

## KERN DSP 1 - DIGITAL STEREO PHOTOGRAMMETRIC SYSTEM

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### Abstract

Kern introduces the DSP 1 Digital Stereo Photogrammetric System. This entirely digital mapping system uses stereo digital images as input and a completely digital measuring system to allow extraction of 3-D coordinate information. Photogrammetric and image processing techniques have been combined to produce a system that represents digital mapping in all senses. Over and above conventional photogrammetric capabilities, image processing has been applied to allow image correlation and enhancement to ensure that the required amount of information may be extracted from the images as efficiently as possible.

### 1. Introduction

Kern is proud to present the DSP 1 - the Digital Stereo Photogrammetric System - which allows data collection and information extraction directly from stereo digital images.

Some of the considerations for introducing an entirely digital stereo plotter today are :

- availability of digital image stereo products.
- sufficient cost effective processing power.
- sufficient cost effective RAM for holding complete digital images.
- ease of implementation of digital image processing techniques to enhance digital images.
- simple mechanical and optical design.

As the majority of data acquisition for mapping is in the form of aerial photography rather than digital imagery, at present, the all digital plotter is no substitute for the traditional analytical plotter, such as the Kern DSR, but it does open up a new range of applications with the integration of digital image products and processing techniques into the mapping world.

In the last fifteen years, the photogrammetric industry has seen revolutionary changes from analogue to digital (Petrie, 1983), primarily due to the developments which have taken place in computer hardware and software:

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- analogue equipment has been equipped with encoders and computing power to produce digital coordinate output, eg Kern PG2 / MAPS 200.
- the analogue space rods providing the relationship between photographic coordinates and 3D ground coordinates have been replaced by mathematical transformations carried out by computers, eg Kern DSR.
- CCD cameras and analogue to digital conversion capabilities have been fitted to analytical plotters to allow automation of some photogrammetric processes using digital image processing techniques, e,g. Kern ACOR correlator.

the logical conclusion to this photogrammetric revolution is the entirely digital approach, with digital image data input to digital measuring systems, eg Kern DSP 1 Digital Stereo Photogrammetric System.

The concept of an all digital stereo plotter was presented many years ago. It was proposed to replace the analogue photographic diapositives with digital images, thus retaining the conventional capabilities of a photogrammetric plotter and adding the possibilities of digital image processing techniques.

Entirely digital mono plotters have been realised in educational institutes (Petrie, 1983) and commercially (Stokes, 1987). They use a combination of digital imagery and DTM information to produce three dimensional coordinates of points of interest. A digital stereo plotter has been developed by University College London (Gugan, 1986).

Sarjakoski (1981) outlined some of the advantages of an all digital stereo plotter system, which included:

- no high precision optical or mechanical components or the necessity of regular instrument calibration.
- digital imagery is inherently stable and requires no inner orientation.
- image presentation can be optimised using image processing techniques.
- many procedures are, or can be, automated such as loading images from storage, and image correlation.

Systems may be developed on existing image processing systems which allow it to function as a stereo digital plotter, with little hardware development, as long as the essential requirements for a photogrammetric stereoplotter are met, namely stereo viewing, real-time scanning of a three dimensional model, capability to handle large images, and sub-pixel measurement accuracy.

Amongst others, the US Defense Mapping Agency has been involved in the development of a Digital Stereo Comparator/Compiler (DSCC) (Case, 1982) which meets these basic requirements and also contains additional features including model orientation

possibilities, real-time image correlation, data superimposition.

This paper will outline the development of the Kern DSP 1 Digital Stereo Photogrammetric System, and describe the various hardware and software components of the product.

## 2. The Kern DSP 1 Development.

Some rather broad aims were set for the DSP 1, and, as the system was based on image processing hardware and software, a joint project was proposed to a company specialising in this field.

Specifications and strategies for the first stage of the system development were then defined and carried out to produce the Kern DSP 1.

### 2.1 The Aims

The aims of the Kern DSP 1 Digital Stereo Photogrammetric System were threefold :

- replace photographic diapositives by digital images.
- replace the current Kern DSR.
- optics and mechanics with reduced optics for stereo viewing, digital image processing hardware and software for image movement and measurement.
- implement the use of digital image processing techniques for ease of image measurement and automation of procedures, eg: image correlation, image enhancement.

### 2.2 Our Partners

In order to realize these goals, Kern formed a joint development for the DSP 1 Project with GEMS of Cambridge, who are recognised as a leader in the production of digital image processing systems.

