

# Automating the Ping-To-Chart Workflow

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## Abstract

The production of a nautical chart, pipeline inspection map, sediment map or any similar products involves many complex steps between data collection and final delivery. At the same time, these complexities are generally well understood and well defined in the industry, which makes these tasks ripe for automation.

Teledyne CARIS<sup>1</sup> has introduced a new automation tool called Process Designer, part of a larger effort to bring comprehensive, intuitive automation to their product line. Process Designer allows the user to capture business logic, i.e. their standard processing steps, as a series of automated tasks to be executed on incoming data. Designed with flexibility in mind, this new model will allow users to automate the generation of clean, production-ready data during acquisition with CARIS Onboard<sup>2</sup>, as well as their post-processing analysis and product compilation tasks performed in HIPS<sup>2</sup> and SIPS<sup>2</sup> and Bathy DataBASE<sup>2</sup> on the desktop.

A harbour survey dataset will be taken from raw sensor data through to a nautical chart to show the benefits of using the Process Designer to automate the Ping-to-Chart<sup>2</sup> workflow, while still allowing human input at critical stages.

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## Introduction

Under the current paradigm, the creation of many navigational products involves many complex steps between the first measurement and the final product. Raw measurements, typically consisting of multibeam pings, positioning, attitude, tide measurements, and sound velocity profiles are collected over the course of the survey. Certain acquisition systems will apply corrections in real-time, including ray-tracing the multibeam data using the sound velocity profiles, and marrying the positioning and attitude measurements to produce geo-referenced measurements. Whether done in real-time or in post-processing, these geo-referenced measurements are then typically used to produce a gridded dataset, which feeds the generation of representative vector features like contours and soundings. The vector features are then used to generate new charts or seabed maps, or used to update existing ones.

During the Meso American-Caribbean Sea Hydrographic Commission (MACHC) meeting, which was held in December 2015 in Antigua, an unmanned hydrographic survey was conducted using a Teledyne Oceanscience Z-Boat equipped with a MB1 multibeam echo sounder and ancillary sensors to work as a fully integrated hydrographic survey platform. Sent as a complete package, the vessel was set up before the survey, packed into a single crate and shipped to the survey area as a turn-key vessel. Operated from the shore, the vessel was controlled by a radio link to an operator who could access the onboard computer through a long range Wi-Fi link. The Z-Boat was deployed in Jolly Harbour to survey the harbour and the dredged channel around the approaches to the harbour to confirm the charted depths in the area.



*Figure 1 - Z-Boat using CARIS Onboard software*

Whilst the survey was taking place, the data was concurrently being processed onboard the Z-Boat using CARIS Onboard software. This required a data processing workflow, defined by the surveyor before the start of the work and used by the software to import,

clean and correct the multibeam data at the end of each survey line. As processing was occurring on the platform, the surveyor was able to observe the bathymetry uploaded line by line and visualized on a shore-based workstation. This allowed for a near real-time assessment of the data quality. Then when the vessel was recovered, the dataset was simply downloaded and viewed immediately in HIPS and SIPS software.



*Figure 2 - Survey area in Jolly Harbour, Antigua*

Immediately after the data download, the gridded surface generated during the survey was sent via email to CARIS staff in the USA. Using CARIS BASE Editor<sup>3</sup> and Paper Chart Composer<sup>3</sup>, soundings were generated from the source data and plotted onto the existing paper nautical chart for the area. Further comparative analysis was then demonstrated between the new dataset and formerly charted soundings. In total the survey gathered over 500,000 multibeam soundings over a period of seven hours, and the total time from the first ping to the production of the chart was less than 24 hours.

