

TECHNOLOGICAL INNOVATIONS FOR INTEGRATING SUBSEA SYSTEMS PLANNING, INSTALLATION, AND MAINTENANCE

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1.0 ABSTRACT

As the time between initial concept and commissioning of submarine cable systems decreases, the need for automated tools and procedures to facilitate the acceleration of the route and cable engineering processes increases. Cable installers are now faced with more projects and less time to design, engineer, and install these systems. These increased demands mean that, in many cases, traditional methods break down and new methods must be used to meet the requirements of very aggressive delivery schedules.

This paper observes the flow of data in submarine cable planning, installation, and maintenance and discusses how recent technological innovations have allowed for data integration between these processes. It shows how these technological advancements have permitted Racal Pelagos' software products to move data seamlessly through the process. Finally, a glimpse of the future shows how new advancements in technology will continue to redefine the way that these processes occur.

2.0 INTRODUCTION

2.1 Racal Submarine Cable Capabilities

Racal Survey Limited has been supporting the submarine cable industry for over a decade. Initially this support was in the area of cable-related software products, SkyFix DGPS services, and navigation support services. However, in recent years this support has included other related activities, such as desktop studies, cable route surveys, ROV services, and the provision of support vessels.

Racal Pelagos, Inc. (RPI), an independent operating company of Racal Survey, provides software and services to the submarine cable installation industry. The company's software systems have been used on cable burial, cable lay, cable repair, pre-lay grapnel, post-lay inspection, and burial operations around the world. Other systems have been used in cable route design, planning and engineering, as-laid charting, and cable maintenance. Since 1987, RPI has participated in over 120 submarine cable installation projects supporting fourteen different installation companies. Currently, software systems are permanently installed on eighteen cable vessels worldwide.

2.2 The Need for Integration

As the time between initial concept and commissioning of submarine cable systems decreases, the need for automated tools and procedures to facilitate the acceleration of the route and cable engineering processes increases. Route engineering, cable engineering, and installation must now occur in a shorter time than ever before. In an effort to meet these demanding schedules, while still maintaining quality, the industry is searching for technological innovations to allow for the integration of the planning and archival of subsea systems. This integration would improve efficiency and accuracy, reduce costs, increase reliability, reduce planning time, and provide better engineering decisions.

Since 1995, RPI has been working towards a “cradle to grave” concept for handling submarine cable data. Since that time, all of RPI’s software products have been developed around a central database that moves data seamlessly through various phases of the submarine cable planning, installation, and maintenance process. Advancements in personal computers, databases, 3D graphics, and Geographic Information Systems (GIS) technologies have turned this concept into reality. Data can now be moved from initial concept to route engineering, cable engineering, installation, and finally, to archival through a single common database, with no need for manual transcription or data reformatting.

Continuing advancements in these areas, as well as the introduction and development of spatial warehousing technology, mean that there will continue to be significant improvements in the way that data are moved between various phases of the submarine cable installation process.

