ADVANCES IN PRACTICAL MULTIBEAM SONAR AND DATA PROCESSING TECHNOLOGY

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INTRODUCTION

This presentation will give an in-depth exposition of some recent advances with respect to underwater acoustic sensor technology, with adjoining software solutions for on-line data quality control, data processing and data presentation/interpretation.

1. SONAR TECHNOLOGY
1.1 What is a SeaBat 8101?

The SeaBat 8101 is one of the MultiBeam Systems within the SeaBat 81 series Sonar Systems.
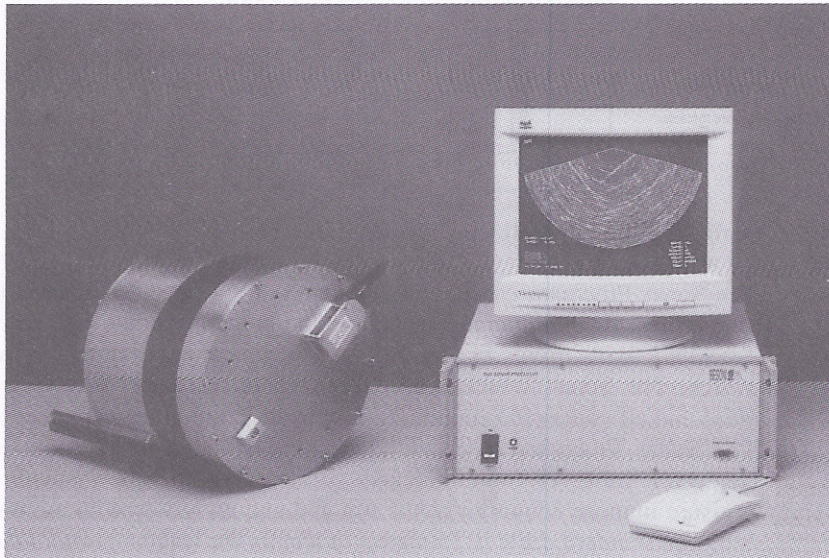

Fig. 1, SeaBat 8101 System

The SeaBat 8101 is a 240 kHz Multibeam Echosounder (MBES) System, which measures the relative water depths across a wide swath perpendicular to a vessel's track.

The design of the 8101 is a result of years of experience gained from RESON's successful SeaBat series of MBES systems and is intended to be quickly and smoothly integrated into existing hydrographic systems, using interface architecture common to the entire SeaBat 81xx series.

The five standard components of the 8101 system are:
- Sonar Processor (topside or dry end)
- Sonar Processor to Sonar Head Signal and Control cable.
- Sonar Head (wet end)
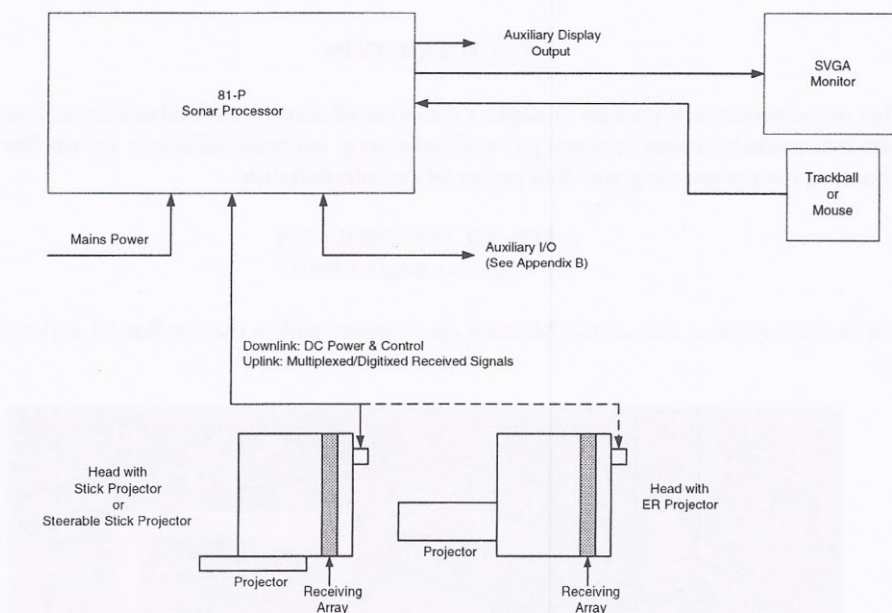- Color (S-VGA) Monitor
- Trackball