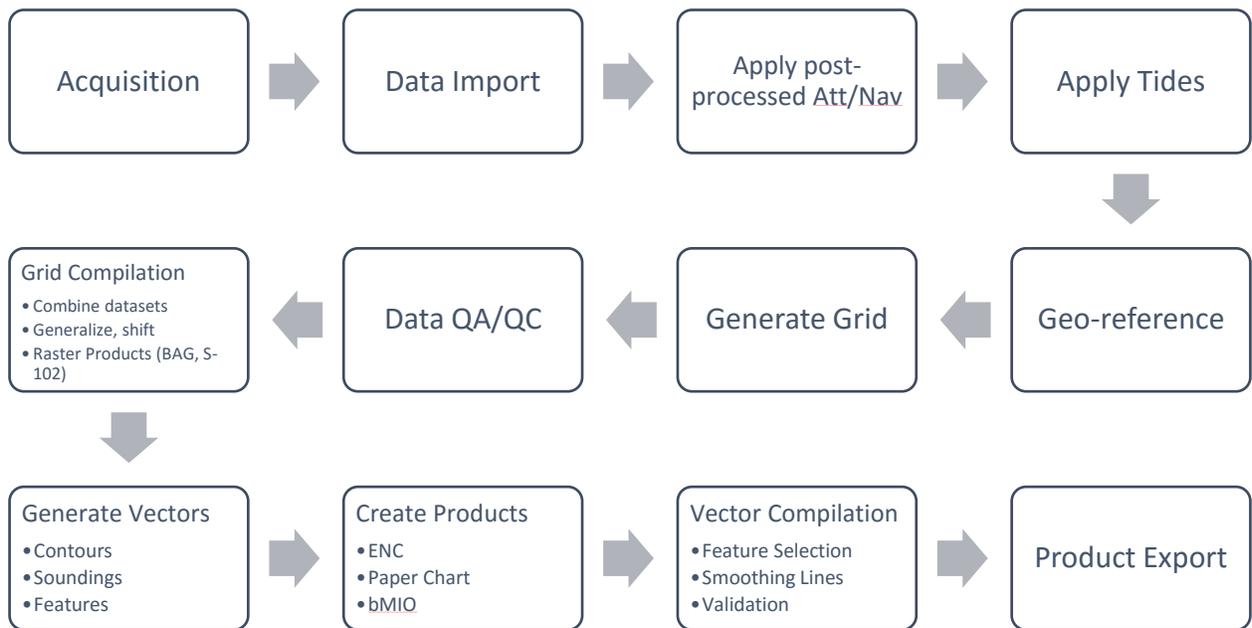
The Process Designer, which is used to configure the workflow for CARIS Onboard, is now available in CARIS' HIPS and SIPS and Bathy DataBASE (BDB) desktop applications. We will explore the use of this automation tool through a complete Ping-to-Chart workflow, by expanding the role it might have played in this survey.

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## Challenges in the Ping-to-Chart Workflow

Teledyne CARIS' full Ping-to-Chart workflow describes a data flow starting from raw data collection through product creation and export (Figure 3). As described above, raw data for the Jolly Harbour survey included multibeam bathymetry, while the products created were a paper chart with an updated sounding selection. What happens in between data collection and product creation has varying levels of complexity, however. Figure 3 outlines several steps including application of various data correctors, data QA/QC, and creation of intermediate products (like grids).



*Figure 3 – Ping-To-Chart Workflow*

Perhaps the most complex step in the workflow is the geo-referencing of the multibeam measurements. The sounding measurements are corrected for refraction, all linear and rotational offsets are applied, and the instantaneous position and orientation of the platform are used to calculate the final location of each measurement. In addition, some vertical reference is chosen and applied appropriately. The inputs for these corrections can vary widely between survey platforms, even specific surveys from the same platform, which has been the driving force in the development of HIPS and SIPS for 25 years. This processing complexity is reflected in the software workflow, where many options are available to the user depending on platform and intended use. The challenge, then, is to provide a broad selection of processing options for the widest possible segment of the user base, while at the same time minimizing complexity for the end user when processing data. This challenge carries over to CARIS Onboard, where

the core processing functionality of HIPS and SIPS is available for application in autonomous survey. Whether working in a purely post-processing or real-time autonomous paradigm, the software must be configured by the end user to produce the desired output.

There are further downstream complexities in the generation of vector representations of the seabed in the form of contours, depth areas, soundings and other charted features, as the features must conform to the safety, legibility, topology and morphology constraints of a navigation product. In an ideal world, these bathymetric features are derived directly from a high-resolution multibeam survey and incorporated into a navigational product with little or no manipulation. The reality is not so straightforward, and in most cases either the vector features or underlying surface must be simplified in order to produce legible information on the chart.

Reducing the complexity in the Ping-to-Chart workflow itself may not be directly possible yet. Depending on the post-processing required, steps in the workflow cannot exactly be eliminated. Therefore, in order to make it easier for the end-user, Teledyne CARIS explored process automation as a solution to complex workflows.

## Process Automation

Process automation has been a focus for several years in both the geomatics community and the development of the CARIS Ping-to-Chart workflow. By automating the mundane or repetitive task which are based purely on numerical models and predefined rule sets, human operators are left to be able to spend their time and focus on aspects of the workflow that are best executed with human input and judgment.

In prior releases, automation has been incorporated into the CARIS product line through the HIPS Batch Engine and BDB's Caris Batch command-line tools and Python API. This allowed segmented automation between the products, but there wasn't direct flow from one product to the next, meaning that the entire Ping-to-Chart workflow could not be fully automated.

The variations in the automation tools also meant there was an inconsistent user experience, requiring specific training in each product. In some cases, to achieve automation of more complex workflows, specialized skills in Python or other scripting languages were required. All of this led to the requirement for a single tool that deploys at the base CARIS application level, which allows the users to design their process models making use of all the modules they have licensed

As discussed earlier, one of the challenges with process automation is the variability in workflows; variations that can be present between organizations, projects or even from one batch of data to the next. The desire is to have a single "Make Map" button that a user can press to create products from raw sensor data. In reality there is no one perfect solution to meet every possible scenario. The approach that can be taken, however, is providing a tool that allows experienced users to build a custom process that encapsulates their workflow, so they make a "Make Map" button tailored to fit their processing workflows and product requirements. This gives way to the need to be able to intuitively build a modeled workflow that allows the fixed steps and properties to be hard coded, while also providing the means specify which variables are accessible at run-time.

