SUCCESSFUL DIGITAL PHOTOGRAMMETRY AT THE ORDNANCE SURVEY OF IRELAND

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ABSTRACT

Ordnance Survey continues its pioneering role as the world's premier national mapping organisation in terms of the adoption of digital photogrammetry for daily production. The first two, well known phases have been supplemented by a third major procurement of workstations, accompanied by installation of a complex network to increase productivity. Special software has been added for quality control of digital orthophoto sheets. A fourth phase, which may include monoplotting from the orthophotos, is at the design stage. Not only is digital photogrammetry productive and successful in its natural roles of generating digital terrain models and image maps, but it is also equal to or better than analytical plotters for feature collection in terms of productivity and operator satisfaction. The Irish procurements have been facilitated by appropriate financing and the new technology has enabled Ordnance Survey to provide the vast amounts of timely information which the European Community's programmes have required.

1. INTRODUCTION

The Ordnance Survey of Ireland (OSI) is Ireland's national mapping organisation, established in 1824 and headquartered in Dublin. A popular history is provided in Anon (1991). OSI's mandate to map Ireland and to create medium and large scale digital databases has necessitated formidable and complex investment in new technology since the 1970s. OSI expanded radically following a decision in 1968 to accelerate the updating of its considerable range of map sheets, some of which had been rather neglected since Ireland had become a free state in 1922. More recently, OSI has invested in modern technology for all aspects of its work, based on a digital mapping system supplied by SysScan (now Sysdeco), running largely on Digital computers interconnected by DECnet. A progress report was given by Walsh (1987). The increases in productivity have been salutary. As a result, mapping staff have been reduced in number to around 270, 65 of whom are in survey control and data acquisition, 140 in large scale digital compilation and 65 in small scale compilation, map production and digital data distribution. OSI's operations are to some extent decentralised: 170 of the above staff are in the Dublin headquarters and 100 in six regional offices.

2.0 PHOTOGRAMMETRY AT OSI

The modernisation programme has included major investments in photogrammetry, necessitated by the extensive requirements.

2.1 OSI's mandate

The current programme is oriented to photogrammetric resurvey rather than labour intensive revision by field methods. The tasks, ranked in order of priority, may be summarised as follows:

(i) maintain the existing 1:1000 urban mapping in a structured digital database and resurvey by photogrammetry whenever updates are required
(ii) establish and maintain a small scale, structured digital database from imagery, mainly aerial photography, capable of graphical output at scales from 1:10,000 to 1:500,000, giving a new 1:50,000 series high priority
(iii) establish and maintain a large scale, structured digital database by photogrammetric resurvey, capable of graphical output at scales from 1:500 to 1:10,000
(iv) participate in the commercial mapping business.

2.2 Analytical photogrammetry

The acquisition of 16 analytical plotters took place at much the same time as the implementation of the digital mapping system. A Kern DSR1 was installed in 1982 and by 1992 there were 11 DSRs, 4 Zeiss P3s and a Leica SD2000; the complement of analogue instruments had been reduced to 4. An increasing number of the systems run KLT ATLAS software for map compilation, though Kern MAPS200, Zeiss PHOCUS and Leica PC-PC-PRO600 with Bentley Systems MicroStation are also in use. The analytical plotters were deployed almost entirely on the large and small scale databases before the digital procurements. Triangulation was performed using natural control, pass and tie points on the DSR1s, adjusted with PAT-MR on a VAX minicomputer. In 1993 a Barco publishing system was added, consisting of Barco workstations and Mercator map finishing software, an IRIS variable inkjet plotter for proofing and a Barco MegaSetter laser plotter, to enable the 1:50,000 sheets to be published in the latest manner. The large scale database, stored on an on-line 300 GB disk system, is also interfaced to OSI's Sysdeco TELLUS publishing system, whereby graphics at any scale from 1:500 to 1:10,000 may be provided in sheet-free form on customer demand on electrostatic plotters or digital media.

