SOME THOUGHTS ON CARTOGRAPHIC PRODUCTION SYSTEMS FOR NAUTICAL CHARTING

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Abstract

In this paper we discuss the Australian Hydrographic Branch's experience with computer-based cartographic production since the early 1970's and outline the current practices adopted by the Australian Hydrographic Office. We attempt to generalise the experience and, with one eye on the potentially extensive development of digital data acquisition systems (both sea- and air-borne) and the other on the likely demands of electronic charting graphics and the consequent need for change in hydrographic information management practices, we suggest some strategies for future hydrographic office procurement of cartographic production systems for nautical charting. Given the limited hydrographic market place in each hydrographic nation, including (relatively) even the largest nations, it is unlikely that the ideal solutions will become readily available from the market-place, despite the optimism of many land and geographic information systems vendors that their products cater for all graphics output requirements. Consequently a heavy development burden will fall on individual hydrographic offices unless international specification can transcend and complement particular governments' procurement policies.

INTRODUCTION

It seems ironic to be penning this article about the Autochart project some fourteen years after it was initially conceived and about two to three years before its hardware is due to be replaced. However, it should still be a useful exercise because the Autochart system has been very much a 'development' system and through it, the Australian Hydrographic Branch has achieved the capability for

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digital chart production. However, it has not been a particularly easy path to tread. The system itself, after fourteen years of in-house development, bears little resemblance to the system initially delivered by the successful contractors, Systemhouse Ltd., in 1979, yet the 'development principles' laid down at the outset have remained sound. The system has had a number of impacts upon the Australian Hydrographic Office, its organisation and its methodologies, and has altered the outlook of many of its staff, both positively and negatively.

Initially constrained by available 1970's technology (e.g. limited graphics capability at terminals, vector plotting, relatively unsophisticated thinking in software development), the Office's chart production attitudes have now been affected by many factors. Some major ones are: technological development; economic; political; organisational; staff availability and, most significantly, the changing demand on the Office to become a 'marine information processing organisation' rather than simply a, limited, 'nautical chart production organisation'. Consequently, there are many factors which, we believe, affect the final development phase of any chart production system and which must be taken into account in any future development or system replacement. We begin by examining the Australian context concentrating only on the major factors of influence.

THE AUSTRALIAN CONTEXT

Australian chart production took the turn towards digital techniques during 1975. In those early days chart production was entirely manual using the hand-drafted compilation as the base from which line-work was manually scribed and typeset lettering affixed. Given the immensity of the Australian Area of Charting Responsibility relative to the resources that had been available, in the context of an Australia that had been through a turbulent economic period as vast natural resource deposits (iron ore, bauxite, coal ...) were discovered and in turn led to the need for new ports and shipping routes, it was becoming clear that chart production was threatened. New chart production was virtually overwhelmed by the need for new editions and Notices to Mariners and so the efficiencies of digital chart production, which offered economical chart revision as a goal, became the objective of the Branch.

Chart production in Australia is a lengthy process for a number of reasons. The variety of regions (compare the Great Barrier Reef to the Great Australian Bight, Torres Strait to Bass Strait...), the number of original data collectors (ranging from private sector surveys, through the Local, State and Common-wealth agencies and to the mariner...), the variety of purposes of data collection (large-scale engineering works to large area strategic surveys ...), the variety of data qualities which arise from the above, in addition to the wide range of ages of some surveys in any given area, all come together to complicate the compilation procedure. Every chart is a major compilation initiative and rarely, if ever, a simple recompilation of existing chartwork.

The Hydrographic Branch had a heavy training overhead in the early

1970's as most chart production staff came from the land-based disciplines. Cartographic courses were few and far-between and more often than not, cartography was taught as a few courses within another major discipline, such as Land and Engineering Survey Drafting, at the technical college level. Traditionally, staff tended to stay 'for the term of their natural life' once trained, but the early seventies began to see a break in such tradition. Thoughts turned towards a more routine chart production procedure to replace the emphasis on production as a 'craft shop'.

