1. THE REQUIREMENTS: A MORE EFFICIENT AIS PROCESS

1.1 Aeronautical Information Services and Aeronautical Charts

Annex 15 to the Convention on International Civil Aviation specifies that each Contracting State shall provide an aeronautical information service (AIS). The AIS is required to collect and distribute information needed to ensure the safety, regularity and efficiency of air navigation. Such information, which includes the availability of air navigation facilities and services and the procedures associated with them, must be provided to flight operations personnel, as well as the air traffic services unit responsible for flight information service and the services responsible for pre-flight information.

In compliance with the International Civil Aviation Organization (ICAO), AIS shall provide aeronautical charts that are published in hard copy, as part of the Aeronautical Information Publications (AIP). ICAO defines the Standards and Recommended Practices applicable to aeronautical charting (chart types, contents, symbology, etc.).

The main chart types that are currently used in civil aviation include the following:

- En-route
- Departure and Arrival
- Instrument approach
- Visual approach
- Airport
- Obstacle
- Various specific charts: minimum radar safety altitudes, noise abatement procedures, one engine-out procedures, etc.

Figure 1: Excerpt from Obstacle Chart
The aeronautical charting objective consists of the depiction of all the necessary information for the intended operations. This depiction must have two major characteristics: it shall be clear and it shall meet the user needs, keeping in mind that the range of chart users is wide. Indeed, the main users of aeronautical charts are either operational users (flight crews, air traffic controllers, general aviation pilots) or technical support users (ground crew engineers, commercial charting services, flight training organisations, navigation database suppliers, system manufacturers). The key user requirements are to get the necessary and sufficient information to conduct operations, to be provided with charts that are easy to read and unambiguous, and to get the necessary and sufficient information for flight management systems.

The information handled by AIS may vary widely in terms of the duration of its applicability. For example, information related to airports and its facilities may remain valid for some months or years while changes in the availability of those facilities (for instance, due to construction or repair) will only be valid for a relatively short period of time. Information may be valid for as short a time as days or weeks. Therefore, aeronautical information is handled differently depending on its urgency, operational significance, scope, volume and the length of time it will remain valid and relevant to users. One of the main methods to achieve this time management is called AIRAC (Aeronautical Information Regulation And Control), a system aimed at advance notification based on common effective dates of circumstances that necessitate significant changes in operating practices. The AIRAC is based upon a 28 day cycle, applicable worldwide.
In France, the « Service de l’Information Aéronautique » (SIA) provides the Aeronautical Information Service as defined in ICAO. With more than 120 staff members, including engineers and technicians from the French National Geographic Institute, SIA manages the whole aeronautical information publications, including a portfolio of 2600 aeronautical charts belonging to 20 various types. The chart scale varies from 1 : 1 000 000 to 1 : 1 000. In average, around 200 out of these 2600 charts are subject to updates every AIRAC cycle.

1.2 Current processes and limitations

Historically, the AIS products were designed to be produced manually and consumed by humans. As a result most of the information was textual. Over time it has been a challenge to communicate increasingly complex aeronautical information, including geographic boundaries of airspace, description of air routes, departure and arrival trajectories or approach procedures using the legacy publications. This has led to a significant growth in the use of aeronautical cartography instead of text information in AIS.

The AIS and aeronautical chart production situation of today can best be described as a semi-automated process which requires significant manual intervention and remains wedded to the principle of a master, paper reference document, even though the information may in many cases be maintained and transmitted electronically. Graphics and text tend to be regarded as separate rather than complementary techniques for presentation of aeronautical information. This has been conditioned by the limitations of supporting technology used in AIS and charting.

New technologies to manage the significant work in the short time available are more and more required. Besides, chart production is closely tied to the design of instrument approach procedures and to the management of airspace. Thus, there is a need for some kind of electronic interoperability between the tools used for procedure and airspace design on one hand, and aeronautical charting on the other hand. In this context, the need for Geographical Information Systems technology in order to manage the huge quantity of data and achieve the tight timescales demanded by the AIRAC cycle is widely acknowledged in the AIS community worldwide.

