

## ENTRY LEVEL DIGITAL PHOTOGRAMMETRY: LATEST DEVELOPMENTS OF THE DVP

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### ABSTRACT:

The DVP Digital Video Plotter is well established as an entry level digital photogrammetric workstation for straightforward capture and updating of map data. The latest developments include an improved stereo viewing system, numerous refinements of the basic software and new modules for aerial triangulation, plane rectification and restitution of SPOT imagery. The DVP is being successfully used for many applications and a wealth of valuable experience has accrued.

**KEY WORDS:** Digital Photogrammetry, Digital Photogrammetric Workstation

### 1. INTRODUCTION

The DVP Digital Video Plotter is now well known. It is an entry level digital photogrammetric workstation, running on a standard personal computer (PC) equipped with a specific graphics card and a digitizing tablet, enabling the user to view pairs of digital images through a simple stereoscopic system (figure 1), orientate stereomodels and acquire data. By making no attempt at panning and preferring to move the measuring marks across stationary image windows, the designers have succeeded with a low cost graphics card instead of the very expensive graphics processors needed in many other digital photogrammetric workstations.



Figure 1 The Leica DVP

The DVP's characteristics, history and development can be traced from a number of papers. The software was originally written as a teaching tool in the Département des Sciences Géodésiques et de Télédétection of Université Laval, Québec, Canada and it was first presented in 1988. Progress has been charted in a number of papers from Laval, notably Agnard *et al.* (1988), Boulianne, Gagnon *et al.* (1990), Gagnon *et al.* (1990, 1991) and Nolette *et al.* (1992), the last of which gives a most informative description. In 1989, the commercial distribution was undertaken by a local land survey company in Québec, Géomatique EMCO, which in 1990 formed a subsidiary, Les Systèmes Photogrammétriques DVP Inc., for this purpose. In

1990, Leica took over worldwide distribution and one result has been a parallel series of papers presenting the DVP within the Leica product range, for example Walker (1991a, 1991b, 1991c) and Cogan, Luhmann and Walker (1991). In view of this profusion of literature, there is no justification to describe the basic characteristics yet again, other than to emphasize the straightforward and low cost nature of the system, reflected in Dowman's categorization of the DVP as a digital photogrammetric workstation with "limited performance and functionality but low cost" (1991, 32).

### 2. HARDWARE DEVELOPMENTS

#### 2.1 New Viewing Systems

In order to provide comfortable stereoscopic observation over longer periods of time, Leica have developed and built a new optical viewer for the DVP. It is based on the principle of the mirror stereoscope. Two lenses mounted in front of four mirrors present the left image to the left eye and the right image to the right eye, focussed at infinity. Thus the accommodation of the eyes is normal, i.e. the user looks at infinity with parallel eye axes. The diameter of each lens is sufficiently large that an eyebase adjustment for interpupillary distance is not necessary, just as in most mirror stereoscopes.

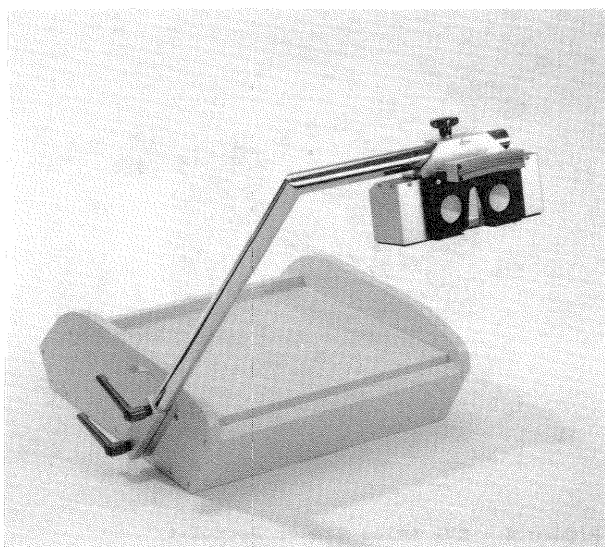


Figure 2 DVP Leica Viewer

Two new Leica viewing systems are available. The DVP Leica Viewer includes a support, adjustable in height and tilt, for the monitor and an inclinable chrome support arm on which the new optical viewer is mounted (figure 2). By adjusting the height and tilt of the shelf inside the monitor support box and the inclination of the support arm, a comfortable seating position can be obtained for different operators, tables and chairs. The support box may be placed on top of the PC, as in figure 2, or directly on the table, giving further scope for the operator's ergonomic preferences. The DVP Leica Viewer is supplied in kit form (figure 3) and can easily be assembled by the customer.