Digital map production techniques and systems were in their infancy in Australia in the early 1970's and it is true to say that there were very few experienced persons available. The Australian Army had just installed the Automap system as their first step towards digital topographic map production and the successful arguments put forward by the Hydrographic Branch for funding became clearly contingent upon two things — the success of Automap and the Branch's ability to exploit the spillover economic benefits coming out of the Automap development. Funding was forthcoming for both reasons balanced against the demonstrable need for a more efficient chart production system and it was against this atmosphere that development of the Autochart system began.

THE AUSTRALIAN EXPERIENCE

The philosophy underlying the development of the Autochart system was shaped by a number of factors: economic, human resources, technological limitations, existing infrastructure and availability of technology. Consequently, a 'clean' start or 'carte blanche brief' was not possible for the design team. Some constraints were obvious and unavoidable, such as the lack of suitable graphic screens, the limitation of the prevailing 16-bit computers, the limitations of plotter manufacturers' approaches to graphics, the emphasis on the capture of map (mainly line) data, the then lack of total systems digital experience in hydrographic agencies and the sheer cost of what today is considered as barely adequate computer memory and power.

Other constraints were more subtle: the over-eagerness of some to equate hardware vendors with expertise and the illicit assumption of some systems suppliers to assume hydrographic expertise, the persistence of attitudes which tended to ignore the data in favour of solving the hardware and software engineering problems and the lack of a general holistic approach to software, the sheer inertia of a Defence bureaucracy which tended to see hydrographic chart production in terms of classic, centralised, commercial ADP solutions and entrenched hydrographic attitudes towards automation of any sort which, frustratingly for the implementation team, could point for a long time to lack of results. The extraordinary delays between design and final implementation in the face of such entrenched attitudes unfortunately fostered skepticism and made every progression a hard-won 'triumph' rather than a step towards achieving Branch objectives. Unfortunately, some hostility still exists today from this early struggle which is occasionally translated into industrial comment and which

unfortunately dictates that the full potential of the initial systems design will probably never be realised. The advent of Autochart affected the overall work procedures and relationships within the Branch.

A most interesting factor was that the need to define procedures, some of which had been used unchallenged for decades (e.g. the construction of graticules, the understanding of the mathematics behind geodetic principles, the relationship of symbols to position on the Earth, the mathematics of transformation vs. manual graphical methods, the unrelenting precision of co-ordinate representation in automated plotting, bearing on projection ...) challenged the knowledge and expertise of the majority of personnel. Courses sometimes taken years before frequently assumed new importance. As would be expected, many rose to the occasion, but it has taken a long while for authority to be reassumed in the face of proprietary system supply.

Physical hardware limitations were accepted for acquisition but the way around them was seen to lie in innovative software design. Thus the early philosophy was adopted that 16-bit graphics limitations (axes each of $\pm 2^{15}$ integer units) were not to dictate the overall area to be covered. The limitations of hardware-bound symbology construction were circumvented by adopting the approach that all symbology was to be drawn; that is, constructed through stored software routines. The cost of plot-time which arises from this approach was accepted and remains acceptable: despite the fact that a final chart repromat can take 16 to 24 hours to produce it is now virtually 100% ready for the printing plate.

The need for a facility to permit the retention of survey accuracy for critical features (e.g. lights, navaids, shoals, wrecks, conspicuous objects and the like) was achieved by the batch-processing of textual files, formatted for ASCII input, but which contained every discrete element of every symbol for every type of critical feature. Thus, position could be either achieved through manual digitisation of single-point position or by entry of survey co-ordinates for that point, appropriately feature-coded to its symbolised construct record (i.e. line, point, curve or shape elements) so that every single IHO approved symbol and textual presentation could be plotted to repromat photographically.

An early decision had been taken, it should be said, that scribing by plotter was not to be a preferred procedure and the favoured method was for all final plots to be constructed by photo-plot methods. This had the advantage of minimising manual intervention and provided for the same plot-routines to produce detailed verification plots on a ball-point loaded drum-plotter.