Some progress has been made over the past few years thanks to the progressive introduction of new information processing technologies – Computer Aided Design, Databases Management Systems, and Geographic Information Systems. Despite this progress, AIS in general and aeronautical chart production in particular still involves comparatively lengthy timescales for the production and promulgation of information and only offers a limited time for the tailoring of information. Flexibility, timeliness and enhanced quality are key expressed stakeholder requirements, and it is clear that AIS will be increasingly unable to meet these needs unless its concept of operations is developed to keep pace with change. A major impetus to the integration, correlation and provision of digital aeronautical information, including geographic information, is now required.

1.3 The main foreseen evolutions

In order to meet user requirements and contribute to improved safety, increased efficiency and greater cost-effectiveness of the air navigation system, AIS must transition to a broader concept of aeronautical information management (AIM), with a different method of information provision and management through a data-centric approach as opposed to a product-centric nature of traditional AIS.

The main expected benefits from this evolution are:

· Information lifecycle optimization
· Improved data accuracy and precision to support safety critical operations
· Increased scope of aeronautical information to support efficiency, capacity and environmental performance requirements

The AIM concept requires that all aeronautical information be stored as individual standardized data sets to be accessed within the various production stages. This requires the establishment of data-driven processes for the production of the current AIS products and aeronautical charts, through the use of highly structured databases and tools such as Geographic Information Systems.

The master reference information, currently managed in paper, must be held electronically in its component data elements, so as to improve the quality control as well as the consistency and validity of the data. This should minimize the potential for handling errors, facilitate much faster update of status and enable automated access to the data. Whilst the master information is held digitally (rather than paper-based), it should not inhibit the use of a variety of output media - including paper - whether to serve legacy requirements or to fulfill a perceived consumer demand.

The shift from standardizing products (e.g. existing charts) to standardizing data will enable more freedom in the definition of future products (e.g. new and customized aeronautical charts) while maintaining a high
degree of quality, integrity and coherency of the information contained in the various AIS products (including aeronautical charts).

The full potential of data-driven aeronautical charting is expected by integrating a range of geographic and non-geographic data. This requires a database that can handle the relationships between geographic objects and their attributes, and that can manage data from varied sources such as satellite imagery, meteorological data and other mapping in addition to the traditional sources of aeronautical information. As movement of great quantities of data brings about the risk of the introduction of errors, corruption, incomplete data transfer and vulnerability to viruses, this will have to be carefully addressed since this is of particular concern in a field using safety-critical data.

The operational goal of improved electronic charts is to improve the efficiency and safety of flight operations. Some expected results of using an electronic charts include increased positional awareness, reduction in pilot deviations, increased ability to detect data entry and flight planning errors. In this context, operational users demand that the overall quality of aeronautical charts be improved in such a way that they can be presented with information in a more easily assimilated way, with layered or de-cluttered charts, including information of lower priority held out of view (but accessible on request).

In an effort to meet these demanding requirements for information management and cartography with the adaptability to agency defined specifications, SIA is leveraging AIP-GIS Charting® developed by CGx AERO in SYS. This technology aims to improve: the chart production process, management of charts, and overall data quality.

**Figure 3: Aeronautical Data Driven Cartography**

**2. A DATA-DRIVEN AERONAUTICAL CHARTING PROCESS**

**2.1 Data centric architecture**

The development of a data driven cartographic system is based on a centralized database of aeronautical features rich in attributes. Using an Oracle database with Esri’s ArcSDE application server to spatially enable the geographic data, features can be entered into the database or modified, then allowing the system and all chart products real time access to the updated information with little human intervention. The ArcSDE technology provides the framework to facilitate a versioned database environment that is key for temporal data management. The information stored in the Oracle database can be categorized into three main subsets of information: aeronautical and geographic data, cartographic data, and business related information.
2.1.1 Aeronautical data

The aeronautical data managed by SIA is stored in a schema that conforms to a leading aeronautical industry standard called AIXM (Aeronautical Information eXchange Model). AIXM is a XML based exchange format that supports an agency’s data centric environment and its ability to disseminate the information it collects and manages. The data is captured in two primary ways, one through data input screens developed by Thales Air Systems and the second is through the use of ArcGIS Data Interoperability Extension that can load data from various sources in an easy to use framework.