### 2.3 The Specifications

The features of the system to be developed in the first stage were determined :

- display and orientation of digitised perspective aerial photography and SPOT imagery with both stereo and mono viewing.
- image enhancement using some digital image processing techniques.
- 3D data capture from stereo imagery.
- automatic height disparity control (removal of

- x-parallax) while planimetric movement under operator control.
- superimposition of vector information on the image.
- full image DTM computation and display of axionometric views

## 2.4 The Development Strategy

The philosophy of distributed hardware processing and modular software adopted by Kern many years ago again displayed its strength when the development of the DSP 1 was being planned and implemented, as many existing modules could be used directly or with little modification.

### Distributed Hardware

The well known hardware design of the Kern DSR (Fig.1) consists of :

#### - Processors

- P1 - the main processor running orientation and application software.
- P2 - the dedicated processor for movement of the stage plates.
- P3 - the dedicated processor for operator footpedal and keypad input.

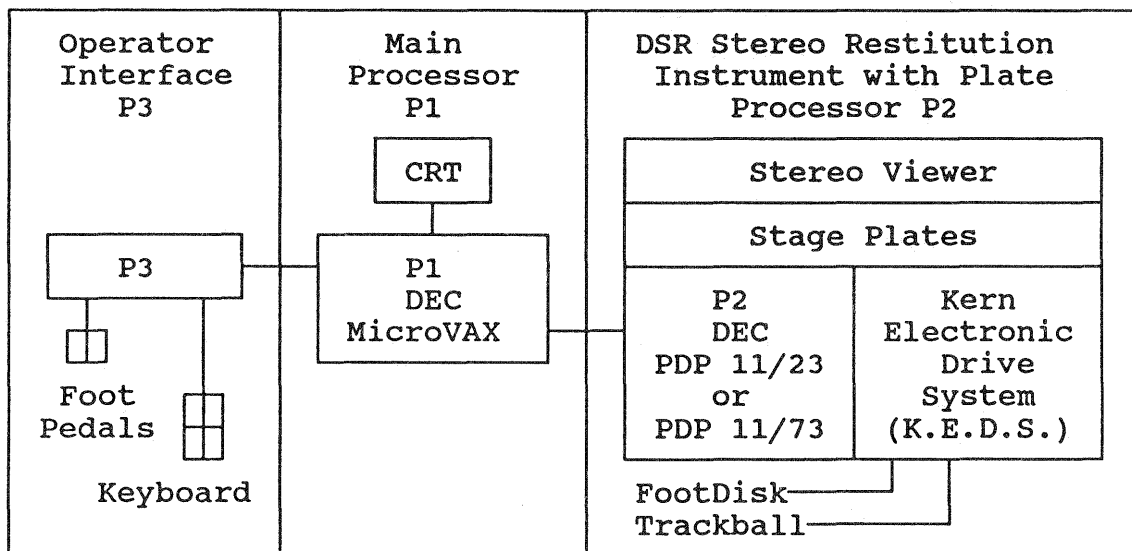


Fig. 1 Kern DSR Hardware

#### - Viewer

#### Optics

- to view photographic images in stereo with possibilities of correction for

Mechanics - to hold the photographic images, read  
 electronics stage plates positions and move the  
 stage to computed positions

Similarly, the hardware design of the Kern DSP 1 is distributed (Fig. 2) and consists of :

- Processors

- P1 - the main processor running orientation and application software
- P2 - the dedicated processor for the image display hardware with memory to hold the digital images.
- P3 - the dedicated processor for operator footpedal and keypad input.
- P7 - Transputer hardware for high speed parallel processing (P4, P5, and P6 are used in the Kern GP1 graphic peripheral).

- Viewer

- Monitor - to display digital images.
- Optics - to view digital images in stereo with some possibilities of correction for squint, image rotation.

