Making Paper Charts Out of ENCs

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In recent years, ENC Production & Maintenance has grown from pure R&D, to one of the common tasks performed by a Hydrographic Office. As the volume of ENCs produced is growing, the data producer is faced with the problem of consistency of information between ENCs and traditional nautical charts. This problem concerns both the production and updating.

This paper outlines different approaches that can be used to combine production and maintenance of traditional paper charts and ENCs. It also offers a deep insight into the technology behind dKart Publisher developed by HydroService AS, with the purpose of ENC-based paper charts production and maintenance.

Moving Forward

Production and maintenance of traditional paper charts and ENCs can potentially be organised in two completely independent production lines. However, this approach may imply a doubling of resources, as most operations are duplicated and therefore raises the potential risk of data error and inconsistency. An alternative way is to use a single unified production line.

Considering simultaneous production and maintenance of paper charts and ENCs a data producer may choose one of the following options:

- Produce and maintain ENCs based on paper charts

- Produce and maintain paper charts based on ENCs
- Produce and maintain both products based on a unified database of hydrographic source information

The first option implies digitising/attribution of paper charts and updating of the resulting electronic charts on the basis of traditional Notices to Mariners. An obvious advantage of this approach is that it has a minimum impact on the traditional production line. However, production and maintenance of electronic charts becomes difficult due to the following:

- Typically, an ENC provides much more detail than a paper chart as it may also contain, for instance, information from Light Lists. Therefore, in order to produce an ENC, one is forced to use additional sources of information, which in turn makes consistent updating very complicated
- Positional accuracy of data derived from paper charts may be not suitable for modern navigation due to various reasons (e.g. data generalisation)
- Coverage of paper charts and ENCs differs in general (e.g. in data limits and scales)
- Selecting and applying Notices to Mariners (issued for paper charts) to ENCs is not an easy and straightforward task (e.g. due to difference in data limits and contents, a change to a paper chart may be not applicable to the relevant ENC or vice versa)

Also, it should be noted that digitising and attribution is usually a lengthy process and therefore real consistency between paper charts and ENCs can hardly be expected. Well-organised data and resource management may solve to some extent the mentioned problems.

Let us skip the ENC-based paper chart production and maintenance for a while, as this will be covered later on in the article. It is, however, worth mentioning that these two approaches (ENC out of Paper Chart and vice versa) may appear quite similar only at first glance. An ENC actually bears much more information than a paper chart and further, it does not suffer from such 'presentation drawbacks', as absence and/or rounding of cartographic data.

The third option is a so-called 'unified hydrographic database', that proposes a most straightforward way of achieving consistency between traditional charts and ENCs. This is when a data producer creates and maintains one database containing all source cartographic features. Products such as ENCs and paper charts become extracts from this database, matching applicable product specifications. This idea is ingenious in theory, however, let us take a look at the practical side. The first problem is the difficulty of building a 'unified' database that will embrace all possible uses of cartographic data, including scale-dependence and generalisation of data. This task is extremely complicated even in theory; practical solutions do not really exist and their implementation will apparently require extensive resources and money.

Looking at the 'technical' side of the unified database approach, one has to consider the ways in which, such a database will be organised. A possible approach is to start from an ENC (i.e. S-57 data model), which provides all the advantages of vector digital data, and to extend it by adding new objects/attributes required for paper chart production. A question arising then is: who should be responsible for the information contents of these 'extensions' when populating/maintaining the database? It should be most probably an ENC-operator (otherwise there may be a problem of inconsistent data). However, it may be illogical for the ENC-operator to deal with aspects that have nothing in common with the ENC-operator's main task (for example, dealing with ENCs the operator is not concerned with the presentation of data, which is built automatically). Bearing in mind that there are occasions when the ENC and paper chart coverage is different, the situation becomes even more difficult. More problems in the structure of the database and work management may arise when the data producer maintains more than one chart series (e.g. national and international charts).

It should also be noticed that if the ENC and paper chart production lines already exist in an HO, combining them by introducing a 'unified database' will most likely lead to a fundamental restructuring of the HO organisation and infrastructure. A more preferable solution would be to add a new component into one of the existing lines (probably to ENC production) that will allow such a combination without completely shifting the existing technology.