Before any of this could be achieved the complete IHO symbols set had to be minutely analysed and broken down into their elementary parts. Combination presentations of symbols (e.g. underlined sounding ...) had to be detailed and every single part had to be digitised into the Autochart system's stored library routines, a massive, labour-intensive task that took well over six months intensive effort in conjunction with the contractor, Systemhouse Ltd. Their approach to the flexible achievement of complete hydrographic symbology, which was hydrographic user defined rather than software programmer defined, allowed adjustment and addition to proceed as the system itself was introduced. In the Autochart way of classifying symbology, all IHO symbols fall into one, two or all

of the following groups: simple lines (e.g. coastline, isobaths, dredged channel limit ...); symbology about a point (e.g. soundings, buoys, lights ...); complex lines (e.g. maritime boundaries such as prohibited anchorage or fishing zone ...). Thus, simple manual digitising procedures could be employed at the tablet. All Feature Coded symbols inherently led back to the appropriate symbolisation so the person digitising could concentrate on accurate positioning of the cursor for point, multiple-point or continuous-point digitisation. Numeric clusters at the digitiser cursor facilitated manual entry of z co-ordinates (i.e. soundings, drying heights, spot heights). The final outcome was the complete photo-plotting capability for the production of Australian chart repromat.
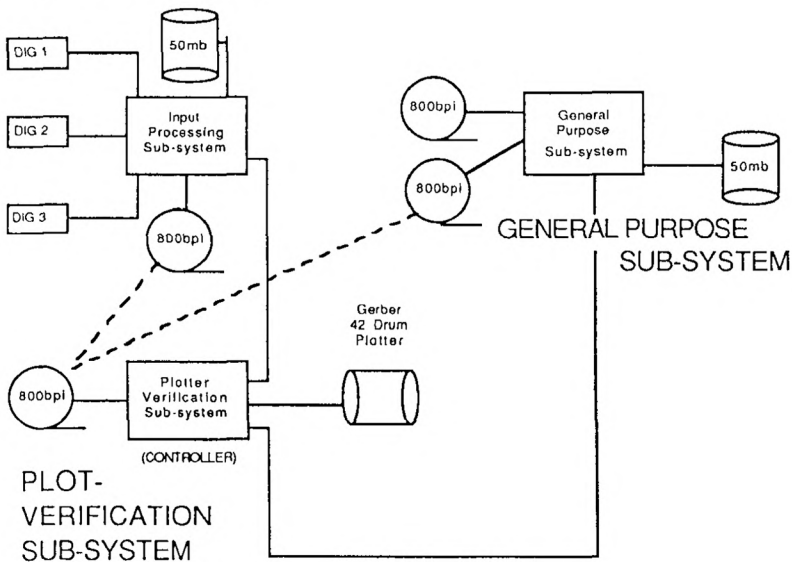

FIG. 1.— Autochart: Initial 1979 Configuration.

The initial configuration of Autochart (circa 1979) is represented above in Figure 1. This indicates the original three main sub-systems: input, plot verification and general purpose to which, shortly afterwards, a separate Plot Sub-system comprising a Kongsberg GT5000 flatbed plotter was added, together with three Tektronix 4115 graphics screens. The compiler was required to digitise each input document, which had been prepared for digitising by having the chosen control points highlighted and defined and the appropriate data selection made. Each document was iterated through an edit process a number of times and formed one of a number of models which were eventually transformed to the same projection upon which the chart was to be produced and then merged into the same final file from which the chart was plotted. A number of editing stages were taken and graticules mathematically and automatically constructed around the data. Separation of the appropriate Feature Codes provided separate plots for the magenta overlay. Other data, such as Decca curves, were constructed mathematically and combined photographically with some cartographic intervention. The

process was complicated by the fact that the cartographer seemed to lose the 'feel' of the overall picture. This was partly due to the 'models approach' which focussed the compiler's attention at any one time on a relatively small area of the chart, but was mainly due to the lack of graphics feedback during the actual digitising process. Compilers had to rely on textual prompts and were 'one-step removed' from the result of their work having to wait for a verification plot to be made at the end of the session. Despite these early difficulties many compilers became most proficient at compiling by this method.

The new technology had an immediate impact on the organisation of the Branch. It was realised that, if the promised economies of digital production were to become real, then a whole region needed to be digitised rather than just *ad hoc* charts. The original survey data were still not digital and so the chart area was to become the database. The south-west region of Western Australia was chosen as the initial area and digital production began. The early procedures outlined above, whilst allowing a more modular, production approach to compilation and chart production, proved difficult for relatively inexperienced staff to quality control. The final result of experience is to complete the compilation as far as practicable, perform full editing and quality control checks and to then directly digitise the compilation as a discrete unit in the chart database. Whilst the original planned economies were thereby lost, better control of the process of compilation has been maintained. At the time of publication of this paper about one seventh of the total chart series, or 105 charts, have been published by Autochart digital methods.

