

# Digital Photogrammetric Systems Approach Maturity

## A Global Survey of System Suppliers

After the first commercially marketed digital photogrammetric workstation (DPW), the Kern DSP1, was introduced at the 16th ISPRS Congress held in 1988 in Kyoto, there followed a rapid development of the technology, including high-precision film scanners as well as DPWs. This was evidenced by the large number of these systems that were introduced and demonstrated at the next two ISPRS Congresses held in Washington (in 1992) and Vienna (in 1996). Now, twelve years after that first introduction and approaching the 19th Congress to be held in Amsterdam in July, the technology is much more mature. Thus real innovations are fewer and, in general, there is now a concentration by the system suppliers on making numerous small but useful additions and refinements to existing systems. The emphasis with these improvements is to make the systems faster, more capable and more user-friendly than their predecessors.

By Professor Gordon Petrie and Dr. Stewart Walker

In parallel with this development, a highly competitive market place has been created in which the prices of DPWs have dropped quite significantly. In turn, this has allowed a far greater number of users to adopt the technology. The long predicted supplanting of analytical plotters (APs) by DPWs has at last taken place, at least in terms of sales of new systems. However large numbers of these older instruments remain in production in mapping agencies and companies

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and a limited number of new-build APs are still being sold. Furthermore there are still a significant number of sales of analogue-to-analytical conversions (by Qasco, Adam Technology, LH Systems, etc.) and of PC-based upgrades to

existing APs (by DAT/EM, ABC Software Developers, etc.). The starting point or base line for this review of recent developments in the digital photogrammetric field will be the three papers produced by the authors (Walker & Petrie, 1996 and Petrie, 1997a and b) at the time of the last Congress held in Vienna. The present article aims to review the developments and trends that have taken place since then and thus prepare participants for what they can expect to encounter in this area at the Amsterdam Congress. However the specialist field of close-range, non-topographic photogrammetry will not be covered in this review.

### High-Precision Film Scanners

At the top end in terms of performance, sophistication and price (>\$120,000), the two major suppliers - **Z/I Imaging** and **LH Systems** - have continued to develop and add refinements to their existing SCAI/PhotoScan TD and DSW models respectively. Using these highly sophisticated systems, there is now a greater

acceptance of scanning negative roll films on the part of users. Partly this comes from the elimination of the need to make diapositives prior to scanning. However it is also the result of the developments in dodging and colour balancing software that have taken



The Z/I Imaging PhotoScan TD flatbed scanner showing the automatic roll-film unit for use with negative films. The scanner is controlled by a powerful Intergraph TDZ 2000 workstation running Z/I Imaging's AutoScan software. (Courtesy Z/I Imaging)

place over the last two or three years. Both of these high-end systems require powerful high-performance Unix (SGI or Sun) or Windows NT workstations to drive them. Examples are the ScanServer from Z/I Imaging with dual Pentium III processors and a built-in RAID disk array and the new DSW500 from LH Systems with a similar specification. The DSW500 allows pixel sizes down to 4mm, which is attractive to the intelligence community. In 1997, **ISM** purchased the rights to the OrthoVision 950 scanner from its former constructor, XL Vision, re-named it XL 10 and dropped its own DiSC device. The XL10 scanner also offers automatic roll film transport, but occupies a somewhat lower price range at around \$95,000. The **Vexcel Imaging** VX4000 scanner also occupies an intermediate position in terms of sophistication and cost (circa \$85,000) and continues to be unique in terms of its ability to handle large-format (23 x 46cm) aerial photography used primarily for military mapping purposes. At a much lower cost (circa \$55,000) is the simpler **Wehrli** RasterMaster which has recently introduced a revised and



The new UltraScan 5000 high-precision scanner from Vexcel Imaging Austria with the optional roll-film adapter in place to handle uncut rolls of negative film. (Courtesy Vexcel Imaging Austria)

improved RM-2/NT model. However this still does not possess a roll-film capability. The **GeoSystems** Delta-Scan from the Ukraine (cost \$35,000 in 1996) was shown at the last Congress in Vienna. It also accepts quite large films such as the Russian 30 x 30cm format. A new model with colour capability, a roll film unit and a smaller pixel size than before is promised for the Amsterdam Congress.

