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(U) OVERALL DESCRIPTION OF AN ANALYSIS AND SIMULATION TOOL FOR ACOUSTIC ASW SENSORS

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Director of Research

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b)	Evaluation tool	b)	Evalueringsverktøy
c)	Analysis	c)	Analyse
d)	Simulation	d)	Simulering
e)	Anti Submarine Warfare	e)	Anti-ubåtkrigføring

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8) ABSTRACT

This report describes the sonar analysis and simulation to be performed by the ASW sonar and combat system evaluation tool. The tool will be developed in FFI project 849 SIMSON, and will be used in analysis of properties and performance of the active ASW sonars of the Fridjof Nansen class frigates. This also includes the helicopter dipping sonar. The analysis will be based on recorded sonar data and reference data. To facilitate detailed study of algorithms, parts of the processing chain of the sonars will be implemented. Simulation of sensor data based on detailed environmental input, will aid the understanding of the sonar performance, and allow sensitivity studies for different parameters settings and environmental conditions. The most commonly used processing modes of the sonars will be analysed and simulated. A module for realistic sonar simulations will be delivered for implementation in the Action Speed Tactical Trainer.

The solutions for analysis and simulation will be further detailed in the development process eventually leading up to the implementation of a complete evaluation tool. The process is composed of specifying requirements and detailing the design solution before implementing the software solution.

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CONTENTS

(U) OVERALL DESCRIPTION OF AN ANALYSIS AND SIMULATION TOOL FOR ACOUSTIC ASW SENSORS

1 INTRODUCTION

The Royal Norwegian Navy (RoNoNavy) is acquiring five new frigates, the first will be entering service in the year 2005. The goal of the navy is the best possible exploitation of on board equipment involved in the ASW process. To achieve this goal, the FFI project 849 SIMSON is employed in strengthening the ability of the RoNoNavy and FFI to simulate and evaluate underwater warfare systems and ASW operations. This is to be capable of conducting realistic considerations with respect to effectiveness and tactics in addition to new concepts for underwater warfare. Emphasis will be on complex and coordinated analysis of ASW operations involving both frigates and submarines.

Subproject 1 (DP1), Simulations of acoustic ASW sensors, will concentrate on detailed modelling, analysis and simulations of the sonar systems in a most realistic environment as possible. A goal is also to generate realistic sensor data into the tactical trainer at the training centre at KNM Tordenskjold at Haakonsvern in Bergen.

An underlying goal under DP1 is to develop software for systematic survey and analysis of the performance of the new frigates' ASW-sensors in different scenarios. This is required in order to develop realistic simulations tools. This report describes the range of applications and properties for such an analysis and simulation tool software system. The ASW-sensors included will be the Hull mounted sonar (HMS), the active towed array sonar (ATAS) and in addition the helicopter based dipping sonar.

The analysis and simulation tool for the sonars will be developed together with the analysis tool for the whole ASW combat management system to be developed. The combat management evaluation tool system is described in (7).

This report gives the initial description of the intended use of the analysis and simulation tool (Milestone 1.1.1 and 1.4.1) and also some of its properties. And covers the first reports of *Workpackage 1.1 User need and specifications* and *Workpackage 1.4 Simulation of sonardata in realistic scenario*. The other workpackages in DP1 are *WP1.2 – Map and analyse sensorperformance*, *WP1.3 – Modelling the sonar processing chain*, *WP1.5 – LYBIN (Acoustic predictions)*. See (1).

Chapter 4 gives a description of the overall functionality of the tool. A more detailed description of analysis options is given in chapter 5. In chapter 6 the simulation output of the tool is described. A first description of the "layout" of the tool is given in chapter 3 and 8.

2 MOTIVATION

The motivation for the final version of the analysis and simulation tool is development of tactics for the Nansen-class frigates. Testing the performance and effectiveness of using different processing modes and parameter settings is included in this in addition to finding the preferred modes and parameter settings according to the actual situation. The tool is also believed to play an important role in the technical and operative evaluations of the new frigates, where it will be used for the testing and evaluation of sonar processing and ASW-operations.

As the tool includes contribution from both environmental data such as bathymetry and acoustic simulations, it will enable the operators to find close to optimal operation of the sonar resources given realistic conditions.

More concretely, the tool will consist of one or more computers, including databases for environmental data, analysis tool for recorded sonar data, off-line processing capacity with possibility for flexible choices of parameters and algorithms, simulations of sonar data and sonar performance. The software is intended to run in conjunction with a tactical trainer for the testing of ASW tactics in realistic environment. The software may also be used for the post analysis of sensor performance during ASW operations and exercises.

3 OVERALL DESCRIPTION OF ANALYSIS AND SIMULATION TOOL

The figure below describes the layout of the analysis and simulation:

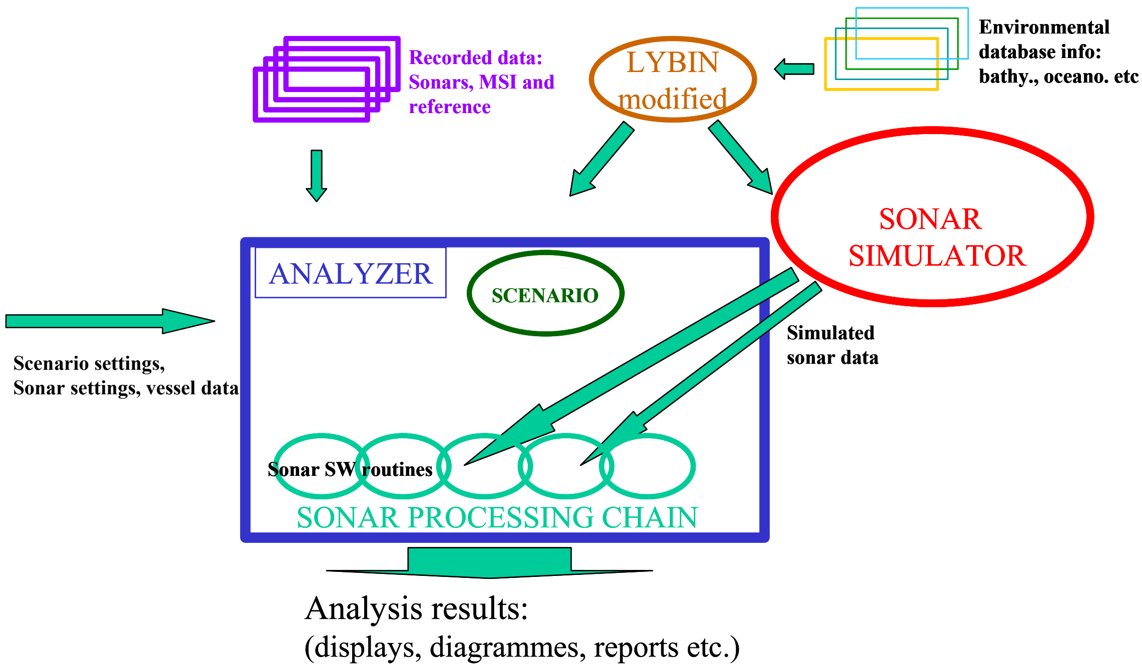

Figure 2.1: Layout of analysis and simulation tool

Basis for the analysis is recorded sonar data and reference data from units involved in an exercise or experiment. The sonar data are recorded at different processing levels. To get an overview, recorded data are visualized and presented together with reference data and environmental data. The performance is measured by comparison with reference data. In order to explain the variation in performance, recorded sonar data are compared with simulated sonar data. The simulations will be based on our best knowledge of the environment (like direct measurements during the trial, forecasts or database information). We are also interested in investigating the performance in situations where recorded data are not available. (example: another pulse type, tilt, sonar depth, or even in a different season or in a different area). We then need to simulate/generate the scenario settings and the sonar settings and we simulate sonar data from the sonar simulator. To be able to assess the performance of the different processing algorithms, a full sonar processing chain for the most common active sonar processing modes will be implemented in the analysis tool. Different processing algorithms and parameter settings can then be tested. If available, software from the vendor will be implemented.