To solve the proposed problem, a graphical programming tool was built and packaged as the Process Designer (Figure 4). The Process Designer allows users to build a process model that can run anything from a single operation, to the most complex of user workflows. To design a process model, a user drags the individual tools they require onto a design grid. Each tool has a series of input and output ports that can be interconnected, defining the flow of data between each tool. Each tool has a set of properties that can be explicitly defined, or optionally set as an input, allowing the value to come from another tool in the model. Aside from being predefined in the model, any property can optionally be set as an input to the process model, which means the operator will be able to set it at run time.

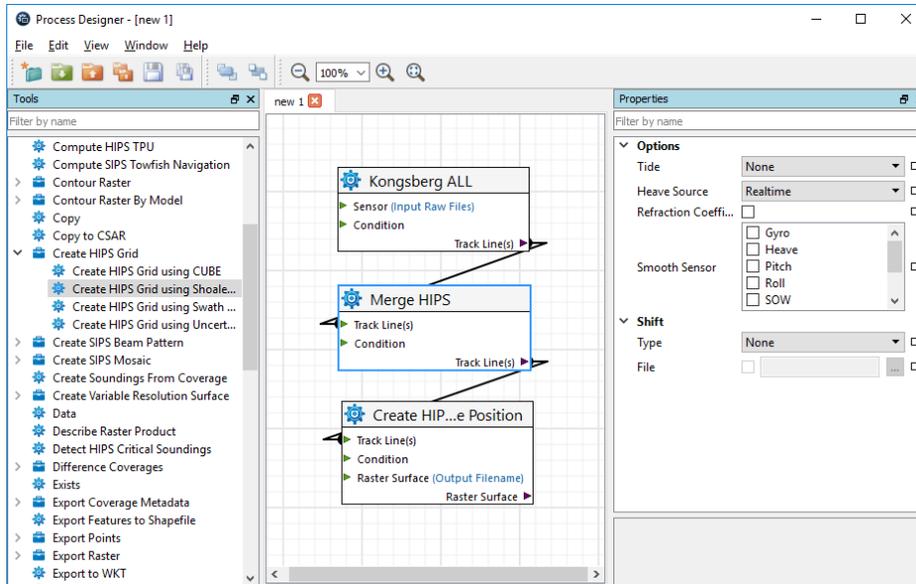


Figure 4 - CARIS Process Designer Interface

The Process Designer allows complex workflows to be encapsulated, and appear as a single process to the operator at run-time. When run, the properties set as input to the model are displayed as the options. As an example, a process model that takes raw sonar data through to contours and a sounding layer for an ENC could run as a single process. The only options presented to the operator are the location of the raw sonar files and the name for the output products (Figure 5).

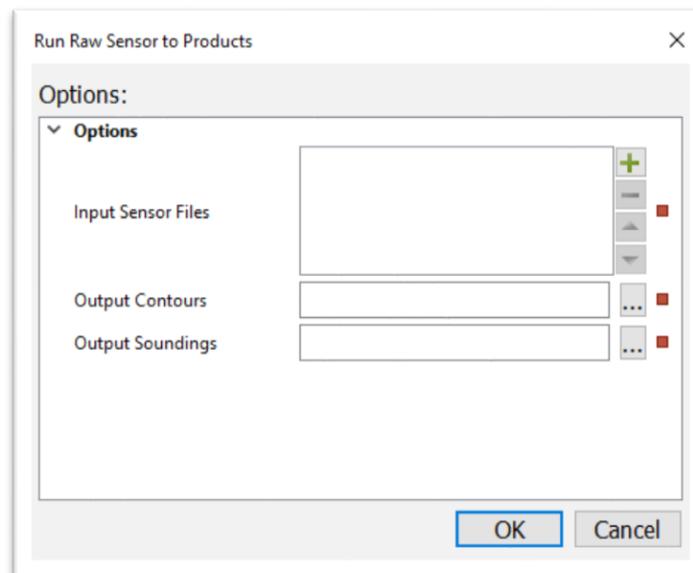


Figure 5 - User Prompts when Running a Model

One navigational product in particular that benefits from an automated approach is bathymetric Marine Information Overlays (also referred to as bMIOs, bENCs or

bIENCs). These high precision products are used in high traffic or high-risk areas where demand to accommodate deep draught vessels requires very accurate and up to date depth modeling. These products complement and augment an ENC; they do not replace it. The bathymetric features are provided at a much higher resolution than a traditional navigation chart and typically have a very frequent replacement rate. In some cases, a channel may be surveyed on a daily basis with new bENC overlays also generated daily. In this scenario, an automated workflow is a critical.

Another automated production workflow on the horizon is the creation and maintenance of S-102 Bathymetric Surfaces. These products defined under the IHO S-100 mandate, will meet a similar need as the bENC products but providing a raster surface as the seabed model rather than a vector representation. As with the bENCs, the same need for high accuracy, temporally relevant data is required so an automated production environment is key. The S-102 product specification has been approved by the IHO and there are currently several pilot projects around the world devoted to the creation of S-102 products (Journault 2012).