2.3 The decision for digital

More recently, decisions were made to make major procurements of digital photogrammetric systems, initially for the production of digital terrain models (DTMs), then for orthophotos and finally for vector data capture for large and medium scale mapping. These decisions followed from a 15 month evaluation begun in 1992, which concluded in favour of digital rather than analytical photogrammetry on grounds of: value, in terms of output per unit cost; stereo superimposition as a standard feature; orthophotography as a standard by-product; easier training and supervision; more flexible work planning; generation of DTMs and contours. The negative aspects were unit cost of digital photogrammetric workstations (DPWs) and the cost of scanners, unless each served a considerable number of DPWs. The digital systems were to coexist with the analogue and analytical workstations. The procurement processes were rigorous, with a period of systematic assessment followed by bench-marking a short list, and the selected vendor was Leica-Helava.

3.0 DIGITAL PHOTOGRAMMETRY

The situation until autumn 1995 has been described by Miller *et al.* (1995) and Kirwan (1995). There have been three procurements and a fourth one is imminent.

3.1 Phase one

Although not the first national mapping organisation to select Leica-Helava systems - Newby (1991) and Han (1992) give counter examples - OSI invested on a large scale. The first procurement, in 1993, consisted of a DSW 100 scanner, equipped for colour and black and white imagery and running on an 80486 PC, and four DPWs on SPARCstation 10s with Helava's SOCET SET® software. One of the DPWs was monoscopic, for project management and to play a server role for the three stereoscopic units. The systems were connected with Ethernet using TCP/IP protocols and one of the DPWs was also connected to OSI's main network with its DECnet protocols, using DECnet Interface hardware and software in the monoscopic workstation.

The foremost application was the generation of DTMs from 1:10,000 and 1:30,000 black and white photography for the large and small scale databases, which were specified to include 1 and 10 metre contours respectively. It was found that at the larger scale the DTMs were distorted in places by the effects of features like hedges, dykes and isolated trees. To some extent this could be ameliorated by tuning the DTM "strategies" (Miller and Devenecia, 1992), but the response of the vendor was to add editing tools capable, for example, of "bulldozing" the DTM within a corridor around a linear feature and making the terrain in the corridor blend smoothly into the surrounding fields. Another solution was a batch process whereby vector data previously captured on the analytical plotters could be imported from the Sysdeco database and used in editing. The Helava SOCET SET contains a rich variety of DTM editing tools, but at both scales a major stumblingblock, addressed by additional training, was the tendency for operators to continue editing until the DTMs were almost "perfect", i.e. far superior to the underlying specifications. Dense DTMs of 150,000-250,000 points per model are merged across boundaries of 6-10 stereomodels to provide large DTMs of 900,000-1,600,000 points for final contours. ATLAS is used to measure some additional spot heights manually.

The other challenge which emerged was workflow management. OSI was well versed in deployment of analytical workstations for feature collection, but the new system was primarily used for DTM generation and also incorporated a scanning phase. Thus management was partly a matter of applying existing expertise and partly of ramping up production as skills in optimising the output of the new technology accrued. One operator, for example, was allocated the tasks of scanning and routing the image data to the destination workstations, setting up each model and initiating the automated DTM generation, ready for the longer editing phase. This was done with the DPW670 and the model set up achieved with the image coordinate files associated with the DSR1 models input to PAT-MR, together with the results of the PAT-MR adjustment. After editing, this same operator would export the final contours to the SysScan database, after translation into SysScan format.

3.2 Phase two

Several national mapping organisations made initial procurements of Leica-Helava systems (Armenakis, Dow and Regan, 1995; Collignon, 1995; Ducloux, 1996; El-Kady *et al.*, 1994; Johansson *et al.*, 1995), but OSI went further. Towards the end of 1993 an additional stereoscopic workstation was added for the evaluation of DPWs for collection of vector data in comparison to analytical workstations. The results of this analysis were inconclusive, but the need for additional capacity together with the possibilities of hand controllers the same as the Leica SD2000 analytical workstation and the same ATLAS mapping package as installed on most of the analytical and analogue workstations swung the balance in favour of a second procurement of digital systems. The reasons were: similar unit cost to analytical plotters; OSI's need for superimposition in the future; orthophotos seen as a bonus; DTMs and contours; digital photogrammetry, despite its shortfalls for map compilation, was the area where future developments were most likely, given that analytical plotters were reaching the end of their product cycle; finally, a big investment should be seen to be made in new technology.