The analysis tool is built around several simulators. The sonar processing chains may not be complete as the availability of original frigate software is limited. To compensate for this, alternative algorithms must be implemented. Thus simulating signal-processing components. To run through the sonar processing chain, not all required data will be available from recordings. One therefore has to simulate or synthesize some sonar data. For this, processing of an acoustic model must be included to simulate the effect of the medium on the sound. While running the analyser in the synthesized data mode, a scenario simulator must also be included. A scenario simulator must provide the position and dynamics of all involved vessels. This is to achieve realistic processing through a scenario.

A description of required input data and output is given.

3.1 Recorded data

3.1.1 Sonar data

Input to the analyser is the recorded data from the sonars or prototypes of the FN-class' sonars. The optimum is recorded sonar data for a complete run including data from the all bearings and complete range for each ping. The recordings will be of different formats at the following processing output levels:

<u>HMS (Spherion MRS-2000)</u>
hydrophone timeseries (all hydrophones)
beamformed data (what is available)
normalized matched filter o/p (all beams)
echo data (ref. (4))
track data
audio data (demodulated)

<u>CAPTAS</u>
hydrophone time series (all hydrophones)
beamformed data in frequency domain, 256 channels covering TX-pulse frequency, 12 adjacent beams (not available when performing adaptive beamforming)
non-normalized matched filter o/p (12 adjacent beams)
echo data (detections)
track data
audio data

<u>Dipping sonar</u>
hydrophone timeseries (if available)
beamformed data (if available)
matched filter o/p (if available)
echo data (if available)
track data (if available)
audio data (if available)

A more detailed description of recorded sonardata will be given in a separate report (reference SIMSON milestone 1.2.1, see (1))

3.1.2 Reference data

By reference data we usually mean accurate position, speed, heading of involved vessels. Reference data from own platform could also include status of systems possibly influencing sonar performance; engine mode, machinery noise, manoeuvring, use of other systems like underwater telephone, decoys etc.

In cases where sonar data are recorded, it is just as important to record GPS-positions of vessels in the area including radar tracks of vessels for which GPS-positions are not recorded.

It is important that most of the sea trials are conducted at locations where the access to detailed and updated environmental data are guaranteed.

3.1.3 Other recorded data

When possible information of the environment should be recorded. This includes data from weather stations, probes measuring the sound speed profile, observations of weather, sea state, observations of ships.

Important for analysis is also contact information on a tactical level (in the combat management system or at link level). Subproject 2 of SIMSON will be involved in the analysis of information on tactical level.

3.2 Environmental data

By the term environmental data it is meant bathymetric, oceanographic and meteorologic data. The data should be of best possible resolution available and should cover the complete area of the scenario. The maximum range of the sonar should at any time be within the scenario or the extent of the environmental data. If available, other bottom characteristics than depth should be included as well as any non-sub database data.

Again, if possible, the sea trials should take place in areas where detailed and updated environmental data are guaranteed. The access to environmental data necessitates cooperation with the FFI-projects SWASI-3 and METOC.

A more detailed description of required environmental data will given in a separate report (ref milestones 1.1.2 and 1.4.2, see (1))

Examples of required environmental data are:

- Bathymetry: Both as vector based maps 2-D visualisation and digital elevation data for 3D- visualisation and input to acoustic model.
- Oceanography: Vertical distribution of sound speed is needed as input to acoustic model. The datasource can be measurements, climatologic data or forecasts.
- Wind and wave heights: Needed for acoustic model. Datasource can be visual observations, measurements, climatologic data or forecasts.
- Sediment: Needed for acoustic model. Sparse data are available in international databases.
- Non-sub: Example of objects is wrecks, pipelines and other underwater installation. Also positions of previous reported unexplained sonar contacts should be available for the tool.

A requirement of the SIMSON tool is to be capable of analysing operations and sonar performance not only in Norway, but also in areas where international operations are conducted. This implies that the tool will be used also when no environmental data are available or when only low resolution environmental data are available.

3.3 Operator inputs

The operations of the analysis require the following inputs before processing:

- Type of operation/analysis
- Loading of scenario (in case the analyser is operated as stand-alone mode as opposed to connected to a trainer/simulator generating scenario data on its own)
- Specification of output format; textual reports, graphs, diagrams, display output, data

3.4 Output format

3.4.1 Textual reports

This format type is dedicated to table listings, performance comparisons, scenario descriptions etc. Examples are the listing of GPS navigation data, track listing of a single track or multiple tracks, algorithm status and situation descriptions.

3.4.2 Graphs and diagrams

Graphical presentations such line plots, bar graphs, surface plots etc should be possible. The quality of such output must be so that it can be included in reports and presentations as a minimum. One has to take this into account when using colours and dots/line thickness.

3.4.3 Display outputs

Results of the analyses should also presented on displays and this again printed out using dump screen. The analyser will be fitted with two displays; one representing a tactical display with geographically related information mostly. The other display is more a technical display for operator instructions, data listing and graph plotting display.

3.4.4 Data output

Binary or ASCII data resulting from processing will also be output. Such information should be storable on single files, file databases also storing recorded data or as files readable to MS Excel.

4 OVERALL FUNCTIONALITY

The system will be operation in two main modes:

- Analysis Main Mode (AMM)
- Simulation Main Mode (SMM)

In the analysis main mode, the operation mode alternatives are:

1. Analysis of attitude compensation
2. Analysis of beam forming algorithm/beam discrimination
3. Analysis of left-right ambiguity
4. Analysis of matched filter processing
5. Analysis of normalization
6. Analysis of detection
7. Analysis of post detection processing
8. Analysis of target tracking algorithm
9. Analysis of kinematic examination
10. Analysis of false alarm reduction effectiveness
11. Analysis of transmission loss estimation

12. Analysis of reverberation and ambient noise
13. Analysis of self noise
14. Analysis of probability of detection/signal excess
15. Analysis of spatial variability
16. Analysis of bottom properties
17. Analysis of local curvature of the topography relative to the position of the sonar

In the simulation main mode, the operation mode alternatives are:

1. Simulation of hydrophone data
2. Simulation of audio data
3. Simulation of matched filter output
4. Simulation of echoes/detections
5. Simulation of tracks
6. Simulation of beam forming algorithm
7. Simulation of detector
8. Simulation of target tracking
9. Simulation of false alarm rate (FAR) reduction.
10. Simulation of vessel motion
11. Simulation of scenario

The design of the tool will reflect full flexibility of choosing between the modes.

5 ANALYSIS DETAILS

In this chapter, the sonar analysis performed will be explained in detail.
The analyses to be performed may be listed as:

- General analysis of recorded data from exercises and sea trials
- Analysis of echoes and false contact generating phenomena
- Analysis of bathymetric features causing echoes
- Analysis of synthesized sonar data at different processing levels
- Analysis of sonar processing routines
- Analysis of sonar performance
- Analysis of the effect of combining multiple data types for achieving a higher PD/PFA-rate.

5.1 Analysis of data from sea trials and exercises

The tool will be used for general analysis of recorded sonar data. This is in order to understand the sonar performance and the sonar output of different scenarios and trials. This is for analysis following dedicated sea trials, but also following naval exercises given that sufficient reference data are collected. The primary goal with such analysis is to get an overview of the recorded situation. Possible additional subjects to investigate will be the output of the different processing levels, the sonar conditions for detection and tracking in addition to the overall efficiency of the ASW-task in combination with 5.5 and 5.6. From this analysis, general conclusion of the ASW and sonar operations may be drawn. The effects of sonar processing will also be observed.

5.2 Analysis of echoes and false contact generating phenomena

One major challenge in ASW is believed to be the false alarm rate (FAR). With longer-range sonars such as the Nansen-class' CAPTAS, this challenge is expected to increase in importance. The analysis tool specified under SIMSON will enable investigation of the phenomena causing false alarms (FAs) including the detections/echoes ending up as potential FAs. For this the correlation between bathymetry and/or reverberations must also be checked by plotting the data together and possibly estimating the correlation. For this work, extracting the local curvature of the topography will be required. The goal of this analysis is to investigate what features are causing false alarms. The result is eventually to be used as input for the simulation of sonar data.