## Application

Using a small portable USV like the Z-Boat to perform a harbour survey presents many benefits. It is much easier and lower cost to mobilize, and due to its maneuverability, it can easily map in and around the many obstacles that are often present in a marina or harbour. However, conducting a hydrographic survey with a USV does not come without its own set of challenges. The challenges from a data processing perspective tie back to the data being stored on the vehicle, and the first opportunity to begin processing is after the vehicle has returned to base and the data is downloaded off the platform. This introduces a bottleneck in the Ping-to-Chart timeline, and also means there is no coverage and quality feedback loop to be used for operational decision making (Czotter 2016).

To address the data processing challenges related to USV surveys, the first automation stage of the Ping-to-Chart time line is introduced. CARIS Onboard is an automated service running on the platform. Onboard is able to monitor the raw sensor files produced by the acquisition system, and once it detects that the file is finished being written to, it automatically triggers the model defined in the Process Designer. Through this service the first processing stages, as predefined by the surveyor, are all completed on the platform during survey operations. As a result, products generated from the corrected, cleaned, and geo-referenced soundings are available to the hydrographer during operations when this information is most valuable. Additionally, when the platform returns, the data has already had many sensor processing and initial product generation stages completed.

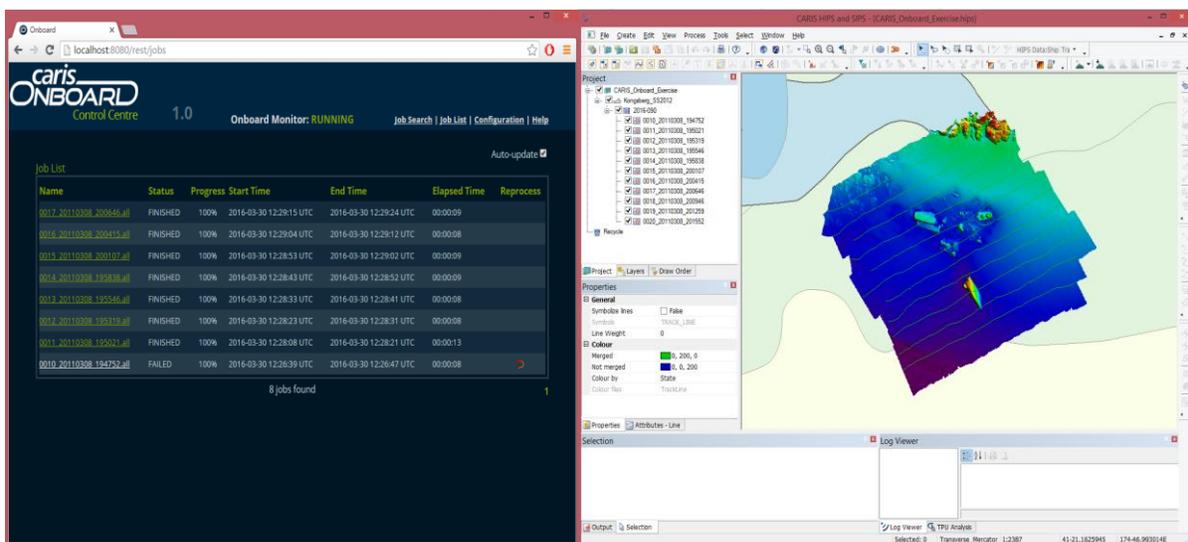


Figure 6 - Left: Onboard Control Centre Right: Remote Surface Connection from CARIS Desktop

During the harbour survey in Antigua, the process model loaded to Onboard (Figure 7) included a series of tools that corrected the data for tidal variations, applied automated

cleaning algorithms, and produced a gridded bathymetric surface (using the CUBE algorithm).