By 1986, the Autochart system had virtually replaced the cartographic scribing and photo-typesetting procedures to provide for the complete transfer of the compilation into 'repromat'. This process was aided by the partial introduction of graphics editing capability with the addition of Tektronix terminals to two of the digitiser work-stations (a budget limitation rather than a technical one) (see Fig. 2).

Meanwhile, the final preparation of stored symbol routines, such as compass roses, metric conversion tables and tidal panels, had been completed. The final development remains to tighten the link between repromat correction and correction of the digital base. The foundations of this have been laid with the current system configuration (see Fig. 3) which fully incorporates graphics editing capability at each work station. Each sub-system is self-contained and operates independently. All systems can access the disks attached to CPU 3 which minimises transfer of chart-files by magnetic tape. Although transfer to the Kongsberg GT5000 Plot Sub-system (not shown in the Figures) could be effected on-line this is always done by magnetic tape. The original long-term configuration design aims have been met and as the equipment (basically Hewlett-Packard System 1000 — E series) draws to the end of its viable life and replacement of the Autochart facility hardware is under consideration, it is appropriate to draw together the threads of experience within the present Australian environment with a view to generalising the experience for future systems procurement.
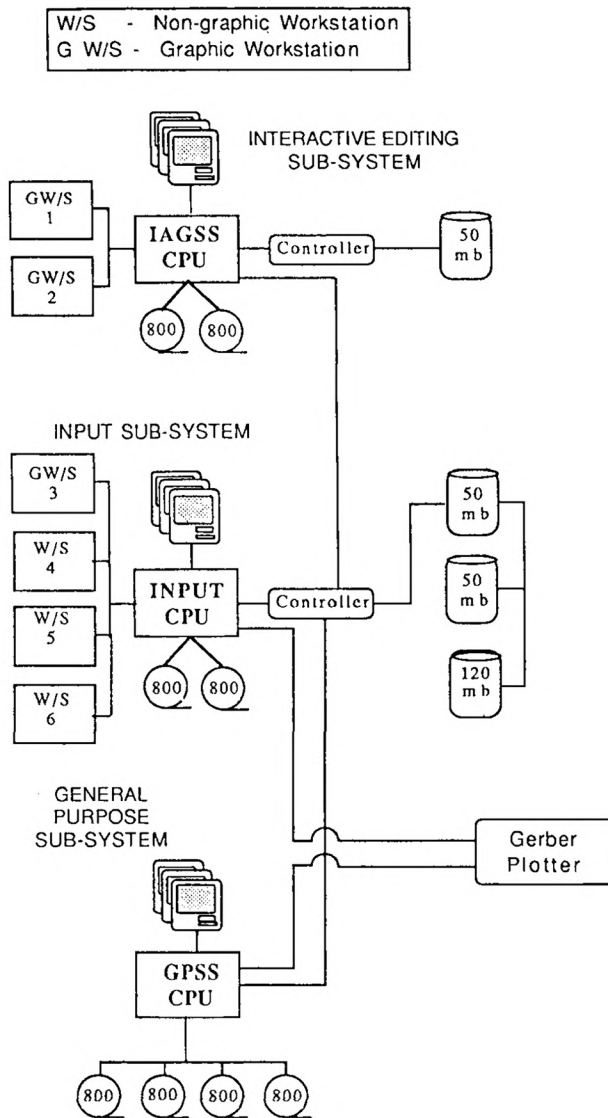
FIG. 2.— Autochart Configuration to 1989.