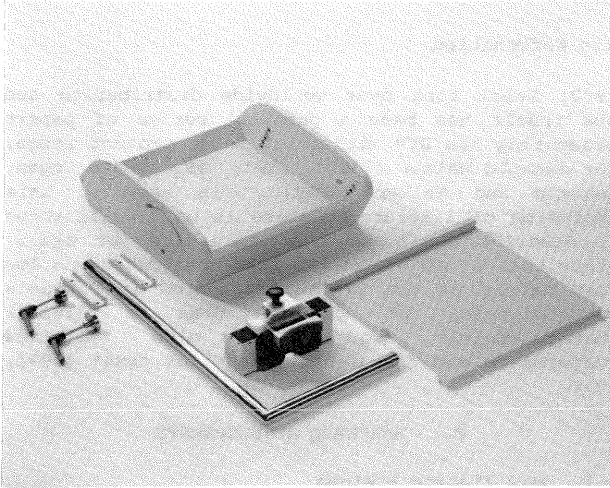


Figure 3 DVP Leica Viewer as supplied

The DVP Leica Viewer Retrofit consists only of the new optical unit (figure 4). This can be retrofitted to existing DVP installations with the plexiglass frame to replace the old viewer, which was less satisfactory because it had four mirrors but no lenses.

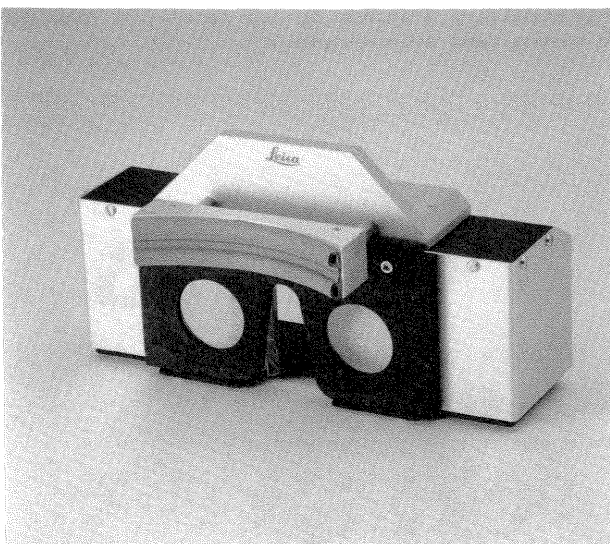


Figure 4 DVP Leica Viewer Retrofit

## 2.2 Z Control with Trackball

With early versions of the DVP software, the operator used the -/+ or F1/F2 keys on the PC keyboard to raise and lower the measuring mark, but this was never regarded as ergonomically optimal and the decision was made to offer the alternative of a trackball or mouse. The improvement was included in release 2.58 of the software, which dates from spring 1992. The trackball is more comfortable to use than the mouse, because the operator's hand can remain in the same position, the ball being rotated by the fingers only.

The left trackball or mouse button can be used to switch the images on and off, the right button to switch the image superimposition on and off and the centre one to change the colour of the measuring marks.

## 3. SOFTWARE DEVELOPMENTS

Most of the early customers were supplied with version 2.44 of the DVP software, which was also used for the first thrust of the Leica sales campaign. Significant improvements were made in subsequent releases and this section summarizes the main advances found in 2.58 compared to 2.44.

### 3.1 TIFF Files

While the DVP has always offered the facility of reading images in TIFF format, experience with the output of a range of scanners revealed that different manufacturers interpreted the TIFF standard in a variety of ways. The software has been generalized, therefore, and carefully reads and interprets the TIFF header. Thus images with different implementations of TIFF can be used successfully.

### 3.2 Image buffer

The image windows displayed on the split screen of the DVP are contained in the video RAM of the graphics card. In order to speed up the refresh of this card when the user recentres, a software enhancement has been developed whereby spare RAM in the PC is purloined as an image buffer into which the portions of the images bordering the displayed windows are loaded. Refresh is then performed from RAM, which is much faster than disk and reduces any possible irritation or impatience on the part of the operator.