5.3 Analysis of bathymetric features causing echoes

The analysis tool is also to be used for investigating bathymetric features causing the generation of echoes. Such features may be edges/ridges, potholes, boulders, slopes and topography which causes sound to be strongly reflected towards sonar platform. For this, detailed visualization of both bathymetry and sonar output for different processing must be done in addition to detailed acoustic model output. Again, extracting the local curvature of the topography is required. The goal is to simulate realistic false alarms with respect to the scenarios the sonars is supposed to operate within.

5.4 Analysis of synthesized sonar data at different processing levels

The realism and effectiveness of the synthesized sonar data needs to be checked. For this, detailed visualization of both bathymetry and sonar output for different processing must be done. The generation of such data in real time is also a critical checkpoint. The goal is to ensure correct and timely sonar data simulation for the sonar simulations to be performed at KNMT, Haakonsvern.

5.5 Analysis of sonar processing routines

One of the core analysis of the project is the analysis of sonar processing routines of all central active modes of the HMS, CAPTAS and dipping sonar. This point also includes the unique processing modes of the different sonars. The goal of this part is to find any weaknesses or room for improvements in the sonar processing chain. The objective is to evaluate the sonar processing of the frigate's active sonars. Input will be either recorded data from tests, or simulated (synthesized) data.

5.6 Analysis of sonar performance

The effectiveness of the sonars in different operational environment is also to be looked into. By environment is meant the different geographic locations with different bottom characteristics including bathymetry. Unique oceanography and meteorology of the different seasons will be applied. The goal is to find the sonar performance (or coverage) of the different sonars including their operational advantages with respect to each other. Including under what conditions the processing modes of the sonar are best suited. This also includes parameter settings such as array depth, tilt and bandwidth.

5.7 Analysis of the effect of combining multiple data types for high PD/PFA-rate

In order to reduce the sonar false alarm rate (FAR) in ASW, SIMSON will look into the effects of combining multiple data types. The data types are sonar data at different processing stages, results from acoustic simulations and information of the local environment such as the bottom characteristics. Both the use of such methods onboard the Nansen-class and other possibilities will be looked into. The effectiveness of such a method is of course limited by the access to the data types in question. However, if data from a single sea trial or from a local area only offer the opportunity of performing an interesting test, the analysis may still be conducted. The motivation for this work is FAR-reduction for the frigates in the long term.

6 SIMULATION DETAILS

In this chapter, the simulations performed will be explained in detail.
The simulations do be done are:

- Synthesize sonar data at different processing levels (single beam audio, beam formed time series around echo time, echoes, tracks)
- Model sonar performance (signal excess)
- Simulate sonar processing using a set of sonar processing routines
- Synthesize dynamics of vessels in a scenario
- Synthesize false targets

6.1 Sonar data simulation

Central to both analysis and simulation performed within SIMSON will be the use of LYBIN (8). However, not all simulations depend on acoustic modelling.

6.1.1 Sonar response of surface and subsurface vessels

This component requires input of the position and dynamics of the vessels involved. Such data are:
Position (easting, northing, depth)
Orientation
Heading
Speed

From the dynamic parameters of the vessels including own ship, Doppler information is extracted directly and noise added to make then slightly more realistic. Sonar data simulated on different processing levels desirable to include in a sonar emulator are: hydrophone output, beam formed audio, beam formed time series, normalized matched filter output (FM), detections (Doppler echoes and non-doppler echoes), tracks and contacts.

6.1.1.1 Hydrophone output

The synthesis of the hydrophone output is based on the envelope generated by the LYBIN echo level. LYBIN must generate the output in high resolution (25m minimum). In this mode time series output for each hydrophone will be generated, with time delay and phase corresponding to direction of arrival of a pulse. Multipath effects will be included. The aim of this simulation is to generate data for testing of beam forming algorithms, attitude compensation and fine bearing resolution. An overview of LYBIN is given in a separate report (3). Comparison of LYBIN with another model is documented in (2).

For received signals from the target, the effect of highlights and of different vertical arrival angles (eigenrays) will be included.

Reverberation will be given a Doppler shift corresponding to platform speed and horizontal arrival angle. It is not decided how noise and reverberation will be generated (with regards to statistical properties).

6.1.1.2 Beamformed audio and time series

The synthesis of the beamformed output is based on the envelope generated by the LYBIN echo level. LYBIN must generate the output in high resolution (25m minimum). Preferably LYBIN should base the simulations on a representative bottom profile for each audio beam. This envelope is modulated by the audio centre frequency. Where there should be a Doppler, this must again shift the signal frequency. Eventually, noise and reverberation should be added to make the signal realistic. Signal to noise (or signal to reverberation) ratio will be according to LYBIN simulations.

Time series simulations are performed in similar manner. For this the centre frequency of the transmitted pulse is used instead of the audio modulation frequency.

The aim of this simulation is to generate data the audio-channel in the sonar simulator, and also to generate data for testing of the coherent processing (matched filter).

6.1.1.3 Non-normalized and normalized matched filter data

The matched filter (MF) output data are generated using the echo level from high resolution LYBIN-simulations. Noise of high resolution (resolution of the pulse) (Rayleigh?) should be added to make the data more realistic.

The time spread effect of target highlights and multipath propagation will be included. Also the effect of the beampattern will be included (the target visible in several neighbouring beams). The response from target-like features will be simulated, probably by using an empirical function for the time spread and spread over neighbouring beams.

Normalized MF-output is generated simply by normalizing by subtracting the data with local mean and dividing with local standard deviation (SD). The local mean and SD is estimated from a surrounding data window of size about 2 x 125m.

The aim of this simulation is to generate data for testing of the detector, the classification displays (detailed A-scan) and for the sonar “raw data” display (B-scan).

6.1.1.4 Sonar echoes and tracks

Based on type, size, Doppler and orientation of target vessel, a target strength level is given. For the specified positions of the sonar and the target, Signal to noise ratio (SNR) and Probability of detection (PoD) is then estimated using LYBIN. Input to LYBIN is the sonar characteristics and settings and environmental input for the given scenario. (bottom profile, SSP, wind and bottom characteristics). Time spread or multipath structure of the reflected signal will also be estimated using LYBIN. As a result, SNR, position and Doppler information is obtained. Some stochastic variation on the PoD and the time spread should be added to make the data them more realistic. From this, both echoes and a track may be simulated for both surface and subsurface vessels and objects (like wrecks and pipelines). Tracks are generated simply by processing the echoes using a target tracking algorithm.

The sonar picture also consists of non-sub echoes and corresponding tracks. These echoes are often results of scattering from man made objects or other inhomogeneities in the water or at the sea floor. Studies have indicated that such natural phenomena often occur in bottom reverberation intensive areas, which may easily be extracted given a SSP and high-resolution bathymetry, ref. (5). Given that such areas can be identified and localized, some gradient detection processing may be applied to find the path a potential false track may be following. The extent to which a track may be traversing in such topography is determined by the local curvature of the topography in addition to the path of the sonar platform. Parallel paths are more likely to generate longer lasting tracks of high probability of track (PoT) as opposed to paths normal to each other. The survival time of a track is often following to the PoT-number. LYBIN-processing may be used to determine the survival time of any target. As the path of any track is suggested, the position of the echoes may be plotted. The echo position of a ping is assumed to be positioned most likely where the contours lie normal to the position of the sonar platform. Again, stochastic variation may be added to make the echoes or tracks more realistic. The relative peak level of the reverberation level is one reference to the echo SNR. Also the weighting of the contributions from other beams should be taken into account when estimating the bearing position. Up until this point, the track generating features are covered. In the sonar picture there are also many more or less randomly positions echoes. They may be caused by random peaks in the masking level (noise + reverberation), multipaths or water volume and bottom features acting as small reflectors.

The RoNoNavy ray based acoustic model LYBIN will be used for the sonar data simulations, ref (8). The sonar data simulations require a non-interactive version of LYBIN vs. 4.0 or later. Output required from LYBIN will be the masking level components (bottom, surface and volume reverberation and noise) and the PoD. The SNR (signal to noise ratio) must be calculated from the PoD and sonar parameters. A requirement is that the data is estimated for the complete sonar range, with a resolution that is not compromising the realism in the data.

When operating together with an Action Speed Tactical Trainer (ASTT), it is assumed that all the required dynamics and positional parameters are received from the ASTT. In a stand-alone mode however, a scenario simulator must be included to supply the required parameters. In analysis mode the positional parameters will be given by the recorded positions of the involved units.