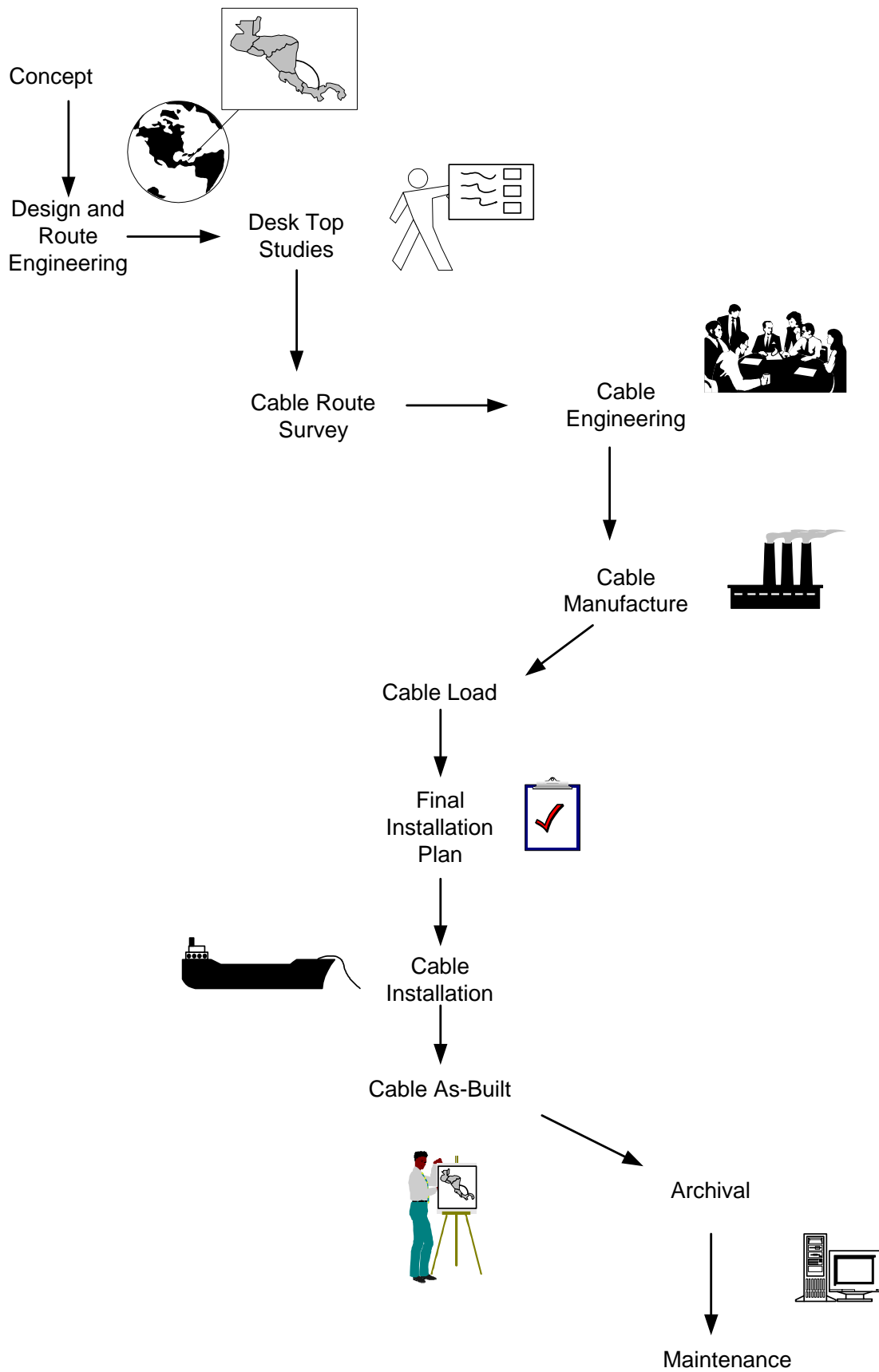
3.0 THE PLANNING, INSTALLATION, AND MAINTENANCE PROCESS

3.1 Data Flow

The planning, installation, and maintenance process of submarine cable systems involves a series of steps that require the movement of data from one phase to another. There is a distinct data flow that, in general, is serial in nature. In recent years, there has been a trend to reduce the time allocated to tasks, reduce the time between tasks, and even run tasks in parallel. However, this has often resulted in increased costs due to rework, incorrect conclusions, or compromised system design. Thus, the challenge is to maintain the same tasks and accelerate time frames, without compromising the quality of the process or the data.

The following summarizes the main phases of the submarine cable engineering, installation, and maintenance process. This list addresses solely “survey type” data that are related to the position and lengths of systems. It does not consider tasks that are related to sales, marketing, financing, or optical and component engineering.

- Concept
- Design and Route Selection
- Desk Top Study
- Cable Route Survey
- Cable Engineering
- Cable Manufacturing
- Cable Loading
- Installation
- Archival
- Maintenance



The above data flow is not always continuous and in most cases, it is necessary to revisit the design and route selection phase after analyzing the results of the desk top study and cable route survey. Similarly, cable spans, lengths, and associated cable body positions must be revisited after both cable manufacturing and cable loading. Prior to installation, both cable and route data are combined in the final installation plan.

3.2 Traditional Approach

In recent years, there has been tremendous pressure to have the above process accelerated. In many cases, traditional tools have been rendered ineffective in these new reduced timeframes. Historically, route planning and development was often completed using published charts. In some instances, other data were superimposed on these charts or, more likely, a separate set of charts would be required for each type of information required. Coordinates would be scaled off of charts to develop routes. These coordinates would then be manually transcribed into a “route position list” that would be used for a desktop study. The report and charts produced by the desktop study would be reviewed in conjunction with the original planning charts and any required route changes would be made. A revised route position list would then be used for the route survey. Again, the enormous volume of text and charts generated by the route survey would be used in conjunction with charts from the desktop study and the original planning phase to make required route changes. The process combined a series of iterative steps that involved scaling coordinates off of charts and manually transcribing them into coordinate listings.

While the above process worked, it is easy to see its limitations. Since all charts, reports, and data were typically in paper format, there was a tremendous physical space requirement to simply house and organize these products. Furthermore, the system was very slow, due to the fact that data had to be pulled from various charts and merged with interpreted results of desktop studies and route surveys. The process of scaling coordinates off of charts, replotting them on other charts, and transcribing these into route position lists was, obviously, very slow, inefficient, and error prone. Finally, it was very difficult to manage the huge volume of data that was available, but not easily consolidated.

