Ordnance Survey Ireland and its Transition to Digital Photogrammetry

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Introduction

Ordnance Survey Ireland (*OSi*) is the National Mapping Agency (NMA) of Ireland, responsible for providing topographic information, in both hardcopy and digital form, to various specifications, of all areas of Ireland. Since 1980 it has adopted photogrammetry as the principal technique for capturing raw data for input to its databases and geographic information systems (GIS). A series of major investments furnished the organization initially with a large number of analogue and analytical plotters. Most importantly, since a decision to "go digital" in 1992, *OSi* has installed many digital systems. It is now the world's largest user of digital photogrammetric systems outside the National Imagery and Mapping Agency (NIMA) in the United States. *OSi* has achieved this in partnership with its supplier, LH Systems (formerly Leica and Helava).

This article briefly introduces *OSi*, its mandate, size, finances and the change process it has undergone to make it one of the most completely computerized mapping organizations in the world.

Overview of Ordnance Survey Ireland

OSi is currently a department within the civil service responsible to the Minister for Finance. There are some 300 people employed at seven locations throughout the country. Headquarters are located in the Phoenix Park, Dublin. Annual expenditure is £10 million ($15 million) and income in 1998 was expected to exceed £5.5 million ($8.3 million). In a 1996 report on the future status of *OSi*, senior management recommended to the then Minister for Finance that *OSi* should be given a more independent status than is currently held; one that is more appropriate to its current and future business potential. As a result, he appointed a board of directors drawn from the public and private sectors to advise on a corporate structure for *OSi* and oversee its transition to the new status. The board is currently finalizing its recommendations.

The overall responsibilities of *OSi* were set out in a revised Statement of Strategy. They are:

- provide a national, up-to-date database for users of mapping and GIS in support of national economic and social development;
- develop the service to exploit the potential of existing and new public and commercial markets;
- within the context of developing the organization, develop appropriate financial management systems, improve value for money, and reduce reliance on the exchequer;
- implement policies so that *OSi* has an adequate supply of skilled and highly motivated staff to deliver its key programs, and provide a satisfying working environment.

OSi is responsible for all national mapping in Ireland. It also has a commercial mandate for activities related to national mapping. The national mapping program itself has two major components for which there are individual databases:

- Large-scale mapping which incorporates scales from 1:500 to 1:10,000. This includes urban mapping that is currently updated on an annual basis. It also includes rural mapping where a total resurvey of the country is underway using photogrammetric methods.
- Small-scale mapping incorporates scales from 1:10,000 to 1:1,000,000. A new database that was completely resurveyed using photogrammetric methods was completed at the end of 1998. The highly acclaimed *Discovery Series* at 1:50,000 scale is the major product of this database.

All *OSi* mapping is in digital form. The urban mapping, the resurveyed rural mapping and the small-scale mapping are held in fully structured databases that provide additional benefits to the users. The older part of the rural database is in raster form; it was not considered economical to convert it to vector.

As a result of the re-mapping program, *OSi* mapping is now compatible with GPS. In addition, *OSi* proposes to base the resurvey of the remainder of the rural mapping program on the European Terrestrial Reference Frame (ETRF), a precise realization of WGS84 , and store it in that form. There will be a dual service of providing data in either ETRF or National Grid thereby satisfying both traditional and technology driven users.

Virtually all processes at *OSi* are computerized. Data collection, production, publications and map sales outlets all have computerized systems that are fully integrated with each other and have comprehensive links to the fully structured databases. *OSi* is probably the most comprehensively and completely computerized mapping organization in the world, when the level of integration within the systems is considered, together with the complexity of the databases.

Under its public sector responsibilities and commercial mandate *OSi* supplies maps and data to government departments, local authorities, utility companies, and engineering, commercial, and financial organizations.