Fig. 2, SeaBat 8101 System Block Diagram

- The Sonar Processor can be rack mounted in the operating space. There is no requirement for the operator to handle the processor other than to connect the Trackball to its front, or rear, panel and operate the system Power On/Off switch. The Sonar Processor is the source of operating power for the Sonar Head and all system I/O connections are made at the processor's rear panel.
- The Sonar Processor to Sonar Head Signal and Control cable is a multi-conductor cable of water-blocked construction with a molded waterproof pressure immune connector at the wet end and an MS-type connector at the dry end. The standard cable is 25 meters in length; for lengths greater than standard, contact RESON.

- The Sonar Head is compact, with no moving parts. It may be temporarily mounted on a retractable structure, such as a bracket or pole, or permanently on an extension through the hull in a moon pool, sea-chest configuration, or on a Remotely Operated Vehicle (ROV) . The head is available in a titanium alloy depth rated to 1500 meters and anodized aluminum with depth ratings of 100 and 300 meters.
- The Color (S-VGA) Monitor is a standard PC-type SVGA monitor and should be table mounted with sufficient working area to accommodate the Trackball.
- The Trackball (or mouse) is a standard off-the-shelf three button unit.

1.2 How Does the SeaBat 8101 Work?

The transmit array (projector) section of the Sonar Head transmits a pulse of acoustic energy, which travels through the water medium and is reflected by the sea floor, or any objects in its path. The reflected signal is received by the receive array (hydrophone) section of the Sonar Head, digitized by internal electronics, sent to the topside Sonar Processor for beamforming and processing. The Sonar Processor generates the video displayed on the monitor and functions as the control interface between the operator and the sonar system as well as formatting a digital output to be used by a peripheral bathymetric data processing system.

1.3 How Far Does the SeaBat 8101 "See"?

480 meters is the maximum selectable range scale. The 8101 system illuminates a swath on the sea floor that is 150° across track by 1.5° along track. The swath consists of 101 individual 1.5° by 1.5° beams (the 210° Option uses 141 beams) with a bottom detection range resolution of 1.25 cm. The system was designed to International Hydrographic Organization (IHO) standards to measure the seafloor to a maximum range of 320 meters.

If equipped with the Extended Range projector (Option 040), this range increases to 450 meters. Refer to Chapter 4 for additional information on this option. Option 040 is standard on all deep-water versions of the SeaBat 8101 (those rated to 1500 meters submergence depth, or more).

1.4 How Much Seafloor Does it Measure?

With an across track subtended angle of 150°, The SeaBat 8101 measures a swath width of 7.4 times the water depth, when in depths of 1 to 70 meters. At depths greater than 70 meters, the ratio of water depth to swath coverage decreases, as noted in Table 1 (all calculations assume the center of the swath to be vertical).

Table 1, Seafloor Coverage

Depth in meters	Coverage (x water depth)
1-70	7.4
70-100	4.2*
100-150	2.7*
105-200	1.6*
200-250	1.8*
250-300	1.3*
	* typical value

2.HARDWARE COMPONENTS

The five major components of the SeaBat 8101 system are described below

Sonar Processor
- Sends DC power to the Sonar Head via the Signal and Control cable.
- Sends control signals to the Sonar Head.
- Receives and demultiplexes digitized hydrophone signals from the Sonar Head.
- Beamforms the received hydrophone signals.
- Manages seafloor bottom detection.
- Processes the bottom detection data for local display.
- Processes the bottom detection data for export to peripheral systems such as bathymetric data acquisition systems via an RS-232 interface or Ethernet connection.
- Receives and processes operator input.
- Generates the graphical display.

Processor to Head Signal and Control Cable
- Waterproof pressure-immune connector at wet end.
- Single MS-type connector at dry end.
- Conducts operating power for Sonar Head electronics.
- Conducts control signals for Sonar Head electronics (downlink).
- Conducts multiplexed digitized hydrophone signals to the Sonar Processor (uplink).
- Shields internal signals from vessel electrical noise.

