DIGITAL PHOTOGRAMMETRY - OPTIONS AND OPPORTUNITIES

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ABSTRACT:

The paper will outline, against the background of its new agency status, the options open to the Ordnance Survey of Great Britain (OSGB) for the utilization of the emerging all-digital technologies and the range of flexible opportunities opened up by the 'soft copy', stereo and monoscopic, workstations becoming available. Results of early trials on extending the range of Ordnance Survey photogrammetric capabilities will be discribed.

KEY WORDS: Digital Dystems, DTM, Feature Extraction, Mapping, Orthophoto.

1. BACKGROUND

1.1 Introduction

The paper gives a brief outline of strategic and marketing issues, where they can be considered to impact on the potential for the use of digital photogrammetry within the Ordnance Survey (OS), Great Britain's official mapping Department. The options which are available from use of this technology will then be discussed to be followed by a brief description of trials into how such options may work in practice. Possible market opportunities are then explored.

1.2 Financial Environment

In April 1990, as part of a Central Government "Next Steps" initiative, the OS became an Executive Agency. Whilst retaining an element of Government Vote funding for core activities, the proportion of expenditure recovered by revenue earning activities has steadily risen from 41% in 1982 to a figure of about 68% by 1991/92. The Government sets its Executive Agencies challenging targets and each year OS is expected to increase the revenue proportions, with the long term aim of reaching 100% cost recovery as soon as possible.

1.3 Key Objectives

1.3.1 The mapping of UK , at the basic scales of 1:1250, 1:2500 and 1:10,000 was completed in the early 1980s. The revision of these maps is a current major activity which is reflected in one of the OS key corporate objectives.

'- To keep the national mapping of Great Britain up to date within criterea judged to be acceptable to users, and ultimately to achieve uniform levels of revision on all products.'

1.3.2 In parallel with this gradual move to a dominantly revision role has been the steady introduction of digital methods. Initially this was done with the aim of reducing the costs of the cartographic processes, but increasingly as a means of directly recording the mapped objects into a digital form, and for sale in response to customer needs. This is also apparent in another key objective.

'- To convert the archive of basic scales mapping into digital form where required by customers, and to establish and maintain a cost-effective digital revision service.'

1.3.3 The role of photogrammetry in OS and its use in support of these revision objectives has been described in (Newby, 1990) and (Farrow, 1991).

1.4 Digital Archive

All of the published urban 1:1250 plans are now in digital form and the number of digital large scale plans has reached 142,000 out of approximately 220,000 in total. The current OS corporate plan is to achieve the completion of this digitising programme by 1995. This may be compared with a target date of 2005 given in (Proctor, 1987), and is largely due to a significant report (House of Lords, 1982) from the Select Committee on Science and Technology which covered the topics of Remote Sensing and Digital Mapping. Their recommendations led to further support for the OS digital mapping programme and the Treasury were persuaded to grant additional funds to accelerate the rate of digitising, mainly by employing private contractors. As part of the Government response to the Select Committee's report, a Committee of Enquiry into the Handling of Geographic Information was appointed (Chorley, 1987). This led to a proposal for collaboration between OS and the Utilities (Electricity, Gas, Telecom, & Water), traditionally major customers for OS products; OS would continue to control the digital conversion programme but digitising contracts would be let by the customer to an agreed reduced specification known as "OS88". Quality control (QC) procedures known as "NJUG 13" were adopted, giving an example of successful collaboration between the National Joint Utilities Group (NJUG) and the OS. Maps which passed this statistical QC would be incorporated into the OS Digital Archive, to be updated and sold to other purchasers to the mutual benefit of OS and the customer letting the original contract.

1.5 Recent Initiatives

1.5.1 Theme Products The stimulus given by the Chorley report to the GIS community has led ·OS to progessively shift its emphasis from digital mapping to the possibilities of creating layered theme products. As a foundation for this a programme is in hand to retrospectively replace the current map based tiles of the digital archive with a continuous, edgematched and geometrically consistent data set in which unique junctions will be created where features intersect, over or undershoots and double digitised points will be removed, and free ends resolved. From this base, topological objects can be formed to suit customer requirements and will ensure a level of uniformity which will ease the exchange of data between users. The recent 1991 National Census has led to the generation of an administrative boundary polygon data set with attribute information. Enumeration District boundaries, used by the Office of Population and Census Surveys to segment areas for ease of census data collection, are also being created as a linked data set by a consortium which includes OS. A road centreline network data set is well under way following demands from the vehicle navigation sector. The most recent proposals are for a geocoded address data set linked to the postcodes from the Royal Mail.