An interesting newcomer to the film scanner field is **Vexcel Imaging Austria**. This company has introduced its UltraScan 5000 scanner which is manufactured on its behalf by Wild-Austria. This will be shown at the forthcoming ISPRS Congress. The device has a photogrammetric specification in terms of its measuring accuracy, geometric resolution and radiometric performance specifications. There is also an optional roll film capability available. However it is also aimed at the much larger graphics arts and printing/publishing industries and at forensic applications and the medical imaging market in order to achieve volume sales and be available at a lower cost (\$40,000). Thus the development of the UltraScan 5000 has been carried out in cooperation with a Danish company, Purup Eskofot, that is active within the graphics arts field

and with a Swedish company, Cox Analytical Systems, in the forensic field. Their particular versions of the scanner technology are called EskoScan and Maxcan respectively.

### Lower Precision Scanners

It must be said that quite a number of commercial mapping companies have also adopted the still lower cost (<\$25,000) scanners that are in widespread use in the graphics arts and desktop publishing (DTP) worlds. Usually these devices are designed to accommodate A3-sized originals, including hard copy prints as well as transparencies. In general, they have a much lower geometric accuracy than the purpose-built photogrammetric film scanners. Thus they tend to be used with larger pixel sizes and on less demanding applications than the specialist devices. Furthermore they lack the motorised roll film drives and sophisticated software that are necessary if negative roll films are to be scanned and digitized. While the Agfa Horizon and Sharp JX-610 are examples that have been used previously, newer models that have come into use recently are the Cicon, Linoscan and Nexscan flatbed scanners (all with an A3 format) from **Heidelberg CPS** - which has taken over the Linotype-Hell organisation. Other similar devices include the Mirage II flatbed scanner from the Taiwanese company, **UMAX Technologies**, and the new **Agfa** T5000 scanner. Interestingly a special kit, called ScanCorrect, comprising a precise grid plate and accompanying software - including automated measurement of the positions of the crosses contained in the scanned image of the grid - is on offer from the Russian Racurs company. This is designed specifically to carry out the geometric calibration of DTP scanners with a view to their use in digital photogrammetric applications. A similar kit has also been available from the Canadian DVP compa-

ny for some time and another, called MasterScan, is being introduced by the Siscam company from Italy. It will be interesting to see whether tests of these new lower cost scanners are reported at the Amsterdam Congress and, if so, what results are obtained in terms of their geometric accuracy and resolution on the one hand and their radiometric performance on the other. Previous tests of the older devices gave rather poor results.

### DPW Hardware

With regard to the **computer hardware** and **operating systems** being used in DPWs, a major change since the last Congress is that the combination of a Sun or SGI graphics workstation and the Unix OS has steadily lost ground. Now virtually every supplier of DPWs offers systems that utilize Pentium-based PCs with current processor speeds up to 733MHz running under Windows 95 or NT. Indeed many suppliers only offer their DPWs on the PC platform. For power applications on both scanners and DPWs, use is

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made of PCs equipped with dual processors and threaded code by LH Systems and Z/I Imaging. Furthermore, many users have turned to using locally built PCs as the basis of their DPWs rather than use the Dell, Compaq, Gateway and other branded machines which are more expensive, but do offer world wide support. Memory is also much less expensive than before and many DPWs are now equipped

with 0.5 to 1 GB of RAM, which can be employed very usefully in many of the DPW's internal operations. As many readers will realize from using their own home computers, a 15 to 20 GB hard disk is now quite commonly found on those PCs used as the basis for a DPW. But the problems of storing, archiving and managing large volumes of image data are now looming ever larger as more photos are scanned and more DPWs are installed. The storage and management of tens or hundreds of terabytes of image data are now being considered instead of the hundreds of gigabytes that were being handled before.