3.3 New Methods

Technological innovations have permitted the creation of new systems that can now be used in the submarine cable planning, installation, and maintenance process. New tools, techniques, and methods are now available that address many of the problems discussed above. Of course, technology continues to evolve and the transition is far from complete, but a trend is starting to emerge.

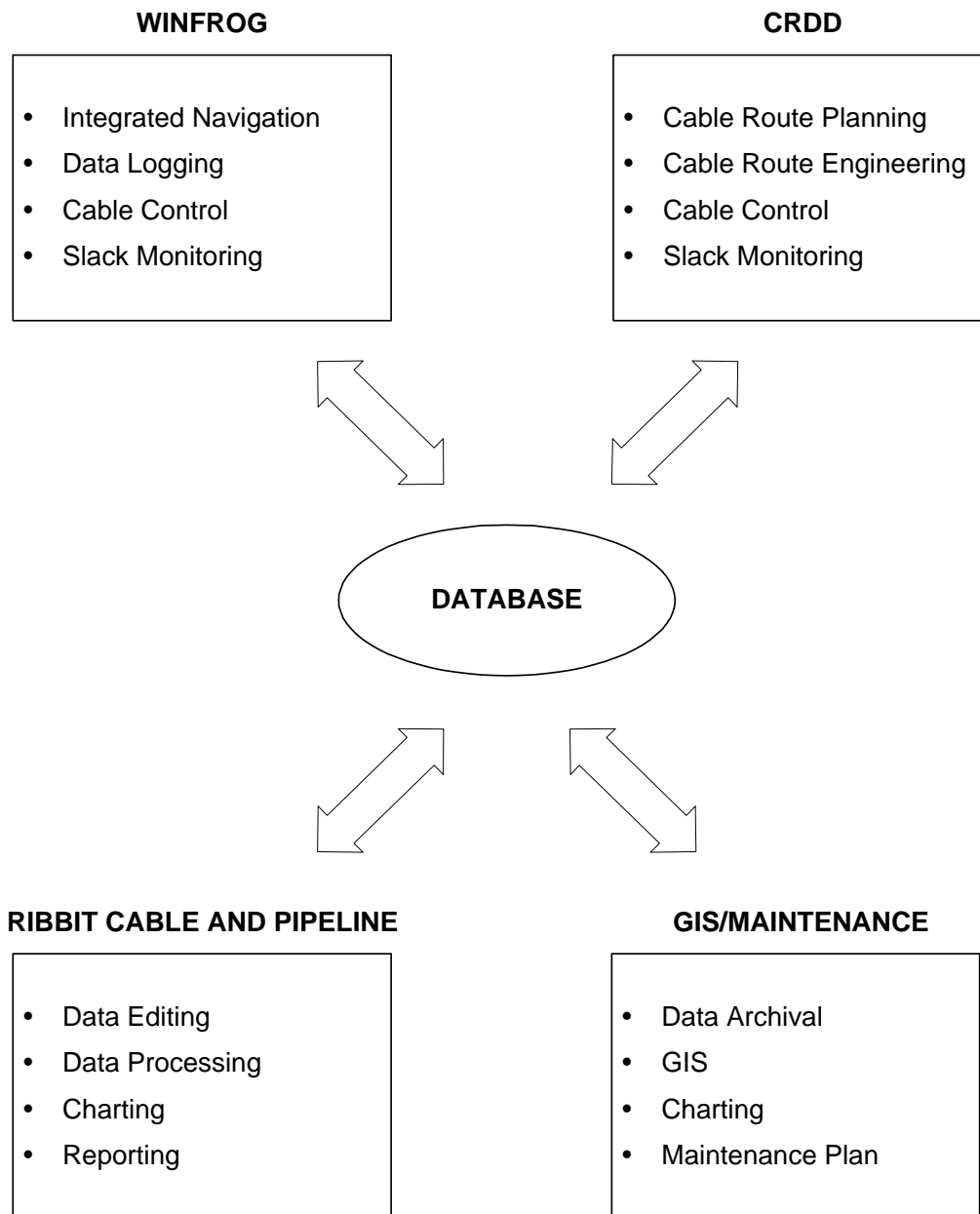
It is now possible to conduct planning and route development on electronic charts. Several organizations now provide electronic charts in various formats. Depending upon the product, nautical chart data for the entire world can be provided on as few as two CD-ROMS. Regular updates are also available which help to ensure that the electronic chart database always has the latest information. Since electronic charts systems operate in real world coordinates, the need for scaling has been eliminated.