With the current release of AIXM version 5.1, this evolutionary change brings with it the ability to better describe the geographic component of aeronautical data through the use of Geography Markup Language (GML). The introduction of GML enables AIXM to be better aligned with ISO standards for geospatial information. Furthermore it paves the way for commercial products to integrate AIXM with other geographic data for a comprehensive view of a given area of interest providing end users with the situational awareness required to make better decisions.

Another key component of AIXM version 5.1 is the inclusion of an exhaustive temporality model. This important evolution provides a backbone to managing the dynamic and fluid nature of data changes that is common in aviation. The ability for AIXM to support both permanent changes and temporary changes is a key distinction with other temporal requirements. The temporary status of a feature, for example a navaid be inoperable due to standard maintenance, must be captured and communicated to the aviation community, most commonly in the form of NOTAMs (Notice to Airmen).

Once the data is captured in the AIXM compliant database, that data can be used to serve a multitude of services and products including data products (AIXM, Shapefiles, etc.), Web services (WFS, WMS, KML), and traditional paper products (e.g. aeronautical charts). The aeronautical data stored in the AIXM structure serves as the basis as it holds all the critical information for flight safety in France. It includes data for airspace, airways, navigational aids, airports, runways, airport lighting, and much more.

2.1.2 Cartographic data

The same aeronautical data may, and often times exist on many different types of charts, however the rules for depicting the data may vary widely. This presents unique challenges for the cartographer to properly depict the information accurately according to the rules and also manage the information as it appears on multiple chart types and eventually charts.

To manage this second category of data, SIA leverages CGx AERO in SYS AIP-GIS Charting® built on the Esri Aeronautical Solution framework and its concept of cartographic features. AIP-GIS Charting® takes the aeronautical non-spatial data, and uses the attributes that describe the geometry to build geometry that can be stored and managed by a GIS. During this creation process additional attributes are stored on the feature to adequately create joins to the AIXM data and for users to provide specific cartographic information regarding the feature for proper depiction on a given chart. For each area of interest (chart foot print) that a base feature intersects, a cartographic copy of the feature is created, stored, and managed in the database by the software.

2.1.3 Business rules

The third category of information managed by the system is all of the business related information for cartography. This is a broad category that covers many sub-categories including the storage of charts and their associated templates in a document management system, associated rules for feature depiction (symbols), and tracking and monitoring of chart production.

This type of information consists of the business rules for proper depiction of features on the charts. Not only is this the information that tells the system the specific features to display, but also the precise manner in which they are displayed. For example on certain charts, only airports that a have runway that exceeds a certain length should be displayed. How that airport is displayed depends largely on if the airport is primarily used for civil purposes or military purposes.

Other business rules stored in the database include when and how features are labeled, how these labels might mask other features, and one of the most important concepts, the management of the chart templates and the individual charts.

2.2 Configuration of the system

There are several key areas to configure in order to achieve a fully automated data driven cartography system. The key areas include chart templates, Visual Specifications, cartographic feature creation, and the Product Library. These tasks must be complete prior to beginning chart production.

2.2.1 Product library
Within the charting system exists a tool to store and manage the chart templates for SIA, the Product Library. As the name suggests, it is the mechanism by which all chart products and their templates are managed in a library structure. Charts are organized and accessed through a tree view through check-in and check-out permissions for users. In addition to storing the templates and individual charts, product specifications can also be managed and stored. More specifically, cartographic production parameters are stored in the Product Library to facilitate the automation required by the system such as the symbology rules, data models, spatial references, and masking rules. Each of these is configurable and adaptable to user specific needs.

**Figure 4: Product Library**

### 2.2 Area of interest

An area of interest is defined as the geographic extent that is to be charted for a given product (chart). The area of interest must cover the infrastructure of aeronautical data that supports the intended chart type. Defining this area of interest allows the system to identify changes that occur within geographic extent and make appropriate revisions to the feature and any related information as required.

### 2.2.3 Carto manager

Supporting the concept of cartographic features requires some specialized tools to manage the creation and update of those features. Using the AIP-GIS Charting® Carto Manager, filters are configured to determine which cartographical features must be created for each chart without any alteration of the associated AIXM data (base feature).
2.2.4 Chart templates

For each type of chart to be produced, a chart template must be configured. The template is used to store information about of location of the chart elements including the title, the map/data frame frame, the layers in the map and their associated properties, the settings of the vertical profile for Instrument Approach Charts (IACs), and the data driven tables and their properties.