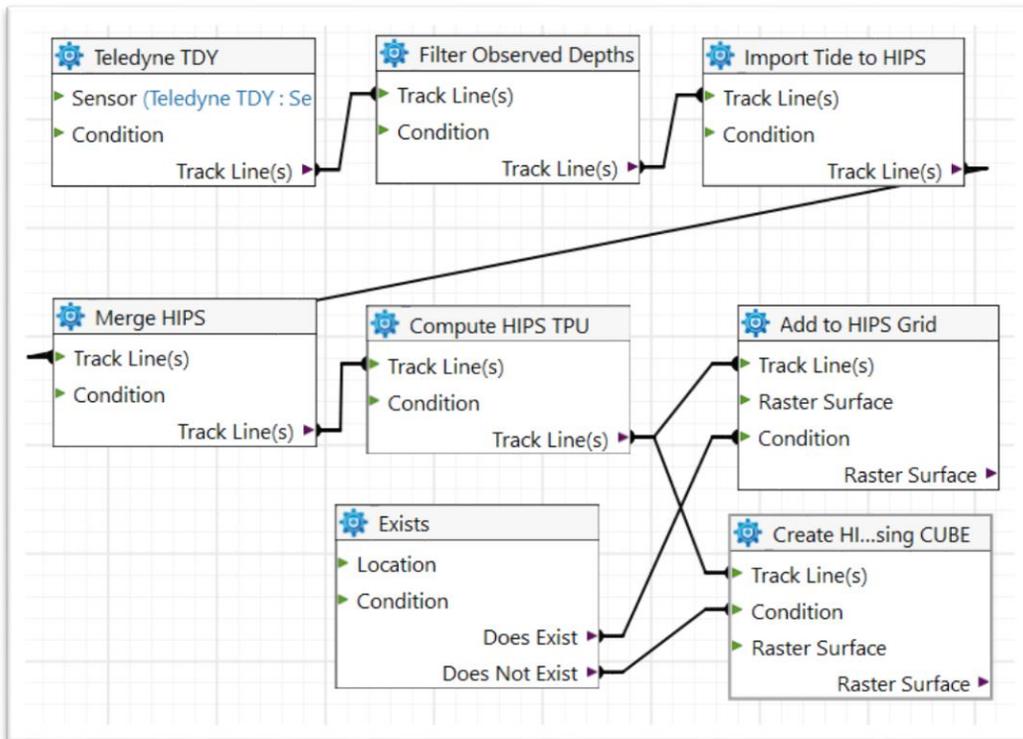


Figure 7 - Onboard Process Model

The CUBE surface generated by Onboard was available to the shore-based operator through a remote connection in HIPS and SIPS, allowing them the ability to make informed operational decisions. At the end of the survey, the complete HIPS project and CUBE surface were downloaded from the platform. Through this workflow, rather than starting with raw data, the data processor only had to perform quality checks on the project before finalizing the surface and triggering the product generation stages of the Ping-to-Chart workflow.

The processing stage is now complete and the output from the automated process is a raster surface. Figure 8 shows the steps automated in the Ping-to-Chart workflow. In this case, post-processed positioning was not applied, and predicted tides were used in acquisition.

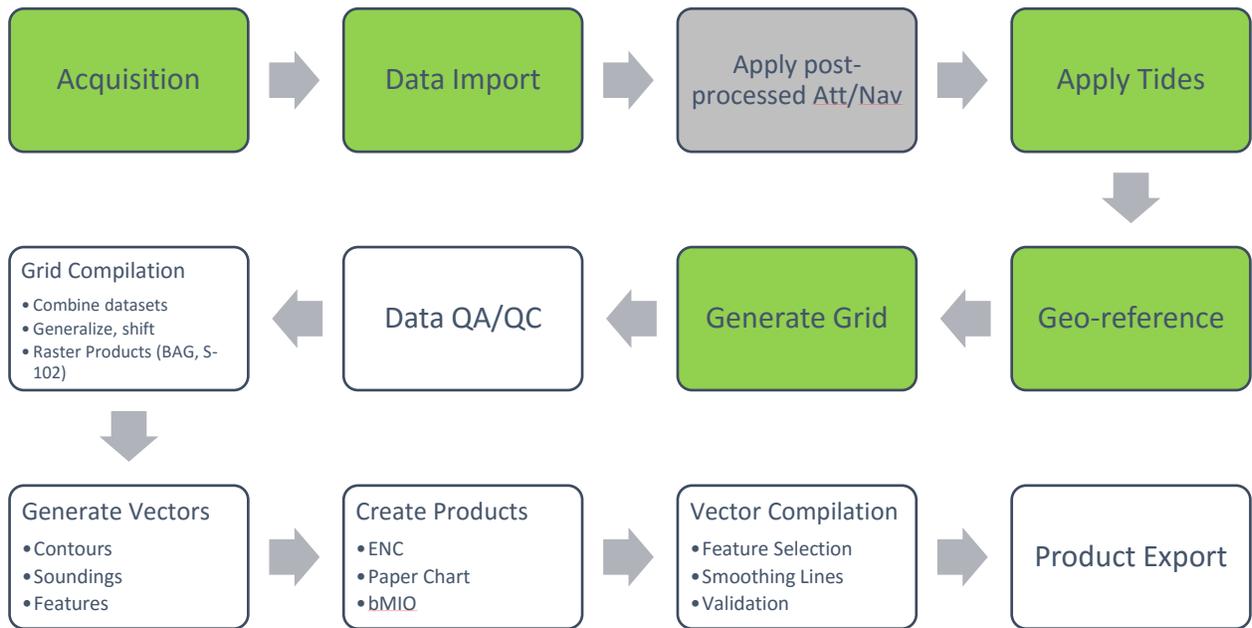


Figure 8 – Ping-To-Chart, Initial Automated Steps (green), Skipped Steps (grey)

At this stage, human input may be beneficial; a person could pause the automated workflow to QC the results of the processing in the HIPS application. In this case, there were areas with mis-tracking that the CUBE algorithm dealt with in a less than ideal manner, so this is an opportunity for the operator to validate and reprocess if required.

