment could be specified.

The report documents in subsequent sections the findings of the first two tasks. It then summarizes the conclusions that were reached on the overall simulator design, on the required features of the simulator and on the effort required to develop an operational simulator from the various hardware components. Finally, recommendations are made on the equipment to be purchased in the light of the recommended configuration, the discussion with equipment suppliers under Task 3 and the budget allocated.

2. REVIEW OF EXISTING FACILITIES

Visits were made to a number of existing driving simulators. These ranged from the very elaborate, such as that maintained by Daimler-Benz in Berlin which is reputed to have cost about 33 million DM to build and which has a full-time staff of 21 people to operate it, to the very low-cost, such as the simulator built by King's College for DRIVE Project V1006, DRIVAGE, for which the equipment costs were £6000. The following simulator operators were visited:

1. TRRL
2. VTI in Linköping, Sweden
3. King's College London
4. Institut für Fahrzeugtechnik at the Technical University of Berlin
5. Daimler-Benz in Berlin

The VTI (Nilsson, 1989) and Daimler-Benz (Drosdol and Panik, 1985; Drosdol, Käding and Panik, 1985) facilities are the most advanced of current simulators. They both have mechanical motion systems to provide the driver with the full sensation of driving. The motion systems are of different designs, but both currently provide the driver with about one-third of real-world forces through motion in all six degrees of freedom. There are plans to upgrade both of these simulators to full-scale forces. In both the visual system (the driver's view) is provided through animation. The VTI simulator has three channels of PAL resolution, while the Daimler-Benz system has six channels of 512 x 512 resolution to provide a full 180° field of view. In both, however, the scenes presented tend to be somewhat simple. This is particularly the case for the VTI simulator where the system is oriented towards high-speed rural driving, and in which the scenery is somewhat basic.

Neither animation system provides texture, i.e. the ability to give patterned effects to surfaces. The surfaces are thus flat-shaded, and this leads to a lack of a sense of depth in the image, because the level of detail does not recede properly from foreground to background. The lack of texturing also means that the polygons drawn by the imaging systems tend to have sharp edges, and that the creation of semi-transparent objects (such as realistic trees) is impossible.

The Daimler-Benz system not only has the more elaborate visual system of the two; it also has the capability of changing the vehicle in an hour or two. Pre-instrumented and equipped cars or truck cabs can be lifted into place as required. On the other hand the VTI system has the advantage of extremely rapid response. The lag time incurred from the mechanical and visualization systems is only 8 milliseconds as opposed to 20 milliseconds in the Daimler-Benz unit. It should also be noted that the VTI simulator is essentially purpose-built from in-house designs (this applies even to the visualization hardware), whereas the Daimler-Benz simulator was in the main bought off-the-shelf (e.g. the visualization system) or built by subcontractors (e.g. the motion system).

Both of these simulators represent the acme of current design and both are undergoing continued improvement in their motion and visualization systems. While the Leeds simulator will clearly not be able to emulate the motion systems of these simulators, it is hoped that, in some respects at least, it can surpass the current level of their visual representation of the environment.

The TRRL simulator represents an earlier generation of systems based on scale models. At TRRL the driver's view is generated by a camera which can move laterally but not longitudinally above a moving belt. This belt, which has white lane markings painted on it, represents the roadway and as the driver accelerates the belt moves faster. Other vehicles are represented by scale models which are guided by wire. An extremely realistic representation of a scene can be generated in this way, but at the penalty of a lack of flexibility to alter or manipulate the scene. With the advances in the creation of three-dimensional graphics on computers, TRRL is therefore shifting to an animated system along the lines of VTI and Daimler-Benz, albeit without full motion feedback to the driver.

The system at the Technical University of Berlin represents a middle ground between some of the very elaborate systems and the very basic ones. It too uses real-time computer animation to depict the scene, this time on an off-the-shelf Silicon Graphics workstation which produces a one-channel high-resolution (1024 x 1280) projected image. The vehicle is completely static, but is equipped with a torque motor to provide steering feedback and with sound. A simplified vehicle handling model is run in real time on an AT-compatible that is linked to the workstation.

Because this system was similar in many respects to that anticipated for Leeds, quite a lot of time was spent discussing with the staff at the Technical University of Berlin, the effort required to programme the system. It should be noted that there are no off-the-shelf programmes available either for generating on a graphics workstation the animated images for a driving simulator or for providing a real-time vehicle handling model. The amounts of staff time in the SERC grant application for the Development of an Advanced Driving Simulator, submitted in the 15 March 1990 round, are based in large part on the advice given by personnel at the Technical University of Berlin who had been responsible for the development work there.

The final installation visited was that created by the Electronic and Electrical Engineering Department of King's College London for DRIVE project V1006, which is examining the driving performance of older drivers (DRIVE Project V1006, 1989). As indicated above, this is an extremely low-cost installation. It does, however, present the driver with a very high-quality visualization of the scene. The system operates on an Acorn Archimedes computer, equipped with a laser videodisc. The scene is created on a computer monitor placed just in front of the driver, who sits in the front half of a vehicle. The image is generated from pre-recorded video which has been transferred to the videodisc. Superimposed on the pre-recorded image is a picture of the rear of a vehicle apparently driving down the road ahead of the driver. The object of the exercise is for the driver to follow this vehicle with as constant a gap as possible. As the driver accelerates or brakes, the image responds appropriately. In spite of the generally high quality of the image, there are limitations which prevent the consideration of such a system for a general-purpose simulator:

1. The superimposed image of the car in front does not blend in very well with the background scene. It is extremely difficult, because currently computers cannot calculate the eyepoint on a pre-recorded 3D image, to blend in such an animation with digitised video. For this experiment, the blending has been "eyeballed".

2. The simulator can only present a single path through the environment, following the track of the car from which the scene was filmed. While the driver can brake or accelerate, he or she cannot steer. Thus no kind of vehicle manoeuvring can be simulated. Still less is it possible to simulate interaction with traffic.

This means that a low-cost system of this type, while it can present very high quality and realistic graphics, is not appropriate for use as a general-purpose simulator. Such a general-purpose machine must, at present, be based on a system using animated 3D graphics created in real time in response to driver inputs. This point emerged again and again during the visits to the various installations. It was universally the view that, given current hardware and the current state of the art in computer graphics, an animated system represented the best compromise between the desire for the greatest realism in scene drawing, the requirement to be as flexible as possible in the kinds of experiments permitted and the need to respond in real time to driver actions. In terms of the quality of the animated images it was desirable to have:

- High-resolution (1024 x 1280 or 1024 x 1024) computer graphics.