As solutions to these problems, on the one hand, the issue of **data compression** has risen to the fore with the wavelet-based rivals, MrSID and ECW, joining the fray alongside the longer established JPEG method. On the other hand, many mapping agencies and companies have been forced into buying **RAID drives** or **jukeboxes** of high density cartridge tape drives for the storage of the huge volumes of image data that are now being handled. Needless to say, in this context, **networking** has also become more important with the widespread adoption of Fast Ethernet operating at 100 Mb/s/sec. Instead of the older 10-BaseT Ethernet standard. Another previously important matter - the wide choice of **stereo-viewing systems** - has mostly been settled into a straight choice between the two methods - the "active" StereoGraphics CrystalEyes or "passive" NuVision systems - based on the use of alternating screen images. Interestingly both suppliers now offer both possibilities! Finally, most of the DPW system suppliers appear to have settled for the use of a 3D mouse or a tracker ball with a Z thumb-wheel for **manual control and measurement** functions. Though some users still use the standard mouse and keyboard which, in the opinion of the authors, is far from optimal for the purpose.

**DPWs from the Major Vendors or Groups**

1. Again, if one starts with the the two market leaders - **Z/I Imaging** and **LH Systems** - the current situation is rather different in each case. In the case of the two partners in Z/I Imaging - Intergraph and Zeiss - the former had already adopted the PC/NT platform as the standard for its ImageStation Z series of DPWs, whereas the latter had remained faithful to SGI graphics workstations for its PHODIS DPW. Obviously a decision will now have to be made by the new Z/I Imaging company as to whether to continue both of these separate product lines or, as many observers expect, to standardize on the ImageStation DPW. In conjunction with this decision will be another closely associated one as to whether to continue to utilize the substantial number of the add-on packages or modules that are sourced from outside the Z/I Imaging combination. These include MATCH-AT (for automated aerial triangulation); MATCH-T (for automated DEM generation); PATB/PATM-GPS (for block adjustment) and SCOP (for DTM operations), all of which come from Inpho, and the SPOT software from the Trifid Corporation, which has now been taken over by ORBIMAGE. Besides which, Intergraph had already taken on Atlantis Scientific's EarthView radar processing packages and it now appears that these will continue to be offered under the Z/I Imaging banner. The ImageStation Z series continues to be developed with ever more powerful Pentium processors (including twin and quad processors), while the SSK kit is available to convert a standard PC into a DPW at a lower cost.

2. Similarly the **LH Systems** SOCET SET software suite is continuing to be developed with the incorporation of an ever widening set of sensor models - for aerial frame and panoramic cameras; for Landsat, SPOT, IRS-1C/D and JERS-1 OPS space scanner imagery; for RADARSAT, ERS and JERS-1 SAR imagery; and, of course, for its own new airborne digital sensor (pushroom scanner). Besides those modules such as HATS - now renamed APM (Automatic Point

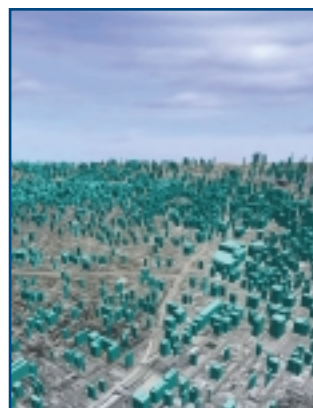


An LH Systems DPW with twin screens running the SOCET SET software under Windows NT on a Dell PC. The operator is utilizing a 3D hand controller to control the position of the measuring mark and is viewing the stereo-model in 3D with the new lower-cost CrystalEyes wired spectacles from StereoGraphics. (Courtesy LH Systems)