The purchase consisted of a second, much faster DSW200 scanner and six DPW770s. The system now totalled two scanners, one DPW670 monoscopic workstation and nine DPW770 stereoscopic workstations. The latter were deployed on both the DTM work and on feature collection. The systems were supplied with SPARCstation 20 hosts and the DSW200 scans a black and white photograph at 25 µm in six minutes, thus supplying all DPWs with enough data. The DPW770s were also equipped with Leica hand controllers and ATLAS, resulting in a familiar, comfortable, productive environment for map compilation. An overview of the OSI system at the end of this second procurement is given in Figure 1.

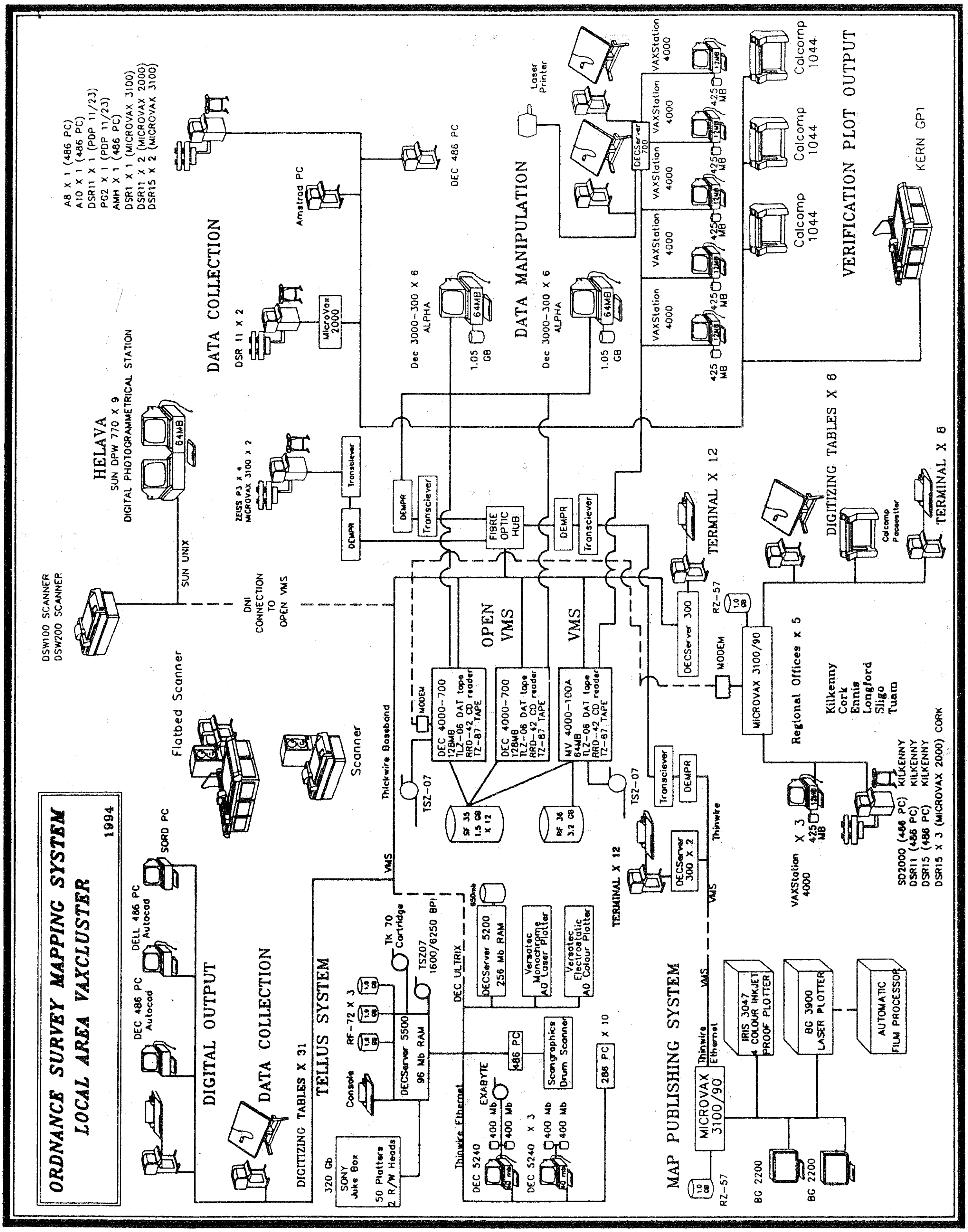

Figure 1. OSI mapping system at the end of the second digital photogrammetric procurement