### 3.3 Interior Orientation

When the measurement of the fiducial marks is finished, both orthogonal and affine transformations are computed and the results presented on the screen. This enables simple blunder detection. The affine transformation is used for further computations.

### 3.4 Relative Orientation

It is now possible to assign point numbers to the relative orientation points. This facilitates the identification of points to be remeasured.

### 3.5 Feature Code File

A feature code file can be created. This file contains the feature code numbers, the descriptions of the features and the display status for the image superimposition, i.e. for each feature code a tabulation indicates whether the display is on or off. Numerous help functions enable fast access to

the feature codes for making modifications, additions, deletions, changes of display status, etc.

### 3.6 Selective Display of Features

The points and vectors in the map data file(s) for a stereomodel can be displayed selectively on the screen by the image superimposition software according to their code numbers. Thus the operator can easily differentiate between the various features and their relevant codes or switch off the features which are not immediately necessary when there are too many lines on the screen.

### 3.7 Manipulation of Files

The user can specify the time interval at which a backup copy should be made.

A new active primary data file can be opened without having to exit from the DVP main program.

The user can open up to five auxiliary reference data files to be displayed by the image superimposition. Thus he can see the relationship between various data files and check for completeness. The elements in the auxiliary data files can be selectively made visible or invisible on the screen. The auxiliary data files can be closed selectively. For each of the auxiliary data files, the relevant feature code files can be downloaded as well and can be accessed for inspection or modification. When various auxiliary data files are displayed on the screen, the function "Info" will display the name of the file containing the feature where the floating mark is located.

Data files can be created in easily readable ASCII format for inspection or translation to other formats.

### 3.8 Tangential Arcs

During digitizing, arc-fitting between two straight line segments is done automatically without changing the digitizing mode.

### 3.9 Different Shapes of Measuring Marks

When a graphics card which emulates the IBM 8514 is used, the DVP8514 version of the software enables the user to change the shape of the measuring marks from the usual cross of 3x3 pixels to a square of 3x3 pixels or a large cross of 7x7 pixels.

### 3.10 Version 3.0

Version 3.0 of the DVP software includes a number of worthwhile improvements over 2.58. At the time of writing (May 1992), this version is in the process of testing and documentation and distribution is planned for autumn 1992. The software has been rewritten in modular form in order to accommodate all the desired enhancements.

The improvements to the fundamental DVP operations include a facility to program keyboard macros. The display of the images includes image processing functions to vary the intensities of the displayed images and to give a better zoom capability. The screen can display 32 colours in addition to the grey scale images, compared to only 2 at present. Immediate reversal of errors by the operator is possible through an "Oops" function.

Perhaps the most exciting features are the semi-automation of interior orientation and the automation of relative orientation.

A command line can be called up to perform coordinate geometry calculations (Gagnon *et al.*, 1991).

The data collection module builds up and refreshes the colour stereo superimposition more quickly than at present and new functions include splitting lines in two, new types of elements such as symbols, curves and text, batch modification of groups of elements and smoothing of contours.

A module has been added for measurement of digital terrain models. Here, as in other parts of the DVP software, a correlation algorithm can be activated, but manual measurement is possible too.

## 4. OTHER DVP PRODUCTS

The product described in the first three sections of this paper is the centrepiece of the DVP range, its digital photogrammetric workstation. Several other software products are also available, however, and can be obtained through the Leica network.

### 4.1 KORK

The DVP has been integrated as a three dimensional digitizer into the KORK system, which is well known in the mapping world as a data collection and editing package with input possibilities from a wide range of stereoplotters and digitizing tablets. Owing to careful memory management, the new product operates in a single PC and the operator can toggle as required between DVP and KORK functions and menus. It is available through both the Leica and KORK networks.

### 4.2 DVR2 Plane Rectification

This software works independently from the main DVP program. It operates in a simple manner and allows the operator to display a single image, identify control points on it and input the ground coordinates of the control points. Planar rectification is then performed in the usual way. Objects that have been photographed at an angle to the object plane will be rectified by pixel resampling. The most obvious application is the rectification of facades of buildings in architectural photogrammetry. In aerial photogrammetry this software is suitable for flat terrain.