From the clean and validated raster surface, the automated workflow can resume, making use of the tools in the BASE Editor and Compose modules in BDB. In order to generate bathymetric features that are appropriately down-sampled for a specific chart scale, the operator can either generalize the surface or generalize the contours generated from the raster surface. Some other preparation may be required to fill holidays in the surface, adjust the vertical reference datum or integrate data from other sources such as shallow water LiDAR. In most cases, these data preparation tasks incorporate easily into the automated workflow.

The workflow shown in Figure 9 follows generalization of the surface through to the creation of a S-102 Bathymetric Surface and simultaneous production of a bMIO overlay.

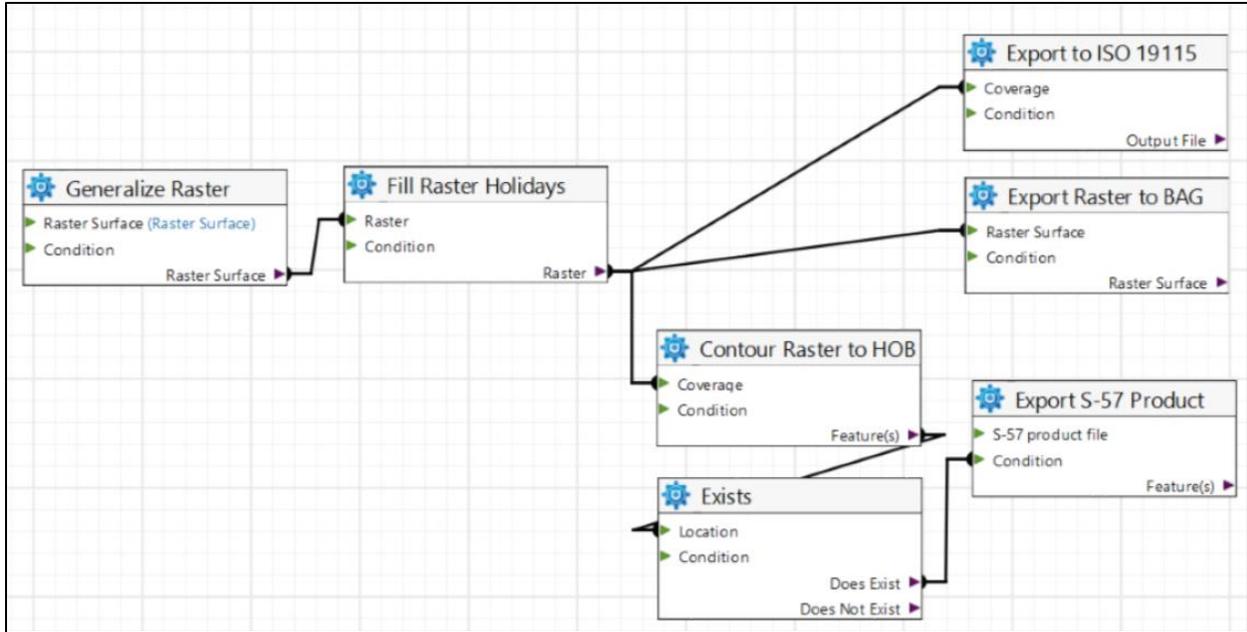


Figure 9 - BASE Editor and Compose Process Model

In this case, the contour and depth features required some further preparation so the workflow was augmented with line smoothing (Figure 10).