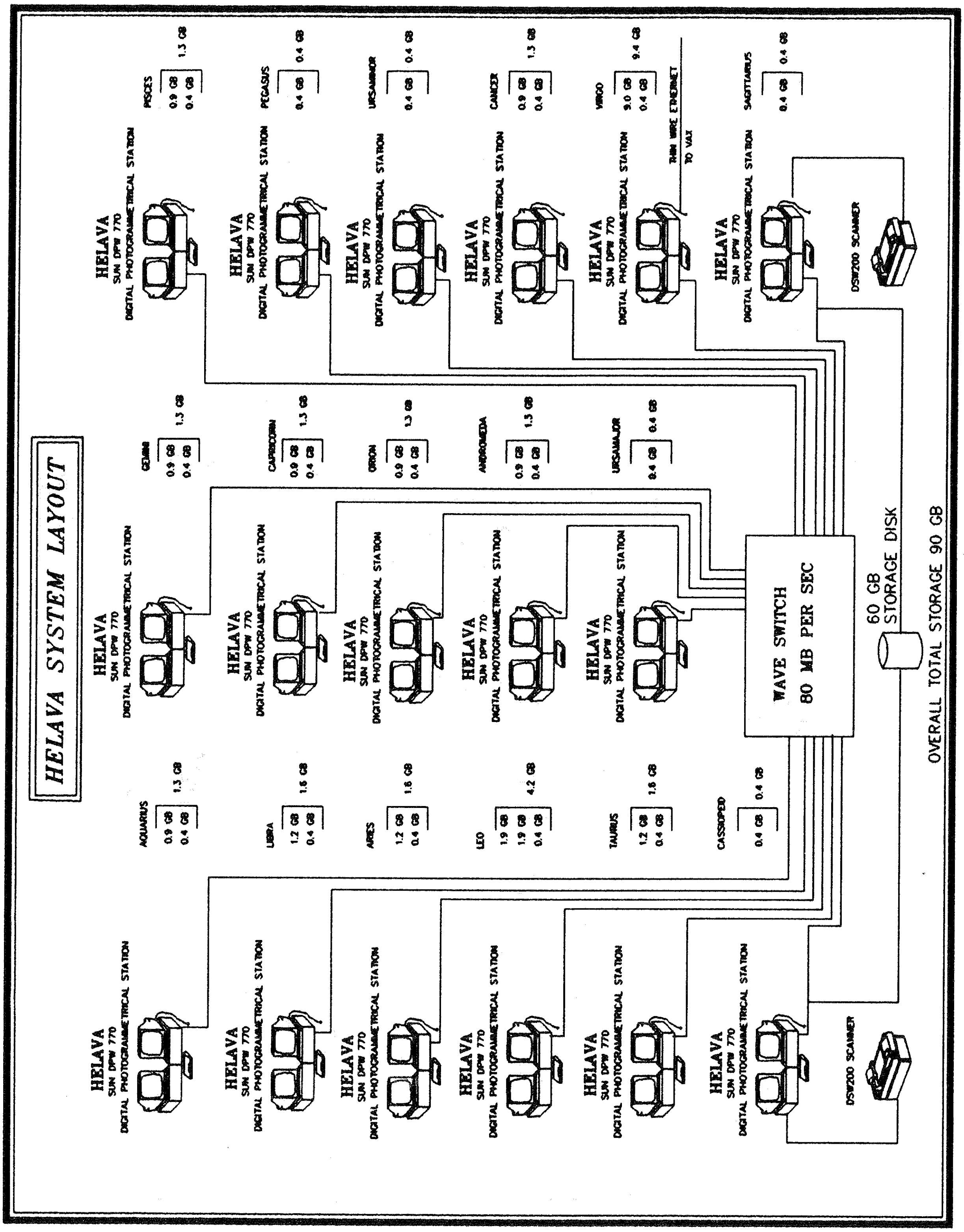

Figure 2. OSI Helava system at the end of the third digital photogrammetric procurement

3.3 Phase three

In 1995 a third procurement was made, confirming OSI's confidence in digital photogrammetry. This reflected a need for additional capacity to meet deadlines on some of the programmes. The intention was to focus the new units on data capture for the large scale rural database, which is being totally resurveyed. The opportunity was taken also to upgrade the system generally. Thus the slower DSW 100 scanner was traded in for a second DSW200. Five new stereoscopic workstations were purchased and the monoscopic one was upgraded to stereo. The first DSW200 was provided with a more powerful host computer and its existing host redeployed as the basis of one of the DPWs. The scanners were also equipped with dual screens and full stereoscopic viewing, in order to run the Helava Automated Triangulation System module. They share a 60 GB RAID array for top disk performance. Total disk capacity on the 17 workstations is around 100 GB. Many of the software modules were issued on a floating licence basis to reduce costs. Importantly, considerable efforts were made to improve network performance, on which the transfer of the 80 MB images obtained by scanning at a resolution of 25 µm placed considerable demands. Switching hub technology consisting of a wave switch with 80 MB per second total transfer rate and a fibre optic link to the DECnet was added: each scanner has a Fast Ethernet (100-BaseT) line and each DPW a dedicated 10-BaseT connection. This gives the scanners much faster links, eliminates network collisions and enables any DPW to contact the DECnet directly. The current system is summarised in Figure 2.

3.4 Software for quality control

Towards the end of this phase, OSI were commissioned by the Department of Agriculture to quality control newly generated orthophotos obtained from 1:40,000 aerial photography of Ireland. The orthophotos were required for the validation of claims made by farmers for subsidies under the European Common Agricultural Policy. In all