### 4.3 SPOT

Some further work has been done on the DVP module for panchromatic SPOT stereopairs reported, for example, in Walker (1991c). It is based on the algorithms of Toutin (1985, 1986) and has been developed with the cooperation of the Canadian Centre for Geomatics and the Canadian Centre for Remote Sensing. Distribution is planned for late 1992.

### 4.4 Aerial Triangulation

The thinking behind this module has also been previously reported (Agnard and Gagnon, 1991). It includes interior and relative orientation and numerical point transfer and the output from the triangulation includes the absolute orientation of the individual models. The conclusion of Agnard and Gagnon (*ibid.*) that triangulation should be

performed at a scanning resolution twice as high as map data acquisition has been under further investigation and the product is proceeding to exhaustive testing and documentation.

#### 4.5 Perspective Plot Program

A plot program has been developed especially for foresters who wish to plot previously interpreted tree stands, i.e. outlines of polygons appearing on existing forestry maps, on a transparent overlay together with the fiducial marks in the perspective projection of new aerial photography. This transparent overlay is then physically superimposed on the new photograph and can be taken into the field by foresters to carry out field verification. This product is available now and obviously need not be restricted to forestry applications, since it is clearly useful for a variety of map revision tasks.

### 5. APPLICATIONS

As a low cost digital photogrammetric workstation, the DVP is extremely suitable for those institutions and companies which have a requirement for a user friendly and economical photogrammetric system with a reasonable accuracy. Instead of having their photogrammetric data acquisition or updating done by other specialized companies, many organizations are becoming able to do their own photogrammetry with their own personnel and their own timing. The most important segments of users are discussed briefly below.

#### 5.1 Land Surveyors and Civil Engineers

Typically, customers in these segments are relatively small firms with PCs and knowledge of CAD, LIS or GIS software. They also have the survey capability for measuring the ground control points and performing field completion. They can add a new service to their organization like mapping and map updating for local communities and expand into services related to other DVP applications like close range photogrammetry, volume control and land development.

A brief, empirical analysis has been carried out of DVP customers in these segments, using a very non-random sample - only those customers in the Province of Québec, Canada! It transpires that the following profile is quite representative. The typical customer in these segments in the Province of Québec is a small company concentrating on legal surveys, land surveys and work related to construction and land development. The main customers for these services are land developers, municipalities, utilities and civil engineers. Turnover is 0.75-1 million Canadian dollars per annum from 10-25 employees of whom 2-4 are professional surveyors or engineers. Equipment includes 1-4 total stations and 2 PCs. AutoCAD and MicroStation are usually the preferred drawing packages. Aerial triangulation is contracted out to mapping firms and scanning, to Géomatique EMCO. Generally, there is one, young operator for the DVP, normally the member of staff who is also allocated to survey computations. This operator may have some technical education, but invariably with little or no photogrammetric content. The most frequently performed tasks involve large scale photographs, often 1:5000, for acquisition of data concerning local land and housing developments and for map updating; only one firm does contouring.

#### 5.2 Data Conversion and Maintenance Companies

These organizations can give photogrammetric service to large utility companies, larger communities and government agencies. They also have knowledge of CAD, LIS or GIS software.

#### 5.3 Close Range Applications

The DVP has a history of application in close range photogrammetry, for example in archaeological applications (Boulianne, Agnard and Gagnon, 1990). The small formats of terrestrial photographs taken by architects, archaeologists and other users enable the use of A4 size scanners, thereby making the digital system even more affordable.

The breadth of close range applications will expand even further when certain planned software upgrades are introduced. Réseaux corrections, for example, will ensure that the full potential of a wider range of cameras is achieved during measurement. Secondly, some cameras also require correction for radial lens distortion, such as the Leica R5. Whereas aerial photographs have insignificant lens distortions or the larger distortions of older lenses are smaller than the pixel sizes of 40-80  $\mu\text{m}$  often favoured by DVP customers, close range photographs can have distortions over 100  $\mu\text{m}$  and even quite small distortions become significant if scanning is performed on enlarged paper prints rather than negatives or transparencies. Thirdly, much close range work is now carried out with CCD cameras, which do not require conventional interior orientation and have different distortion characteristics from their film counterparts. While specialised versions of the DVP have been prepared for such cameras in a research environment, for example by Boulianne et al. (*ibid.*), these enhancements have not percolated down as an option into the standard version.