It is now also possible to consolidate data from many different sources, store it electronically, and view it on a digital display as layers on a map. Oceanographic, meteorological, bathymetric, boundary, maritime safety, fishing, shipping, infrastructure and other data can all be combined in a central GIS for planning and design purposes. Another advancement that is closely related to GIS is the acceptance of survey records and reports in electronic format. As more data are exchanged electronically, it becomes easier to integrate the data into a GIS system. This means that it is now possible to incorporate desktop study, route survey, and as-laid data into a GIS. Another advancement is the large improvements that have been made in the transfer of electronic data. Network technology, such as the Internet and intranets, have advanced to the point that there are virtually no limitations in electronic data transfer. This has made it possible to transfer data almost instantaneously, which has helped eliminate the need for manual transcription.

As a result of these advancements, many of the problems observed with the traditional approach of managing data have been eliminated. Data can now be moved around very quickly, efficiently, and accurately, addressing many of the problems inherent in traditional methods. The data management problem will also be simplified by the fact that all data types can potentially reside on, and be consolidated within, the same system. Current trends suggest that, in the future, volumes and volumes of charts and reports will be replaced with CDs or a network-based library and physical space issues will be virtually eliminated.

4.0 EXISTING SOFTWARE TOOLS

The RPI solution to data integration is based on a combination of four, independent, but closely linked Windows™-based software programs. At the heart of the system is the WinFrog Integrated Navigation and Cable Management System. It is supported by the Cable Route Design Database engineering and planning software, the Ribbit Cable and Pipeline data processing software, and the Cable Maintenance System GIS-based archival and maintenance software. This suite of software products offers all of the elements required for efficient and accurate submarine cable installation.



4.1 Cable Route Design Database (CRDD) – Route Design and Engineering

The CRDD software is an off-line software package that addresses route design and engineering aspects of submarine cable systems. It creates and modifies a Microsoft Access™ database that is used throughout all subsequent phases of a project, including installation and maintenance. The software provides the user interface to this database as well as many powerful cable-related calculation utilities.

CRDD is a tool that facilitates route and cable engineering. The initial database is created through manual entry, import of an ASCII text file, or import from WinFrog. The latter presents a powerful planning capability, as a route can be developed within WinFrog using point and click methods over an electronic chart display. Digital bottom profile data from the route survey can also be imported and a sectionalized profile can be selected and added to the database. Through interactive editing facilities, the user can add, delete, or edit route data, cable data, and profile data. All calculations are linked in such a way that modifications in one area may effect another area. For example, new positions of cable bodies are computed as cable spans are modified.

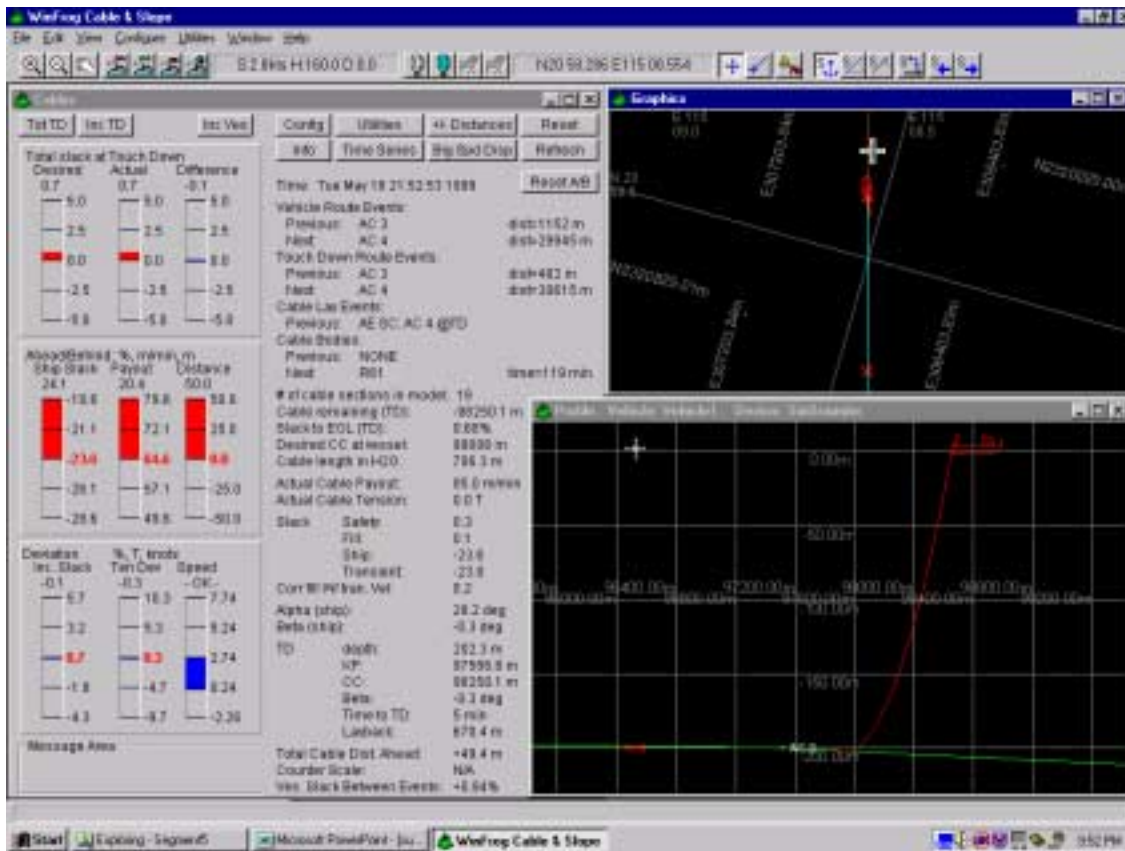
The CRDD software provides several different views of the same database. A Running Sheet presents all cable and route events in a “route position list” type format. The Sailing Sheet shows only the route events from the database, while the Cable Sheet displays only the cable events from the database. As laid information is also recorded directly to the database during installation, via the connection to WinFrog. This data can be viewed through the Block Sheet and Cable Lay Status sheets. The Block Sheet presents as-laid cable and route events in a “route position list” format, while the Cable Lay Status Sheet compares engineered and actual route distances. In addition to these displays, the software can also print route position lists, sailing sheets, and block sheets. DXF graphical outputs of block diagrams and straight-line diagrams can also be produced. Finally, the system can generate a cable management plan for the entire route.