Sonar Head
- Converts received DC power from the Sonar Processor to circuit operating voltages.
- Generates and transmits acoustic pulses via the transmit array (projector).
- Receives reflected acoustic signals via the receiving array (hydrophone).
- Preamplifies and digitizes received acoustic signals.
- Multiplexes and sends digitized received signals to the Sonar Processor via the Signal and Control Cable (uplink).

Color Video Monitor
- Displays received sonar intensity data in operator selectable color palettes.
- Displays processed bottom detection data in real time.
- Displays system status and control menus for operator interaction.

Trackball
- This three-button device enables operator selection of menus, menu items, and status and control functions.
- Trackball connectors are available on the front and rear panel of the sonar processor. These connectors are wired in parallel; simply connect the trackball to the most convenient connector as there is no requirement to select either connector.

2.1 81-P Sonar Processor

The 8101 Sonar Processor is the power, signal, and data distribution point for the 8101 MBES system. The internal electronic configuration is a multiple processor environment consisting of CPU, DSPs, and FPGAs. The system operating software resides in the Sonar Processor and, at power-on, downlinks configuration parameters to the Sonar Head (both the Processor and Head store their firmware in easily upgraded flash memory).

The power supply assembly auto-senses mains voltage to accommodate 90 to 260 VAC and produces the various DC voltages required by Processor and Sonar Head.

The Sonar Processor demultiplexes the signal uplinked from the Sonar Head, applies amplitude and phase adjustments, and distributes these signals to the beamforming processor. Other Sonar Processor functions include: bottom detect management, image processing, graphics processing, and I/O control. The graphics processor produces SVGA (default) or S-Video. Auxiliary video outputs are RGB or composite. S-Video and the auxiliary outputs can be either NTSC or PAL format (see the following paragraph).

2.2 Display Output Interfaces

Five display formats are available as outputs from the sonar processor: S-VGA, S-Video, RGB (green sync), RGB & Sync, and Composite. S-VGA is the default output and is intended for use with the system's standard 800x600 pixel, 72Hz refresh rate, Super-VGA computer monitor. In the S-VGA mode, all other display video outputs are unavailable. The other video outputs are also available in either NTSC or PAL format.

The selection of NTSC or PAL changes the video output to a television format for VCR recording. This format is incompatible with the system's S-VGA monitor and, therefore, it will be blanked in these modes. However, all other video formats will now be available. If an NTSC or PAL video format is selected, a separate compatible monitor must be used with the system.

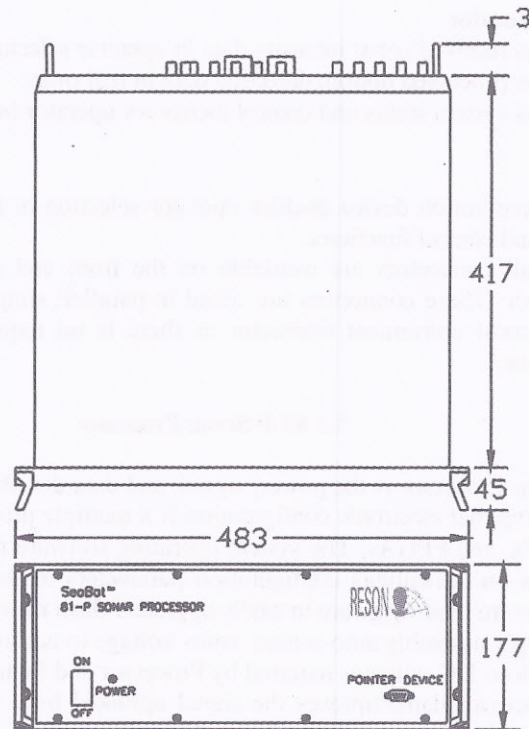The sonar processor will 'remember' the last selected video mode at power-on.