Measurement) - that form part of the SOCET SET suite, refinements have been made both to the ORIMA product for triangulation and to the PRO600 module for feature extraction within the MicroStation GeoGraphics environment. Both of these products have been available for some time on the company's APs: now they are available for use with the DPW. Recently LH Systems has also developed a lower-cost, entry-level DPW product called DP Digital Plotter. This comprises a minimum set of SOCET SET and PRO600 modules together with a stereo-viewing capability to carry out routine feature collection. The overall SOCET SET suite is still being developed in parallel for both the Intel/PC/NT and the Unix platforms, since several large U.S. government mapping agencies are continuing to opt for the latter. Besides LH Systems, SOCET SET is also being offered separately by one of its parents, **BAE SYSTEMS** (the successor to GDE Systems and Marconi Integrated Systems) to military and defence users. In addition, a sub-set of SOCET SET forms the basis of the OrthoEngine AE package which is sold by **PCI Geomatics** into the remote sensing/GIS market. PCI supplements this with its own OrthoEngine SE package which handles a wide range of space imagery.

3. **Autometric** is another fairly large supplier of full-function DPWs in the shape of its SoftPlotter suite. This is supplemented by its stand-alone OrthoKork package, which is one of many orthophoto packages that are on the market.

Till now, SoftPlotter has only been offered on Unix-based Sun and SGI graphics workstations, while OrthoKork is only available on PCs. However the Autometric Web site now mentions SoftPlotterNT, so one may expect a new Windows-based product to emerge soon. **ERDAS** continues to offer the OrthoMAX module which is based on Autometric's software and carries out aerial triangulation, automatic DEM extraction



(a) The on-screen user interface of the Measurement Tool of the new ERDAS Stereo Analyst product. This features re-sizable windows showing the images at different scales.

(b) A visualization of the 3D data acquired by Stereo Analyst for part of the Los Angeles urban area. (Courtesy ERDAS)

and orthorectification within the ERDAS IMAGINE environment on Unix-based machines. However the ERDAS company has also decided to produce its own digital photogrammetric products for PC platforms running Windows 95, 98 and NT. This will comprise three main elements - (i) aerial triangulation and orthorectification (called OrthoBASE); (ii) feature extraction from stereo-models (Stereo Analyst); and (iii) automated DEM extraction from both aerial photos and space imagery. The first of these modules, OrthoBASE, was released at the 1999 ASPRS Convention, while the second, Stereo Analyst, was introduced at the ASPRS Annual Convention held in Washington in May. The European launch is scheduled to take place at the ISPRS Congress in Amsterdam in July. Besides the version contained within the IMAGINE environment, Stereo Analyst will also be available both as a stand-alone package and integrated into the ArcView GIS environment for the purpose of stereo-viewing and stereo-plotting with 3D Shape files. Once all the ERDAS modules have been completed, the company could well become an important player in the DPW market place - as it is already in the remote sensing field.

**DPWs from Smaller North American Vendors**

Under this heading, one may consider the PC-based DPWs from ISM, DVP, R-WEL, KLT, DAT/EM and Amsatek, all of which originate from North America. In general, one can say most of them concentrate on the data acquisition of 3D data using manual stereo-plotting techniques for map production and GIS applications. Some also offer a separate package for orthophoto production, while one or two offer the capability of mapping from SPOT stereo-pairs.

(a) **ISM** from Canada is a strong player in certain markets, especially Canada and Spain. Besides its main DPW, the DiAP-NT, ISM is also offering its simpler, lower-cost DiAP Viewer product which is designed specifically to carry out feature extraction employing stereo-viewing, -mensuration and -superimposition techniques. This is done using



This example of the ISM DiAP-NT is equipped with handwheels, a footdisk and foot pedals for precision stereo-plotting. The infra-red emitter for synchronisation of the "active" wireless stereo-viewing glasses with the alternating screen images is located on top of the display monitor. (Courtesy ISM Europe)

pre-oriented stereo-model files established by aerial triangulation or used previously for photogrammetric mapping. A further recent development has been to introduce an Automatic Image Mensuration (AIM) module for the point transfer and measurement of control and tie points using image matching techniques. This is carried out in association with the Aerial Triangulation Manager (ATM) which has a full interface with the Inpho PATB-GPS block adjustment package. Like most vendors, ISM also offers a stand-alone orthophoto production capability in the form of its SysImage package together with the well known TIN/CIP terrain modelling package. Given that ISM also has the XL-10 high-precision scanner on its product list, the company now offers the most complete range of digital photogrammetric products outside the two market leaders.