- Anti-aliasing, a technique for smoothing the jagged appearance of diagonal lines. This is particularly important if it is necessary to use lower resolution graphics, but it is also valuable for ensuring that lights in a night scene do not shimmer.

- Texturing of surfaces.

- Images projected on to a screen or curved surface via a high-quality projection system.

- As large a field of view for the driver as possible. Thus three-channel projection to the front is far preferable to single-channel projection, which can offer a maximum field of view of 60°.

Other important features were:

- A good quality sound system, preferably using a large speaker placed in the vehicle's engine compartment. Vibration was considered much less important; indeed it was held that, with a good sound system, vibration could be dispensed with.

- A powerful motor to provide steering feel. This is far more critical on a static simulator than on a moving simulator where the illusion of steering feel is provided in the main by the dynamic response of the whole system.

3. THE POTENTIAL FOR COOPERATION IN SOFTWARE DEVELOPMENT

Quite early in the scoping study it became evident that a number of research organizations throughout Europe were on the point of starting the development of driving simulators on graphics workstations, using real-time 3D animated graphics. Organizations about to start development include:

1. TNO Institute for Perception, at Soesterberg in the Netherlands

2. FGAN-FAT, at Wachtberg-Werthoven near Bonn in West Germany

3. The Traffic Research Centre at the University of Groningen in the Netherlands

All of these organizations have expressed an interest in establishing some kind of informal cooperation in software development. This will mean that information can be exchanged on how to solve particular problems in programming and on how to obtain the maximum efficiency from the computing equipment to ensure that the right trade-offs are made between the complexity of the scene and the need to maintain a 30 Hz frame rate to provide the illusion of continuity in the graphics.
A letter from the University of Groningen expressing an interest in collaboration is attached to this report as Appendix A. It is believed that such cooperation will be of benefit to all the organizations involved, and will lead to a more efficient use of development resources. The travel costs in the SERC grant application for the Development of an Advanced Driving Simulator include expenditure for maintaining links with these institutions.

It is also likely to be advantageous to be using the same hardware as other cooperating organizations (for the hardware alternatives, see Section 6). TNO have already decided to purchase a workstation from Megatek, while Groningen is planning on Silicon Graphics equipment. At the moment, it seems likely that FGAN-FAT will also purchase a Silicon Graphics machine. An argument could thus be made that, if all things were equal in machine performance, there was an advantage to purchasing a Silicon Graphics machine for Leeds, because of the greater potential for software exchange on this computer. (It should also be noted that there is more experience generally with this architecture, since the Technical University of Berlin and INRETS in France also use it for their driving simulators.)

4. DISCUSSIONS WITH POTENTIAL USERS

4.1. Mail and Personal Contacts

Over sixty letters were sent out to departments engaged in research on transport issues and on road safety. Two mailing lists were used: that of the Universities Transport Studies Group (UTSG), containing about sixty names, and the list of contacts for the six studies funded by the ESRC's General Accident Initiative. The letter described the proposal to build a driving simulator at Leeds as a tool to be made available for use by the research community. The standard letter sent out is included as Appendix B. Responses were received from seven institutions, all of which welcomed the provision of a simulator and some of which were quite detailed in their specification of desirable features.

In addition to the mail contacts, a visit was made to HUSAT, the Human Sciences and Advanced Technology Research Centre at Loughborough University to discuss the detailed features of the simulator with staff there. HUSAT have an active interest in research on driver behaviour, with a special emphasis on the effect of in-car electronic equipment, such as cellular phones, on driver performance. They also have extensive experience in the operation of instrumented vehicles.

Among the features that were suggested as a result of this process were:

- The need to monitor the driver in the simulator both by recording eye movements and by means of a physiological recorder (EEG machine).
- The need to record driver inputs to the vehicle in the form of acceleration, braking, steering, gear selection and use of the clutch pedal.
- The need to simulate both rural and urban driving environments.
- A capability for creating "risky" situations and to study driver manoeuvring in traffic.
- The provision of an image in the rear-view mirrors of the vehicle.
- Generation of vehicle and traffic sound.
- The ability to include pedestrians in the scene.
- The operation of all the dashboard instruments in the vehicle.
- A capability for the simulator to be used to study not only tactical (manoeuvring-level) driver behaviour, but also strategic behaviour such as route finding in a city or patterns of search for a parking space.

These requests for features have played an important role in the specification of the equipment to be purchased and in planning for the software development under the parallel SERC grant application.

4.2. Workshop on Driving Simulator

It was originally envisaged that the scoping study would use several days' worth of expert consultancy to deal with specific areas of the simulator design. In view of the extensive information acquired through the visits to existing facilities and the exchange of information with the other institutions contemplating the purchase of visual simulation workstations (i.e. TNO, FGAN-FAT and TRC), it was concluded that it would be more advantageous to use the funds originally budgeted to pay the individual consultants for the holding of a workshop at Leeds. At this workshop the proposed specification of the simulator could be presented, and a group discussion could then follow on the extent to which the needs of the various institutions represented were being met. If necessary, the simulator design could then be modified in the light of the discussion.

The institutions invited to the workshop were those that had made the most detailed responses to the circular inviting suggestions on simulator design. They were the Transport Studies Group of University College London, the Transport Studies Unit of Oxford University and HUSAT. From Leeds, staff members of both ITS and the Computer Studies Department attended.

The workshop was held on 26 March 1990. Following the presentation of the proposed simulator, there was a discussion of additional features that it was hoped could be incorporated. These included:

- A capability for interaction between the vehicle and simulated traffic signals.
- The provision of roundabouts in the road environment.
- The recording of vehicle following distances.

It was also suggested that information be circulated to potential users of the simulator warning them that, based on the experiences with other driving simulators:

1. It was difficult to conduct realistic experiments in road-sign reading, because signs in simulated environment could only be read by the driver when they were twice as close as was necessary in the real world.
2. Similar difficulties applied to the observation of traffic lights, although it might be possible to double them in size to compensate for this.
3. Drivers who were subjected to simulated accidents were extremely shaken up by the experience.

A discussion was also held on the potential for using the driving simulator for the observation of driver strategic behaviour. After it had been pointed out by ITS that such an application required very extensive programming, it was agreed that the system software should be "open" and that proper documentation of the software should be provided at the end of the proposed development phase. This would enable other institutions to create the necessary software for their particular applications off-line. It was therefore desirable to purchase a computer workstation for the simulator, for which a cheaper compatible workstation was available. The Silicon Graphics product line was attractive here, since it was possible to purchase a Personal Iris, costing about £25,000, for the creation of databases that could subsequently be used on a more powerful Silicon Graphics machine.