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SeaBat™
81-P SONAR PROCESSOR

RESON

ON
POWER
OFF

POINTER DEVICE

177

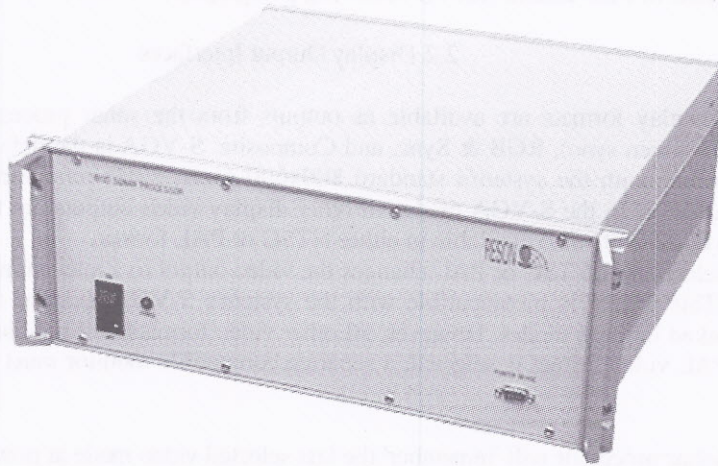Fig. 3, SeaBat Sonar Processor Dimensions (in mm)
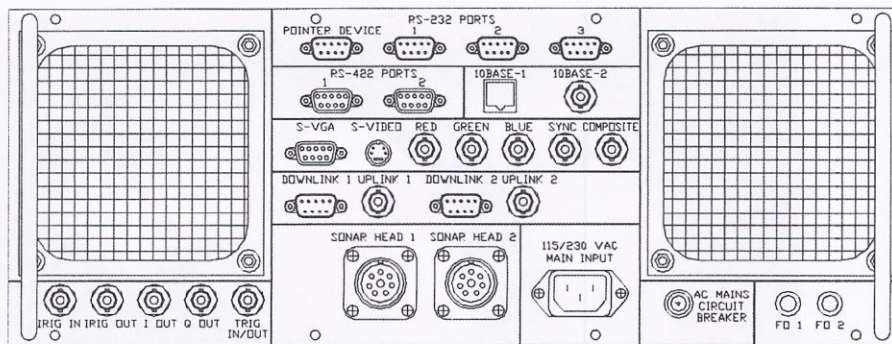
RESON

Fig. 4, SeaBat 8101 Sonar Processor

Fig. 5, SeaBat 8101 Sonar Processor, Rear Panel

2.3 Processor to Head Signal & Control Cable

The interconnection cable between the Sonar Processor and the Sonar Head is of multi-conductor water blocked construction. This cable assembly is supplied from RESON with a molded waterproof pressure immune connector at the wet end and an MS-type connector at the dry end. The standard cable length is 25 meters.

2.4 Sonar Head

The 8101 Sonar Head is the source of high power acoustic energy transmitted into the water and the receiving assembly for the low level signals reflected from targets or other material in the water column. The unit is constructed from either grade 5 titanium or hard anodized aluminum depending on the application.

In addition, the electronics package within the Sonar Head is comprised of:
- DC-to-DC power converter, which changes the supplied 24 VDC input power to the various DC voltages required by the internal electronics, circuits.
- Transmitter circuits to drive the transmit array (projector).
- A TVG amplification stage, followed by analog-to-digital converters required to digitize the received signals from the receiving array (hydrophone).
- Multiplex circuitry to format the uplink data stream.
- A controller that receives and executes downlink commands and controls the transmit repetition rate.
- Diagnostic electronics.

The Sonar Head power supply has been designed to operate ideally at 24 to 28 VDC. However, due to cable losses and the fact that the sonar head may be supplied with power from an external source when mounted on an underwater platform, the unit will function correctly with 20 to 30 VDC input. If the customer-supplied voltages are outside this range, contact RESON Support for additional information.
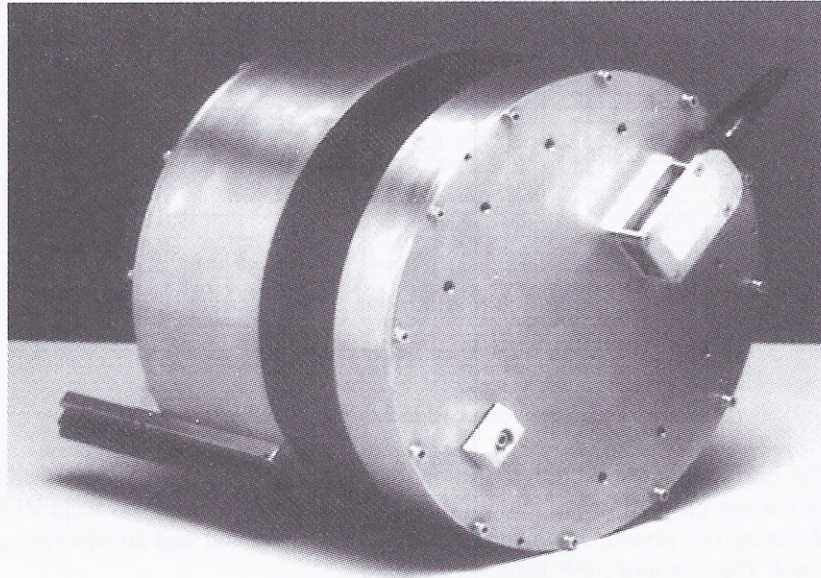
Fig. 6, SeaBat 8101 Sonar Head