The DVR2 plane rectification software described in section 4.2 above is also very useful for architectural photogrammetry.

#### 5.4 Educational Institutions

The DVP is an extremely suitable system for teaching students the orientation procedures and the usefulness of photogrammetric stereorestitution in various applications. Since the Viewer can be pushed out of the way and the graphics card and digitizing tablet are of a general purpose nature, the PC is by no means limited to use in conjunction with the DVP software and other courses can be taught on it also.

#### 5.5 Public Utility Companies

More and more companies are involved in GIS systems for the management of their water, electricity, telephone, gas, cable TV, transport and other networks. Whereas in many cases the graphical or digital database has been compiled for large areas, most of these companies face two very important problems, the unmapped areas and the updating of maps in fast growing localities.

The DVP provides an excellent way to keep the cost of mapping as low as possible. This is because of the possibility of adjusting the balance between accuracy and productivity by selecting the right parameters for flying height and scanner resolution. Generally the utilities do not want

all topographic details on their maps, only selected detail which is important for their special purposes. So they will appreciate the savings accruing from lowering the number of elements on the maps because it will always be possible to add further details on their own DVPS if required.

The low cost of the DVP and the fact that it runs on familiar, readily available PCs mean that these utilities may in the future elect to undertake database populating and updating rather than contracting out the work to photogrammetric service bureaux.

#### 5.6 Municipalities

The need for mapping and map updating is enormous in the fast growing towns and suburbs. Many municipalities do have aerial photographs but no mapping capability, since it was too expensive. With PCs already available, many municipalities may undertake to execute this job using their own technical personnel as it is easy for staff to be trained on the DVP.

#### 5.7 Natural Resources Management

This sector includes private companies and government agencies in forestry, mining, agriculture, environment etc. This is a growing community for GIS and LIS applications. Conventional stereo restitution systems are generally considered too expensive and too accurate by these practitioners. With the DVP, the job can be done in-house and many organisations have qualified employees who can be trained.

Skilled photo interpreters (for geology, forestry, land use, environmental control, agriculture etc.) generally do the interpretation under stereoscopic observation with stereoscopes and draw the outlines, symbols and codes directly on the photographs. Using the analogue photographs, generally in colour or false colour, and high quality mirror stereoscopes, they have the best conditions for their task. They must see the overall picture and often have to refer to adjoining photographs. Their skill is interpretation, not mapping, so they should not do the interpretation on a mapping system. It is simply too slow and too expensive.

The solution is as follows. The annotated photos (paper prints or diapositives) are scanned. Less skilled personnel, e.g. draughtsmen, can then digitize the outlined areas, the symbols, the codes and other required topographical detail on the DVP, thus generating the digital thematic map. The perspective plot program described in section 4.5 above is an aid to field completion prepared in response to demands from this market segment.

#### 5.8 Mapping Firms

This segment has traditionally been by far the largest user of photogrammetry, purchasing the most precise and expensive analogue and analytical workstations. These companies have naturally been sceptical about the lower accuracy of the DVP, but it is certainly true that there are projects where specifications are less stringent and the lower cost per hour of the DVP can be very attractive. Applications of this nature could include special work to be done for public utilities or resources management. Furthermore, the DVP has colour stereo superimposition, which is indispensable for digital

mapping and map revision. Superimposition is a standard feature, not an expensive optional extra.

The DVP is also a useful tool for in-house training in these larger companies. Many of its operations closely resemble those of the analytical plotters for which staff are required and it is much less expensive.

### 6. EXPERIENCES WITH THE DVP

This section contains little which will surprise expert photogrammetrists with experience on PCs, but it is based on Leica's experience in distributing the DVP to its own network and to customers and is designed to be helpful in a practical way to those interested in the DVP, by pointing out computer difficulties which are avoidable and summarizing experiences with some existing users.

#### 6.1 The Sharp JX-600 scanner

Les Systèmes Photogrammétriques DVP Inc., Leica Heerbrugg AG and a number of Leica sales units, representatives and customers have purchased the Sharp JX-600 scanner, which may be regarded as one of the most expensive of the popular scanners designed for word processing and desk top publishing applications. The maximum resolution is 600 dots per inch, equivalent to a pixel size of 42  $\mu$ m. Its A3 format, which is strongly recommended for comfortable coverage of 230 x 230 mm aerial photographs, and its capability of scanning in either grey scale or colour, the latter not necessary for the current version of the DVP, push up the price.