In the ASTT-mode, the data rate from the LYBIN-model must be sufficiently high to ensure realism and timely updating in the sonar data simulations over the complete run.

6.2 Sonar performance predictions

The aim of this mode is to estimate the detection coverage achieved by the sonar, as a function of the target depth and of the direction and distance to the target.
The effectiveness of a sonar depends very much on the environmental conditions it operates under. These conditions are input to acoustic model that predicts the performance of the sonar assuming fixed processing mode. Performance of the sonar is measured in probability of detection or signal excess. An acoustic model computes the signal, noise and reverberation levels. Tabulated values for processing gain, detection threshold and "system loss" is then included to compute the signal excess. Assuming statistical properties of the signal, the noise and the reverberation, we can then compute the probability of detection and the probability of false alarm. In the SIMSON-project, the environmental conditions are represented by a bottom profile, one or more velocity speed profiles (which may change over range), wind direction and strength in addition to rain level.

The RoNoNavy ray based acoustic model LYBIN can be used for the sonar performance predictions. The sonar performance predictions require a non-interactive version of LYBIN vs. 4.0 or later. Output required from LYBIN should be PoD, TL and surface, volume and bottom RL including noise and self-noise. A requirement is that the data is predicted for the complete sonar range, with a resolution that is not compromising the realism in the data.

6.3 Sonar processing routine simulations

This considers the off board simulation of the onboard sonar signal processing software. Not all sonar processing routines of the active sonars onboard the Nansen-class will be available for others due to proprietor information. However, as the SIMSON-project has the ambition of modelling more or less the complete sonar processing chain in the most common active processing modes of the HMS, CAPTAS and the helicopter based dipping sonar, some signal processing routines must be coded to complete the sonar processing chain.

The processing modes include both adaptive and left-right ambiguity beamforming and using FM, CW and BPSK-processing where available.
Examples of sonar processing routines are: beamforming, audio modulation, Doppler processing, matched filtering, normalization, thresholding, false alarm reduction, target tracking.

The implemented algorithms will be based on available documentation from the sonar, or vendor software when available. The advantage of having an offline processing chain is that effects of different algorithms and settings not available to the operator, can be studied in detail. The on-board system will not support output for every processing step in the sonar. Also for that reason an offline system is useful.

Detailed description of the processing algorithms will be given in a separate report (WP 1.3, milestone 1.3.1- 31.12.2002. Possibly delayed by 6-8 months.)

6.4 Scenario simulator

To perform analysis on synthetic sonar data, a scenario simulator is required. This simulator will set up a scenario within an area specified by the operator. A scenario simulator generates for each time step, position information for the sonar platform, other units and possible targets (real or false). The scenario set up may take place in an area where there is access to detailed bathymetry charts or no apriori known bathymetry. A scenario is set up using own ship (Nansen-class frigate) as a minimum. The operator must be able to define the complete set of dynamic and positional parameters with default values provided.

A scenario may contain several vessels of predefined dynamics in addition to own ship. These vessel may give rise to tracks. Based on what is observed in sonar recordings, the scenario simulator should also be simulating tracks of false targets (chapter 6.1) with the same range of behaviour as real false targets possess. As opposed to what is described above for sonar data simulations, the false tracks within the scenario simulator may neither depend on processing using the acoustic model nor on the detailed knowledge of the topography.

There has been a wide range for scenario simulators developed under other FFI-projects. It is believed that components from available scenario simulators may be recycled within the SIMSON-project.

7 SOFTWARE IMPLEMENTATION

The analysis and simulation tool for sonar performance will be implemented together with the evaluation tool for ASW combat system. The combat system evaluation tool system is detailed by Nordø (7). Implementation will be according to the architecture specified (6).

8 FIRST VERSION OF ANALYSIS AND SIMULATION TOOL

The listing of analysis and simulation modes in chapter 4 shows the wide range of capabilities required for the SIMSON analysis and simulation tool.

In this chapter we give a preliminary description of a first version of such a tool. When further specifying and implementing the first version, we will prioritise to have the version ready in time rather than have all functionality included. The purpose of the first version is to get feedback from the users, and gain some useful experience for the rest of the job.

To start off programming the first version of the tool, a real-time analyser based on the already developed IDL-program should be developed. This tool focuses on visual analysis and presentation of bathymetry correlation with sonar data and modelled sonar performance.

Its capabilities are:

- Plotting of information within a geo-tactical display window.
- Simple processing of data
- Print out or screen dumps of the display
- File output of processed data

Information content:

Bathymetry:

contour lines (possibly colour coded according to depth)
tilting of the sea floor relative to sonar position (using shades of grey)

Reference data:

grid lines
true paths and positions of vessels involved in the sea trial
MSI-data
beam separating lines

Sonar data:

echo data, colour code options: SNR, ping, track basis
matched filter data (optionally): coloured according to dB or linear strength
tracks incl velocity vector (length ~speed), colour coded according to history, probability of track, speed, pending, active, or lost tracks.

Information within the geo-tactical display window should be switched on/off according to operator desires. Full flexibility w r t historical information and animation generation must be implemented. Animation format should be one of the more common formats, e.g. animated GIF, MPEG or AVI, and should be playable using commonly available media players.

Full flexibility w r t zoom and pan. Also, overview display – or a zoom display where required should be available. A tactical display should at least have the capability of being north oriented.

The inclusion of historic information in terms of sonar data from previous pings, should be possible as operator settings. Historic information should differ from current information as far as practical. This mainly involves use of fixed colours or symbols for the different information.

It should also be possible to choose between different pre-processing of data, e.g. different levels of closeness of proximity filtered data. This also includes comparison of the preprocessed data.

Processing of data include edge detection of bathymetry, curvature of bathymetry relative to a selected position, peak detection and peak correction processing of bathymetry.

Sonar data processing to be included under sonar processing simulation in the first version of the tool are:
post processing of matched filter data such as bearing weighting, peak length filtering of MF-data, proximity filtering, at least one target tracking algorithm with alternative parameter settings possible.

In appendix B more detailed goal of sonar analysis in the first version of the SIMSON tool is presented.

8.1 First version appearance of the sonar analyser and simulator tool

The tool is to consist of two display windows possibly sharing the same mouse, keyboard and loudspeakers. The windows are named GeoTactical window and Technical window. The first configuration, which is used as a laboratory version, consists of the two 3:4 ratio (height: width) displays placed beside each other.

The GeoTactical window is actually a modified version of the MARIA-display. Manipulation of this display should as far as possible be identical to the MARIA-display. It provides a geographical overview of the operation area. Any data put into a geographical context will be presented on this display.

The Technical window presents data not required to be put into a geographical context. Any technical data requiring a more technical presentation in the sense of diagrams and curve plots, appears within this display. The tool should be started from the technical display and the scenario is run from this display.

A few examples of display views within the GeoTactical window are presented in appendix C. Likewise are examples of display windows of the Technical window included in appendix D.

9 SUMMARY

This report describes the sonar analysis and simulation to be performed by the ASW sonar and combat system evaluation tool. The tool will be developed in FFI project 849 SIMSON, and will be used in analysis of properties and performance of the active ASW sonars of the Fridjof Nansen class frigates. This also includes the helicopter dipping sonar. The analysis will be based on recorded sonar data and reference data. To facilitate detailed study of algorithms, parts of the processing chain of the sonars will be implemented. Simulation of sensor data based on detailed environmental input, will aid the understanding of the sonar performance, and allow sensitivity studies for different parameters settings and environmental conditions. The most commonly used processing modes of the sonars will be analysed and simulated. A module for realistic sonar simulations will be delivered for implementation in the Action Speed Tactical Trainer.

The solutions for analysis and simulation will be further detailed in the development process eventually leading up to the implementation of a complete evaluation tool. The process is composed of specifying requirements and detailing the design solution before implementing the software solution.