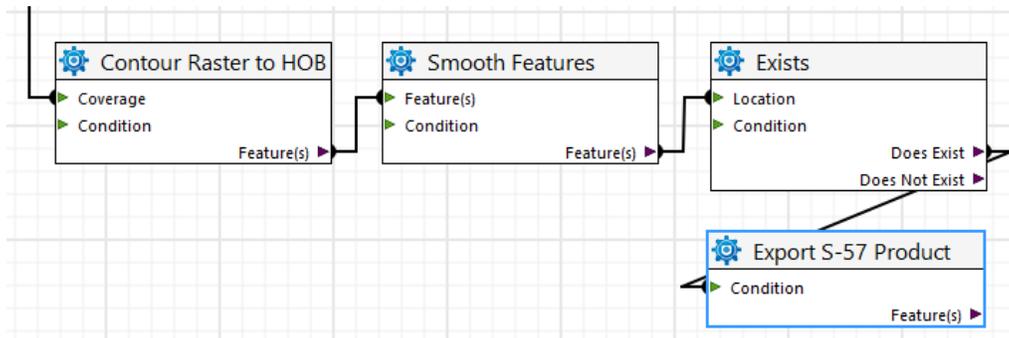
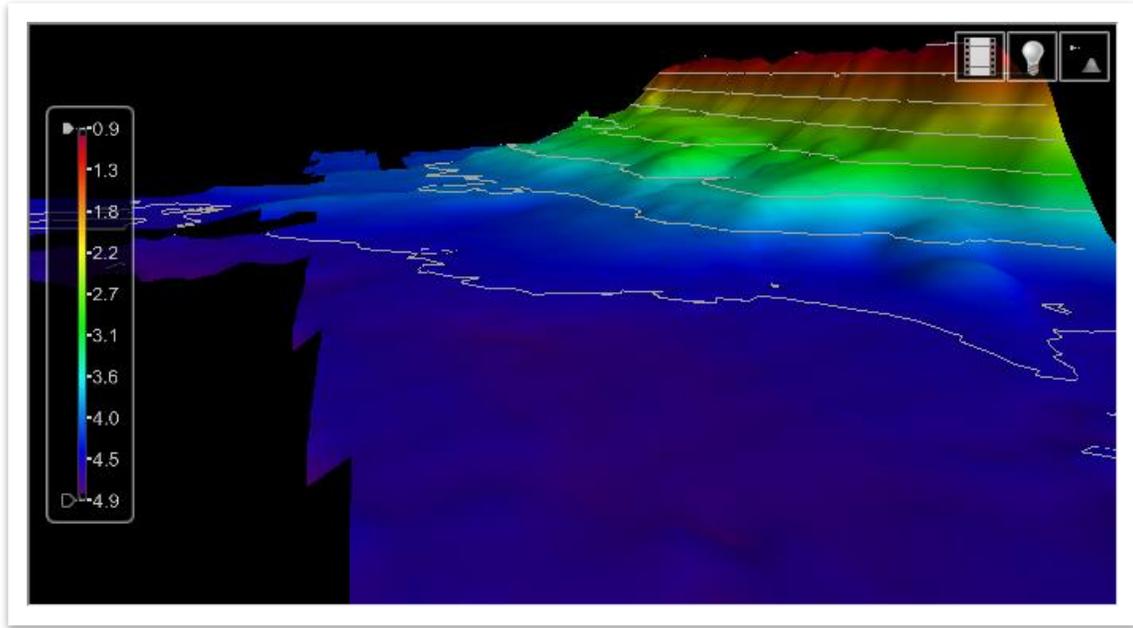


Figure 10 - Smoothing Process Added to Workflow



*Figure 11 - High Resolution Contours Draped on S-102 Surface in 3D*

At this stage, we have automated a significant portion of the full Ping-to-Chart workflow using 3 models in the Process Designer (Figure 12). Note that parts of the workflow such as Data QA/QC, choosing a product to create, and some subsequent vector compilation need human intervention and cannot be automated.

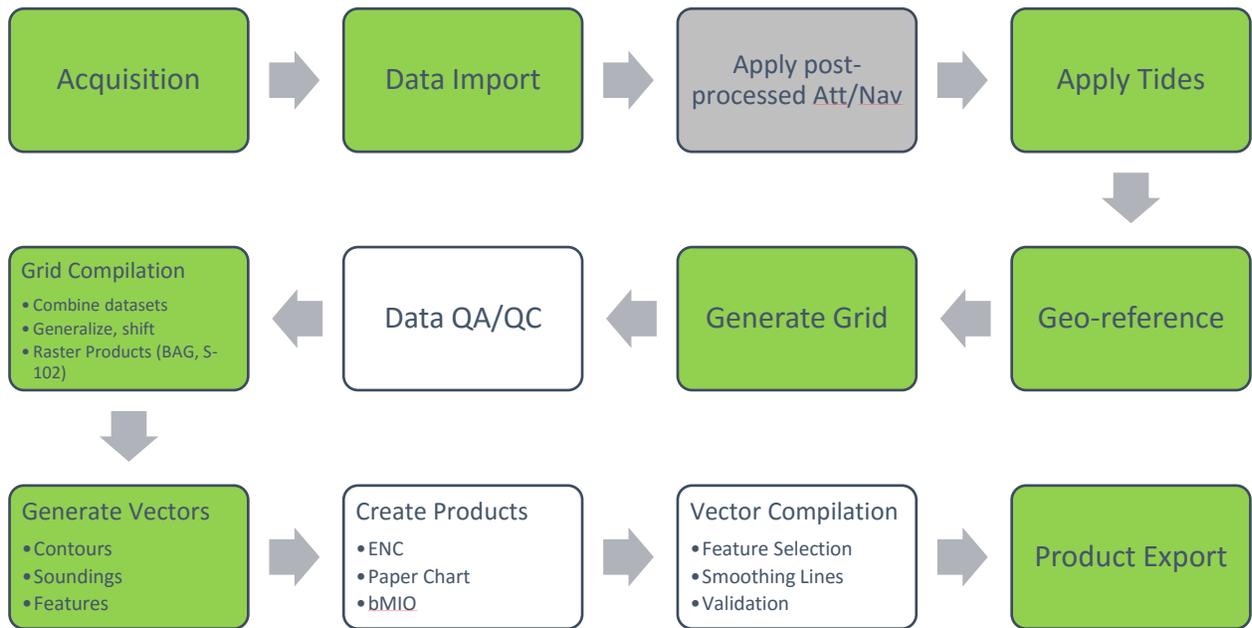


Figure 12 - Ping-To-Chart, Initial Automated Steps (green), Skipped Steps (grey)

The purpose of the workflow for the 2015 survey in Jolly Harbour was to create an updated navigational product. In this case it was a sounding selection overlay from high resolution bathymetry that could be used as an updated paper chart (Figure 13). The bathymetric features generated during this automation exercise were proven to serve the same purpose, and therefore can also be used to provide the basis for updated bathymetry for the paper charts and ENCs in the area.