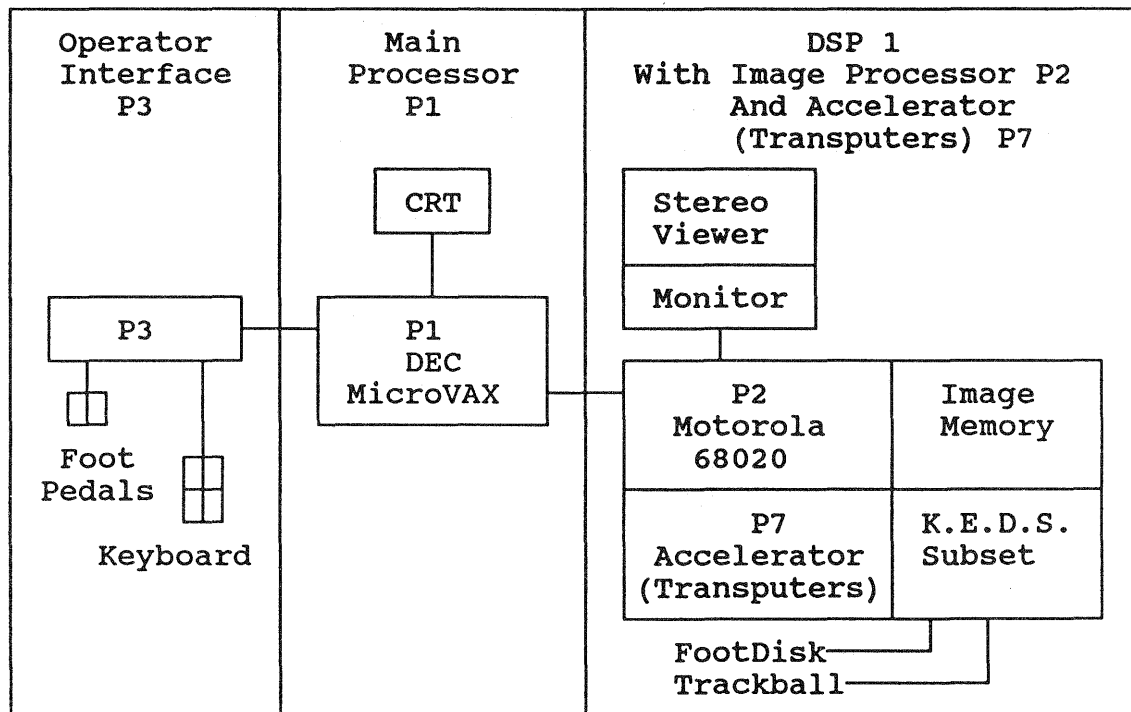


Fig. 2 Kern DSP 1 Hardware

## Modular Software

The modular structure of Kern software which is linked to the distributed hardware processing allowed selected sections of the standard Kern DSR software (Fig. 3) to be modified as required for the Kern DSP 1 (Fig. 4).