Using the templates available in AIP-GIS Charting®, SIA is able to quickly adapt the templates for specific SIA requirements. Templates included in AIP-GIS Charting® are Instrument Approach Chart (IAC), Standard Arrival Chart (STAR), Standard Departure Chart (SID), Area Chart, Aerodrome Chart, Obstacle Charts, and others.

Each of these templates uses a different scale, coordinate system, rules for applying symbology, rules for creating textual labels, and information displayed in the graphic tables. All of these elements are configurable for specific use.

2.2.5 Calculated representations (symbology)

Perhaps one of the most important concepts in cartography is the depiction of features using symbols and colors easily recognizable by the intended user. In a data driven system, this concept is taken to a new level by not just merely storing symbol sets, but rather the rules for feature depiction. The rules for depicting features on a map are stored in the database as representation rules, also called calculated representations. The calculated representations use combinations of feature attributes to determine the symbols for particular features within a feature class. These combinations are configured by SQL Queries that allow joins between tables.

At a minimum the cartographic feature must be joined to the based feature to leverage the base feature attributes. For example, airports are commonly depicted on Visual Approach Charts (VAC) and their depiction varies based on several attributes stored in multiple database tables. The cartographic feature for
an airport stores the symbology used for a specific feature for a specific chart, however must be calculated based on all relevant attributes.

To accomplish this, a join is first made to the base feature class from the cartographic feature class giving the system the needed information about the airport such as whether the airport is used for military or civilian purposes. This information alone determines the color of the symbol. What symbol should be used is driven from information not necessarily stored on the base feature class, but instead in a related feature class or table such as the runway feature class. This means another join must be made between the airports and the runways. Once this join is made the system can then analyze runway attributes such as length and pavement type to determine the precise symbol needed.

Users are able to create one or multiple SQL statements that are saved and later used to apply the symbology to features. In some cases, SQL statements alone are not enough to determine symbology. The resulting selection from the SQL query may return with it multiple related records as is the case for an airport with multiple runways. In such a case, VB scripting can be used to further analyze the result set. The ultimate depiction of the airport symbol relies on the length of the longest runway and even characteristics of that runway such pavement type. The SQL results are passed to the scripting engine and users can interrogate even further the information to set the precise symbol for the airport.

Figure 6: Screenshot of Visual Specifications Dialog

2.2.6 Calculated fields (text)

Most aeronautical charts have an extensive amount of text that must be displayed to communicate clearly and effectively all pertinent information for the intended user. The text displayed on the charts can be specifically associated with an aeronautical feature displayed in the chart or the text could be displayed in tables or text elements in the marginalia of the chart. In either case, the information must come from the database to maximize automation.

Calculated text is handled the same as calculated representations in that the information must be first gathered from the database (using SQL queries) and then that information should be analyzed and acted on (VB script). Instead of calculating the representation, the end result is a formatted text string that the ArcGIS engine can interpret and display. Again, sticking with the airport example, the text in the label of the airport should contain information from the airport as well as information from related runways and other tables. This requires multiple joins to be performed in the SQL query. Once the joins are made and the data retrieved, the data can be analyzed and the output text formatted for display. Formatting of the text is accomplished using HTML like tagging to change the appearance of the text. Using tags for font (type, size, and color), bolding the text, inserting new line breaks, etc. Although the stored result of the calculated text may appear cryptic to a human, this method allows the ArcGIS graphics engine to display the text in its final formatted form on the chart.

2.2.7 Advanced elements

Aeronautical charts provide some of the most difficult and challenging types of charts from a cartographic perspective. To facilitate the production of these charts, advanced layout elements were developed to portray all the required information and do so in a manner that is clear for the user of the chart. Examples
of these highly complex elements include: the profile view for Instrument Approach Charts, navaid and airspace annotation, and data driven tables.