Ongoing Change and Development at *OSi*

Change has been an integral part of the business of *OSi* for at least 20 years. In 1978, when *OSi* management introduced profound technological innovation for the first time, there was a general realization that the NMAs of the future would have a changed role and operate under different conditions. *OSi* management recognized that technology would revolutionize the demands of customers, that governments would not continue to provide ongoing large subsidies to NMAs and that unlimited staff resources were no longer a reality. *OSi* management developed a strategy for technological change that would secure the organization's position for the future. This strategy had to take into account civil service policy constraints of the time and the general condition of apathy towards the emerging GIS industry. The main constraint in relation to the civil service has been recruitment. General government policies have prohibited recruitment or replacement of staff for over 17 years. Salary scales for skilled professionals also have been rigid.

Key points in understanding *OSi*'s management of changes are:

- The main justification for such fundamental change was based on productivity gains. During the long implementation phase *OSi* lost almost 25% of its staff, yet output increased.
- There was little interest from customers in digital products, hence an argument that there was a demand for digital information could not be effectively made.
- Specialists or other staff could not be recruited and salary scales were rigid.
- As a result, *OSi* made the fundamental decision that contractors would be responsible for all development and implementation issues.
- Continuing staff wastage meant that technology would be continuously introduced and upgraded as long as it offered productivity enhancements.
- *OSi* should stretch the capabilities of hardware and software, and indeed contractors and consultants, so that *OSi* could create databases that would stand the test of time.

In recent years, a further set of factors has influenced the on-going development of *OSi*. NMAs worldwide are grappling with complex issues on their future role and function in an information society. Some of the major factors that OSi has managed in charting the future of the organization include:

- European Union (EU) and government attitudes to NMAs,
- effects of technology on information availability,
- market demands for information, and
- the ability of NMAs to adapt to rapidly changing conditions.

EU and Government

Various EU directives and legislation affect NMAs and *OSi*, just as they affect most governmental bodies. Deregulation, competition law, and continued use of subsidies are all beginning to influence the way NMAs operate. Already, *OSi* must tender for other government department mapping contracts, despite being the government agency for mapping. The question of how uneconomic, yet nationally important, mapping can be subsidized in the future will be guided by EU regulation. Recent experience has shown that the EU has an ambivalent attitude towards NMA. The demand for a more efficient public service will, of necessity, mean that organizations like *OSi* must look for more efficient operating conditions to provide greater returns on investment.

The Market

Regardless of government or EU attitudes, *OSi* must be able to meet market demands for geospatial information from both public and private sectors if it is to continue to have relevance. It must be able to provide information in a timely and suitable manner and to be a market maker, rather than a market follower. The monopoly *de facto* position of NMAs is no longer sustainable or desirable.

Technology

The ever decreasing costs together with the increasing power and sophistication of systems create, on the one hand, opportunities for *OSi*; but, on the other hand, threats. It will allow greater uses to be made of geospatial information but invariably introduce greater competition for information from other sources. *OSi* has to continue to use technological advances to its best advantage.

Internal Organization

The organizational structure of *OSi* must be suitable for the above challenges. *OSi* has used technology to become more efficient and to overcome recruitment difficulties. But these difficulties have left structural weaknesses in that business development is not currently adequately resourced and the skills that are now necessary for service development are scarce.

However all of these issues are now being addressed. *OSi* is adopting a more customer-focused approach and a more proactive approach to business. It is a critical *OSi* objective, no matter what its future organizational form to be at the forefront of geospatial information in Ireland.

CONTINUED ON PAGE 221

CONTINUED FROM PAGE 219

Role and Implementation of Photogrammetry

Photogrammetry has played a key role in advancing *OSi*. With the help of photogrammetry, *OSi* has undertaken a new compilation of its small scale and large-scale rural databases to provide geometrically consistent geospatial information and, hopefully, technology-proof databases into the future. Every development of photogrammetry has provided *OSi* with an opportunity to introduce elements of improvement into the generation and maintenance of its databases. The addition of encoders and very basic computers allowed a realistic approach to intelligent data capture to be introduced in the early 1970s. Analytical plotters of the 1980s enhanced that capability and also improved the speed with which data could be captured. The addition of faster and more powerful computers, together with the integration of the analytical plotters with GIS systems, improved that capability further. Digital photogrammetry has added even more. Automatic DTM generation, superimposition, orthophotos and greater flexibility with data collection are some of the main advantages.