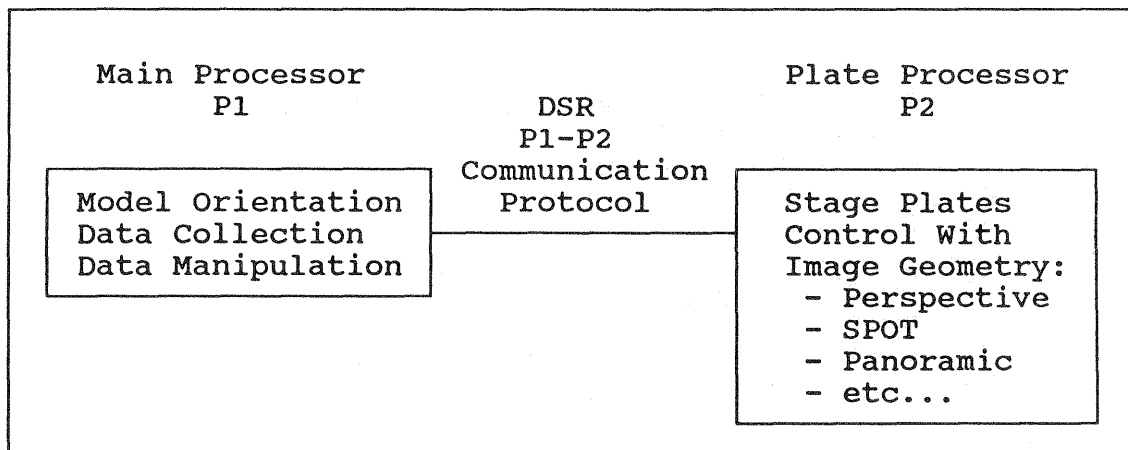


Fig. 3 Kern DSR Software

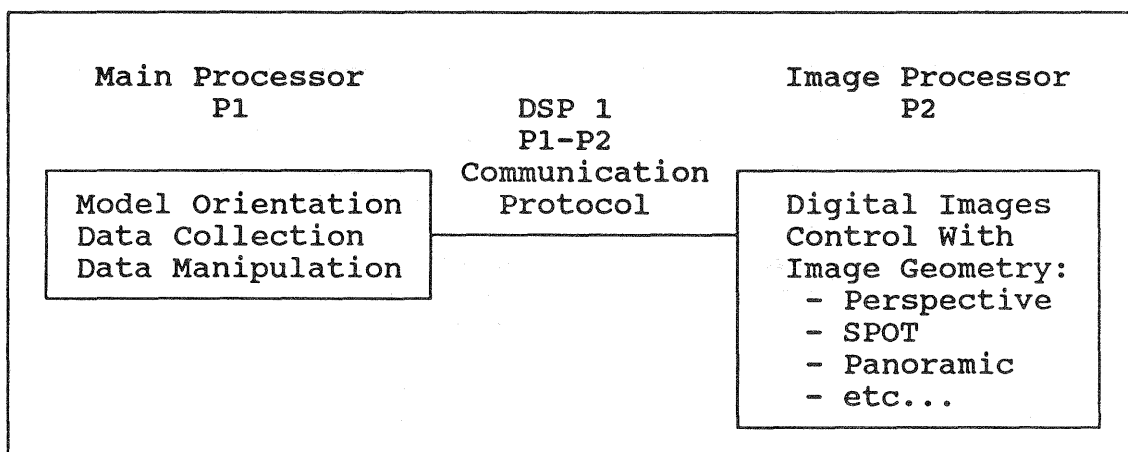


Fig. 4 Kern DSP 1 Software

- P1 software - the main processor

Model orientation and application programs which run on the main processor and communicate with the Plate Processor, P2, remain the same as in both the DSR and the DSP with some additional functions implemented.

- P2 software - the dedicated processor for movement of the stage plates

The P2 software is considerably extended to handle not only the real-time geometrical computations but now also the image handling routines to control the digital image displays (mono/stereo, zoom), the image movement (panning, speed control) and processing routines to enhance the digital images.

- P7 software - the accelerator processor for image correlation

Transputers and parallel programming handle the computationally intensive task of real-time image correlation.

### 3. The Kern DSP 1 Product Overview

The DSP 1 may be used in a similar manner to the Kern DSR eg, model orientation, data collection, but many features have been added to take advantage of the stereo digital images.

The executable program to control the movement of the digital images according to their image geometry, is sent from the main processor, P1, to the image processor, P2.

The software which resides on the Transputers is further transmitted from P2 to the accelerator, P7. This program is responsible for the high-speed correlation of the left and right images using parallel processing, to produce automatically determined heights.

Next, the stereo digital images are sent from the P1 processor, where they are stored on disk or tape, to P2. There, the digital images are held in random access memory (RAM).

The user may view these images either monoscopically, with one image covering the entire monitor, or stereoscopically, with the corresponding overlapping parts of the left and right digital images being displayed using the split-screen facility, and the images being viewed using a binocular viewing device.

Digital symbols generated and overlaid on the images serve as the measuring marks which are used exactly as in a normal photogrammetric instrument to measure the 3D coordinates of points in the model.

Model orientation and data collection may be performed as for photographic images, but some image processing techniques have been introduced which provide considerable help to the operator.

Automatic determination of individual heights may be requested, or the operator may choose to remain in a continuous correlation mode, ie, as the operator moves around the stereo-

model in planimetry, the height of the current position is computed automatically by the accelerator. This real-time correlation is possible due to the extremely fast parallel processing of the transputers.

In addition, the operator has several image-processing facilities at hand to enable easier identification and measurement of features, eg, contrast stretching of images, edge enhancement.

#### 4. Kern DSP 1 Hardware

Almost all of the hardware for the DSP 1 existed either as GEMS image processing equipment or as modules on the Kern DSR. The only hardware developments were interfaces between various modules (Fig. 5).