5. CONCLUSIONS ON SIMULATOR DESIGN AND REQUIRED FEATURES

As a result of the visits to existing simulators, the discussions with potential users a list of desirable features was compiled. Many of these features were established early in the study, and were thus able to be incorporated in the discussions with potential equipment suppliers which began very soon after the start of the study. Some of these features were judged to be requirements (R below), while other were judged to be desirable (D below). The features were:

1. Very fast 3D graphics (R). The machine should be capable of creating frames at 30Hz to provide jerk-free motion.

2. Very fast screen clear (R). Slow screen clear could cause noticeable lags in the system.

3. Projected images (R). The use of monitors for presenting the image to the driver resulted in an unacceptable loss of realism.

4. Multi-channel capabilities (R). For wide-angle front projection it would be necessary to use at least three channels. A fourth channel would be required to provide a scene in the rear-view mirrors of the vehicle. Therefore, even if it was not feasible to provide full four-channel projection at the outset (because of cost constraints), the graphics hardware should have the capability for upgrading to four-channel output.

5. Analogue-to-digital conversion for reading and recording driver/vehicle inputs (R).

6. A means of monitoring driver status, preferably through an EEG (polygraph) machine (R).

7. Sound (R). There were almost universal comments about the need to incorporate a high-quality sound system.

8. Texturing (D). This provides a far greater sense of depth of field than flat shading. It also allows complex details to be incorporated in, for example, building fronts. Textured surfaces can be incorporated from scanned images (e.g. photographs) or from captured video. Finally texturing permits the drawing of realistic semi-transparent objects such as trees and the painting of realistic backdrops such as the sky.

9. Anti-aliasing (D). This allows diagonals to be smoothed and prevents small bright objects such as lights from shimmering, when they should be clear. It is particularly important if it is necessary to use lower resolution graphics for projection in order to save costs, since jagged lines are much more apparent at lower resolutions.

10. Special effects such as fog and haze (D). Although this capability was not mentioned in the responses to the circular, it was a feature that was available in several existing simulators and was thought desirable because it permitted the testing of visibility effects on driver performance.

11. Flexibility in video resolution (D). Although it might be necessary because of cost constraints to use lower resolution such as PAL for multi-channel output, it would be desirable to have a capability built in for single-channel projection at the highest available resolution (1024 x 1280). This would mean that experiments requiring such high resolution could be carried out without altering the hardware.

12. Off-line programming on cheaper, compatible machines (D). Some experiments might require very lengthy programme development, which might

be done at other institutions under their own research grants. It would be preferable for this to be done on a compatible workstation to ensure that the databases and code created would run on the simulator.

Many of these features are not currently available even on the most advanced existing simulators. However, it was fortunate that, as this study began, a new generation of visual simulation workstations was announced by at least two manufacturers. These new machines can provide virtually every feature in the above list, although this can not necessarily be done within the available equipment budget. The aim was therefore to achieve the best performance for the price, while at the same time being mindful of the goal of compatibility with the systems being developed at other institutions.

6. RECOMMENDED EQUIPMENT

The recommendations on equipment and share of the overall budget are made here. The total available, after allowing for the cost of the Scoping Study is £144,000. Since it is important to know how much of this is available for the major items of equipment after various pieces of essential ancillary equipment are allowed for, the costs for the smaller items are presented first.

6.1. The Vehicle and Associated Equipment

It is assumed that a vehicle can be purchased from a scrapyard for a nominal sum (say £500). It is hoped, however, that it may be possible to persuade a vehicle manufacturer to donate a new vehicle for use in the simulator. It is expected that the simulator will generate quite a large amount of publicity and that a manufacturer can be persuaded of the benefit to be obtained by a particular vehicle being featured in the publicity.

The equipping of the vehicle for use in the simulator will cost considerably more than the vehicle itself. The torque motor for use in the steering will cost several thousand pounds; a multi-channel analogue-to-digital converter will cost over £1000; and a large number of smaller items will have to be purchased. Based on discussions with other institutions that have similarly equipped vehicles for use in a simulator, it is recommended that around £10,000 be reserved for the vehicle and its equipment.

6.2. Driver Monitoring

The Psychology Department at the University of Leeds have agreed to donate an EEG machine for use in the driving simulator. ITS already has a number of video cameras available (both standard VHS and Video 8), one of which can be used in the simulator. Driver monitoring can therefore be accomplished at no cost in equipment.

6.3. Computer Workstation

After seeking advice from the Computer Studies Department at Leeds, discussions were held with three computer manufacturers on the supply of equipment. Each manufacturer was informed of the overall budget, of the basic requirements of the system, and of the need for ease of use in the software. After numerous meetings in which the specifications of the systems to be provided were refined, each manufacturer submitted a final quotation. These quotations are included in Appendix C.

The three manufacturers of graphics workstations approached were:
1. Megatek Ltd.
2. Silicon Graphics Ltd.
3. Stardent Computer Ltd.

Among these, it soon became clear that the first two were the real contenders. The Stardent 2000 system, which was proposed by Stardent, did not have many of the capabilities listed as required or desirable in Section 5. For example, it featured a maximum of two-channel output, and did not offer texture or anti-alias even as options. It was significantly slower than the machines of the other two manufacturer: for example its benchmark performance was 160,000 polygons a second as opposed to the 1,000,000 polygons a second of the Silicon Graphics PowerVision machine. And finally it was actually *more* expensive than the machines of the other two manufacturers at £107,000 for a single-head unit.

The other two manufacturers are both offering equipment that has just arrived on the market and therefore offers the latest in features. The machines are both aimed at the visual simulation market and are therefore designed to offer the graphics performance required for real-time 3D operation. The performance difference between the Megatek 944 and the Silicon Graphics Iris 210VGX PowerVision is probably marginal. Any difference in benchmark performance is likely to be negated by the different designs of the machines, so that their real-world performance is virtually identical. In the last resort, the advantage has been given to the Silicon Graphics machine because:

1. It is somewhat cheaper *if ordered before the end of April.*

2. It includes anti-aliasing and fog/haze (the latter while feasible on the Megatek 944 as quoted is not the true fog and haze that can be obtained by the addition of a special board).

3. It includes texturing from day 1, whereas Megatek is promising the availability of texture in the third quarter of 1990. Its performance with texture can thus be established now.

4. It is part of a wider product range including cheaper but compatible workstations that would permit off-line programming.