In general, experiences have been positive and the scanner has produced pleasing images which have yielded satisfactory measurements on the DVP. With a little experience, an operator can scan photographs at the rate of two per hour, including time for experimenting with scanner parameters before scanning the first photograph, format translation into TIFF and backup on tape cartridges. The peculiarities of the brands of TIFF generated by the various software packages supplied with the JX-600 no longer disconcert the DVP, as explained in section 3.1 above; this of course applies to other scanners too.

There is always a question of geometric accuracy surrounding all but the expensive, specifically photogrammetric scanners. Some systematic errors, of course, are removed during interior orientation and others, perhaps, by flexibility in the transformations of relative and absolute. Experiments by researchers from Université Laval, however, have revealed the possible existence of local errors up to four pixels in magnitude. These may not exist on some or most examples of the JX-600, but if they do they could certainly be prejudicial to accurate mapping. On the other hand, results from orientations and checks of numerous stereomodels on a variety of DVP sites do not support the hypothesis of widespread scanner errors. Nevertheless, the Laval team is preparing software to enable users to calibrate their scanners, whether Sharp JX-600 or some other model, and correct the images for significant errors. This requires, of course, that some approximate reference position is established, most easily by tape on the platen of the scanner, so that the calibration grid and the photographs themselves are always located in the same place on the platen and the corrections applied in the appropriate locations on each scanned image.

## 6.2 PC issues

Compared with, say, some popular word processing and graphics packages, installation of the DVP software is very easy. Some low level manipulation of the PC system parameters may be necessary, however, to ensure that the DVP image buffer described in section 3.2 above is properly implemented.

Even the briefest experience with the DVP underlines the truism that extensive disk space is essential. Public and private organisations working with small and medium sized projects and educational institutions which wish to have a number of types of small projects readily to hand quickly require one or more gigabytes of hard disk capacity. Only two or three years ago, capacities of this magnitude were regarded as very large for ordinary PCs, but one gigabyte is sufficient for only 30-35 aerial photographs scanned at a resolution of 42  $\mu\text{m}$ . Purchase of such peripherals is easy, but PC novices are reminded that the SCSI bus communications often used by large disks may render installation a little awkward.

Backup and archiving facilities are equally crucial. Again, purchase of tape cartridge devices or read/write optical disk drives is easy if customers cannot use existing archiving facilities on their organisations' computer networks. Installation is often fairly straightforward. A danger arises only in situations where the user may wish to archive on one PC system and read the tape data on another, perhaps in a branch office. The point to note is that there is a multiplicity of devices, compounded by innumerable combinations of media and software, their only common feature being their incompatibility with one another: to be sure of being able to read on one PC data archived on another, both systems should preferably have the same model of archiving device and the same accompanying software.

## 6.3 Accuracy

Several tests of the accuracy of the DVP have already been reported, for example by Gagnon et al. (1991) and Nolette et al. (1992). A consensus is emerging that accuracies obtained by measurement of check points in orientated stereomodels is around 0.5 pixel size in X or Y, i.e. 0.7 pixel in planimetry. Height accuracy is a function of vertical step, i.e. the change in height as a result of a one pixel movement on the image. Clearly, this interval is the pixel size multiplied by the ratio of the principal distance over the photobase. The root mean square error is 0.7 of this vertical step. Numerous tests have supported this inference.

Agnard and Gagnon (1991) have given results from tests in which the DVP was used for aerial triangulation. Once again, root mean square errors less than one pixel were obtained in several tests.

## 7. CONCLUSIONS

The DVP digital photogrammetric workstation was introduced in 1988 as an entry level system for display, orientation and measurement of pairs of photographs digitized in low cost scanners. Responsibility for the distribution of the product was assumed by the Leica organisation in 1990. This paper has listed some of the literature already published on the product and has summarised the main features of the latest hardware and software facilities. Importantly, sections have

been included to discuss applications and experiences with the product that are worth passing on to a wider audience. It is clear from the activities within the Leica network over the past two years that the DVP is a significant product, that it has satisfied a number of users involved in a range of applications and that the continuing introduction of enhancements and new products, in conjunction with the inevitable diffusion of digital photogrammetry in the next few years, will guarantee healthy growth and diversification in the customer base.

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