there were 27,000 orthophoto tiles covering an area of 2 km x 1.5 km each. Each tile was 3 MB in size and delivered by the contractor on CD-ROM. This was a daunting task and quality control software to semi-automate the process was commissioned from Helava. The need for quality control of orthophotos has drawn comment from users of digital photogrammetric systems (Armenakis, Regan and Dow, 1995; Manzer, 1995) and, indeed, ASPRS has instituted a committee charged with developing appropriate standards (Nale, 1995).

The software performs two groups of straightforward, useful checks. There are batch checks on all orthophotos: presence; existence of associated support files; correctness of formats, for example TIFF; confirmation that files contain images; grey scale histograms. These are complemented by interactive checks on a sample: rmse of measured coordinates of ground control points; image quality; visual checks on mosaicking and edge matching; and image completeness. At the time of writing, this software is operational and initial experiences have been satisfactory.

3.5 Phase four

At the time of writing, OSI is reconsidering the specification requirements for the rural mapping database. This review will include a comprehensive redefinition of the content and accuracy of the database. It is likely that the specification will vary for different parts of the country depending on terrain and population density. Without preempting the result of the review, it is reasonable to say that an alternative to stereoplotting is being considered. Head-up digitising on a monoscopic screen from digital orthophotos or monoscopic plotting from raw imagery with on-line DTM is being examined. OSI already has an accurate DTM generated by the Helava systems. New approaches are being assessed so that progress with the resurvey and the creation of the rural database can be accelerated. Moreover, cost factors plus the shortage of operators noted below make stereoplotting less attractive. The review should be complete by the end of June 1996, when it is expected that a decision on the fourth procurement will be made.