With aeronautical charts rich in textual labels, it was necessary to be creative in how the information is portrayed to the user. Navigational aids (navaid) and airspace labels represent the more complex labels that are required for aeronautical charting. Navaid labels maybe enclosed in a box with the bottom portion of the box split to accommodate the coordinates of the navaid. Additionally the label must stack the text vertically and display the navaid identifier in morse code all the while keeping the label as a single piece of annotation for ease should the cartographer need to move the annotation.

Much of the information that cannot be portrayed in the primary map frame and even in a geographic viewer must still find its way onto the final product. Two of these elements are the Profile View that is associated with the Instrument Approach Chart and tables that exist on many of the aeronautical charts.

The profile view provides the pilots using this type of chart, a graphic depiction of the vertical descent to the runway showing key checkpoints and elevations along the track. What makes this particular element difficult to automate is the high variability for depiction from chart to chart. With only loose rules and guidelines for portrayal, the profile view leverages the cartographer’s knowledge of the approach to the runway and other information that may not be readily available to the software. Interpretation of the aeronautical data relies on specific coding of the track segments and that coding may or may not be complete. Further complicating how the software can automate drawing of this element is how one agency’s interpretation and method of drawing the data can vary greatly from another agency’s rules, even when the data used by the two agencies are identical. In the end, the graphic is created from the data stored in the database and the user has options to alter the final display.

[Figure 7: Profile View]

Dynamic graphic tables in an aeronautical chart offer another way to display information that cannot fit in the primary map display or information that has no geographic component, but is still critical for the end user.

These tables are fully configurable and can be dynamic in such that the number of records in the table is driven by the data. If a feature for example is deleted, the record in the table is automatically removed as well. In some cases, when a chart becomes extremely congested, it is no longer feasible or safe to try and place all feature information in the map frame. Instead a cartographer can simply set a flag on a feature that will remove the information from the map frame and instead display that information in a table in the marginalia.
2.3 Production process

Once the charting system is configured, the chart production process may begin in earnest. Chart production begins with the receipt of data or data changes. Once the data is received and loaded into the database, the automation of the chart takes full flight. First, cartographic features are processed to create new cartographic features, delete any that have been removed from the upstream source, or update feature geometry for changes to feature geometry. This automation is performed for each chart maintained within the system.

Once the cartographic features have been created and/or modified, the stored business rules for symbology and labeling (calculated representations and fields) are applied to the new or modified data. During this process, if features are found that do not have coherent attributes, those features can be flagged for review. Again this process is performed on each chart during batch processing.

Once the labeling fields have been calculated, users will run a tool that extracts the calculated labels stored in the field, and convert that to annotation (text stored in the database that can be manipulated by the cartographer). During this step, the tools will automatically attempt to de-conflict any text overlap with features and other text. After the annotation is created the user may need to manually de-conflict areas with a high concentration of features and annotation. During the maintenance phase, this step is made easy with the software identifying the specific features and elements in the chart that have received a change. This is where the advantage of a data driven system starts to shine: its ability to show users what is changing in a chart, report that change, and for a cartographer to react to the change.

Additional cartographic tools from CGx AERO in SYS may be run depending on the type of chart. For example, Instrument approach charts require the creation or update of a profile view while enroute charts must utilize the Off-Route Trajectory tool to display text or symbols for routes going out the chart extents.

3. CONCLUSION AND PERSPECTIVES

Aeronautical chart production involves complex databases, the transfer of information and the presentation of that information in the form of standardized charts. Adopting new techniques presented in this paper enables high quality, accurate charts to be produced and updated in a timely manner and, new applications and features become possible for producer and user alike by bringing together data streams (geographical or otherwise) from previously independent sectors.
This shift in philosophy from disparate data systems to a unified approach to data management, promotes better collaboration within SIA and also with its partners and users of its products. By achieving a data centric architecture for chart production, SIA is now in position to create and provide new products and services to a wider range of users while maintaining data quality and even improving it. The platform is now in place to disseminate web based services of the information managed by SIA providing real time or near real time access to its aeronautical information for better and quicker decision making.

The techniques described in this paper apply not only to aeronautical information but also all types of information that needs to be displayed on charts for operational use (weather, flight plans, etc.). They can be implemented across other domains to support the global information management concept. This concept aims at providing timely, relevant, accurate, accredited and quality-assured information to collaborate and make informed decisions within the Air Traffic Management community for safe and efficient operations.