Let us now approach the task from another perspective. We have the hydrographic reality and different ways to model it – ENCs and paper charts.
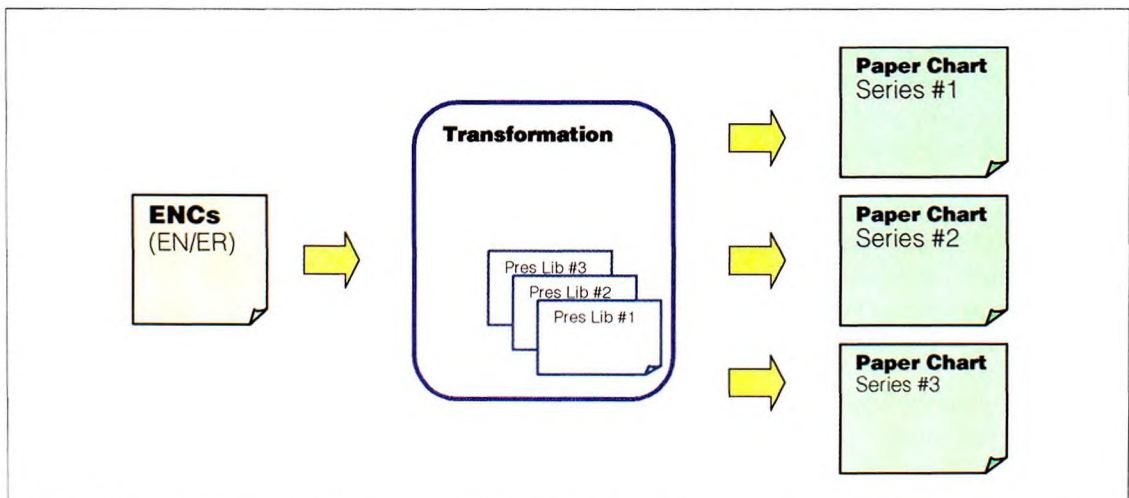

Figure 1: ENC-based paper chart production scheme

The information provided by an ENC and the related paper chart is essentially the same because both represent the same hydrographic situation. The main difference is the data presentation. Since one of the core ideas for ENC is separation of cartographic data from its presentation, all information required for the paper chart is already contained in the ENC. To get a paper chart, it is enough to output this information according to the applicable presentation rules. Here we come to the ENC-based approach to paper chart production and maintenance, where the starting point is a ready product, namely the ENC.

See Figure 1 for a typical technological chain.

Selected method, when a paper chart is produced and maintained on the basis of ENC(s), it enables the user to resolve the problem of inconsistent production and maintenance of traditional and electronic charts, by overcoming the difficulties of the 'unified database' approach:

- Tools can be easily integrated into the existing production infrastructure as 'add-on' components
- The solution is easily expandable (the same ENC can be used to produce and maintain paper charts built according to different presentation rules)
- The ENC operator deals with his/her natural task only (i.e. production and maintenance of ENC)

Tools

Having selected the 'ENC to Paper Chart Transform' approach, one has to think about the software. Two options are available: general-purpose GIS packages and specially developed tools. The main advantage of a GIS is that it is a widely used COTS (Commercial Off The Shelf) package. However, here we face some difficulties.

First, the ENC is a very specific product. For example, ENC uses 'chain-node' topological model (geometry is described in terms of edges and nodes; edges and connected nodes are topologically linked), which is unnatural for a general-purpose GIS that deals with 'spaghetti' topological model (lines and points do not relate to each other). Therefore, to make a GIS work with an ENC, one is required to force the GIS to do things for which it was not originally designed for. Usually it is

achieved by programming inside the GIS environment in a special language, thus eliminating the COTS advantage.

Next comes the question of the cartographic specificity. The chart production operator is, above all, a cartographer/hydrographer and therefore he/she is not necessarily familiar with graphic and desktop publishing issues, such as selection of graphic primitives (lines, arcs), combination of cartographic symbols (e.g. a light flare and buoy) setting RGB/CMYK colours, and so on. It would be more natural to simplify the operator's duties, by allowing him/her to deal with well-known cartographic features such as buoys, depth contours, compass roses, etc. At the same time, automation of the operator's work will ensure that it is more fault-proof because all 'low-level' editing (e.g. setting of colour tints, line widths) will be done automatically based on 'high-level' cartographic editing made by the cartographer.