Photogrammetry came to *OSi* in the 1960s, following a review in 1964 by a committee of map users. The recommendations included urban resurvey at 1:1,000 scale, new nationwide contouring, and a new 1:50,000 series. A Wild A8 was installed in 1965 and the Irish Air Corps supplied photography from a Wild RC8 aerial camera. The expansion of photogrammetry was exceedingly slow, however, and it was not until the mid 1970s that a Wild A10 was added.

Towards the end of the 1970s, air survey benefited from an overall expansion in *OSi*. Aerial triangulation was introduced with PAT-M4 running on a PDP 11/34. In 1979 a Kern PG2 analogue stereoplotter was added and, not much later, a Wild AMH. The organization adopted computer-assisted methods. The analogue stereoplotters were equipped with PDP11 computers and Kern MAPS200 software, and in 1980 the SysScan digital mapping system was installed. Photogrammetric data were successfully transferred from the PDP11 computers hosting the analogue instruments to the VAX machines of the SysScan system.

The program accelerated after another review in 1980. The focus was on reduction of Civil Service staff numbers, to which *OSi* was vulnerable owing to its small size. Moreover, its parent, the Department of Finance, did not accept the need for large scale mapping of the whole country. Decisions were made to:

- maintain existing 1:1,000 urban mapping in a fully structured digital database and perform photogrammetric resurvey, as required;
- establish and maintain a small-scale, fully structured digital database from imagery, mostly aerial photography, capable of graphic output at scales from 1:10,000 to 1:50,000, with initial priority given to publishing a new 1:50,000 series;
- resurvey by photogrammetry and establish a large-scale, fully structured digital database, capable of graphic output at scales from 1:1,000 to 1:10,000;
- support the private sector on a commercial basis with special purpose maps.

The large-scale database was being constructed in a fully structured vector format and the existing rural maps were scanned into a flexible raster database. Both the rural and urban mapping was combined in a SysScan (now Sysdeco) Tellus database of more than 150 GB, capable of mapping on demand in either hardcopy or digital form.

The emphasis on resurvey arose from several factors. The existing small-scale mapping went back to the early 1900s at 1:126,720. Resurvey appeared to be more economical than attempting to update this mapping. It was decided to create a database using photogrammetry capable of output from 1:10,000 to 1:500,000. In considering the large-scale database, *OSi* tested a DSR analytical plotter and found its productivity to exceed traditional methods by 2:1, i.e. the economics strongly favored photogrammetric resurvey instead of revision by ground survey.

In the late 1970s, *OSi* had contracted out some aerial photography to commercial companies since the Air Corps' schedule often did not meet mapping requirements. For example, the country was flown at 1:30,000 by the French NMA, Institut Géographique National, but in 1980 *OSi* decided to fly its own photography with a hired aircraft and crew. The RC8 continued to be used and in the mid-1980s a Carl Zeiss Jena LMK aerial camera was purchased. As a result, *OSi* became the main provider of aerial photography in Ireland and began to sell these services commercially and build a national archive of photography. A second LMK camera and aircraft were added in 1992. The imminent installation of Carl Zeiss RMK TOP camera systems, with integrated GPS navigation and control, will further enhance *OSi* capabilities and improve efficiency.