APPENDICIES

A ABBREVIATIONS

3D	Three Dimensional
AML	Additional Military Layers
AMM	Analysis Main Mode
ASTT	Action Speed Tactical Trainer
ASW	Anti Submarine Warfare
ATAS	Activated Towed Array System
AVI	Audio Video Interleave (format standard for animation files)
BPSK	Binary Phase Shift Keying
CAPTAS	Combined Active/Passive Towed Array Sonar
CW	Continuous Wave
DP1 / DP2	SIMSON Subproject 1 / SIMSON Subproject 2
DT	Detection Threshold
FA	False Alarm
FAR	False Alarm Rate
FFI	Forsvarets Forskningsinstitutt (Norwegian Defence Research Organisation)
FM	Frequency Modulation
FN	Fritjof Nansen
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Generic Sonar Model
HF	High Frequency
HMS	Hull Mounted Sonar
IDL	Interactive Data Language
JPEG	Joint Photographics Experts Group (also the name of an image compression standard)
KDA	Kongsberg Defence and Aerospace
LF	Low Frequency
LYBIN	LYdBane og Intensitetsprogram (NDLO/Sea acoustic model)
MARIA	Maritime Information Application
MF	Matched filter
METOC	Meteorology and Oceanography (also the name of a FFI project)
MMI	Man Machine Interface
MPEG	Moving Picture Experts Group (also compression standard for animation files)
MSI	Multi Sensor Integration
MSIFC	Multi Sensor Integration and Fire Control
NATO	North Atlantic Treaty Organization
NDLO	Norwegian Defence Logistics Organization
NDLO-Sea	NDLO Navy

NERSC	Nansen Environmental and Remote Sensing Center
NF	New Frigates
OSCAR	Object-oriented Simulation for the Combat Analysis of Requirements
PFA	Probability of False Alarm
POD/PoD	Probability Of Detection
POT/PoT	Probability Of Track
RoNoNavy	Royal Norwegian Navy
RL	Reverberation Level
RVPU	Receiver Video Processing Unit (Sonar data recording format designation on Oslo-class sonars)
RX	Receive
SACLANT	Supreme Allied Commander Atlantic
SACLANTCEN	SACLANT Undersea Research Centre
SD	Standard Deviation
SE	Signal Excess
SIMSON	FFI project 849 Simulation and evaluation of sonar and ASW operations
SNR	Signal to Noise Ratio
SMM	Simulation Main Mode
SWASI	FFI project Shallow Waters Acoustics Survey Initiative
TCM	Torpedo CounterMeasure
TL	Transmission Loss
TS	Target Strength
TUS	Thales Underwater Systems
TX	Transmit
VDS	Variable Depth Sonar
WP	Work Package

B SIMSON VS 1.0 OUTLINE (FROM POWERPOINT FILE)

SIMSON vs. 1.0 is the first version of the SIMSON analysis tool having a limited number of options for analysis. This version will be well suited for review by the intended users of the analysis tool, even though only limited set of data will be presented.

Forsvarets forskningsinstitutt

Versjon 1 av SIMSON verktøyet

Simulering og evaluering av sonarsystemer og anti-ubåt operasjoner

04.02 2003

Forsvarets forskningsinstitutt

SIMSON vs. 1.0 - main features

- First version of a versatile, but limited tool for the display and analysis of recorded combat system data, sonar data, sonar performance estimations.
- Is to be installed at KNM T/Haakonsvern for initial user trials.

Forsvarets forskningsinstitutt

Motivation

- 1st version of ASW analysis system of 849 SIMSON
- Supply KNM T with a display and analysis system for initial user trials
- Receive feedback from KNM T

Forsvarets forskningsinstitutt

SIMSON vs. 1.0

• A workstation tool for overall display and basic analysis of recorded ship and sonar data from the Oslo-class frigates.

• Provide simple archieving of on-board navigation and sensor data recorded using disk and tapes.

•Provides limited bathymetry data coverage over parts of the coastal area of Norway.

• Provides display of topography data, navigational data, sonar data.

• Output format: display dumps, screen movies, table listings

• Analysis of run 14/99 Bjørnafjord, FLOTEX2000, 49/2000 in Bjørnafjord (ULA)

Forsvarets forskningsinstitutt

Technical features of SIMSON tool:

- Close integration with and software development within existing tools for presentation, calculations and GIS (Maria, Matlab, IDL,…).
- PC and Microsoft's new development environment .NET with integrated UML modelling
- Programmering languages: primary C#, some C++ (Maria), MATLAB and IDL and possibly JAVA (MSIFC input)
- Integration of existing tools using COM technology and .NET/COM interoperability
- Industry standards for data storage: RDB (SQL Server 2000), XML,..
- Distribution? (.NET remoting, SOAP ? CORBA ?)

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Using vs. 1.0, the operator may:

- Access and display recorded RVPU-data (Oslo-class sonar data recordings) and GPS.
- Access and display recorded DACULA-data
- Display reference and sonar data superimposed on hi-res bathymetry data
- Run & display tracker (ref. UNISON UWW-station tracker)
- Perform common display operations
- Perform basic analysis of recorded data (e.g. rel. dist and bear.)

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Vs. 1.0 input requirements:

- Reading disk recorded RVPU-data
- Reading MSI-3100 track information (FORACS-recording)
- Reading log-files of GPS data, DACULA
- Reading chart data
- Archiving of sonar data, navigation, chart data etc

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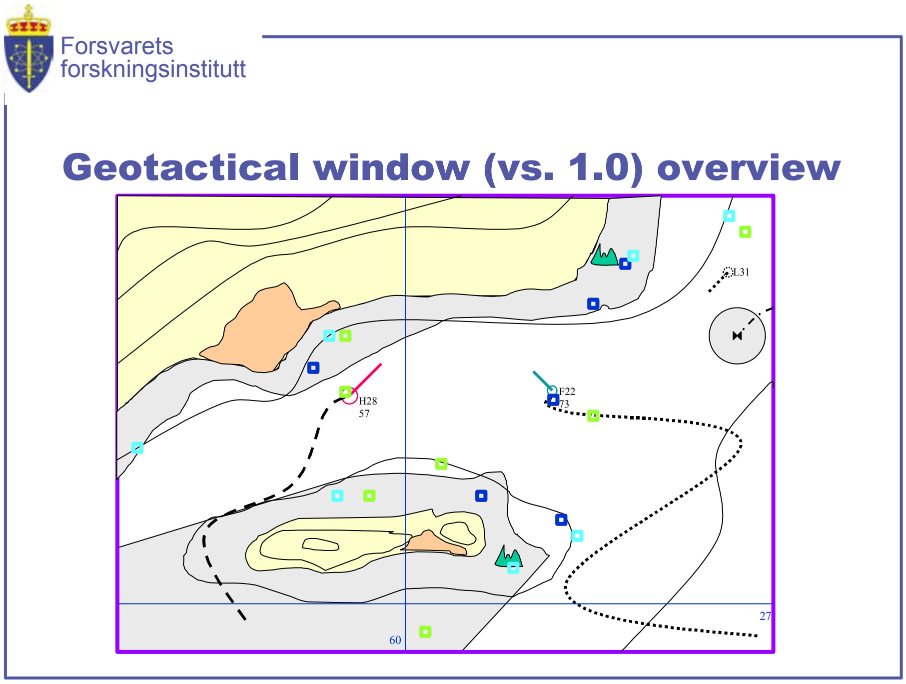
Vs. 1.0 restrictions/guidelines:

- Based on SIMSON software architecture
- MARIA based geotactical window
- While running thru' a scenario, the scenario should easily be paused and restarted (possibly scrollbar operation of scenarios)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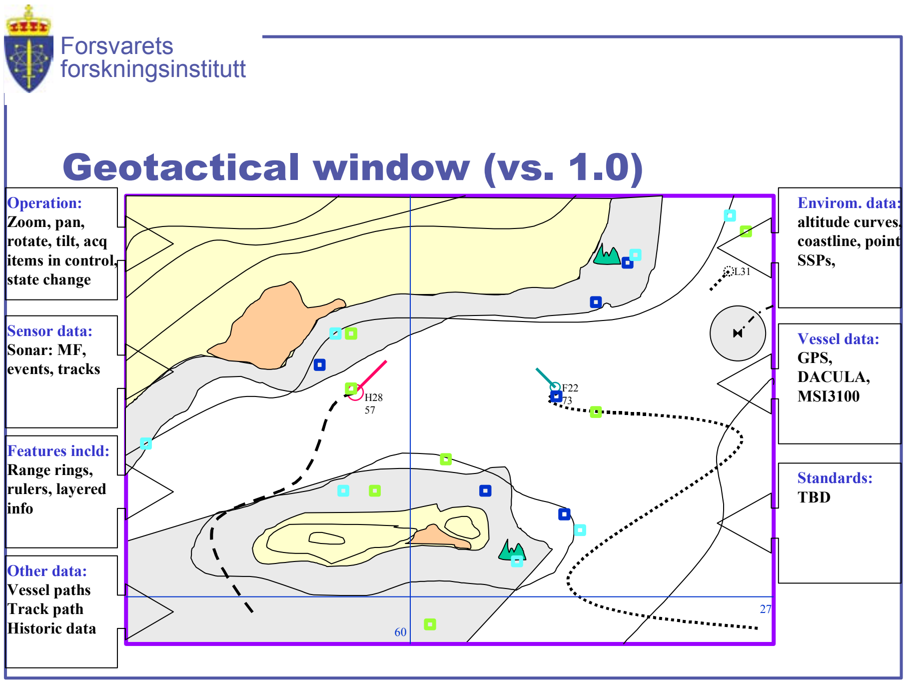
Geotactical window (vs. 1.0) overview
L31
H28
57
F22
73
60
27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Geotactical window (vs. 1.0)
Operation:
Zoom, pan, rotate, tilt, acq items in control, state change
Sensor data:
Sonar: MF, events, tracks
Features incld:
Range rings, rulers, layered info
Other data:
Vessel paths
Track path
Historic data
Envirom. data:
altitude curves, coastline, point SSPs,
Vessel data:
GPS, DACULA, MSI3100
Standards:
TBD
L31
H28
57
F22
73
60
27

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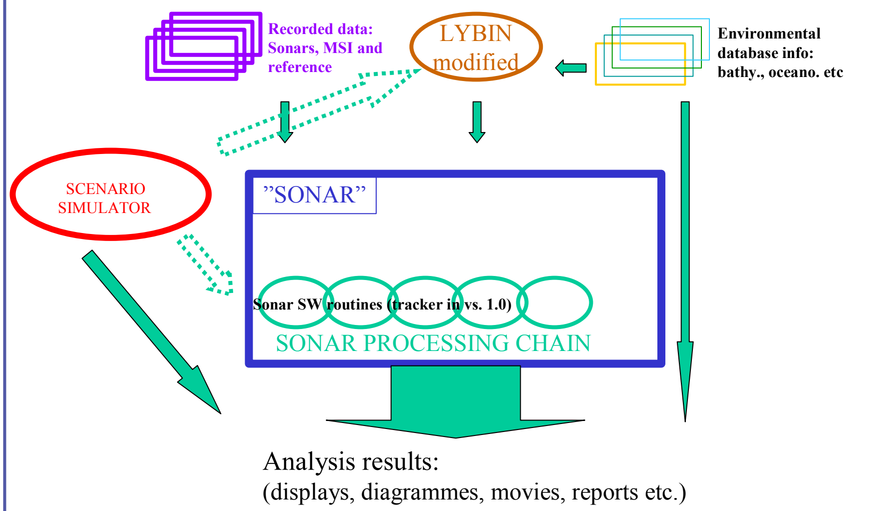
Technical windows (vs. 1.0) (TBD !)

- Scenario control
- Analyses:
  - Sonar output data analyses:
    - Sonar events analysis (SNR, position)
    - Sonar events correlation with topography
    - Track listing

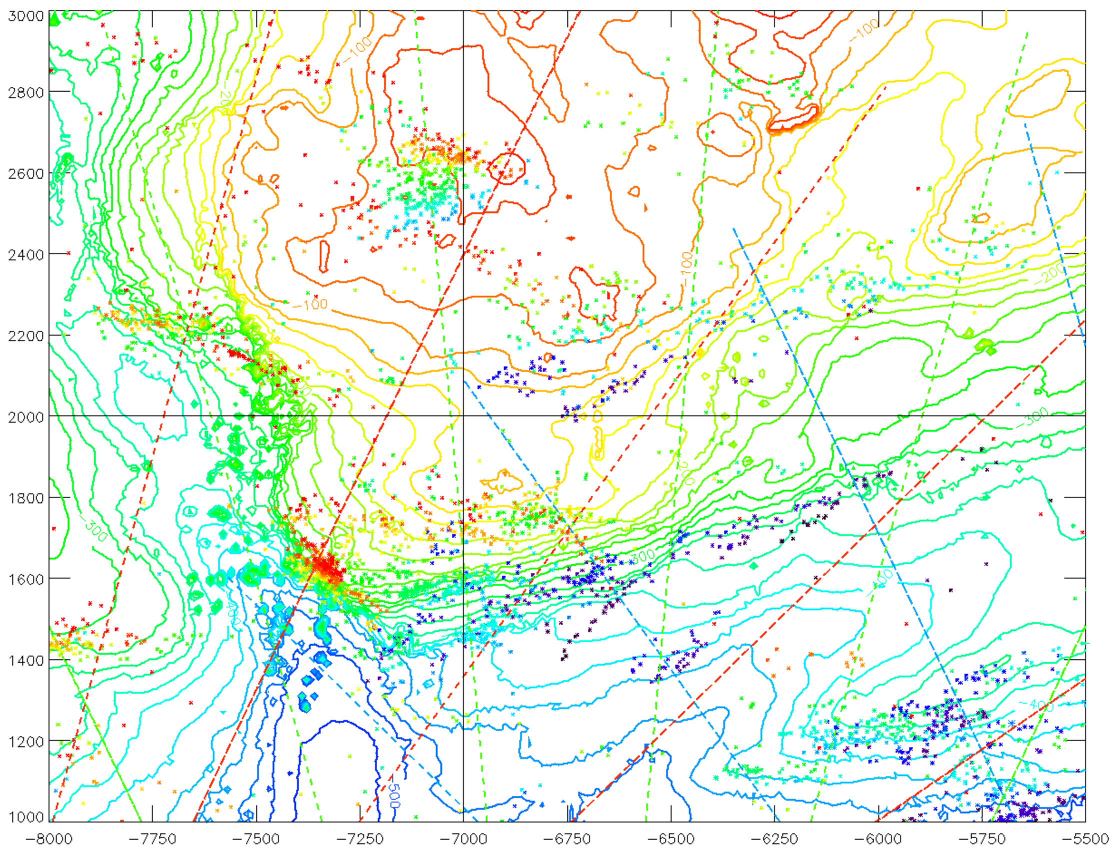
Forsvarets forskningsinstitutt

SIMSON schematics :