5. It features a "programmable video option", which permits the resolution of the projected video to be changed to any standard resolution (PAL, NTSC, 1024 x 1280, etc.). This also permits the generation of four PAL windows (and thus projection outputs) from one graphics channel.

6. Silicon Graphics has more longevity in the business and a much larger market share. Indeed it is the market leader in 3D graphics workstations. It may therefore be a more reliable supplier than Megatek which is a comparatively new entrant into this area. Megatek's system is based on a Sun 4, and there is certainly a possibility that Sun will wish to enter this market itself and therefore choose to squeeze out Megatek.

Silicon Graphics are offering a substantial discount if the order is placed before the end of April, since this will permit payment in their current financial year (see letter of 10 April 1990 in Appendix C). With this discount, the recommended Silicon Graphics 210VGX costs £97,531. The price rises to at least £100,784 if ordered after the end of April, with the ending of the discount offer and with the possibility of an increase in list price). With the addition of VAT at 15% the amount for the early purchase of the system comes to £112,161.

In addition to system purchase, it is vital to ensure that the computer remains operational during the envisaged development phase of two years. A maintenance contract is therefore included on the costs estimates. It is anticipated that, after the development phase is over, it will be possible to cover the costs of maintenance through the fees to charge users for time on the system. The Silicon Graphics quotation for a two-year maintenance contract is £12,340.60. This makes the total cost of the system is £124,501.60.

6.4. Projection Equipment

The expenditures outlined above for the vehicle, its equipment, and the visual simulation workstation account for all but £10,000 of the total budget. This is the amount available for projection equipment.

Information was sought on a number of projector lines (most simulators use BARCO projectors) in consultation with the Audio Visual Service at the University of Leeds. In the past a single high-resolution (1024 x 1280) projector has cost upwards of £18,000, but Sony has recently announced equipment that significantly undercuts that price, while maintaining impressive features and performance. The Sony VPH-1270QM offers multiscan capabilities (i.e. it can lock on to a large range of scanning frequencies) and can thus be used for both PAL and high-resolution output. Different configurations can be stored in memory, thus permitting rapid change from one resolution to another. A demonstration was conducted at the University to test for compatibility with Silicon Graphics products, and the projector performed flawlessly at various synchronization rates. The cost of a single projector is £11,595 exclusive of VAT. It should be noted that, as stated in the quotation from Erricks' VCD included in Appendix C, *this price is only good until the end of April,* when a price rise is anticipated.

6.5. The Need for Urgency

As noted above, the prices for both computer and projection equipment are likely to increase substantially after the end of April. This will essentially mean that it is impossible to buy the planned equipment within the budget allocated. Indeed, this is already difficult, since the prices outlined above add up to slightly more than the overall £144,000 remaining after allowing for the Scoping Study. It is likely, however, that the cost of the Scoping Study will actually come out to slightly less than £6,000. In addition, it may be possible to reduce slightly the amount set aside for the vehicle and its equipment. Nevertheless, it is critical that an early go-ahead be given for the ordering of equipment. Otherwise, cheaper and less adequate system will have to be purchased.

6.6. The Option of an Increase in Funding

The proposed computer workstation will have the capability for multi-channel projection, but the equipment to be purchased within the original allocation of £150,000 will only provide single-channel projection. When the estimate was originally made of the amount needed to equip a driving simulator, it was not based on a full examination of the options, but rather on the best evidence available at the time. The Scoping Study was intended to shed light on the various options and to recommend the best available equipment for the money.

As a result of the Scoping Study, it is now felt that a relatively small increase in the funds allocated would result in a large improvement in simulator performance by permitting the purchase of additional projectors. It is recommended that funds be provided for at least two but preferably three additional projectors. Two additional projectors would provide the large field of view for the driver which is particularly critical for urban driving. A third additional projector would provide working rear-view mirrors. This feature had emerged as highly desirable in the discusions with academic colleagues, in part because it would increase the reliability of observed driver performance in the system. Two more projectors would add £22,667 to the costs, while three additional projectors would add £32,002 (both inclusive of VAT). These costs might rise slightly in view of Sony's planned price increase.

7. CONCLUSION

The proposed equipment will result in a driving simulator that has many of the performance features of the most advanced present-day systems, some of which have cost millions of pounds. Indeed, the simulator will in some significant ways out-perform those systems by, for example, providing texture and by having the capability for four-channel projection. The workstation proposed offers something like a ten-fold increase in performance over previous generations of equipment and represents a new level of machine specifically aimed at the visual simulation market. It is anticipated that the simulator will be a valuable tool for the research community.

8. ACKNOWLEDGEMENTS

The author would like to thank his colleagues at the University of Leeds, Ken Brodlie from Computer Studies and Miles Tight from ITS, for the time and enthusiasm that they have committed to this study. Staff at a number of UK institutions submitted comments and suggestions, and some of these people also attended the workshop. The author is grateful for all the effort spent on this input. Finally, he would like to thank all the institutions that extended their time and hospitality in demonstrating their own installations.

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19 December 1989

REALISTIC DRIVING SIMULATOR

Dear Colleague,

The Institute for Transport Studies has been awarded a grant of £150,000 by the Science and Engineering Research Council to purchase the equipment for a realistic driving simulator. A proposal to SERC has also been submitted by ITS together with the Computer Studies and Psychology Departments at Leeds for the funding of the necessary development work. The simulator is, once it has been developed, intended to be used as a shared resource by the research community.

The kind of system presently envisaged would use animated three-dimensional graphics (possibly with the super-imposition of photographic images). High resolution video output would be created in real time on a fast graphics workstation and there would be interaction between the driver, the vehicle and the video projection. Some steering and braking feedback would be provided to the vehicle and thus the driver, but a full vehicle handling model is not likely to be feasible within the planned costs. Similarly it is virtually certain that any kind of real movement of the vehicle is not feasible, although sound capabilities could be built in.

At the moment, SERC is funding an initial "scoping study" at ITS to determine the applications for which capabilities should be built in and the most suitable equipment to be purchased. The report on this scoping study is due at the end of March 1990, but it is hoped that the general findings of the scoping study can be established even sooner. Because the simulator will be a general resource, ITS is seeking suggestions and recommendations from as wide a circle as possible — transport studies groups, psychologists and road safety experts in the applications area, and graphics and engineering experts in the software design and hardware areas. It is hoped that a consensus can be reached on the general capabilities of the system and on the trade-offs that will be required in view of the resources allocated.