1.5.2 Collaborative Ventures The rise in customer interest in raster backdrop layers to support their GIS applications has led to proposals to supply tiled raster versions of OS medium scale maps as a joint scheme with external commercial partners, the two small scale series of 1:625,000 and 1:250,000 being already available as vector layers. The 1:50,000 contour and derived DTM data sets have been created jointly by Military Survey and OS, with the basic digitising being done by the private sector. Many other examples of successful collaboration could be cited throughout the range of OS activities.

1.6 Customer Care Two other initiatives are worthy of mention, firstly in 1990 the OS formally embraced the concept of Total Quality Management (TQM) as a means of improving the quality of its service, both internally to improve efficiency, and externally to ensure customer requirements are clearly understood and satisfied. This has been underlined in 1991 by the Government Citizen's Charter programme which also places significant emphasis on service to the customer.

It is against this OS historical and cultural background that the options and opportunities for digital photogrammetry must be considered.
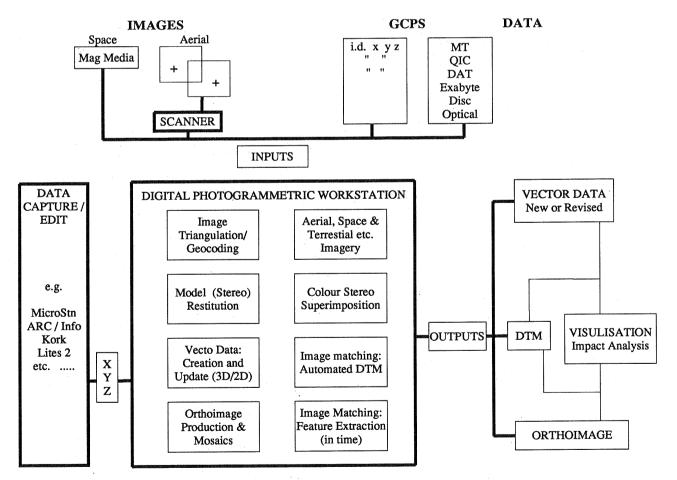

FIGURE 1. DIGITAL PHOTOGRAMMETRIC WORKSTATION PRODUCTS

2. DIGITAL PHOTOGRAMMETRY - OPTIONS

2.1 Definitions

The ISPRS Intercommission WG II/III on Design and Algorithmic Aspects of Digital Photogrammetric Systems has done much in the last few years to stimulate the public debate on the use of digital images in support of photogrammetric tasks. Not least is the discussion on nomenclature, should it be a Digital Photogrammetric 'System'(DPS) or 'Workstation'(DPW) as in (Dowman, 1991) ?, or is it a Digital 'Softcopy' Workstation(DSW) as in (Leberl, 1991) ?

The essential elements of an all-digital system are that it handles digital images from a variety of sensors, has a significant amount of automation but allows fast effective user interaction, and performs rigorous photogrammetric solutions. To this can be added the desirable requirement that the computer system platform should be 'commercial off the shelf' (COTS) (Greve et al, 1992).

2.2 Inputs

Digital systems do not suffer from the limitations of film-based photogrammetry, being capable of receiving and rectifying inputs from a variety of sensors with differing geometric properties in addition to scanned photography; eg electro-optical (SPOT etc), satellite radar imaging (ERS-1 etc), high resolution spectrometers (MIES etc), video-cameras and CCD-array sensors. Future proposed satellite sensors will have fore/down/aft linear arrays allowing more reliable automatic 3-D reconstruction than hitherto. The system should also allow an direct access into existing data bases.

2.3 Hardware

Early developments in digital photogrammetry were in support of defence requirements and needed specialised hardware systems to achieve a tolerable performance. The almost exponential rise in processor performance coupled with falling prices has led to the situation where COTS hardware can now be assembled to execute most of the desired commercial functions.