2.5 Color (S-VGA) Monitor

The SeaBat 8101 system Color Video Monitor is a standard off-the-shelf PC compatible S-VGA monitor capable of accepting a resolution of 800x600 at 72Hz refresh rate. Other monitors are available as special options.

2.6 Trackball

The trackball supplied with the SeaBat 8101 system is a standard off-the-shelf three-button unit. Please refer to the manufacturer's User's Guide for additional technical information. In the event of damage, or failure, a three-button serial mouse (Logitech, or Mouse Systems) may be used to replace the Trackball. Mouse Systems is the default configuration, although the Sonar Processor will auto-detect the replacement device without the requirement to load software or drivers.

3. DATA PROCESSING AND PRESENTATION SOFTWARE
3.1 Purpose

6041 is a sonar data processing and analysis system. The main purpose of the system is to process and analyze raw data to provide the operator with relevant and clear synthetic information. The definition of this information depends on the field of application. A pipeline surveyor may be looking for free-span while an Autonomous Underwater Vehicle may be looking for obstacles. This information can be displayed, stored or broadcasted depending on the working environment. 6041 can handle data from Multibeam Echosounders (MBES), Side-Looking Sonars (SLS), Forward-Looking Sonars (FLS), MRU, Compass, DGPS and RTK.

Based on a common framework, different applications can be provided, like:

  - Mosaicing
  - Despiking
  - Automatic object detection
  - Automatic pipeline tracking and free-span detection

6041 can work online when interfacing with the 6042 Version 7, or can operate offline. The offline input consists of database files from 6042 and XTF files. Most of these modules run online provided that 6041 runs on a dedicated PC.

6041 provides a complete set of displays that are combined to form more complex visualization tools. The operator can thus easily monitor the performances of the automatic processing.

The processing is performed online in real-time when the 6041 software is connected to the 6042 data collection software. A RESON SeaBat can also be directly connected to the 6041 for specific processing.

3.2 Interfaces

The 6041 software provides a set of input and output functionalities:
Inputs
  - network interface with the 6042 data collection software
  - network interface to the SeaBat sonars
  - 6042 database files
  - XTF files
Outputs
  - GeoTIFF files
  - Terramodel pts files
  - MS Word document automated reporting

Those features are summarized in figure 7.
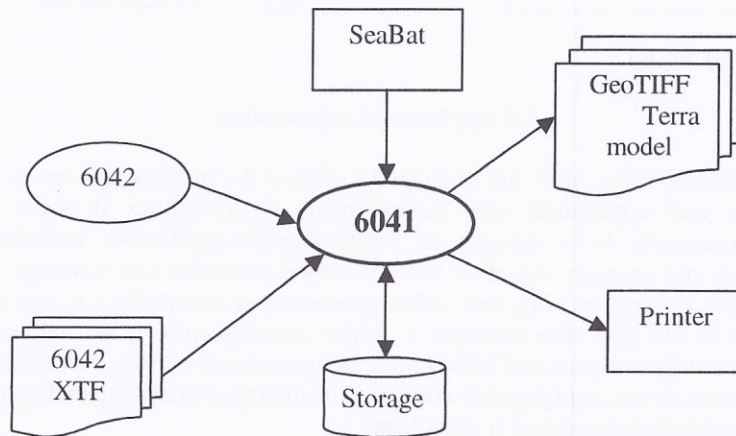
Fig. 7. Interfaces of 6041