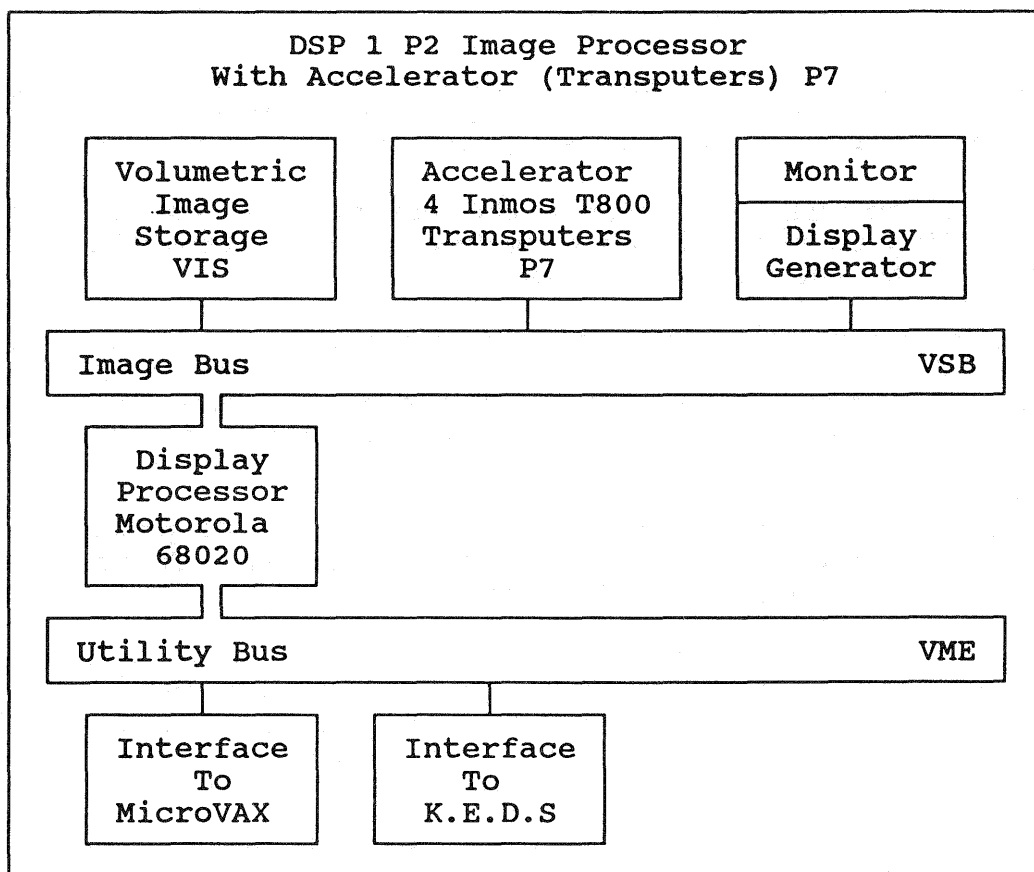


Fig. 5 Kern DSP 1 P2 Hardware



#### 4.1 P1 Main Processor

As with the Kern DSR, the main processor is a DEC MicroVAX. All image orientation and data collection software runs on this processor. Downloading of images and programs to the P2 Plate Processor and also communication with P2, is over a parallel interface.

#### 4.2 P2 Plate Processor

The heart of the DSP 1 is the GEMSYS 35 hardware from GEMS which fulfills the functions of the P2 Plate Processor and image storage device. It is used in stand alone mode, thus all run-time programs and input data for the system are downloaded to the P2 from the P1 main processor, operating in a similar way to the Kern DSR.

##### - Display Processor

The Display Processor is based on a Motorola MC68020 microprocessor with an MC68881 floating point coprocessor.

It is connected onto both the Utility Bus, VME, for communication with external devices, and also onto the high speed Image Bus, VSB, for communication with the other GEMSYS 35 modules.

##### - Volumetric Image Store (VIS)

Up to 256 MB of RAM Volumetric Image Store may be installed on the Image Bus - enough memory to hold 7 full panchromatic SPOT images.

##### - Accelerator

A hardware accelerator consisting of four INMOS T800 floating point transputers is installed on the Image Bus. One of the tasks of the transputers is to allow the parallel processing of image correlation algorithms.

##### - Communication with P1

Digital images and programs sent from P1 to the P2 Plate Processor, and also all commands and transfer of data between P1 and P2 are over a parallel, DMA, interface developed by GEMS.

##### - Communication with Image Movements Controls

A subset of the Kern DSR electronics is implemented as the user interface for moving the images under operator control. This connects to the GEMSYS 35 hardware via an interface developed by GEMS.