Whilst the digital system removes the need for specialist high performance optical-mechanical or electro-servo mechanisms, film based photogrammetry leads to a need for scanners to convert the images to a pixel format. Medium to low resolution scanners can be considered as COTS items, being driven by the expanding document scanning industry. However scanners capable of giving pixel sizes commensurate with the expectations of the photogrammetric accuracies achievable from the current range of films are not so freely available. There is still debate on the desirable resolution; 7.5 μm as is possible on the Intergraph Photoscan (Kaiser, 1991), 20-25 μm at about half the average photogrammetric measuring mark, or 40 μm to give an equivalent ground cover of 1m from 1: 25,000 scale images. If the outputs are to be map graphics then a film writer will also be needed.

Digital images also generate large data files and hence potential data storage problems (Greve, 1992). Again technology advances in storage systems and compression facilities (Sarjakoski, 1991) are reducing this to manageable proportions for many applications.

2.4 Software

In all of the discussions the importance of the software modules is continually emphasised as being more critical than the hardware. The ability to migrate software to new higher performance hardware can now be achieved with minor, if any, modifications provided there has been conformance to Open System standards. Greve (1992) reported significant increases in speed moving between COTS platforms with no software changes since developing their system within a Motif and X-Windows environment.

2.4.1 Photogrammetric The main real-time module connects the stereomonitor cursors to the 3-D user control mouse/cursor via the mathematical model relating the sensor images. In addition there will be coordinate processing modules for inner,relative, and absolute orientation plus block adjustment.

2.4.2 Image Processing An advantage of the digital system is to be able to use image processing modules to modify the images to be better suited for display or analysis. Resampling can be performed to ease subsequent correlation, or to generate ortho-images.

2.4.3 Automation Matching the performance and functionality of the analytical plotter to include automatic object interpretation has yet to be realised (Dowman, 1991), and is still thought to be a considerable way off, though some robotic and machine vision systems show promise in some selected tasks. However automatic image matching to support DTM and ortho-images is clearly possible now (Miller, 1992 and Greve, 1992). Extraction of partial edges to enable

2.4.4 Standard Photogrammetric Products Manual tracing of point and line features, symbol generation and vector superimposition are an essential characteristic for the transition from analytical systems. If an ortho-image has been generated it is possible to digitise features in the workstation without the need for stereo viewing. DTM creation, editing and visualisation capabilities must also exist and show economic gains.

2.4.5 GIS Interface The digital system can supply the image layer as part of a GIS database, be used to extract specific information, or act as an update process (Sarjakoski, 1992). The needs of the GIS community, when given the opportunity to move from using the information derived from the map maker's interpretation to doing his own analysis of digital data within/or from images, may well impact on the traditional role of the photogrammet-rist (Leberl, 1991).

2.5 Outputs

2.5.1 Digital Elevation Models It can be accepted that automatic generation is generally operational, though correlation can still be unsuccessful in areas of some types of image. Smaller scales of images where the heights of surface objects become insignificant give the most successful results. There is still a need for clear statements on accuracy and quality measures (Dowman, 1991).

2.5.2 Orthophotography This is another product that is mature (Boniface, 1992) and which does not necessarily depend on an automatically derived DTM. At least eight of the 15 systems listed as at spring 1991 (Leberl, 1991) offer digital

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┌─────────────────────────────┐
│         INPUTS:             │
│         Imagery             │
│   Orientation Parameters    │
│           DTM               │
├─────────────────────────────┤
│      ORTHOIMAGE             │
│      CREATION:              │
│  Take inputs and resample to│
│  user defined limit/pixel size│
├─────────────────────────────┤
│        OUTPUTS:             │
│  Orthoimage by Photo area   │
└─────────────────────────────┘
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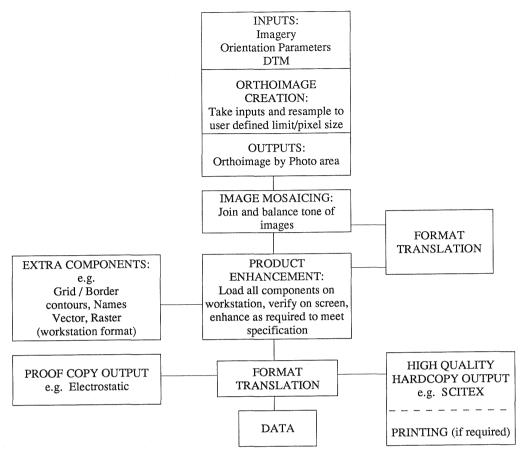
FIGURE 2. MAJOR STAGES & REQUIREMENTS OF AN ORTHOIMAGE

orthoimages, with others to be seen in various journals. The possibilities for colour orthophotos are discussed in (Bahr, 1991) with a cautionary word on the proportion of manual effort in linking the necessary modules together. See fig 2. for a schematic which illustrates this point.