3.3 Survey set-up

A typical setup for a survey is presented Figure 8. The 6042 data collection software is in charge of collecting, time-stamping and storing the data from various sensors. The software also broadcast these data over a network to 6041. The use of two computers serves multiple purposes. The first one is an operational requirement. Most surveys involve one operator in charge of the actual conduct of the work while a second operator is in charge of the data analysis. Others issues like CPU loads and available space on the displays are handled in a much efficient and reliable manner using two computers.
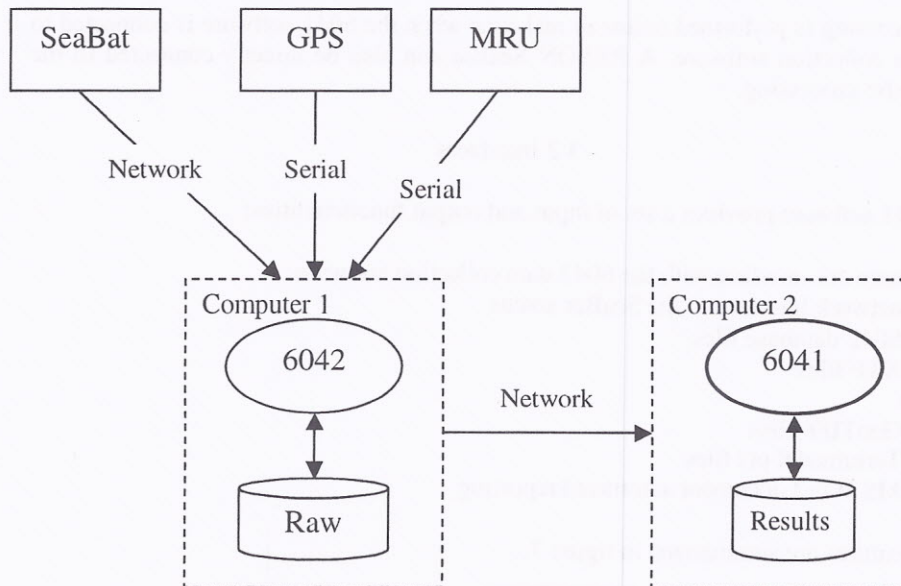
Fig. 8, Survey set-up

3.4 Applications organization

The applications within 6041 are organized to follow the processing steps of a survey. This means that one application may include many functionalities if those could be performed simultaneously. As an example, an "offshore online application" includes pipeline selection, tracking and anomaly detection but also object detection and coverage plot. The separation between online processing and offline processing is essentially a matter of dealing with redundancy in the data. For example a simple coverage plot is an online function, however creating a fully compensated DTM and draping a mosaic implies despiking the data, correcting navigation errors, applying tide correction, resolving overlapping ambiguities. This can only be achieved when the survey is completed.

A typical processing flow is presented in Figure 9. During the online processing the operator selects the pipeline to be processed. This triggers the automatic detection, tracking and anomaly detection process of 6041. While the automated process is working the operator can interact with the software to input his own information like a free-span. All the processing results are stored in a file. Those results can then be further processed offline to merged together separate sections of the same pipeline. This merging triggers the automatic

computation of updated Kps. The final result can then be presented in a map display and send to a plotter. The results of the processing can also be imported into a Microsoft Word document using a specific import function.
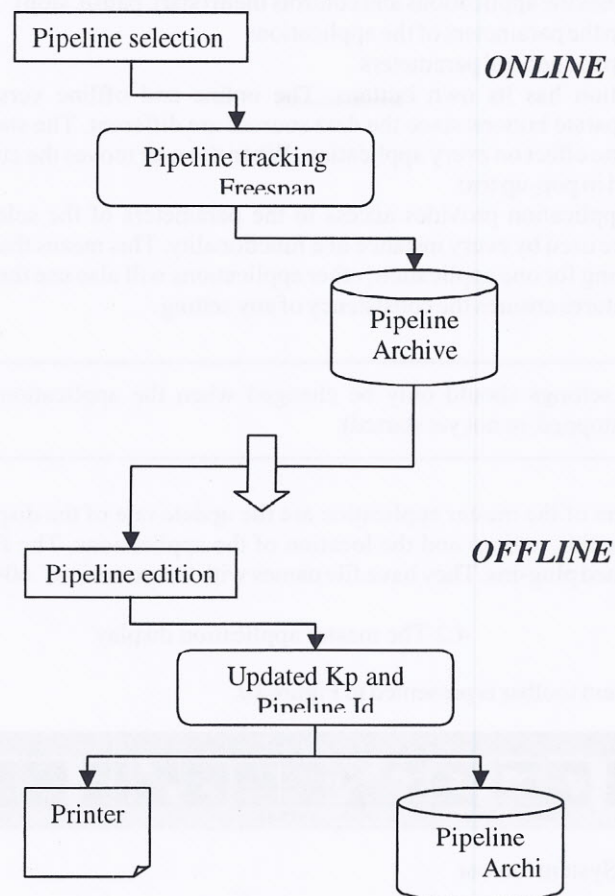
Pipeline selection