DISCUSSION

A number of statements which stem directly from the Australian experience with Autochart are appropriate. The most important and the one which seems most obvious, and yet the one which we wish to emphasize, is that the expertise in hydrographic chart production resides within the national hydrographic organisation and those few producers who work closely with the national autho-
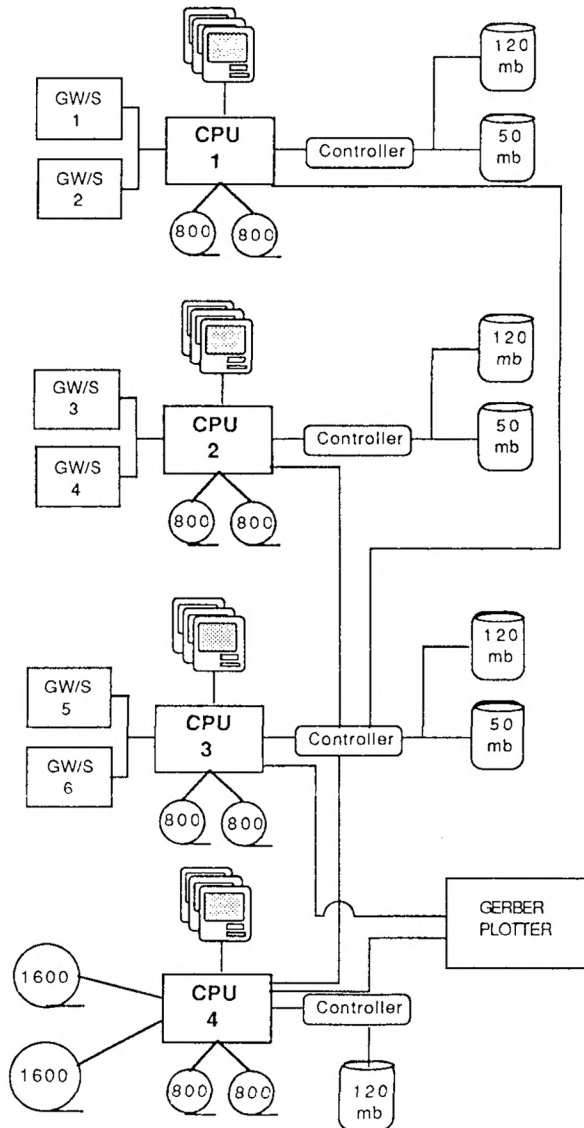
FIG. 3.— Current Autochart Configuration.

rity. Systems vendors, no matter how ingenious their particular algorithm solution of a specific hydrographic problem, rarely have the experience or insight of the overall hydrographic picture. The second comment concerns this present period of transition through which we are passing. No longer, we believe, can hydrographic agencies perceive themselves as solely chart producers. They are clearly becoming data custodians and, thus, hydrographic information managers. This requires a fundamental change of outlook. The advent of digital surveys, swath devices, airborne lasers and so on, are only now bringing to the fore the early foresight of the Autochart planning philosophy. At the user end, the ECDIS impe-

rative is placing its demands on total graphics capability with at least some topological structuring of the underlying database. The development of the Hydrographic Information System is the topic of another paper in this journal. This development recognises the gradual transition of the Australian Hydrographic Branch towards information management whilst retaining complete control of flexible graphic output such as that dictated by effective ECDIS implementation.

Future cartographic production systems must recognise the changing capabilities of the underlying database and allow for complete user control of the final output graphic. The final location of this electronic graphic on the ship's bridge must be uppermost in the mind of the compiler.

Finally, we believe that the recent work of the IHO Committees on ECDIS (COE) and the Exchange of Digital Data (CEDD) clearly lays down guidance to the market place of systems vendors from the authoritative base of world hydrography. In the Australian context, government procedures often seem to favour the vendor as expert. Thus the Australian Hydrographic Branch has had to bear a decade or so of development, sometimes at odds (though generally in co-operation) with its favoured systems supplier. Systems suppliers have a natural and understandable myopia which focuses sharply on the virtues of their own, generally partial, solutions. The published results of the work coming out of IHO-COE and IHO-CEDD offer the authoritative base from which hydrographic development can proceed in co-operation with vendors rather than in conflict. There is a clear need for government agency/vendor co-operation which eventually protects the former's considerable intellectual inputs into the process, and which is not hampered by more conservative, or traditional methods of government procurement. Thus, we conclude that the next generation of cartographic production systems for nautical charting will need to draw on the strengths of both sectors and must meet the unique imperatives of both the hydrographic data set and the user requirements — flexible, controlled graphics from structured, contemporary databases!

Acknowledgements