Those wishing to have an input into the design of the simulator, especially those desiring to have particular capabilities built or programmed into the system, are urged to get in touch with me. The preferred means for making suggestions is to submit them in writing by the end of January, but I can also be reached by phone at (0532) 335348.

Yours faithfully,

Oliver Carsten

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Date	Telephone	Your reference	Our reference
12 March 1990	+3150636758		TR/JvD/90.183

Subject

Dear Dr. Carsten,

After more than 5 years of experience with low-level driver simulators, the Traffic Research Centre plans to embark upon the development of a more advanced level simulator in the near future on the basis of an IRIS configuration. I understood from earlier talks I had with you, that the ITS is entertaining plans in a similar direction. Given the fact that the TRC and ITS are planning to obtain the same type of equipment, it may be beneficial to both to engage in some form of co-operation with regard to software development. In our talks you have clarified that the University of Leeds has particular expertise in the AI/visualisation aspects of software development. At TRC, we have been focusing on the driver task apects of the same. Given this state of affairs, the TRC would be interested in pursuing some form of collaboration which would entail the mutual exchange of software program development undertaken at our respective institutes. However, I should mention that the TRC is, at the moment, also involved in a co-operation with Philips Research Laboratories. For this reason, it will be necessary to reach some form of formal agreement.

As a first step, I believe it would be useful to establish our mutual interest in collaboration. Following this we could attempt to specify our specific contributions within a possible collaboration agreement. It is our intention to realize a running system before the end of 1990. For this reason, I am looking forward to your reply at your earliest convenience.

Yours sincerely,

Dr. J.A. Rothengatter
associate director

APPENDIX C

SUPPLIERS' QUOTATIONS

MEGATEK LTD
A UNITED TELECOM COMPANY

Megatek Limited
Winchester House
19 - 23 Winchester Street
Basingstoke, Hampshire
RG21 1EE, United Kingdom
Telephone: 0256 - 844636
Fax: 0256 - 475300

30th March 1990

Dr Oliver Carstens
Institute of Transport Studies
Leesd University
LEEDS
LS2/9JT

Dear Oliver,

Thank you for affording us some of your valuable time on wednesday, providing us with an opportunity to outline our revised proposals to you.

As discussed, I have pleasure in enclosing the revised quotation for the Megatek solution and would draw your attention to the following areas:

1. We have included in the system the texturing processor board which will dramatically improve the realism of the scenarios. It comes complete with texture input and generation facilities, 8MB of storage RAM allowing a wide variety of textures to be used, and operates at full system speed.

2. Regarding maintenance ,we have quoted for a full 8 hour on-site facility This figure of 6% is fixed and firm at todays's prices

3. Megatek will provide the Institute of Transport Studies with models for their simulator covering several vehicle types, these will be free of charge and include the source code allowing for duplication or modification as required.

4. We will provide you with support to integrate the 944 to the simulator including projector alignment , vehicle interfacing (steering, throttle etc.) and provide source code of our demonstration software to minimise your learning curve on the system.

MEGATEK LTD
A UNITED TELECOM COMPANY

The 944 is specifically designed as a simulation graphics tool and offers many facilities in this respect including lazer ranging, weather effects and fast hidden surface removal etc which minimises the software effort required for database creation, display and modification.

I hope this clarifies our position Oliver, we look forward to a positive descision later next week. Should you have any further queries concerning this proposal ,or further action required on our part , then please do not hesitate to contact either Gareth Jones or me.

Yours sincerely

Steve Brain

(Steven Brain)

MEGATEK LTD
A UNITED TELECOM COMPANY

Megatek Limited
Winchester House
19 - 23 Winchester Street
Basingstoke, Hampshire
RG21 1EE, United Kingdom
Telephone: 0256 - 844636

QUOTATION

TO:
Dr Oliver Carstens
Institute of Transport Studies
Leeds University
Leeds
LS2 9JT

QUOTE No. UK/0235/sb/a
DATE 30 March 1990
TERMS ~~30 days~~
F.O.B. ~~Basingstoke~~
REFERENCE Steven Brain
VALID FOR 30 days

ITEM	PART No./MODEL No.	DESCRIPTION	QTY.	UNIT PRICE	TOTAL
1	00014066	944 Visual image generation system 12 slot pedestal 230 VAC	1		
2	00014052	Expanded display list memory to 4MB	1		
3	00014061	Workstation display options keyboard/mouse/monochrome monitor	1		
4	00014050	654 MB formatted disk system/ 150 MB 1/4" cartridge tape	1		
5	00014023	19" RGB Monitor 1024 x 1024 @ 60Mhz non-interlaced	1		
6	00014091	Display 2/Display 3 Frame buffers	2		
7	00014090/T	Megatek 944 texturing processor board with 8MB texture storage RAM	1		
8	00014054	944 Software distribution Media including RSR GRAPHICS LIBRARY SOURCE CODE and THE CARRERA PROTOTYPING TOOL	1		

These prices are based on an exchange rate of $ 1.65 to the £1. The prices invoiced will be based on the actual exchange rate current at the time.

Plus V.A.T. @ 15 % or % ruling at time of delivery.

This quotation is subject to the terms and conditions on the reverse side.

DELIVERY:
6 - 8 weeks

BY Steven Brain

Refer inquiries to David Denton - Steven Brain

MEGATEK LTD
A UNITED TELECOM COMPANY

Megatek Limited
Winchester House
19 - 23 Winchester Street
Basingstoke, Hampshire
RG21 1EE, United Kingdom
Telephone: 0256 - 844636

CONTINUATION PAGE

CUSTOMER Institute of Transport Studies

MEGATEK QUOTE No. UK/0235/sb /a

ITEM	PART No./MODEL No.	DESCRIPTION	QTY.	UNIT PRICE	TOTAL
9	00014056	944 Unix Software distribution Media	1		
10	00014057	944 RSR Graphics Users Reference Manuals	1		
11	00014026	944 Unix operating system documentation	1		
		TOTALSYSTEM PRICE (inclusive of education discount, excluding VAT)			100258.00

MEGATEK LTD
A UNITED TELECOM COMPANY

APPENDIX TO QUOTATION NO UK/0214

944 VISUAL GENERATOR SYSTEM

Part Nos:

00014066	Integral Host Processor - 16 MIPS SPARC™ General Purpose Processor - TI 8847 Floating Point Processor - 8 Mbytes Parity Main Processor Memory - Ethernet™ Interface with NFS™ Support - Four RS-423 Serial Interfaces - UNIX Operating System License - "C" Compiler with Program Development Tools
	944 Display List Processor - 1 Mbyte Hi-Speed Video RAM Display List Memory (Expandable to 4 Mbyte) - Multiple Micro-Coded Processors traversal, full transformations, 6-plane clip perspective) - 125k Visible Shaded Triangles per sec (320 pixels each) - 80 MFLOPS Processing Capacity
	944 Span Processor - 20 Mbyte Double Buffered DRAM Span Buffer - 300k Light Point per sec Processing Rate - 2.5 Million Spans per sec Processing Rate - 40 MFLOPS Processing Capacity
	944 Pixel Processor - Full Shading Support (Flat, Gouraud) - Virtual Resoluation up to 2048 x 2048 - 32-bit Floating Point Hidden Surface Removal - 120 MFLOPS Processing Capacity - 40 Million Pixels per sec Processing Rate
	944 Imsage Frame Buffer - 24-bit Double Buffered VRAM Architecture - Multiple Look-up Table Support - On-Board TI34010 Programmable Processor - Auxiliary 8-bit Alpha & Beta Buffers with Image Keying - On-Board Genlock and Composite PAL Video Output
	944 System Description and Installation Manual
	RSR Software Single System License
	944 STANDARD 12 SLOT-SYSTEM PEDESTAL MOUNT Note: 3 Spares VME Slots 3 Graphics Option Slots 230 VAC/10 AMP
00014052	EXPANDED DISPLAY LIST UPGRADE Includes 3 Mbytes additional Video RAM factory installed to increase total display list memory to 4 Mbytes on a single Display List Processor

MEGATEK LTD
A UNITED TELECOM COMPANY

00014061	WORKSTATION DISPLAY OPTION Includes low profile keyboard and mouse point device, 19" Landscape Monochrome Monitor, 1600 x 1280 resolution, monochrome image buffer for window management display, 66 Hz non-interlaced video support. Note: Require 1 VME Slot
00014050	MASS STORAGE DISK/TAPE SYSTEM (654 MB) Includes 150 Mbyte 1/4" Cartridge Tape System, 654 Mbyte formatted disk System.
00014023	RGB MONITOR 19" 60 Hz (1024) 230 VAC Includes tilt & Swivel base, 15' RGB video cable, 6' power cable, 1024 x 1024 resolution, 60 Hz non-interlaced, for visual system image display output.
00014090/T	TEXTURE PROCESSOR Includes 8MB texture storage RAM. Full transparency, photographic and pattern mapping. Parrallel operation maintains full system performance.

SOFTWARE DISTRIBUTION

00014054	944 SOFTWARE DISTRIBUTION Includes RSR graphics library source executable, diagostic and demo programs in 1/4" cartridge tape format.
00014056	944 UNIX SOFTWARE DISTRIBUTION Includes Operating System Software, C Compiler, Standard Development Tools in 1/4" cartridge tape format.

DOCUMENTATION

00014057	944 RSR GRAPHICS USER'S REFERENCE MANUAL
00014026	UNIX OPERATING SYSTEM DOCUMENTATION

MEGATEK LTD
A UNITED TELECOM COMPANY

Megatek Limited
Winchester House
19 - 23 Winchester Street
Basingstoke, Hampshire
RG21 1EE, United Kingdom
Telephone: 0256 - 844636

QUOTATION

TO:

Oliver Carsten
Institute of Transport Studies
Leeds University
Leeds
LS2 9JT

QUOTE No. UK/0235/sb/b
DATE 30 March 1990
TERMS 30 days
F.O.B. Basingstoke
REFERENCE Steven Brain
VALID FOR 30 days

ITEM	PART No./MODEL No.	DESCRIPTION	QTY.	UNIT PRICE	TOTAL
1	Maintenance	On site maintenance with 8 hour response time. Coverage for two years. These percentage figures relate to the full UK list price of the equipment purchased by Leeds University			6% Per Annum

These prices are based on an exchange rate of $ 1.65 to the £1. The prices invoiced will be based on the actual exchange rate current at the time.

Plus V.A.T. @ 15% % or % ruling at time of delivery.

This quotation is subject to the terms and conditions on the reverse side.

DELIVERY:

BY Steven Brain

Refer inquiries to David DEnton - Steven Brain

Silicon Graphics Ltd
Computer Systems

The Genesis Centre
Science Park South
Birchwood
Warrington
WA3 7BH

Tel: 0925 830086
Fax: 0925 812282

NR/HL/0034

7th March, 1990

Dr O Carston
Institute of Transport Studies
University of Leeds
Leeds
LS2 9JT

Dear Dr Carston,

Following our meeting and subsequent discussions with Angus Henderson, I am now able to make recommendations of appropriate equipment for your driving simulator.

The system is based on a POWER Series 4D/210 which has the ability to cope both with driving the Graphics subsystem and to run your simulation tasks. The IRIX operating system has real time extensions to support this and this solution will offer ease of integration and programming vs. connected PCs.

The Graphics subsystem proposed is a MBVGX which consists of the POWERVISION VGX Graphics with FX and multi-buffer MB options (see attached descriptions). These provide all the enhanced functionality we discussed including:

- Texturing
- Sub-pixel positioning
- Anti-aliasing for ALL system primitives (polygons, vectors, points)
- New lighting models incl directional spotlighting (for headlights etc.)
- Transparency (views through trees etc.)
- Fog and haze weather effects

Together with the unrivalled performance of the VGX hardware for visual simulation you will have the state of the art solution for your application.

The following notes together with the accompanying diagram details how this system would work in conjunction with projectors etc.

- The Programmable video option will be provided as an upgrade to provide 4 x 640 x 512 signal and BNC connectors for four TV standard 625 line projectors. This is included in our costings and we are confident of November availability. This attaches directly to the memory bus and replaces the need to purchase 4 scan converters.