The principal problem for the general-purpose GIS however, is chart updating. An ENC is maintained using digital updates ('ER files' that are relatively small data, sets carrying changes to ENC only). ER-files do not contain instructions directly applicable to paper chart updating. To apply a digital update to a paper chart, the software should be able to understand ER-file format and, what is more important, be able to correlate information of ENC with that of a paper chart. This is the task for which none of the general-purpose GIS' have been designed.

Based on all the above facts it seems quite logical that an 'S-57 native' cartographic editor should be used if possible.

Tasks To Solve

Let us review the typical tasks that ENC-to-paper-chart software should be capable of accomplishing.

During the initial ENC to paper chart transformation, the most critical issues are:

- The presentation of the same cartographic information (objects) differs between traditional and electronic charts. Therefore one needs an intelligent converter equipped with specially designed libraries of cartographic symbols and line / area patterns
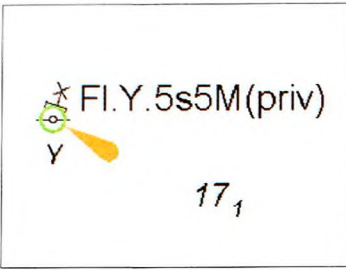- Paper and electronic charts may differ in

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*Figure 2:
Sample of
several objects
sharing one
node*

scales, data limits and projections. Therefore there is a need for automated data transformation/compilation tools

- A data producer may simultaneously support several chart series that differ in presentation. The presentation may change with time. Therefore both the presentation of paper chart and the transformation routines must be configurable
- It is hardly possible to achieve 100 per cent automation of ENC to paper chart transformation (factors such as text placement, smoothing and masking of lines can hardly be formalised and therefore are subjects to reviewing and manual editing). Therefore a tool for manual cartographic editing is required
- A paper chart usually makes use of additional information (e.g. tides tables, notes) provided either as files or as a separate database. Therefore, there is a need to import information and to process data stored in an external database

In order to be able to maintain a paper chart using digital updates created for the source ENC(s), the software should be capable of recognising cartographic elements of a paper chart affected by the ER-file contents. The most logical solution would be to create a link between paper chart entities and the 'parent' ENC object(s) during the transformation and to maintain this link automatically throughout the paper chart lifecycle.

The Result: Digital Paper Chart

Let us now take a look at the result of the operator's work that is a digital paper chart. A digital paper chart here is an electronic chart with defined borders, scale, projection and datum built in accordance with S-57 Data Model. Use of the S-57 Data Model has the following implications:

- The information is divided into entities called 'objects' ('an identifiable set of information'). An object has attributes that describe its presentational characteristics
- Like S-57, objects are divided into two groups: paper chart objects (presenting cartographic data just like feature objects in ENC) and spatial objects (providing positional information). A paper chart object (or simply 'object') cannot exist on its own, as it is always linked to a spatial object (even design elements, such as chart title, have underlying geometry defining its' placement on a resulting sheet. However, such a spatial object have no 'cartographic' meaning). Several objects can be linked to the same spatial object. For example, a light buoy may be encoded as four objects (buoy symbol, topmark symbol, light symbol, light description string) sharing the same node but having different positional attributes (shifts, orientation, etc.)
- Each paper chart object belongs to a certain object class in accordance with 'paper chart dictionary'. The dictionary includes all typical cartographic elements such as symbols, lines, sectors, images (raster pictures), etc. Additional object classes are introduced in order to link information of a paper chart with source ENC(s) and stipulate combining of different charts/insets on one paper sheet. It should be noted that automatic creation and maintenance of links between paper chart and ENC objects is an extremely important feature as it provides a way to automate updating of a paper chart based on ENC-updates. It also provides the operator with means to analyse and validate the paper chart against the source ENC(s). The ability to collate several charts into a single final product should also be widely used in the program. Almost all design elements such as frames, titles, compass roses and grids may be implemented as independent insets, which are combined on the resulting sheet. Use of insets helps dividing the work between operators (e.g. the first operator makes the main chart, the second deals with frame and outframe design, the third makes the plan and source diagram, etc.)
- Spatial objects fall into the following classes:

- Node (zero-dimensional object)
- Edge (one-dimensional object)
- Line (set of edges)
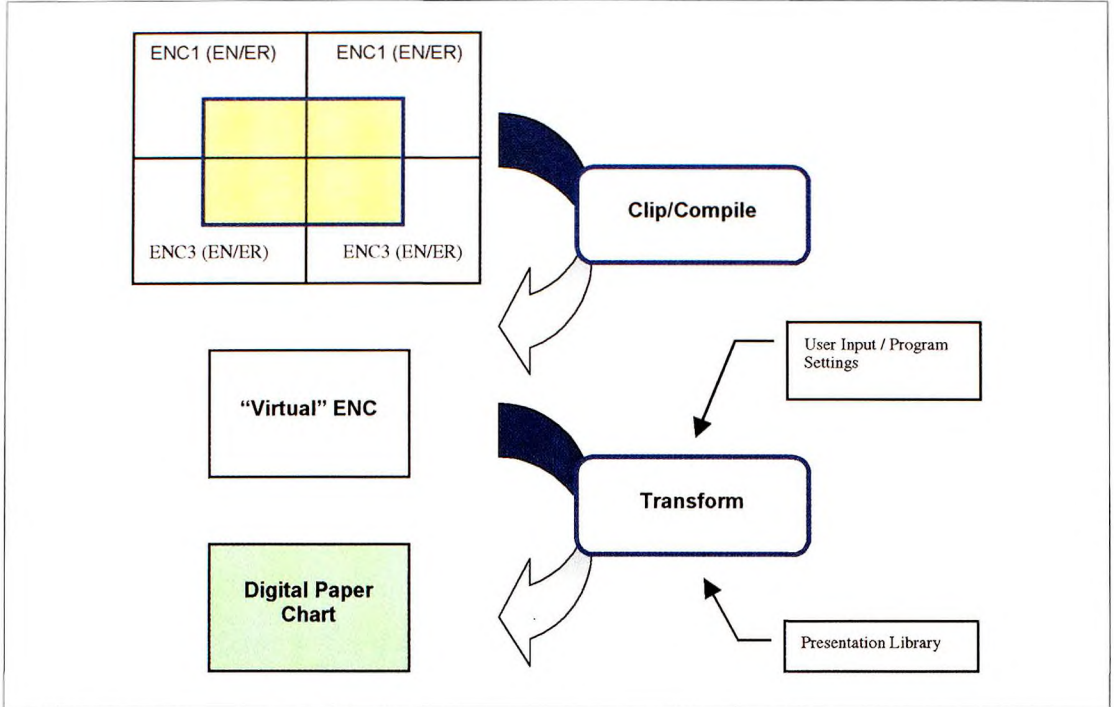- Area (two-dimensional object, set of closed lines)

Figure 3: ENC to paper chart transformation layout

As opposed to ENCs, there are two new classes of spatial objects – lines and areas. These classes have been introduced in order to stipulate the existence of 1:1 relationships between paper chart objects and underlying geometry.

It should be noted that spatial objects define a 'flat picture'. In order to place objects relative to each other along the Z-axis (e.g. put a compass rose atop of a depth area region), a 'priority' attribute may be used; in some way priorities create the layered picture.

It is easy to see that the selected way of storing/handling paper chart contents makes this solution compatible with S-57.

Creating Paper Charts Out of ENCs

An automatic conversion from an S-57 data model to a digital paper chart will exploit the idea of S-52 Presentation Library. The Presentation Library here is a formal description of rules for cartographic information presentation designed/approved by the data producer. It includes symbols, fonts, colour tables, patterns, etc. The program reads the library and builds the output according to cartographic rules for paper charts.

In brief, the process of paper chart production from ENC will need to embrace the following steps (see Figure 3):

- Source ENC(s) are loaded into the program
- An empty paper chart of required datum, projection, scale and borders is created
- Guided by the Presentation Library, the automatic conversion starts. During the conversion, the software creates a virtual ENC that has borders as of resulting paper chart and contents taken from sources; objects of this virtual ENC are converted into paper chart objects
- The automatic conversion creates a draft paper chart that is subjected to validation at this stage. The operator also performs a final 'make-up' of the paper chart that includes fine positioning of texts and symbols (where results of automatic conversion turns to be unsuitable), manual or semi-automated masking of lines, adding texts, pictures and tables from external sources, positioning insets, frames and other design elements
- The resulting digital paper chart is saved as a file of printable format (e.g. PostScript[i], PDF[ii], DGN[iii])

Let us now consider some of the technical aspects in more detail.