In a series of procurements beginning in 1982, 11 Kern DSR analytical plotters and a GP1 flatbed plotting table were purchased and deployed not only in Dublin but also in Kilkenny. At the beginning of the 1990s, 4 Carl Zeiss P3s and a Leica SD2000 were added. From the software point of view, the analogue instruments and DSRs were at first equipped with the Kern MAPS200

CONTINUED ON PAGE 222

CONTINUED FROM PAGE 221

package for feature collection, which had no interactive graphics but relied on drum plotting for quality check plots. The P3s were delivered with PHOCUS and the SD2000, with PC-PRO600/MicroStation. Around 1993, the analogue instruments, the DSRs and most of the P3s were upgraded with ATLAS, from the Boston software house KLT. The analogue and analytical plotters were heavily used for 1:1,000 urban resurvey, establishing the new 1:50,000 series, and various commercial contracts, most of them at large scales.

Decision to go Digital

A third program review took place in 1992 as *OSi* took note of the rapid development of digital photogrammetry. The automated generation of contours and DTMs was investigated first, because this was a time consuming task and seemed well suited to digital photogrammetry. It was decided to go for digital systems, for the following reasons:

- double the productivity for height generation compared to that obtainable from analytical plotters;
- stereo superimposition, orthophoto generation, easier training, greater flexibility in planning workflows;
- the high cost of workstations and high cost of scanning if each scanner fed only a small number of workstations were fully understood; and,
- the future benefits of digital photogrammetry and the additional benefits likely to accrue from R&D.

Indeed, digital methods gave benefits on the order of 4:1 over conventional methods across the entire flowline (loading and orientation of images compilation, editing, final output of hardcopy, digital contours, and production of DTMs).

In 1993-94, further trials were run to assess the potential of digital photogrammetry for feature collection for the large-scale database. Traditional methods appeared to offer a slight advantage, but *OSi* elected to go the digital route because:

- the cost differential was small, given the need for superimposition;
- orthophotos were an added benefit;
- digital photogrammetry had unarguable advantages for spot heights, contours and DTMs;
- analytical photogrammetry was in the summer or autumn of its life cycle and was unlikely to be blessed by further developments, for which digital photogrammetry had far greater potential; and,
- investment in an old technology was inappropriate since a new one had come on to the market.

Despite there being no clear win-

ner in the tests, digital photogrammetry turned out to provide a significant advantage in production feature collection, owing mainly to superimposition of the old raster database during data capture.

Tests of automatic aerial triangulation came later, but suggested a productivity improvement of 4:1 versus analytical procedures. Adoption of this approach has signaled the final demise of analogue instruments owing to the practical difficulty of transferring orientation elements obtained from the digital triangulation to these instruments.

The Various Procurements

Several competitive procurements have taken place over the last five years. The first, in 1993, consisted of four SOCET SET workstations on SPARCstation 10 hardware, three of them stereo and one mono, and a DSW 100 scanner with color kit. These were linked to each other with a 10-baseT network and to the Sysdeco digital map and database system by means of a LAN bridge. This ensured considerable independence from the main network, so that the latter would not be compromised in performance during transfers of large images between the photogrammetric systems.

The second phase in 1994 added a DSW200 scanner and six stereo SOCET SET workstations on SPARCstation 20 hardware. The newer scanner proved enormously faster and also capable of superior image quality than the DSW 100. Since the SOCET SET workstations were to be used for feature collection for the large-scale database, they were equipped with hand controllers and ATLAS software.

The third phase, in 1995, included five more SOCET SET stereo workstations and many upgrades, including conversion of the mono station to stereo and replacement of the DSW 100 by a second DSW200. The network was upgraded to 100-baseT. The total, after three procurements, was 15 workstations and two scanners, though the latter had been equipped with SOCET SET and stereoscopic viewing, so were very flexible in terms of capability according to workload requirements. The hard disk storage increased beyond 100 MB, to the current capacity of some 205 GB in Dublin. By this time Sun Ultra 1 workstations were available.