(b) Another Canadian company, **DVP Geomatic Systems**, is also quite strong in certain countries, e.g. in Greece, Turkey, Belarus and Mexico, as well as in North America. The company offers quite a wide range of digital photogrammetric products, including modules for orthophoto generation and monoplotting, besides its current model of DPW - called the DV400P. Like ISM, it also offers a simplified 3D digitizing station using pre-oriented stereo-models. This associated with an interesting and innovative new product called the Active Virtual Stereo Index that was introduced at the GIS 2000 Conference held recently in



The user interface of the new DVP Stereo Index product introduced at the recent GIS 2000 Conference held in Toronto. The right-hand window of the monitor screen shows the index or overview of all the stereo-models in the area of interest. The left-hand window shows the selected stereo-model at an enlarged scale. This can be viewed either using cheap, simple anaglyphic (red/blue) spectacles or a more sophisticated and more expensive viewing system such as that from StereoGraphics using its CrystalEyes alternating shutter spectacles. (Courtesy DVP Geomatics).

Toronto. This creates an index of these pre-oriented stereo-models and displays them in a window on the monitor screen. Thereafter the user can mark the desired area within this window and the relevant stereo-model will be displayed within another window on the screen. Thus the user can move freely within the seamless mosaic of stereo-models while still maintaining stereo-viewing of the terrain. Furthermore, rather unusually for this class of DPW, the company also offers its DVP-SPOT module which allows 3D data collection from stereo-pairs of SPOT digital images. This development has resulted from a collaboration with the Canada Centre of Remote Sensing (CCRS).

(c) Turning next to considering the smaller American companies, **R-WEL**, which, like DVP, was an early university-derived entrant into the digital photogrammetric field, continues to offer its DMS package mainly for feature extraction and map revision purposes. However, unusually for this group of vendors, it also offers automated DEM generation and orthophoto production, both from stereo-pairs of aerial photos and SPOT space images.

(d) **KLT Associates** is very well known in the photogrammetric world for its Atlas digital data collection software used with analogue stereo-plotters and

APs. It also offers digital photogrammetric products in the shape of its Atlas/DSP digital stereo-plotter (DPW) for feature extraction and 3D digital data collection and its Atlas/Ortho and Atlas/TIN products.

(e) **DAT/EM's** Summit PC, first announced in 1997, took some time before it appeared in a fully operational form last year. This late arrival has meant that, as yet, it only has a small share of the DPW market. However the company has been very active in upgrading Intergraph APs through its IMA-to-DMA conversion kits and in the supply of its well known DWG/CAPTURE and DGN/CAPTURE data collection software for analogue and analytical stereo-plotters. The Summit PC also places an emphasis on feature extraction using DAT/EM's own CAPTURE-NT software operating directly within AutoCAD or



The DAT/EM Summit PC which allows feature extraction and map compilation to be carried out in AutoCAD or MicroStation using StereoGraphics CrystalEyes "active" stereo-viewing system. (Courtesy DAT/EM)

MicroStation. Like Z/I Imaging, DAT/EM also offers the MATCH-AT, MATCH-T and PATB-GPS products from Inpho as add-on packages to the Summit PC.

(f) **Amsatek** has been active in the GIS field for some time - its current products in this field include the AMSA98/NT digital mapping system; the AMSA-RIS (Relational Information System); and the Connex-A/I software for the bi-directional conversion of data between the AutoCAD and MicroStation CAD packages. To complement these, it also offers the AMSA-DC (Digital Compiler) for feature extraction from stereo-pairs and the AMSA-Digital Orthophoto module for orthophoto generation using DEMs derived from other sources.