Source Zones

It has been mentioned before that a paper chart can be made from several ENCs, each having its own geodetic parameters and geographic extent, which may even overlap. Before converting to the resulting chart, a cartographer has to define which part of the paper chart is to be taken from which ENC. For that, he/she defines special areas such as source zones and associates them with source materials. This division will then be maintained during the whole life span of the paper chart (e.g., digital updates will be selected depending on source zone configuration and so on).

Transformation Routine

Generally speaking, the transformation routine can be described as follows:

- Source ENCs are loaded into the program
- An ENC object (set of logically related objects) is being read
- Presentation Library is loaded and applicable rules are selected
- Paper chart object(s) are constructed. This step is usually performed in several stages. The software starts from objects that can be converted independently from the rest of the chart. The following iterations convert the remaining objects based on the results from the previous stages

- Created objects are placed according to the applicable rules. At this stage, the program starts from the default object position (i.e. as described in the Presentation Library) and checks if this position is already occupied by another object. If it is, the software searches for another placement rule
- Automatic testing of the resulting chart is performed and detected problems are fixed

The transformation routine might be implemented as a Look-Up Table (direct analogue to S-52 presentation in ENC) additionally enriched with procedural rules handling the complexity of the paper chart presentation (that is, comparing to ENC, subjected to much more numerous regulations imposed by international and national standards). Procedural rules might be implemented as separate scripts written in a programming language (e.g. Java).

The important point here is that both the Presentation Libraries and the transformation scripts are 'external' to the software and can be easily substituted without re-designing or even re-installing the program thus allowing the support of different final products (e.g. charts of national and international series, plans, inlets). The same scripting engine can be used to process the data stored in external files or in a database. A trained user might complete all the required customisation in-house.

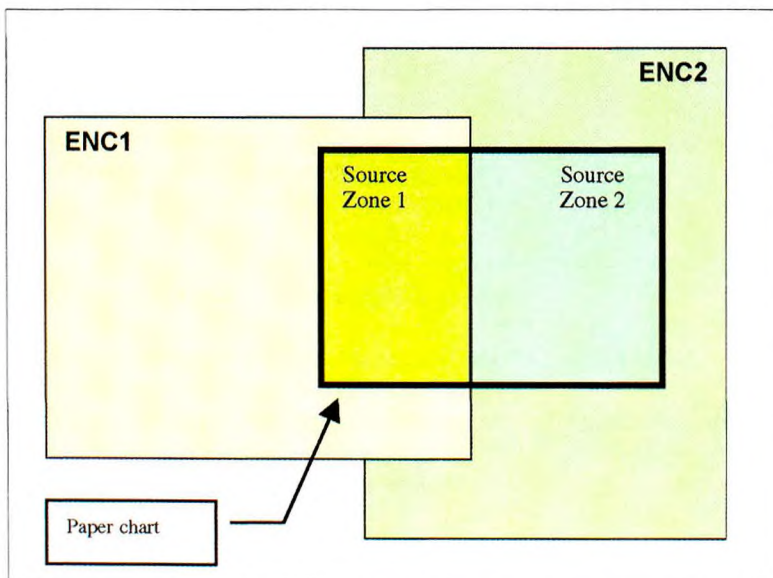Let us consider an illustrative example, see Figure