4.0 PERSONNEL ISSUES

At first there were some doubts about digital photogrammetry on the part of the instrument operators, many of whom had considerable experience in triangulation or compilation, primarily on analytical plotters. Moreover, it proved impossible in Dublin to recruit additional staff to operate the new equipment being procured in the public sector, owing to an embargo on recruitment. This problem was addressed by decentralisation: the Kern and Leica analytical plotters were relocated to the regional offices, as shown in Figure 2. Moreover, the change from revision to resurvey caused the 100 revision staff to be reduced to eight, but much of this was achieved by relocation to regional offices.

Dissatisfaction with the daily work decreased as the early tendency to subject DTMs to excessive editing was curbed, workflows suited to digital rather than analytical photogrammetry emerged and the software became more user friendly, for example the triangulation module and ATLAS. KLT have implemented the latter on the DPWs such that it runs as smoothly as on the analogue and analytical workstations. As staff become "Unix literate", lead operators acquire skills in systems administration, which reduce any residual fear of the technology. Today, operators prefer digital to analytical workstations.

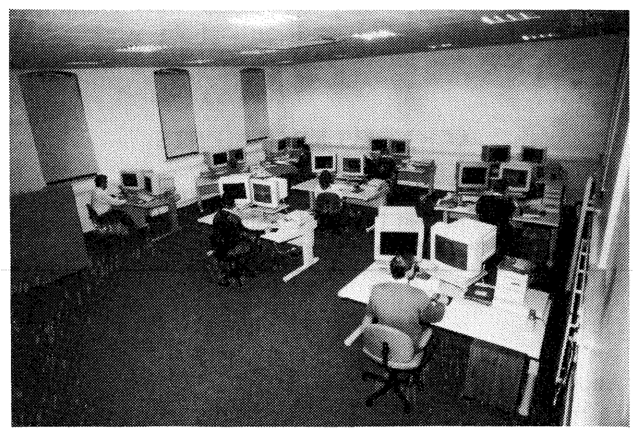

Figure 3. One of the two digital photogrammetry rooms, showing a number of the DPW770s with SPARCstation 20s and NuVision stereoscopic viewing systems

Tremendous *esprit de corps* has been engendered by the sheer size of the new installation. The digital systems have been installed in two newly equipped rooms, with filtered air and new electrical and computer cabling (Figure 3). These make an impressive sight and have attracted a stream of international visitors. Presentations by OSI staff have generated great interest too, adding to the high morale.

5.0 CONCLUSIONS

With two scanners and 15 DPWs, OSI is probably the foremost organisation in the world in the use of digital photogrammetry, with the exception of DMA. The new technology, however, is underlain by more subtle factors in the success, such as: extensive training by an experienced instructor; integration of the system with OSI's existing systems and procedures, for example very fast set ups of the DPWs using plate coordinates from the DSR1 in conjunction with ground coordinates from PAT-MR; colour stereo superimposition, meaning that any of the 15 DPWs is suitable for deployment on feature collection for database revision, so that OSI will derive considerable benefits in the future in its continuous updating programme; and careful attention to system management combined with the flexibility to change in the light of experience. Though feature collection will only become more attractive on the digital workstations as automated tools become available, a modern national mapping organisation must undoubtedly have DTMs and orthophotos on its product palette.

It has been fortunate that national funding was available at the time when radical solutions to OSI's customers' demands were urgently required. OSI has been equal to the challenge and responsibility of such major investments, but it continues to learn that the successful application of digital photogrammetry owes as much to dedication and experience as technology. The installation of such a large system in several phases, the connection to existing systems in terms both of computer networking and flows of image, control, DTM and vector data, the training of staff in both procedures and workflows, and the continuing upgrading of hardware and software *in situ* have been challenging tasks. It is almost three years since the first system was installed and useful experience has accrued. Production targets are being met and not only is digital photogrammetry essential for the DTM and orthophoto work but it performs very well for map compilation too.

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