-

Silicon Graphics Ltd
Computer Systems

QUOTATION

Windrush Court
Blacklands Way
Abingdon Business Park
Abingdon Oxon
OX14 1SY
Tel: (0235) 554444 Sales
Fax: (0235) 554440

Customer Name: Dr O Carston

Address: Institute of Transport Studies
University of Leeds
Leeds
Leeds, LS2 9JT

Quote No.: NR/HQ/0038

Date: 7th March 1990

Item	[illegible]	[illegible]	Description	[illegible]	[illegible]
1	1	W-4D210MBVGX	IRIS 4D 240VGX POWERVISION Supercomputer Workstation with multi-buffer option in deskside enclosure 8Mb ECC RAM, 1 x 25 Mhz R3000 RISC CPU with 1 x 25 MHz R3010 floating point assist, 2 x RS232 ports 19" 1280 x 1024 60/120Hz monitor, 64 bit planes display memory for colour and transparency, 24 bit planes for Z-buffer, 96 bit texture memory planes with alpha, 64 bit accumulation buffer, 8 bit stencil planes, 4 bit planes for window update, 4 bit planes for window display, 4 bit planes for overlay and underlay, 10 Span processors for a fill rate of 200 million pixels/sec, Ethernet interface, SCSI port, keyboard and optical mouse, TCP/IP software, 4Sight Window Manager, Graphics Library, TruTexture, ImageVision Library,UNIX and C licences, manuals		
2	1	SD4-M4E38	380 Mb 5.25" full height ESDI System Disk (320 Mb formatted) with 4 channel controller		
3	1	P4-T4C3B	Internal SCSI 1/4" 150 Mb Cartridge Tape Drive		
4	1	H4-C08X	8 Mb ECC Memory Expansion		
5	1	S4-FTN	Fortran 77 Compiler, IRIS Graphics Library for Fortran, debugging and performance tuning tools and manuals		
6	1	PV-OPT	Programmable Video Option		
7	1	S4-NFS	Network File System		
8	1	X4-EX01	Ethernet Thickwire Transceiver		
9	1	X4-ECD1	Ethernet Drop Cable		
			Total discounted price		**£100,784**

Note: this quotation is effective for 30 days from the above date, and is subject to the terms and conditions of sale on the reverse side hereof and other applicable standard agreement forms. Unless specifically noted above, prices quoted include delivery and installation (within UK Mainland) and ninety days warranty, but exclude VAT.

Authorised Signature: N. Mac Russell

White: Customer copy, Blue: Sales Office, Yellow: Finance

Silicon Graphics Ltd
Computer Systems

Haw Bank House
High Street
Cheadle
Cheshire
SK8 1AL
Tel: 061-428-1559
Fax: 061-428-1974

Ref: NR/L/0002

10th April 1990

Dr O M J Carsten
Institute of Transport Studies
University of Leeds
Leeds
LS2 9JT

Dear Oliver

Please find attached a revised quotation together with maintenance prices for the proposed equipment. As discussed the basis of our offer is for an order by the end of April which will allow delivery of equipment before the company year end. We are offering customers GTX systems with VGX upgrades where quick delivery is required.

The maintenance prices are based on full on-site cover and detail possible discounts. Our Customer Services Manager will also be happy to discuss lower levels of response to reduce cost still further and returns from holiday next week.

You may not require annual software updates as it should be possible to share copies with customers at the University (subject to internal negotiation!).

Please do not hesitate to contact me to discuss any of these points.

Yours sincerely
SILICON GRAPHICS LIMITED

P.P.
N M RUSSELL
Education and Research

10/04 '90 12:47 FAX 061 428 1974 SILICON GRAPHICS 002

Silicon Graphics Ltd
Computer Systems

Haw Bank House
High Street
Cheadle
Cheshire
SK8 1AL
Tel: 061-428-1559
Fax: 061-428-1974

QUOTATION

Customer Name: Dr O M J Carsten

Address: Institute of Transport Studies
University of Leeds
Leeds
LS2 9JT

Quote No.: NR/Q/0002

Date: 10th April 1990

Item	Qty	Product Number	Description	Unit	Amount
			Revised offer for our Quote no NR/HQ/0038 for an order received by the end of April 1990.		£97,531.00
			Maintenance		
			2 years at £11,018.40 equals		£22,036.80
			Less 40% on year 1 only (day 1 contract replacing warranty)		£4,407.36
			Sub-total		£17,629.44
			Less 20% educational discount		£3,525.89
			Sub-total		£14,103.55
			Less 12.5% (2 year contract in advance)		£1,762.95
			TOTAL		**£12,340.60**
			Annual Software Update		
			Operating System		£300
			FORTRAN		£50
			NFS		£50

Note: this quotation is effective for 30 days from the above date, and is subject to the terms and conditions of sale on the reverse side hereof and other applicable standard agreement forms. Unless specifically noted above, prices quoted include delivery and installation (within UK Mainland) and ninety days warranty, but exclude VAT.

Authorised Signature: J. P. Jacques [signature]

[redacted]

STARDENT COMPUTER LIMITED

Type of Agreement
Stardent Agreement No.
Quotation No. ED15002-ISOEURUK
Stardent Sales Office United Kingdom
Customer P.O. No.
Date of Quotation 22/03/90
Quotation Expiration Date 21/04/90
(not to exceed 30 days from date of the Quotation)

PURCHASE, LICENSE AND SERVICE QUOTATION AND ORDER FORM

Machine Type:
Serial No. :

Page 1

CUSTOMER University of Leeds

BILLING ADDRESS and CONTACT	INSTALLATION ADDRESS AND CONTACT
Department of Transport Studies LEEDS, LS2 9JT Dr Oliver Carsten	As billing address

QUOTATION

This Quotation (which includes the attached Product Schedule) shall remain in effect until the date indicated above unless withdrawn, modified or extended in writing by Stardent prior to acceptance by Stardent of an order made hereunder. Any order resulting from this Quotation must be accepted by a duly authorised representative of Stardent Computer Limited at its UK headquarters. This Quotation and any such order shall be governed exclusively by the terms and conditions of the Stardent Agreement signed by Stardent and Customer referenced above and, accordingly no other terms and conditions apply (including without limitation any terms and conditions set forth in any purchase order form of Customer's).

Total Amount of the Quotation	126,214

ORDER

Based upon the above Quotation, Customer hereby places its firm order for the purchase, license and/or service of the Stardent Products listed on the attached Product Schedule and at the prices, fees and/or charges set forth on such Product Schedule. Customer understands and acknowledges that any order (i) is subject to acceptance by an authorised representative of Stardent Computer Limited at its UK headquarters, (ii) is placed pursuant to the Stardent Agreement signed by Stardent and Customer referenced above, and (iii) is subject exclusively to the terms and conditions of the referenced agreement and, accordingly, no other terms and conditions apply (including without limitation any terms and conditions set forth in any purchase order form of Customer's).

CUSTOMER ______________________

BY ______________________
(Authorised Signature)

NAME ______________________
(Print Name)

TITLE ______________________

Date of Order ______________________

Total Amount of Order ______________________
(must be identical to the Total Amount of the Quotation listed above)

Requested Delivery Date ______________________

ORDER ACCEPTANCE

This Order Acceptance is not valid unless and until (i) the Stardent Agreement referenced above has been signed by Stardent and Customer, and (ii) this Order Acceptance has been signed by a duly authorised representative of Stardent Computer Limited at its UK headquarters.