4.2 WinFrog – Integrated Navigation and Cable Management

The WinFrog Integrated Navigation and Cable Management System is a real-time application that provides precise navigation, cable management, and data acquisition for cable installation and maintenance projects. The WinFrog software combines data from various sensors, then computes and displays data that aid in the deployment of submarine cable. For example, surface and subsea positioning sensors can be used to accurately position both the vessel and submersible vehicles. The positional and speed data can be combined with data read from linear cable engines, cable drums, and tension meters to compute and display cable touchdown and bottom slack information, which can then be compared to installation goals. In addition to free-lay applications, WinFrog also supports burial and retro-burial systems. Interfaces to subsea plows, seabed tractors, and “work-class” ROVs have all been developed to allow WinFrog to read and record burial and other sensor data that facilitate the subsequent processing and charting of installation data via Ribbit Cable and Pipeline.

Once WinFrog is linked to the database created by CRDD, it becomes possible to lay cable to meet calculated design objectives. Given vessel speed, cable is paid out at a specific rate in order to produce the engineered slack values. A 3D force-based model is used to track the geometry of the cable to the seabed, where touchdown position and bottom slack are derived. The model considers laying angles, bottom inclinations, and water depth in determining touchdown positions. The computed bottom slack is compared to the design goals and adjustments are made to achieve those goals. The model takes any vessel speed, cable speed, and cable transition changes into account and translates them into geometrical changes that, in turn, can be used to deduce a touchdown position.

WinFrog also serves as a central data logger that consolidates all data and references with both time and position. This is important as it reduces the time required for subsequent processing and charting of as-laid records. In addition, the real-time link to the CRDD database means that as-laid block sheets can essentially be created “on the fly.”



4.3 Ribbit Cable and Pipeline – Data Processing and Data Management

Ribbit Cable and Pipeline is an off-line data processing software package that was developed specifically to manage data logged by WinFrog. It is quite powerful and provides several key functions to aid in the review and processing of line-based data. Basic statistics are available on all data sets and an audit trail of all operations is available both on screen and logged to a file. Data cleaning and editing are possible via several automated filtering and thinning tools, as well as graphical and text-based editors. There is also a sophisticated KP generation feature that offers several KP generation options. Data interpolation and de-skewing tools are available, as well as some limited reprocessing capabilities, such as conversion of geodetics during post-processing. Data files from both CRDD and WinFrog can be loaded by the system and can then be used in subsequent processing.

Several data output options are available, including both graphical and text-based outputs. Data can be output to user-defined ASCII text files or to configurable DXF graphics files. It is possible to incorporate date/time, cable count, and KP references in the DXF files that are generated. These DXF files are typically imported into a commercial graphics package, where a template and legend are added and physical plots are created. The user can customize the layout, scale, size, and content of these plots. Plots typically include a base panel, showing a plan view of the as-built route, along with one or more sub-panels displaying data parameters such as water depth, cable burial depth, cable tension, slack, and other data that may be readable from the sensor suite. Properly equipped cable ships can produce this type of summary onboard, effectively documenting the project in near real-time.