The fourth phase began in 1996 and was concluded in 1997. This included 10 more workstations, bringing the total to 27 and replacement of the older DSW200 with a DSW300 with roll film capability. Seven of the new workstations were Windows NT systems, whereas all previous ones had run on Unix. These systems were supplied to the regional offices in Kilkenny and Sligo with PRO600, a SOCET SET compatible version of the software for feature collection in the MicroStation® environment, as already fitted on the SD2000 and one of the analogue instruments. The remaining three workstations in this procurement were Unix systems installed in the Dublin headquarters, where the complement of systems at the time of writing is 20, including the two scanners. The Unix hosts were a variety of Sun workstations and the PCs, as in all the Windows NT procurements, were simply the most powerful "off-the-shelf" PCs currently available. Disk capacity in the Region Offices are 25 GB in Sligo and 35 GB in Kilkenny, with tape drive units for each location to transfer model and control files to and from the scanners and aerial triangulation systems in Dublin. An additional feature of this procurement was to trade in seven analytical plotters (six DSRs and the SD2000).

In April 1998, PRO600 was installed on all the Unix systems in Dublin, except the scanners, so that all systems would have the same software for feature collection

Procurement continues. An order has recently been fulfilled for 10 more NT systems, seven of which are installed in the regional office in Cork, two in Kilkenny and a further one added to the Sligo systems. In addition, as part of the *OSi* strategy to migrate to NT, four Unix systems have been replaced in Dublin and a monoscopic NT system added for data preparation. All of the stereo systems include PRO600, which now runs with MicroStation® GeoGraphics®. Since these systems will be heavily used for feature collection, they will soon be upgraded with the latest graphics cards and release 4.1 of SOCET SET, which provides smooth image roaming across the entire stereomodel. It is interesting that this roaming feature, which was taken for granted with analogue and analytical instruments, has proved so challenging in the digital environment. The data flows are forbidding when it is remembered that image refresh rates of around 60 Hz for each eye are necessary to give the impression of silky smoothness. Equally, the host processors are powerful: most likely these new workstations will be based on Dell high end PCs with dual 450 MHz processors, 256 MB RAM and 18 GB high performance hard disk storage per seat! These workstations, therefore, take the total to 38 and for the first time the digital photogrammetry rooms in the Dublin headquarters experience a mixed Unix/Windows NT environment and, inevitably, some issues of efficient data transfer between the two platforms. The ever expanding work programs at *OSi*, the increase in scan resolution and improvements in the workflow of imagery since the introduction of digital aerial triangulation software require the increase of disk capacity from the current 205 GB in Dublin to over 300.

CONTINUED ON PAGE 225

CONTINUED FROM PAGE 223

Practical Aspects of Adoption

For the small-scale database, planimetric data are typically captured on analytical plotters, and heights on digital photogrammetric workstations. The large-scale rural database is captured on a mixture of the two types of workstations. Both flowlines have bi-directional, on-line connections with the main vector and raster databases and a Barco map publishing system (consisting of Barco map editing workstations with MERCATOR software, an IRIS variable inkjet plotter for proofing and a Barco MegaSetter laser raster plotter). The interfaces between the systems are complex and demand effort, goodwill, and commitment by all systems contractors. Without these smooth, bi-directional flows of information, digital photogrammetry would not be efficient or productive.

Indeed, the decision to go digital was courageous. The requirement was for extensive, immediate production, surely a *prima facie* case for sticking with existing, proven technologies. Without an R&D department, *OSi* had to demand that the system vendors take responsibility for ensuring that their systems worked and were linked together into smooth workflows. In practice, the new digital systems worked well, but extensive refinement was required to achieve adequate productivity.

The advantages of digital photogrammetry for generating height information and orthophotos are unarguable. Yet significant development still is required for flowline tools. The continuing absence of tools for automated feature extraction, especially in view of *OSi*'s huge feature collection effort for the large-scale database, is disappointing. Progress in these areas is not fast enough.