### **4.3 Display Monitor**

The display monitor for the digital images is a high resolution colour monitor with 1480 pixels x 1024 lines. The monitor uses a split screen technique to divide the visible image into two areas of 740 pixels x 1024 lines to allow stereo images to be presented, with each area having independent zooming, panning etc.

### **4.4 Floating Mark**

The left and right image floating marks are defined in an overlay plane at the centre of the appropriate window area. By using this digital floating mark, it is impossible to introduce parallax between the floating mark and the image, thus allowing more flexibility in the optical viewer design.

### **4.5 Stereoviewer**

The observation system is based on the Kern DSR optics and is designed to allow stereoscopic viewing of the monitor. The stereoviewer has the following characteristics :

- the construction of the viewer is such that it can be completely folded away when the operator wishes to view the display monitor directly in order to look at one image monocularly.
- the table to ocular distance is variable.
- correction is made for the screen curvature of the monitor.
- individual image rotation is implemented.
- correction for squint may be applied.

### **4.6 Image Movements Controls**

The trackball and footdisk from the Kern DSR are implemented as the user interface. These allow three dimensional movement by the operator within the displayed stereo model. The device is connected to the GEMSYS 35 hardware via an interface developed by GEMS.

### **4.7 Coordinate Registration**

The user interface for coordinate registration and instrument keypad input are via the P3 processor exactly as in the Kern DSR. This processor is connected with an RS232 serial line to the main processor P1.

## 5. Kern DSP 1 Software

Due to the modular structure of both Kern and GEMS software, many of the required procedures for the DSP 1 already existed and the development of the DSP 1 software was more a question of software integration rather than new software development.

### 5.1 P1 Main Processor to P2 Image Processor Communication

The communication protocol established between the main processor, P1, and the image processor, P2, allows the transfer of digital images, programs and commands from P1 to P2 and also handles all flow of data between P1 and P2.

### 5.2 P1 Main Processor

#### - Download Digital Images

Software was written to transfer SPOT digital images and digitised perspective photography stored on the MicroVAX main processor to the image processor.

#### - Download P2 Image Processor Programs

P2 is a diskless image processing workstation, consequently, programs which run on P2 and on the Accelerator Transputers, PT, must be downloaded from P1 at the startup of the system.

#### - Image Orientation

Orientation of models of perspective or SPOT images use the same software as for the Kern DSR.

#### - Data Collection

Maps 200 On-line data Compilation with the DSP 1 is similar to the Kern DSR, as will be the DTMCOL DTM Collection Package.

### 5.3 P2 Image Processor

#### - Plate Processor Emulation

The plate processor emulation is divided into two sections:

- the algorithms for the image geometry e.g. perspective, SPOT.
- movement of the digital images according to P1 program commands or input from the user interface of trackball and footwheel .

- Optics Emulation

Digital image processing techniques are used to provide functions previously handled by the Kern DSR optics e.g. zoom, mono/stereo image viewing.

- Digital Image Processing

Possibilities of improving the digital images are integrated e.g. edge enhancement, contrast stretching.

#### 5.4 P7 Transputers

An executable program is downloaded to the Accelerator, which comprises 4 transputers. The software computes the height of a particular planimetric position, on request from P2, according to the Vertical Line Locus method (Cogan, Hunter, 1984).

#### 6. Further developments

With the DSP 1 product, Kern has realised a truly digital system which combines digital image processing with photogrammetry.

Many existing Kern DSR features have still to be included, eg installation of all the existing Kern photogrammetry software into the DSP 1, implementation of further correlation techniques such as model orientation.

Many other features can be added to the DSP 1, especially in the area of digital image processing, e.g. pattern recognition, feature extraction. The combination of photogrammetry and digital image processing can also be used as a powerful tool for close range, industrial applications.

In our industry, Geographic Information Systems will be further developed to allow for raster data bases and powerful tools for raster to vector and vector to raster conversion.

#### 7. Conclusions

As digital data acquisition becomes more common, entirely digital plotters such as the Kern DSP 1 will become the standard measurement system.

Kern has once again proven itself to be a leader in harnessing the latest photogrammetric hardware and software innovations, and packaging them in a form which allows them to be used by a wide spectrum of the mapping community.

The philosophy of distributed processing and modular software which Kern adopted many years ago has allowed the development of the DSP 1 Digital Stereo Photogrammetric System, the solution of mapping from digital images today.

This system will be the photogrammetric tool of the future.  
It is our and your investment for tomorrow.

### Acknowledgement

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