4.4 Cable Maintenance System

The Cable Maintenance System (CMS) is an off-line GIS-based system that provides the ability to store, query, maintain, graphically display, and plot cable system data. All cable data are stored and accessed via the same database that is used by CRDD, WinFrog, and Ribbit Cable and Pipeline. The CMS was developed with an open-ended design scheme to permit the rapid expansion of the system and database structure to include links to other databases containing additional information.

The querying, display, and plotting aspects of CMS are handled with a customized version of ArcView GIS™. ArcView is a very popular commercial GIS system developed by Environmental Systems Research Institute, Inc. (ESRI). Racal Pelagos, Inc. has customized the product for cable applications and will continue to expand its capabilities. The customized software directly accesses the cable system databases and provides a means to display these systems along with digital coastlines, raster charts, and other third party data. Full querying capabilities, such as spatial queries and conditional queries are also available. Tools are available for calculating intersections and finding features within a specified proximity of any selected cable system. Capabilities also exist that allow the user to choose to have certain independent systems and cable bodies turned “off” or “on,” as desired. All systems and information in the database can be annotated to display system names and other relevant information. In addition to viewing the cable system information digitally, charts can be produced to provide an overview of cable systems in a specific area.

The system has been designed around the databases created by CRDD as the base information. This means that historical as-laid data can be combined with systems planned for installation and third party data for subsequent planning and route development work. The software can also be used for archival and maintenance purposes where detailed as-laid data can be accessed via the graphical front end. It is envisioned that this system would ultimately replace the hard copy as-laid records that are currently produced.

5.0 EVOLVING TECHNOLOGIES

There have been dramatic developments in several key technologies that have allowed the introduction of software tools, like those offered by RPI, in order to permit sophisticated data integration. Some mentioned briefly in Section 3 and will now be developed further. In all cases, these technologies have not yet fully matured. Additional advancements are ongoing and will continue to change the way that this type of data are handled.

5.1 Personal Computer Advancements

It is obvious that personal computers have revolutionized the way that we live our lives and conduct business. Technological advancements in the personal computer industry have also greatly impacted the submarine cable engineering, installation, and maintenance process. Modern personal computers have increased processor speeds, increased memory, and increased hard drive capacity when compared with personal computers of only a few years ago, yet are smaller and less expensive than ever before. These advancements have been occurring at an exponential rate and most of this growth has occurred within the past few years. All of these factors have combined to create a new breed of personal computers. These computers are better equipped to handle 3D graphics, large database files, and to support full GIS systems. Tasks that could previously be handled only by large workstations or even super computers can now be accomplished on desktop computers.

5.2 3D Computer Graphics Advancements

Another area where technology innovations have changed the way that submarine cable data is handled is in 3D graphics. Algorithms for displaying 3D graphics have actually changed little over the past two decades. However, recent advances in computer hardware technology have now made it possible to render complex, shaded 3D models in near real-time. The display of 3D computer graphics is computationally intensive, with numerous floating-point operations being performed for each point in the model. Better computers with faster central processors, integrated floating-point processing units, and increased RAM have permitted the display of larger models and the use of more computationally efficient rendering techniques. There have also been recent improvements in display hardware. Graphics adapters have built-in hardware acceleration of three-dimensional operations that allows the main processor the “free time” to process the high level computations, while the graphics card handles the actual drawing of primitives to the screen. Finally, the introduction of OpenGL has provided a standard API (Application Programming Interface) for constructing and rendering 3D

models. The use of OpenGL (Silicon Graphics, Inc.) has allowed developers to write device independent code that will be supported by the latest hardware 3D accelerators.