## DPWs from Europe

At the Kyoto ISPRS Congress in 1988, the main photogrammetric system suppliers from Western Europe - Wild, Kern, Zeiss, Matra, Galileo-Siscam, OMI, etc. - with their analytical plotters completely dominated the market. No one then could have predicted or envisaged the dramatic changes that have taken place since, which have resulted in the system supply side largely moving elsewhere, especially to North America. Small numbers of APs are still being made in the former Wild, Zeiss and Galileo factories, re-branded under the LH Systems (SD2000/3000), Z/I Imaging (Planicom P3/33) and Siscam (Stereobit and Stereocart) labels respectively. Furthermore the dominant aerial cameras are still being manufactured in the first two of these factories. But in the DPW field, the situation has completely changed.

(a) The major European player is now the German company **Inpho** with its MATCH (-AT, -T and -I), PAT (-B and -M), SCOP and SKIP products. While it does sell these packages directly, quite a number of its sales are made through system suppliers such as Z/I Imaging and DAT/EM that have adopted some or all of these packages as add-on modules to their DPWs. On its part, Inpho has made no effort till now to enter the field of feature extraction and orthophoto generation, though obviously it has the capability to do so. However Inpho has concluded an agreement recently with the Stellacore Corporation to develop, distribute and support its well known OrthoVista orthophoto mosaicing package, that had been marketed previously by Zeiss.

(b) As noted above, the **Zeiss** PHODIS DPW faces an uncertain future under the new Z/I Imaging grouping. Which means that, if this disappears, then only **Siscam** of the traditional European AP suppliers will remain in the DPW field. At the 1996 Vienna Congress, the Siscam company showed its Stereodigit (a very basic DPW equipped with twin small screens) and Microdigit (a battery powered version with tiny LCD screens). Both of these DPWs were based on PCs. In the interim, both of these

appear to have been dropped. Now, for the Amsterdam Congress, Siscam will show its much improved and more capable DPW, called Stereometric, together with modules for orthophoto generation (Orthomap), automatic DEM generation (A.D.A.), processing of DEMs (DEM Manager) and block adjustment (B.A.T.).

(c) Finally, a small Finnish software company, **ESPA Systems Ltd.**, has entered the market with its *Espa Kernel*, *Espa Block*, *Espa Ortho* and *Espa City* products. These are scheduled to be demonstrated in the Technical Exhibition at the Amsterdam Congress.

#### DPWs from the Former Soviet Union

Gradually quite a number of digital photogrammetric products from the former Soviet Union countries have become known and have entered the market.

(a) At the 1996 ISPRS Congress held in Vienna, a Ukrainian company, **GeoSystems**, made an impact showing quite a comprehensive range of products, including its *Stereoanagraph AP* as well as its *Delta-Scan* photogrammetric scanner, mentioned above, and its *Delta-Station* DPW. All of these products utilize the PC/Windows platform. These products continue to be offered, finding their principal market in the former Eastern Bloc countries, but with sales too in Western Europe, Asia and Africa. Further developments of all of these *GeoSystems* products are promised for the Amsterdam Congress.

(b) Another PC-based system, the *Siberian Digital Stereoplotter (SDS)*, that had been developed at the **Siberian State Academy** of Geodesy in Novosibirsk, was also shown and demonstrated at Vienna, but little has been heard of it since.

(c) However a stronger and more robust development has been the recent introduction of a more comprehensive range of digital photogrammetric products from the **Racurs** company based in Moscow. This includes the *PHOTOMOD* DPW with

modules for automated aerial triangulation (AT) and automatic DEM generation (DTM), besides feature extraction from stereo-models. So far, it has made its main impact on mapping agencies in the former Eastern Bloc, but it has now appointed agents in Western Europe, the Middle East and East Asia and has already delivered DPWs to Syria and Saudi Arabia.