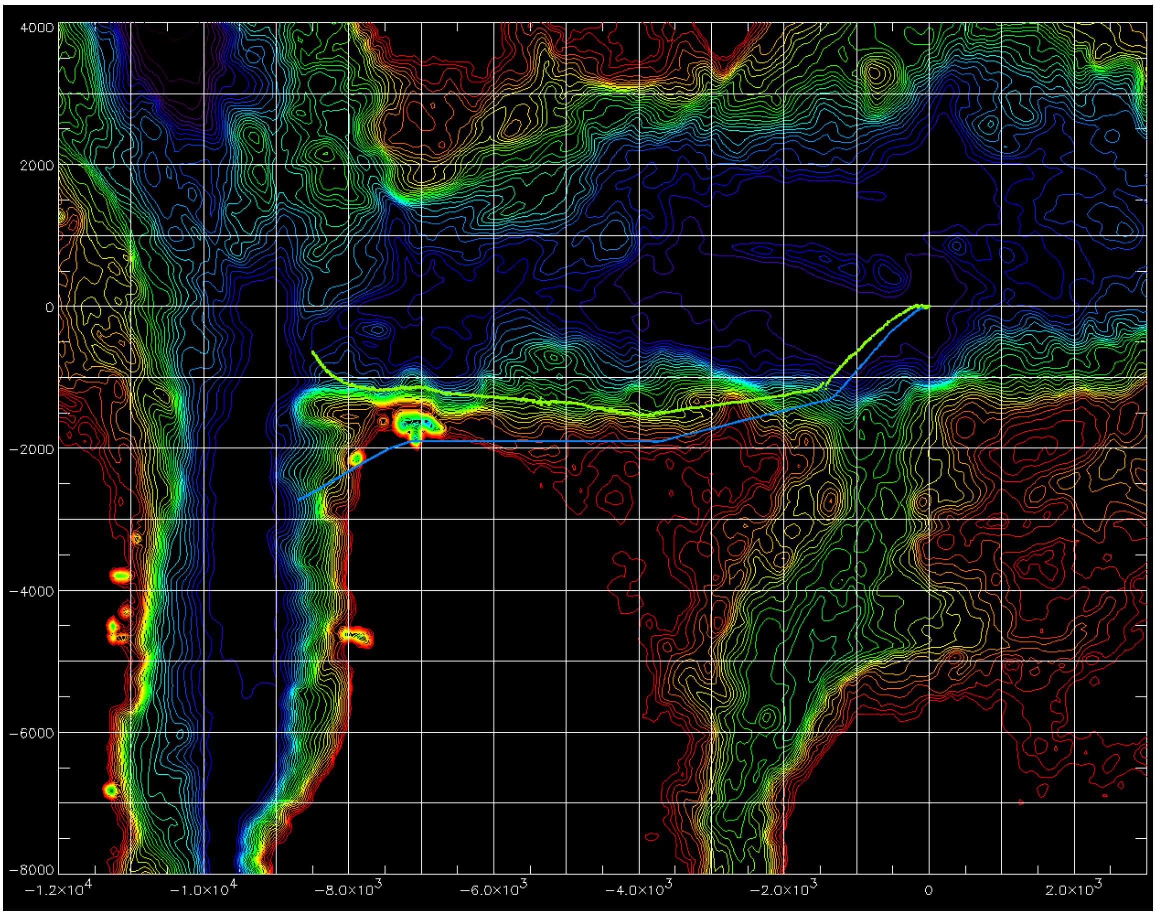


C GEOTACTICAL WINDOW EXAMPLES

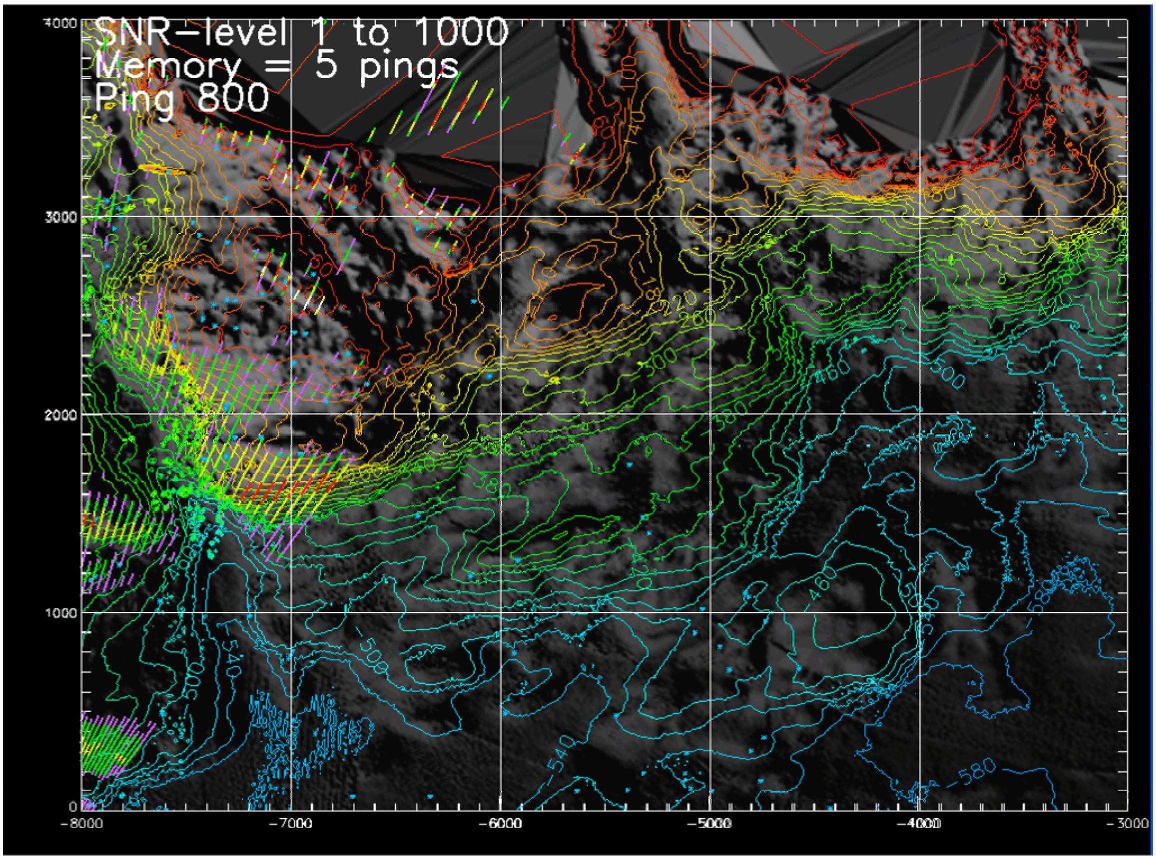
The examples of geotactical display windows show mainly gridded topography charts using contour lines and shading to depict the local bottom topography. Coloured dot or star symbols are the positions of sonar detections / echoes. Colour coding of the echoes may symbolize the pings they are originating from or the amplitude of the signal to noise ratio.



Above diagram shows topography as colour coded contour lines. Lines show the direction to the sonar. The echoes, shown as dots, are coloured according to ping. The lines have the same colour as the echoes for the same ping.



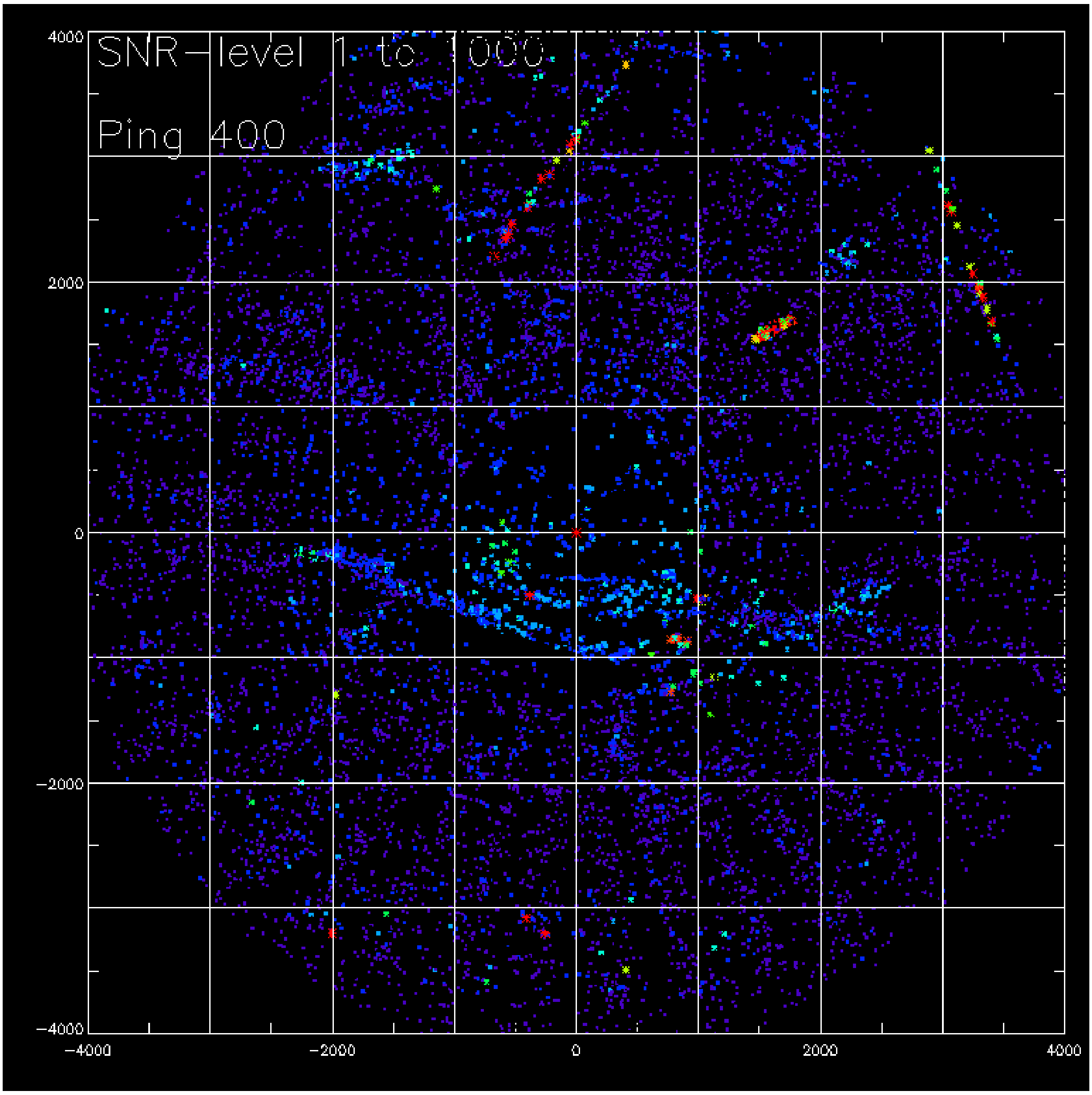
Topography chart having grid and black background. It shows two measurements of sonar platform path (thick blue and green curves).