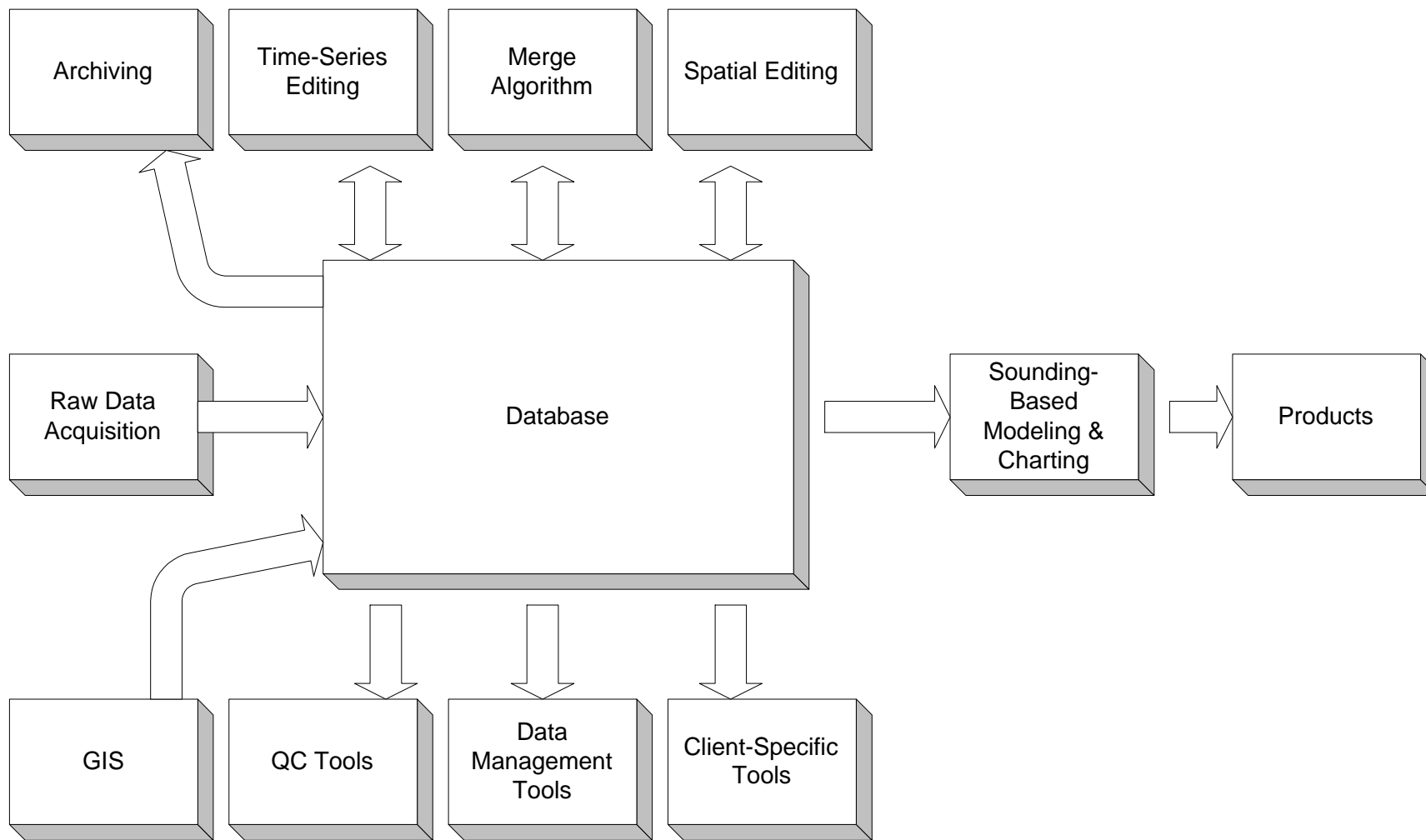
5.3 Database Advancements and the Introduction of Spatial Warehousing Technology

Database advancements and the introduction of spatial warehousing technology have also changed the way that submarine cable data are handled. Again, these innovations have been mostly related to the improvements in computer hardware.

During the 1980's, desktop database access was limited to xBase applications such as dBase (KSoft Inc.), Clipper (Computer Associates Inc.), and FoxPro (Microsoft Corporation), as well as Paradox (Inprise Corporation). It was extremely difficult to share data and move data between various types of databases. Each came with its own programming language, which could not be used with other formats or applications. Then, during the 1990's, Microsoft Access was added to most available desktop database products, meaning that other desktop formats could be accessed through this format. Also during this period, Open Database Connectivity (ODBC) was introduced. This allowed universal access to all desktop databases plus server databases, such as Oracle (Oracle Corporation), Sybase (Sybase, Inc.), and Microsoft's SQL Server through a non-database specific programming language such as C.

The recent introduction of spatial warehousing technology will greatly impact the way that submarine cable data are integrated and exchanged in the future. This technology can be successfully applied to any project involving very large amounts of spatially registered data or requiring rigorous data management.

Currently, there is a problem in modeling hydrographic data over a large geographic area, such as in a cable route corridor. These data are now treated as a series of data sets. These small data sets must appear as a single large data set, which causes problems related to quality control and general management of data, when matching between segments. The fundamental premise behind spatial warehousing is that all data are stored and managed inside a relational database specifically optimized for handling very large quantities of homogenous, spatial data. The 3D data would be available to outside charting and display tools via an interface that enables explicit control over the trade-off between data set and the desired vertical resolution. All of these processes are performed in the database and are subject to a full array of database management tools, such as transaction logs, rollback, security, and access monitoring. Data sets of almost any size could be handled as a single data set, meaning that there would be no need to break a large data set into smaller data sets for processing purposes.



5.4 GIS Advancements

As in the previous two sections, advancements in computer hardware technology have also impacted the evolution of GIS technology. These systems have historically resided on large workstations and required significant processing power. Today however, Windows™-based GIS packages are easier to use and more affordable than ever, meaning that this technology is now within the reach of smaller companies and industries. User-friendly GIS applications, such as ArcView (ESRI), MapInfo (MapInfo Corp), and GeoMedia (Integrat Corporation), provide the user with the ability to analyze and visualize data without being an “expert”. These applications can be easily customized, which allows industry-specific applications to be developed on top of off-the-shelf programs quickly and easily.