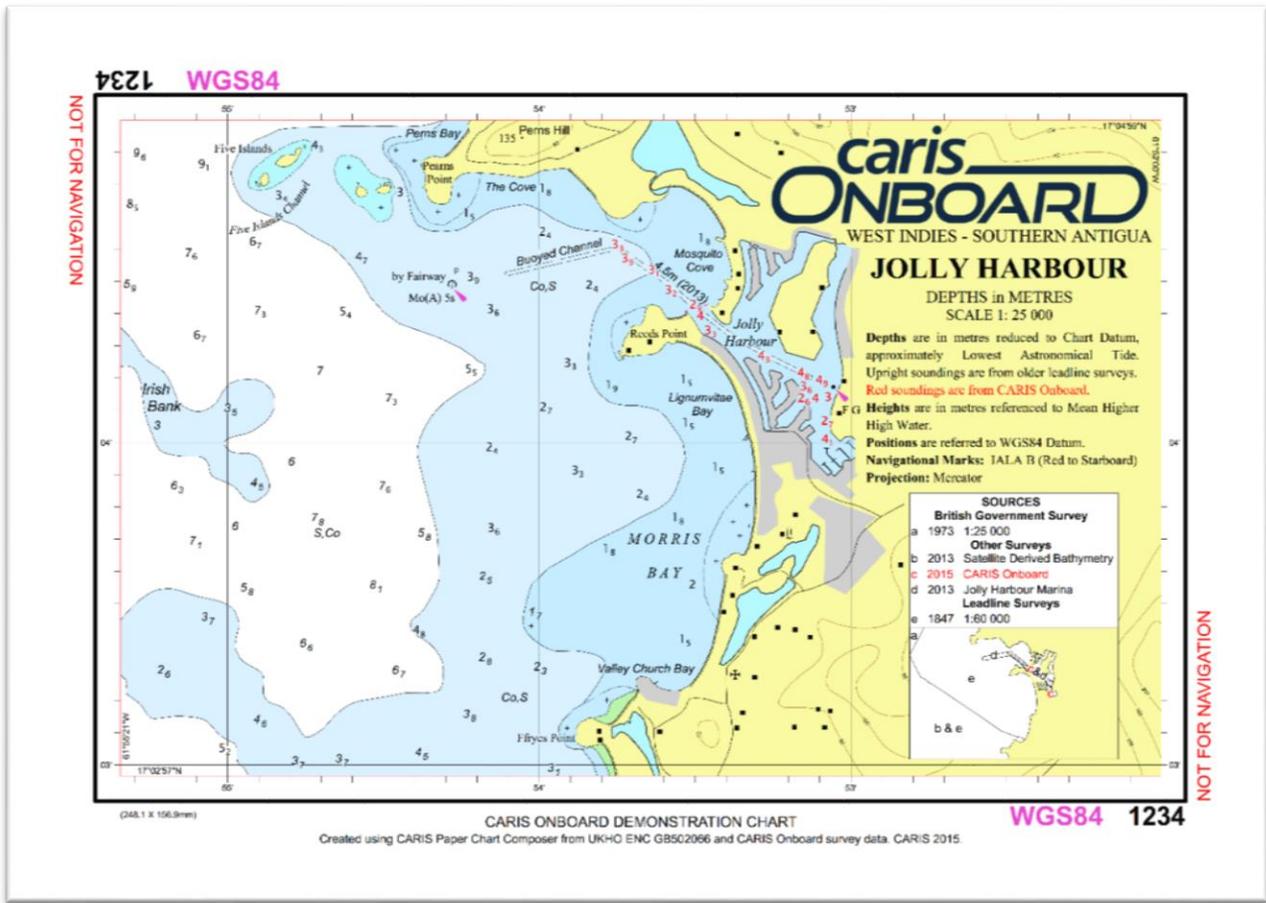


Figure 13 - Paper Chart Updated with New Vector Products

## Conclusion

The Ping-to-Chart workflow encompasses all of the complexity of moving raw data through intermediate QA/QC products, and into finalized electronic and paper products. While these surveys can be quite complicated endeavors, the business logic behind the Ping-to-Chart workflow is well understood. Applying this business logic through automation brings new efficiencies to end users.

The ports and waterway user space has particularly well defined business logic, and their success often depends on having quick product turn around to ensure vessels are navigating based on the most up to date information. Through the automation tools available in CARIS software, the majority of the workflows can be automated, while facilitating human input where required, resulting in time saved and faster turnaround from acquisition to product. The Process Designer is a flexible, intuitive, and comprehensive window into the vast toolkit available in CARIS software. With this tool, knowledgeable operators can chain together complex workflows that request a minimum of input from the end user, reducing the workload on that end user and reducing the chances for mistakes in the data processing chain.

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