2.5.3 Object Interpretation The Canadian Topo-graphic Data Base Revision System (TDBRS) has made some progress in using automated approaches for the extraction of linear features (Ahac et al,1992). Whilst accepting that the human operator is the best means of supplying the semantic interpretation needed for ouputs to GIS they strongly support the use of automated systems to generate the geometric framework for the images, and continue to work towards improving the tools which will minimize the work of the operator.

3. ORDNANCE SURVEY TRIALS

3.1 Photogrammetric Restitution

The first OS trial with a digital photogrammetric system (Newby, 1990), was with the Helava Associates Incorporated (HAI) Digital Comparator Correlator System (DCCS) (Helava, 1987). This practical experience with one of the first building blocks in the construction of an all digital system has been most valuable. Though hosted by what is now a fairly pedestrian Microvax II it demonstrated the practicality of automated fiducial, control and passpoint mensuration, for input to photogrammetric orientation processes and thence to aerial triangulation (AT).

3.2 Digital Terrain Models

A logical progression from restitution and AT was to consideration of automated DTM creation. The PC-386 hosted HAI-500 system (Miller, 1992) became available in late 1990 for beta testing. Using the DCCS scan cameras and upgraded Vax software to generate piecewise scanned images, data files were passed to the faster HAI-500 for reconstruction into whole images and thence input to automatic DTM generation.

The DCCS Microvax has recently been replaced with an upgraded PC-486 host and software that has been ported to work under the X-Windows environment, thus enabling the AT, scanning and image assembly to be done on a single computer. This host will also be capable of running the latest X-Windows based version of HAI-500 software.

Experience was gained in a variety of functions leading up to the creation of an orthophoto image (Newby, 1991). The main problems identified were in relation to the scale of images used for the main OS photogrammetric products. These range from 1:5000 to 1:10000 at which scales the surface objects are large enough to be detected by the correlation. Choosing a strategy which enables buildings and trees to be omitted, if requiring a bare earth DTM; or one which will give an envelope over the obstuctions, if seeking for intervisibility sites, is not easy.

3.3 Orthophotos

The second major capability of the HAI-500 is the generation of orthophoto image files and experience was gained in using the current 1:10,000 photos obtained for revision of 1:2500 maps and earlier 1:25,000 film used for revision of the 1:10,000 map series. Without dedicated facilities for generating graphics a rather tortuous route was used to produce sample plots to demonstrate the feasibility.

3.4 HAI-750

Some of the functionality set out by OS in its original research requirement were not available in the early HAI-500 software, notably batch processing, SPOT modelling and manual feature extraction. Indications were that these were to become part of the HAI-500 package when ported to the PC X-Windows environment. Because of delays in this development HAI, by now a subsidiary of General Dynamics, kindly supplied an HAI-750 system (Miller, 1992) for beta evaluation.

3.4.1 Configuration The HAI-750 is hosted by a Sun Sparc2 GX with 19" colour monitor, supported by a 1.3Gb SCSI disc, 8mm Exabyte tape and CD-ROM. Image processing is supported on a Vitec IP-50 unit (similar to that incorporated into the Intergraph Imagestation (Kaiser, 1991)), with stereo display on a Tektronix SGS625 screen. Mono images can be viewed in a window on the Sun console. Control is by a track-ball/button box and standard mouse. The unit is linked by ethernet to the DCCS Unix PC enabling shared disc storage and reducing time consuming transfers of the large image files.

3.4.2 Capabilities The batch processing requirement can be met by means of the multitasking capability of X-Windows but has not been rigorously tested as would be needed for an efficient production flowline.