Figure 4: 'Source Zone' concept. Note that a source zone is an intersection of the target paper chart and visible part of the source ENC
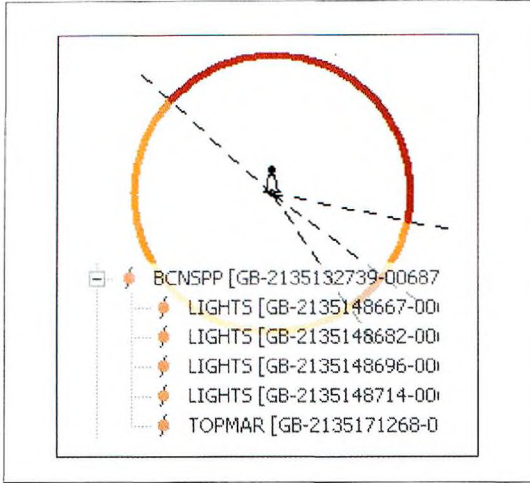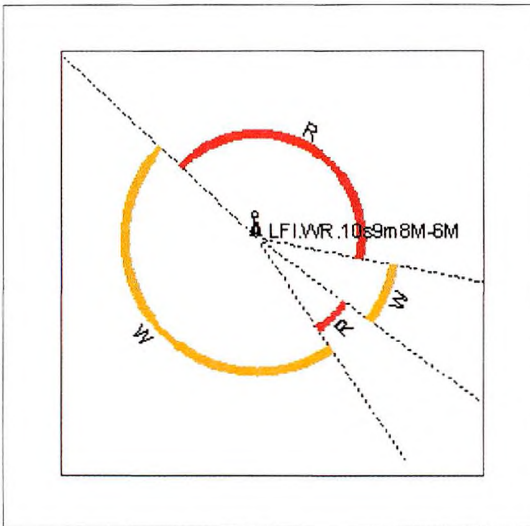
Figure 5.1: 'Lighthouse' on ENC

Figure 5.2: Result of automatic conversion

5.1 and 5.2.

The program takes a 'lighthouse' that is encoded as the following ENC objects grouped into the 'master-slave' hierarchy:

- BCNSPP
- TOPMAR
- 4 x LIGHTS

Having analysed object classes and attributes the program creates the following paper chart objects:

- Bcntow01 symbol for BCNSPP
- Topmar70 symbol for TOPMAR
- 4 different sectors with delimiting bearing lines

and text strings indicating respective light colours are created for LIGHTS
- A light characteristic text string is created (note that the string reflects that more than 2 different visibility ranges are present)

All objects are placed accordingly.

Cartographic Editing

Being a powerful and sophisticated tool, the automatic transformation may perform up to 90% of the work necessary for ENC conversion ('typical' operations). Nevertheless, not all operations can be entirely automated and will still require manual editing.

For this purpose a cartographic editor should be implemented as an integral part of the program. When using the editor, the operator can edit objects either directly on-screen or with the help of precise table input.

A typical editing session includes:

- Placement of complex text
- Editing lines and symbols to avoid clutter in complex cases
- Chart title, tables and pictures placement
- Combination of insets on one paper sheet
- Frames, texts outside the chart border, printing marks
- Pre-print quality control

Editing operations might be enriched with script-based tools that automate lines masking, creation of flaps/continuations, frames and various design elements. It is also quite important that when 'parent' links are used the operator can always get the necessary information on the ENC object related to the paper chart.

ER-based Paper Chart Updating

An ENC is updated via digital updates (ER-files). The paper chart should also be updated accordingly. Application of digital updates directly to a paper chart is the most promising solution stipulating maximum information consistency.

The algorithm for ER-based paper chart updating might be implemented as follows:

- The operator loads ER-file(s)
- The software displays a listing of ER-file actions to the operator additional interface providing 'traditional' presentation of relevant notice can also be implemented
- Highlighting an update instruction in the listing automatically highlights affected object/position on the paper chart (this becomes possible since 'parent' objects maintained in the paper chart allow linking of paper chart information with source ENC)
- The operator invokes applying of the ER-file instructions. The program automatically (or semi-automatically) updates the paper chart by re-applying the transformation routine only to objects affected by the update; all manual changes previously made by the operator to the 'original version' are kept in the modified object

As practice shows this scenario seems to be quite effective and reliable.

Commercially Available Answer

The approach described above lies beneath the whole idea of the dKart Publisher software developed by HydroService AS. dKart Publisher provides all the proposed functionality for ENC-based paper charts production and updating. Several Hydrographic Offices have already implemented this solution with positive results.

Conclusions

Today, a data producer faces a problem of simultaneous production and maintenance of both traditional paper charts and ENCs, and therefore has to think about ways of restructuring the production process in order to minimise costs and sustain maximum quality. This can be achieved by integration of processes into a single technological chain. The ENC-based production and updating of paper charts seems to be a promising way of integration since it allows achieving the highest quality of data with tolerable impact on the existing production infrastructure.

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Biography

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