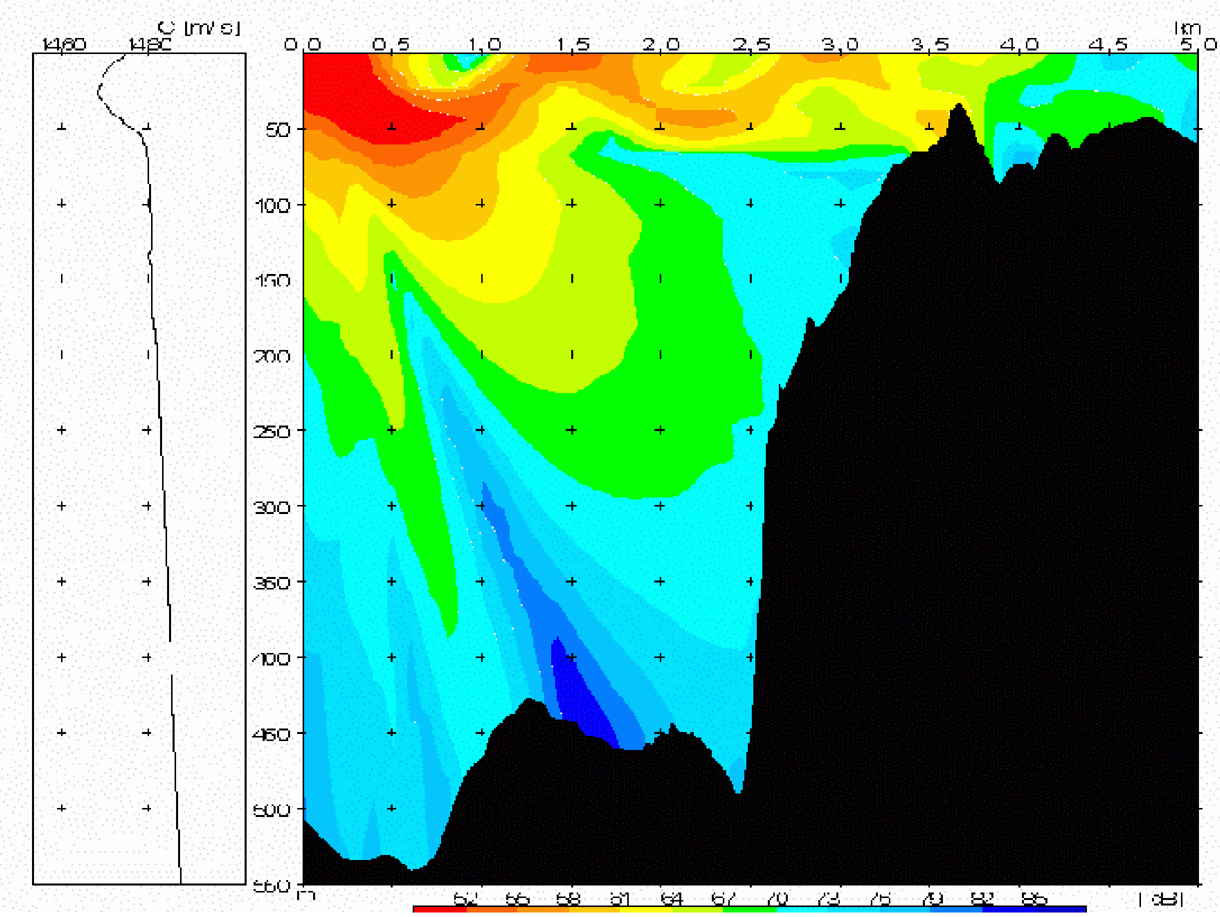
Topography as contour lines and shades of grey to show details. Shaded area shows area of high normalized bottom reverberation level also coloured according to amplitude.

D TECHNICAL WINDOW EXAMPLES

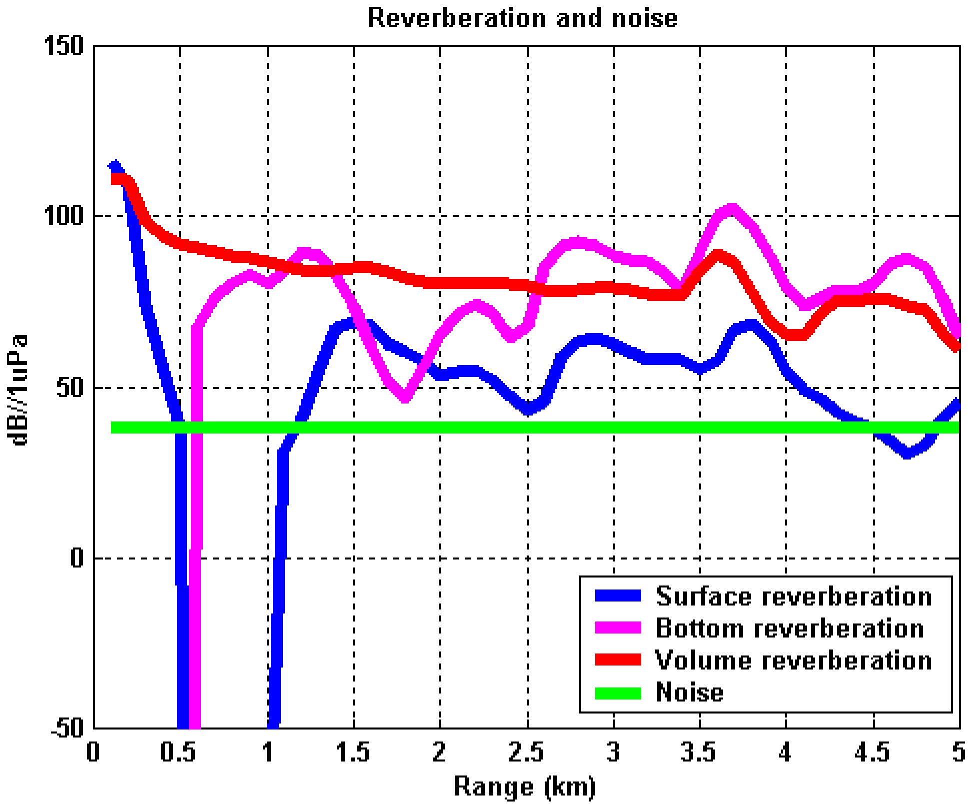
Technical display windows may be composed of many different types of graphs as there is no explicit demand that the data have geographic coordinates.



The above diagram show the sonar echoes (star symbols) of several pings centred around origin (0,0) represented by the position of the sonar at all pings. The colours of the echoes are according to the siagnal-to-noise number.



Above is a composite LYBIN-diagram showing the sound velocity profile to the left and a transmission loss diagram to the right. The transmission loss level is shown using colours from blue (high loss) to red (low loss). Bottom profile is shown in black.



Above is a diagram of curves showing the levels of noise and different types of reverberation.

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