The SPOT processing facility was tested using a model covering an area of Oman. This highlighted problems in coping with the narrow wadi patterns and an area giving widely varying radiometric images compouded by time delays between satellite passes. Several correlation strategies were tried including one supplied by HAI. The results supported previous conclusions that there will always be a need for manual editing of an automatically derived DTM. The ystem allows for input of additional control in the form of ridge and valley lines, or 'geomorphic interpolation', but whilst inclusion of the major breaklines did improve the DTM, much more editing would be required to meet normal map contour specification. A patch of orthophoto was produced using a previously generated DTM from manual contours, thus proving a capability to import 'foreign' DTM data to the system.

The 1:25,000 images used on the HAI-500 tests were rescanned, partly to test the new DCCS X-windows scanner software, and fresh DTMs created. As expected there were performance improvements of up to 60%. The older DCCS cameras cannot take advantage of recent improvements in the HAI procedures which will reduce times to about 20 mins per photo for a 25 micron scan.

After experimenting with various strategies, automatic DTM results were achieved on the HAI-750 which set against the HAI-500 figures showed a reduction of almost 50% when compared to the DTM from standard photogrammetric contours. However both showed significant variations in areas of vegetation and featureless hillsides, and require time consuming manual identification and edit. The DTM edit tools include an improved profiler and some area tools to permit smoothing of flat or plane areas. There are a variety of display options to aid in error detection, though care must be exercised to reach the optimum combination. The concept of automatically generating an orthoimage and its stereomate for inputs in an iterative process as a means of identifying initial correlation errors (Norvelle, 1992) was appealing, but could not be tested. The need to improve the functionality of the total DTM process to minimize the subsequent manual editing is well recognized (Heipke, 1992).

An attempt was made to use the image processing tools to mosaic patches of orthophotos to give a regular tile but the software bug which corrupted the images will not be corrected until the next software release.

3.4.3 Feature extraction Whilst this was only a desirable feature in the original OS requirements it has now assumed a greater importance. The facilities provide many of the vector feature extraction tools needed for capture and revision but could not match the full capabilities within the current OS vector capture systems. It is understood there are plans to provide links to some of the commoner vector systems such as ARC/INFO, Kork or Cadmap (on show at the exhibition in the spring '92 ASPRS/ACSM meeting). If an orthoimage has been produced, feature capture can be either in mono in a Sun window or stereo on the Tektronix.

3.4.5 General Throughout the test migration of data and parameters between the HAI-750 and other systems has been essential and overall has been successful. The X11/Motif interface can be a trifle confusing to the novice and sometimes data was lost, but towards the end both operators became more adept.

4. OPPORTUNITIES

4.1 Revision

As outlined above the major task for photogrammetry at OS is in the revision of its large scale topographic maps. As the coverage of digital data spreads the customer expectations on levels and frequency of revision updates are rising (Farrow, 1991). However a summary of European map revision activity (Macdonald, 1991) highlights the fact that complete replacement of the map is currently the most common approach. Will this remain so in a digital era when currency of information becomes all important? There is already evidence of customer reaction to changed coordinates due to replotted update survey when the ground feature has not moved. The requirement would seem to be for a system capable of rapidly identifying where change has arisen with tools to survey only the changed features for supply as a change-only file. In the GIS theme layers being produced by OS a key element is an inbuilt strategy to cover the future update requirement. However it is not certain that current GIS can handle such selective update information. Photogrammetry is not alone in facing rapid technological advances. Kinematic GPS is fast reaching a point where it is economically viable to survey small developments without the constraint of having to wait for photography.

A challenge for the digital photogrammetric workstation within OS is to service the need of rapid revision surveys at a cost which is competitive with alternative approaches.

4.2 Terrain Model

Digital terrain data for UK is available as a derived product from digitised contours from either 1:50,000, almost total cover, or piecemeal from 1:10,000 mapping, the original photogrammetric source scale for contours of UK. However these contours were produced to a cartographic specification and do not cross manmade surface features such as cuttings and embankments, quarries or opencast mine areas, and are only approximations of ground level in dense vegetation areas. For a quality DTM such deficiences should be removed and one technologically possible method could be based upon using the existing 1:10000 DTM as input to a DPW for supervised revision. A further possible refinement would be to input the known attributed polygon object data available from the large scale digital archive to delineate patches within which the correlation strategy is modified to suit the local characteristics eg wooded or buildings. An alternative could be to define a close grid interval to ensure sufficient nodes fall on the manmade objects and then in a post-process use the polygon data to eliminate the enclosed nodes and replace with a surface interpolated from the surrounding ground points. It is understood that HAI will be introducing a facility to allow for varying correlation strategies within defined areas within one model, whether this will be general enough to include any sized polygon breakdown of the image is not known.