As with database technology, the introduction of ODBC has allowed GIS systems to work with almost any database format. To complement this, the number of public data sources has increased significantly in recent years and many of these sources offer data at no charge. More data are available today than ever before and as web-enabled technology continues to grow, much more of the data will be available via the Internet. Finally, GIS has started to shift away from being a stand-alone application to a component of a larger process. GIS, in the context of the submarine cable engineering, installation, and maintenance process, is a perfect example of this trend.

6.0 FUTURE TRENDS

Future advancements in all of the technologies described above will continue to shape the way that data are integrated, exchanged, and managed in submarine cable engineering, installation, and maintenance. In particular, innovations in spatial warehousing technology will permit significant developments in the area of 3D visualization for both planning and installation, cable/seabed intersections for touchdown monitoring, and real-time GIS integration.

6.1 3D Visualization in Planning

3D-visualization for planning is already possible. The technology currently exists to handle large data files and to display surfaces in three dimensions. However, this now occurs on a file-by-file basis. Each file contains data for a specific area of the seabed and must be exchanged with another file as engineering proceeds down the route. Spatial warehousing technology will permit all data to reside in a single database and will eliminate the problems that currently occur at file transitions. Initial developments at Racal Pelagos Inc. have shown that any block of data within a database, containing 17 million points, can be accessed within 20 seconds.

3D-visualization in planning will permit an immediate and instantaneous correlation between route and bottom profile. Thus, using a 3D-visualization tool that is based on spatial warehousing technology, it will be possible to interactively and immediately see how route

changes affect bottom profile. When an acceptable configuration is found, the route profile could be exported to CRDD, where it could be sectionalized and added to the route position list. Additional route and cable engineering could occur within CRDD, at which time the final installation database could be taken to the vessel and linked in real-time to WinFrog to control the installation.

6.2 3D-Visualization in Installation

The current state and future direction of technology in 3D-visualization as related to installation is similar to that described for planning. Again, spatial warehousing technology will permit all data to be housed in a single database and will eliminate the problems that occur at file transitions. 3D-visualization during installation will permit the three-dimensional display of vessel, seabed surface, water column, and cable model. Such a system will be able to track and display the 3D geometry of the cable from the vessel to the seabed. This process will become more accurate as improvements in touchdown calculations are made.

6.3 Cable/Surface Intersection for Touchdown

The move to a cable/seabed intersection calculation will represent a significant advancement in the way that submarine cable is modeled and bottom interaction is handled. Currently, bottom interaction and touchdown calculations are based on a cable/profile intersection. The geometry of the cable is tracked to the seabed, where it intersects with an assumed profile to derive touchdown position. This approach assumes that the centerline profile represents that of the entire seabed and is valid only as long as cable touchdown stays close to the design route. As touchdown deviates significantly from this line, errors in touchdown position and bottom slack become larger.

Spatial warehousing technology will allow bathymetric survey data for an entire cable corridor to be housed in a single database. As vessel and cable touchdown advance along the route, a small portion of the database is extracted to create a seabed surface model. The geometry of the cable will be tracked to the seabed where it will intersect with the surface that has been modeled and displayed. A profile will actually be developed as touchdown advances, with intersection positions, water depths, and bottom profile captured at cable touchdown.

6.3 Real-Time GIS Integration

Spatial warehousing technology will also permit advancements in GIS technologies and, in particular, in real-time GIS integration. It is conceivable that within a few years, an installation database could contain much more than route, cable, and profile data. It could expand to incorporate desktop study, cable route survey, historical data, or any other third party information. The installation process would become less dependent upon paper charts and survey reports onboard an installation vessel, but all of this information would be available on line and would display as the vessel approaches that area.

7.0 SUMMARY AND CONCLUSIONS

Recent and continuing technological innovations in the area of personal computer hardware, databases, 3D graphics, GIS, and spatial warehousing have permitted the integration of data from the planning, installation, and maintenance phases of submarine cable systems. Racal Pelagos Inc. has developed a suite of software products that operates around a central database to move data seamlessly through various phases of the submarine cable planning and installation process. Such integration greatly improves efficiency, improves accuracy, reduces costs, increases reliability, reduces planning time, and provides better engineering decisions. As the time between initial concept and commissioning of submarine cable systems shrinks, the need for data integration and automated tools capable of accelerating these processes increases. Future advancements in these areas and in spatial warehousing technology will ensure that there will continue to be significant improvements in the way that data are moved between various phases of the submarine cable installation process.

REFERENCES

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