ONLINE

Pipeline tracking
Freespan

Pipeline
Archive

OFFLINE

Pipeline edition

Updated Kp and
Pipeline Id

Printer

Pipeline
Archi

Fig. 9, Processing flow of 6041

3.5 Documentation caveats

The toolbox approach of 6041 ensures the seamless processing of the data and provides the user with a consistent interface. It also helps keep every function used at one specific step in one place. This approach has also been implemented in the documentation whenever possible. This means that the common functions will be described in the documentation of each application which uses them.

4. MASTER APPLICATION
4.1 Functions of the master application

The master application serves three purposes:
- Launches the applications and controls them (start, pause, stop)
- Sets up the parameters of the applications
- Sets up the general parameters

Each application has its own buttons. The online and offline versions of the same application have separate buttons since the data sources are different. The start, pause, and stop buttons have the same effect on every application. When the user moves the cursor over a button, its name is displayed in pop-up text.

The master application provides access to the parameters of the selected applications. These parameters are used by every instance of a functionality. This means that if a user modifies the value of one setting for one application, other applications will also use the modified value of that setting. This features ensures the consistency of any setting.

NOTE: The settings should only be changed when the application is not running (i.e., paused, stopped, or not yet started).

The parameters of the master application are the update rate of the display windows (any display can override this setting) and the location of the applications. The files defining these applications are named plug-ins. They have file names with the extension ".6041".

4.2 The master application display

The 6041 system toolbar is presented in Figure 10.

Fig. 10, 6041 System toolbar

The actual list of button (hence applications) may vary according to the functionalities included in the version of 6041. Table 2 summarizes the existing applications.

	Allows the user to launch an application by choosing its plug-in from a file browser (filenames with the extension "6041")
	Accesses the general settings
	Accesses the settings of the current application
	Launches the Object and/or Pipeline Processing application
	Launches the Threshold Tuning application
	Launches the Mosaic application
	Launches the DTM Generation application
	Launches the XYZ Generation application
	Launches the Despiking application
	Launches the Pipeline Editor application
	Launches the Export application
	Starts the processing of the current application
	Pauses the processing of the current application
	Stops the processing of the current application
	Provides information about the 6041 software

Table 2, List of applications

5. DATA SOURCES
5.1 Introduction

6041 is designed to work online in real-time. In this mode the data are coming from network connections to data collection software running on separate computers. 6041 can also work offline. In this mode the data is read from files. Some applications like the

"threshold tuning" work in both modes while others like "despiking" work only offline. The data source must thus be chosen accordingly. Furthermore 6041 is able to process data from various acoustic sensors collected using different software. SeaBat data are collected using the 6042 software while the Klein data are collected using a dedicated RESON software in combination with the 6041 and the 6042.

5.2 Offline import

6041 reads data from 3 different file formats. Files with extension ".db" are created by the 6042 software. These files are the primary source of data for offline applications. Files with ".xtf" extension can also be read. Both file formats allow the storage of raw data from SeaBat systems (both bathymetry and sidescan data) as well as ancillary sensors. Files with extension ".ksd" are created by the 6041 to store raw Klein sidescan data as well as dedicated ancillary sensor information. Klein data import

For the time being 6041 works online only with Klein data. In this mode the 6041 also serves as a data logging software. Each online application has a data saving functionality.