#### DPWs with a Chinese Connection

(a) The most prominent player in this group is **Supresoft** with its *VirtuoZo* DPW which runs

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on both the Unix and Windows NT platforms, producing DEMs and orthoimages as primary output. Stereo-measurement and 3D data collection may also be carried out using *VirtuoZo*. Extension modules provide automatic tie point generation and an interface to a *PATB* module provided by *Inpho*. The company had its roots in developments that took place at the Wuhan Technical University of Surveying & Mapping in China. Its DPW was then given a Western interface with the aid of an Australian company based in Brisbane. Since then, it has acquired a world-wide distribution network and now has a significant presence in the DPW market place.

(b) Another much more recent entrant is the *Desktop Digital Photogrammetric System (DDPS)* which has been launched by another Australian company, **3D Mapper**, based in Perth in Western Australia. From its literature, the product again appears to have a strong Chinese connection, in that *DDPS* has also been developed by graduates from Wuhan. The principal components of *DDPS* are *StereoMaker* (which carries out the orientation of stereo-models), *StereoMapper* (for 3D

vector mapping) and *OrthoMaker* (for orthophoto generation). Once again, this has been developed solely for PCs running Windows 95, 98 or NT.

#### Remote Sensing System Suppliers

It is interesting also to assess the position of the remote sensing system suppliers with regard to the digital photogrammetric field. As discussed above, *ERDAS* is now making a determined and serious effort in this particular area with the introduction of its *OrthoBASE* and *Stereo Analyst* products. *PCI* has also had some success with its *OrthoEngine* packages. But, in general, the other mainstream suppliers of remote sensing image processing packages - e.g. *Earth Resource Mapping* (with *ER Mapper*), *MicrolImages* (with *TNTmips*), *Research Systems* (with *ENVI*), etc. - have all been content to limit themselves to orthophoto generation, mosaicing and visualization capabilities. However *Sensor Systems* with its *RemoteView* product running under the Unix OS does offer stereo-viewing and measurement using the rational polynomial coefficient (RPC) approach. This utilizes a non-rigorous image geometry model that has come into widespread use within the U.S. intelligence and military com-

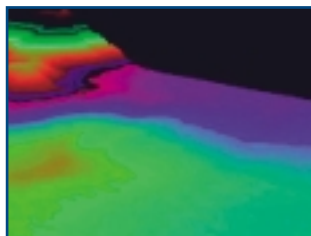
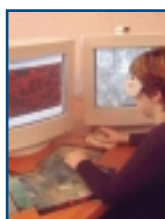
munities. On the basis of this model, the image supplier computes the RPC data for each image and distributes this data to the user along with the actual image. This has a particular application when the user has no information about the geometry of the camera or imaging sensor, in which case, it is not possible to employ a rigorous geometric model. This possibility is also offered by *LH Systems* and *PCI*. But in general, one can say that most of the remote sensing system suppliers do not offer rigorous geometric modelling, triangulation and highly functional feature collection from stereo-models. However these companies do offer a much more extensive range of data input and output formats; image processing algorithms; analysis and classification tools; and image/map fusion capabilities than the photogrammetric vendors. Finally one must note that, besides the many different orthophoto engines offered by the photogrammetric and remote sensing system suppliers, a number of independent vendors, e.g. the *Vexcel Corporation* with its *OrthoGIS*, also offer packages that will generate orthophotos from single images, given the availability of DEM and orientation data from another source.

#### Conclusion

In our review of DPWs for the 1996 Congress (Walker & Petrie 1996), we wrote then that, when we (or our successors) make our report to the ISPRS 2000 Congress, it will be a success story centered on reductions in the cost of mapping. This prediction has turned out to be not too far wide of the mark. Users now have a large range of film scanners and DPWs with a rich variety of solutions, capabilities and price levels from which they can make their choice.

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A *VirtuoZo* DPW with twin screens - the one used for stereo-viewing and measurement; the other used for the display of the plotted features, system information, menus, etc. (b) A layered colour perspective representation of the area of the Columbia Glacier in Alaska constructed from a DEM generated by a *VirtuoZo* DPW. (Courtesy SDS)