On the personnel side, the adoption of digital photogrammetry necessitates a shift in attitudes. The role of the photogrammetry department evolves beyond that of a simple data provider. Different skills are required with systems, networking, workflow, and management expertise proving far more apposite than mere stereoscopic vision. This cultural transformation has not been easy and *OSi* probably underestimated its magnitude in the early days. Thorough training is a *sine qua non* and it is easy to underrate the requirements or make insufficient allowance for this activity in the production environment. The operators themselves have adapted well to the new systems and now prefer them to their analytical and analogue predecessors. Advantages such as ease of use outweigh the "softer" image viewed in the digital systems (though this difference has narrowed as scanners and monitors have improved over the years). There is a tendency for operators to do too much interactive editing, especially of DTMs, resulting in a digital product well within specification, but at too high a cost. Close supervision and good management of people and targets have slowly overcome this.

Current Status and the Near Future

Though *OSi* has purchased orthophoto generation software for many of the SOCET SET workstations, it has not yet done more than dabble with this aspect of digital photogrammetry. Nevertheless, a major orthophoto project is now imminent, which itself has exposed new problems. Extensive work is required to automate the flowline and avoid laborious input of parameters for one orthophoto at a time, in favor of huge batch jobs with scripts generated automatically. Software tools need to be added for simple tasks such as ensuring that the images and DTMs required for each orthophoto are present and for quality control of both geometry and radiometry. While this sounds trivial for a few orthophotos, it is problematical when thousands are involved.

With so many systems installed, one of the major annual tasks is the negotiation and management of maintenance contracts. This covers not only software support and hardware repairs but also extends to training and other technical site visits, which currently run at around nine working days per month. Each year a proportion of the monies in the contract is allocated to hardware repairs and upgrades. The deployment of licenses across workstations must necessarily evolve as demands and workflows change. On the hardware side, there is a general trend towards Windows NT, as part of the overall IT strategy. On the other hand, significant benefits will accrue if the hosts on the two scanners are upgraded from SPARCstation 20s to current Unix boxes, i.e. Ultra 60s.

One concomitant of the lower prices is that digital photogrammetry becomes more easily available to a much wider community of users. The quality of the data becomes all the more important as they are so easily generated on digital systems. Specifications, tolerances, and accuracies must be defined and appropriate metadata entered in the databases. This is critical, as the new technology becomes available to all.

With the probable approval of the expanded rural mapping program, the digital systems at *OSi* are likely to expand further. This will impose additional pressure on *OSi* and its suppliers to develop and maintain the systems required to manage the increasing complexity of the overall organization. With the massive storage and transfer demands of such an expansion, and the introduction of digital photogrammetry to *OSi* regional offices, the development of the wide area network and communication systems is imminent. Ease of access to data and information is key to meeting these demands for both staff and customers. The intro

CONTINUED ON PAGE 226

CONTINUED FROM PAGE 225

duction of hand-held pen computers will further enhance the digital flowlines. Existing systems currently rely on one stage of fieldwork and subsequent digitizing. Within a year this will no longer be the case, with field surveyors directly amending digital data on screen in the field. The introduction of GPS control into aerial triangulation will further reduce the field element and enable *OSi to* index photography digitally into its meta-databases. In the longer term, the development of digital cameras is inevitable. Continuing refinements, improvements, and developments in the surveying and mapping (or geomatics) fields are monitored carefully by *OSi* for ways in which production can be improved.

Conclusions

OSi has undergone a level of technological change few organizations complete as successfully. With the more recent business and organizational change programs, *OSi* is a challenging but exciting organization with which to be involved. There is no doubt that the implementation of digital technologies at *OSi* has placed it in good stead for future challenges.

Overall *OSi* is satisfied with its progress in implementing the technological strategy adopted, of which digital photogrammetry is an important element. *OSi* has thus placed considerable faith in digital photogrammetry. Installations and training courses have gone well in most cases and the systems work satisfactorily, given their size and complexity. Further productivity improvements are, however, always possible. There remains some potential to be realized, and digital photogrammetry must undergo considerable development before its full potential is realized. In the case of automated feature extraction, at least, major breakthroughs are unlikely and incremental progress is worryingly slow.

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