STARDENT COMPUTER LIMITED

BY ______________________

NAME ______________________

TITLE ______________________

Date of Acceptance ______________________

Projected Delivery Date ______________________

Stardent Computer Limited
15 Frederick Sanger Road
The Surrey Research Park
GUILDFORD
Surrey GU2 5YD

(D'

STARDENT COMPUTER LIMITED

PURCHASE, LICENSE AND SERVICE QUOTATION AND ORDER FORM

Quotation No. ED15005-ISOEURUK
Date of Quotation 22/03/90
Quotation Expiration Date 21/04/90
Page: 2

PRODUCT SCHEDULE

CUSTOMER University of Leeds

ITEM NO	DESCRIPTION	QTY	UNIT PURCHASE PRICE/ LICENSE FEE	EXTENDED PRICE/ FEE	MMC
1	Model Number: GS-2025-82-01 Stardent 2040 Stardent Graphics Supercomputer - Includes: MSP, VFP and RP Processors 16MB Main Memory 19-Inch 1280x1024 74Hz. Color Display 150MB .25-Inch Tape Cartridge Drive 1MB Cache Memory 2 Input/Output Processors (IOP's) SPC/386 Service Processor with 1.2MB 5.25-Inch Floppy Disk Drive 1 760MB ESDI Disk with VME Controller 16-Plane Frame Buffer 3 RS-232 Serial Ports Licenses and Documentation for: Stellix Operating System and System Software (SW-1010 or 1011) Stardent Application Visualization System (AVS) (SW-2300) Stardent Unsupported Software (SW-8001) Basic System Documentation (one copy each of MD-000x, 01xx, 1xxx, 2000, 21xx, 230x, 4001) Keyboard and Mouse 25-Foot Monitor/Keyboard/Mouse Cable with RS-232 serial Port Extension 3 User-Available VME Slots 1 Service/Console Port	1	97,440	97,440	656
2	Model Number: MB-0064-01 64MB Main Memory	1	35,952	35,952	199

[redacted]

STARDENT COMPUTER LIMITED

Type of Agreement
Stardent Agreement No.
Quotation No. ED15005-ISOEURUK
Stardent Sales Office United Kingdom
Customer P.O. No.
Date of Quotation 22/03/90
Quotation Expiration Date 21/04/90
(not to exceed 30 days from date of the Quotation)

PURCHASE, LICENSE AND SERVICE QUOTATION AND ORDER FORM

Machine Type :
Serial No. :

Page 1

CUSTOMER University of Leeds

BILLING ADDRESS and CONTACT	INSTALLATION ADDRESS AND CONTACT
Department of Transport Studies LEEDS, LS2 9JT Dr Oliver Carsten	As for billing address

QUOTATION

This Quotation (which includes the attached Product Schedule) shall remain in effect until the date indicated above unless withdrawn, modified or extended in writing by Stardent prior to acceptance by Stardent of an order made hereunder. Any order resulting from this Quotation must be accepted by a duly authorised representative of Stardent Computer Limited at its UK headquarters. This Quotation and any such order shall be governed exclusively by the terms and conditions of the Stardent Agreement signed by Stardent and Customer referenced above and, accordingly no other terms and conditions apply (including without limitation any terms and conditions set forth in any purchase order form of Customer's).

Total Amount of the Quotation	107,310

ORDER

Based upon the above Quotation, Customer hereby places its firm order for the purchase, license and/or service of the Stardent Products listed on the attached Product Schedule and at the prices, fees and/or charges set forth on such Product Schedule. Customer understands and acknowledges that any order (i) is subject to acceptance by an authorised representative of Stardent Computer Limited at its UK headquarters, (ii) is placed pursuant to the Stardent Agreement signed by Stardent and Customer referenced above, and (iii) is subject exclusively to the terms and conditions of the referenced agreement and, accordingly, no other terms and conditions apply (including without limitation any terms and conditions set forth in any purchase order form of Customer's).

CUSTOMER ______________________

BY ______________________
(Authorised Signature)

NAME ______________________
(Print Name)

TITLE ______________________

Date of Order ______________________

Total Amount of Order ______________________
(must be identical to the Total Amount of the Quotation listed above)

Requested Delivery Date ______________________

ORDER ACCEPTANCE

This Order Acceptance is not valid unless and until (i) the Stardent Agreement referenced above has been signed by Stardent and Customer, and (ii) this Order Acceptance has been signed by a duly authorised representative of Stardent Computer Limited at its UK headquarters.

STARDENT COMPUTER LIMITED

BY ______________________

NAME ______________________

TITLE ______________________

Date of Acceptance ______________________

Projected Delivery Date ______________________

Stardent Computer Limited
15 Frederick Sanger Road
The Surrey Research Park
GUILDFORD
Surrey GU2 5YD

STARDENT COMPUTER LIMITED

PURCHASE, LICENSE AND SERVICE QUOTATION AND ORDER FORM

Quotation No. ED15002-ISOEURUK
Date of Quotation 22/03/90
Quotation Expiration Date 21/04/90
Page: 2

PRODUCT SCHEDULE

CUSTOMER University of Leeds

ITEM NO	DESCRIPTION	QTY	UNIT PURCHASE PRICE/ LICENSE FEE	EXTENDED PRICE/ FEE	MMC
1	Model Number: GS-2225-82-01 Stardent 2240 Stardent Graphics Supercomputer - Includes: MSP, VFP and RP Processors 16MB Main Memory 2 19-Inch 1280x1024 74Hz. Color Displays 150MB .25-Inch Tape Cartridge Drive 1MB Cache Memory 2 Input/Output Processors (IOP's) SPC/386 Service Processor with 1.2MB 5.25-Inch Floppy Disk Drive 1 760MB ESDI Disk with VME Controller 16-Plane Frame Buffer 2 RS-232 Serial Ports Licenses and Documentation for: Stellix Operating System and System Software (SW-1010 or 1011) Stardent Application Visualization System (AVS) (SW-2300) Stardent Unsupported Software (SW-8001) Basic System Documentation (one copy each of MD-000x, 01xx, 1xxx, 2000, 21xx, 230x, 4001) 2 Keyboards and Mice 2 25-Foot Monitor/Keyboard/Mouse Cable with RS-232 serial Port Extension 3 User-Available VME Slots 1 Service/Console Port	1	110,040	110,040	731
2	Model Number: MB-0064-01 64MB Main Memory	1	35,952	35,952	199