There is mounting evidence that the radio propogation industry will be needing increasingly finer resolution models for critical site planning. Currently the practice is to attempt to generate heighted objects to be added to a ground DTM. Since it is likely that such a DTM derived from maps will be an approximation, using a DPW derived 'envelope' should give a better solution.

4.3 Orthoimage

Unlike in the USA and parts of Europe the orthophoto derived image map did not blossom in UK in the days of optical mechanical systems, or even when the more sophisticated Gestalt, Orthocomp or OR1 sytems came along. Whilst the takeup of GIS in UK has not proceeded as fast as in USA it is nevertheless expanding. Systems which are being demonstrated now almost invariably claim a mixed vector and raster capability. The latter embraces pixel images and given sufficient storage it is feasible to contemplate an image layer in addition to other relevant customer vector layers, as outlined in 2.4.5 above. An advantage is that features of particular interest which may appear on the photography but are not in the map specification, for reasons of historical map design, could be viewed and extracted, if and when needed, by the specialist user.

The DPW would enable OS to produce the rigourously rectified images to satisfy this, so far, dormant market. Tracing selected features from a mono image might well be an effective solution, but will these customers be prepared, or even prefer, to interpret and update their own GIS database directly from these rectified images ? A related issue is the required accuracy for the geometry of the objects to be held within a GIS. For many users it is the existence of an object which is important rather than the exact geometry. These may prefer a do-it-yourself option rather than wait for a precise solution. The advances in near-lossless compression solutions (Sarjakoski, 1991) may appeal to such users.

Unlike most of the other European countries OSGB makes little use, if any, of photogrammetric techniques for its medium scale 1:25,000 or 1:50,000 map series. The DPW gives the potential to create orthoimage data sets as adjuncts or even replacements for some uses at or near these scales. The acquisition of timely imagery over selected areas is notoriously difficult in UK, and is potentially more so if flying for small scale photography. However there is a window of opportunity for such imagery until the arrival, if ever, of higher resolution satellite systems.

4.4 Visualisation

In the discussion which followed the presentation of (Greve, 1992) the potential for the worldwide market for data sets for input to visualisation, impact analysis or simulation systems was strongly argued. Development planning appeals are a fruitful source of income for architectural surveyors who are making increasing use of CAD modelling to present their cases. A draped orthoimage on its parent DTM can give an impressive static visual display and systems (Gross, 1991, and Greve, 1992) exist which can be used to produce extremely realistic 'fly-throughs'. The cost and availability of colour imagery is now much closer to that of normal panchromatic film and would be a prerequisite for such systems. Whilst there is a well established usage of computer models in the simulator market, many could be improved by use of a DPW output. The growth of the leisure industry and 'virtual reality' systems must represent a widening market place for a quality image output system. Like the GIS user the accuracy needed for visualisation may not be as demanding as for classical topographic mapping and compressed, but rectified, images may suffice.

4.5 Close Range Applications

The paper has been written from an OS viewpoint and has therefore only briefly touched upon this broad field of applications, eminently suited to the use of digital photogrammetric techniques, and a group of users who may well sustain the progressive development if the topographic sector are slow to adopt the DPW.

5. SUMMARY

The role of the OS is changing as the milestone of complete digital cover draws closer. The efficient management of this data base and its timely update will be the main challenge. The expectation profile of the future all-digital customers may well differ from the current paper map users. To survive as an Agency new strategies will need to be adopted, and the recent collaborative ventures are early signs of this process. The possibilities for new products are being actively pursued, but there must first be a clear market need. Photogrammmetry is likely to continue to play an important role provided the techniques remain cost effective in comparison with other methods. The Digital Photogrammetric Workstation, when fully developed, is clearly capable of meeting the current OS photogrammetric revision needs and has the flexibility to sustain a wide range of new products with good market potential. Continuing to evaluate leading edge systems should enable OS to be in a position to quickly respond to new customer needs as they arise.

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