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Acoustic server for MALO technology demonstrator project

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Contract Number: W7707-03-2088/001/HAL

Contract Scientific Authority: D. Ellis and S. Pecknold, 902-426-3100 ext 104

Defence R&D Canada – Atlantic

Contract Report
DRDC Atlantic CR 2007-189
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Canada

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Approved by

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Abstract

The Maritime Air Littoral Operations Technology Demonstrator Project (MALO TDP) required acoustic information for sea-based surface and subsurface targets. An acoustic server, derived from available sonar models, was developed to provide this information.

Résumé

Le projet de démonstration de technologies Opérations navales et aériennes côtières (MALO) nécessite des informations acoustiques pour les cibles de surface et les cibles sous-marines. Un serveur acoustique, dérivé des modèles sonar courants a été mis au point pour fournir ces informations.

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Executive summary

Introduction

The Maritime Air Operations Technology Demonstrator Project (MALO TDP) is a combination, or federation, of several computer-based simulation systems, compliant with the High Level Architecture (HLA) standard. The individual simulation systems are known as federates.

Results

In the MALO simulation, there are several surface and subsurface vessels or targets, and one or more sonars. A requirement of this simulation was the ability to determine the probability of detection of each target by each sonar. An acoustic server federate was developed to provide the probability values.

Significance

Construction of the acoustic server has added a good-fidelity acoustic modeling and simulation capability to the MALO simulation, as required.

Future Plans

Further development of the acoustic server may be undertaken to increase the fidelity of the acoustic modeling. The acoustic server may also be modified to improve its ability to use the REA database.

David Chang. 2007. Acoustic server for MALO technology demonstrator project. DRDC Atlantic CR 2007-189. Defence R&D Canada - Atlantic.

Sommaire

Introduction

Le projet de démonstration de technologies Opérations maritimes et aériennes (PDT MALO) consiste en une combinaison ou en un groupement de plusieurs systèmes de simulation informatisés, répondant à la norme de l'architecture de haut niveau (HLA). Les systèmes de simulation sont connus chacun sous le nom de fédérés.

Résultats

La simulation MALO met en jeu plusieurs navires de surface et sous-marins ou cibles et un sonar ou plus. Elle exige la capacité de déterminer la probabilité de détection de chaque cible par chaque sonar. Un serveur acoustique fédéré a été mis au point pour fournir les valeurs de probabilité.

Portée

La construction du serveur acoustique ajoutait à la simulation MALO une capacité de simulation et de modélisation acoustique de bonne fidélité, au besoin.

Future recherches

Il se peut qu'on développe le serveur acoustique pour accroître la fidélité de la modélisation acoustique. Le serveur acoustique peut aussi être modifié pour améliorer sa capacité d'utiliser la base de données de l'évaluation rapide de l'environnement (REA).

David Chang. 2007. Acoustic server for MALO technology demonstrator project. DRDC Atlantic CR 2007-189. Defence R&D Canada - Atlantic.

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Overview of software

The MALO federation passes information about the characteristics, position and speed of the targets and sonars to the acoustic server federate (figure 1). From this information, the acoustic server federate computes the probability of detection of each target by each sonar, and returns the probability values to the MALO federation.

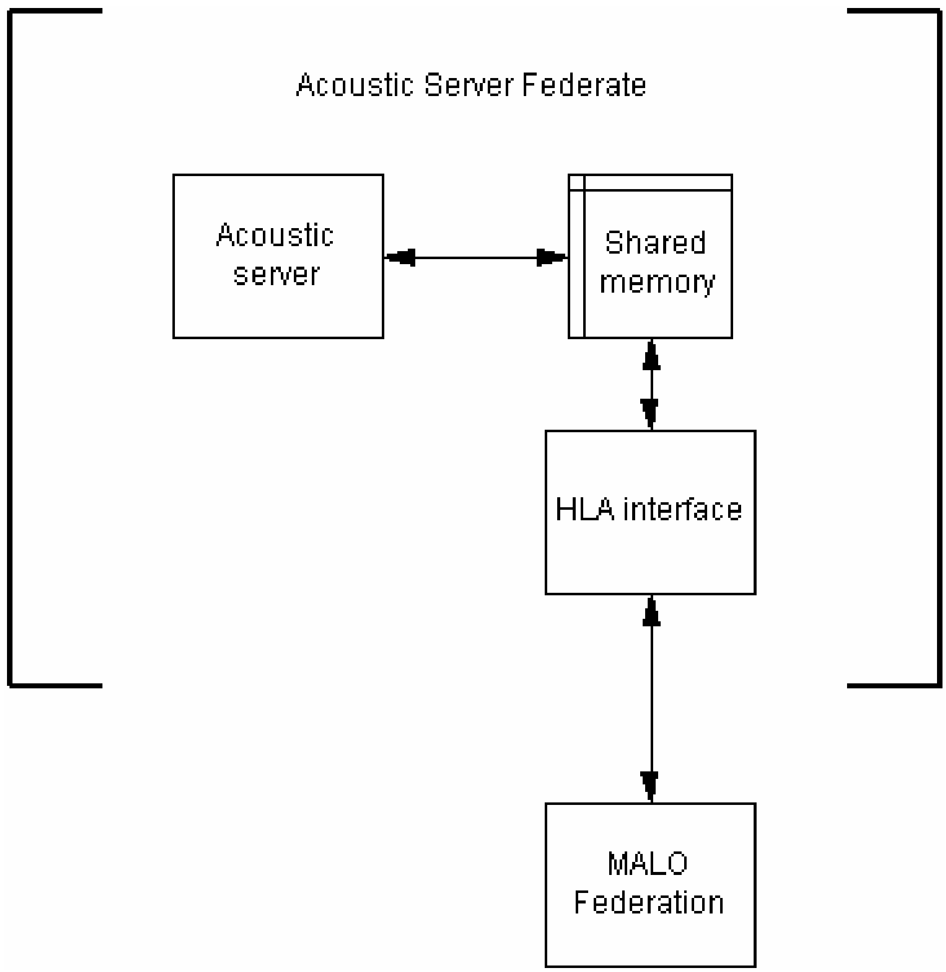

Figure 1. *Acoustic server federate and MALO federation*

As indicated in figure 1, the acoustic server federate consists of three components:

- A High Level Architecture (HLA) interface (DMSO [1]) that communicates with the MALO federation.

- The acoustic server that calculates the probability of detection values.
- Shared memory that is used to pass data between the HLA interface and the acoustic server.

The HLA interface obtains sonar and target data from the MALO federation, and places that information in shared memory. The acoustic server retrieves the data from the shared memory, computes the probability of detection of each target by each sonar, and writes the probability values to the shared memory. The HLA interface retrieves the probability values from shared memory, and passes them to the MALO federation.

Dan Bleichman of the Aerospace and Cognitive Engineering (ACE) Lab, Carleton University, Ottawa, wrote the HLA interface. Details of the HLA interface and the MALO federation will not be discussed in this report.

Acoustic server

The acoustic server has three main processes as shown in figure 2.

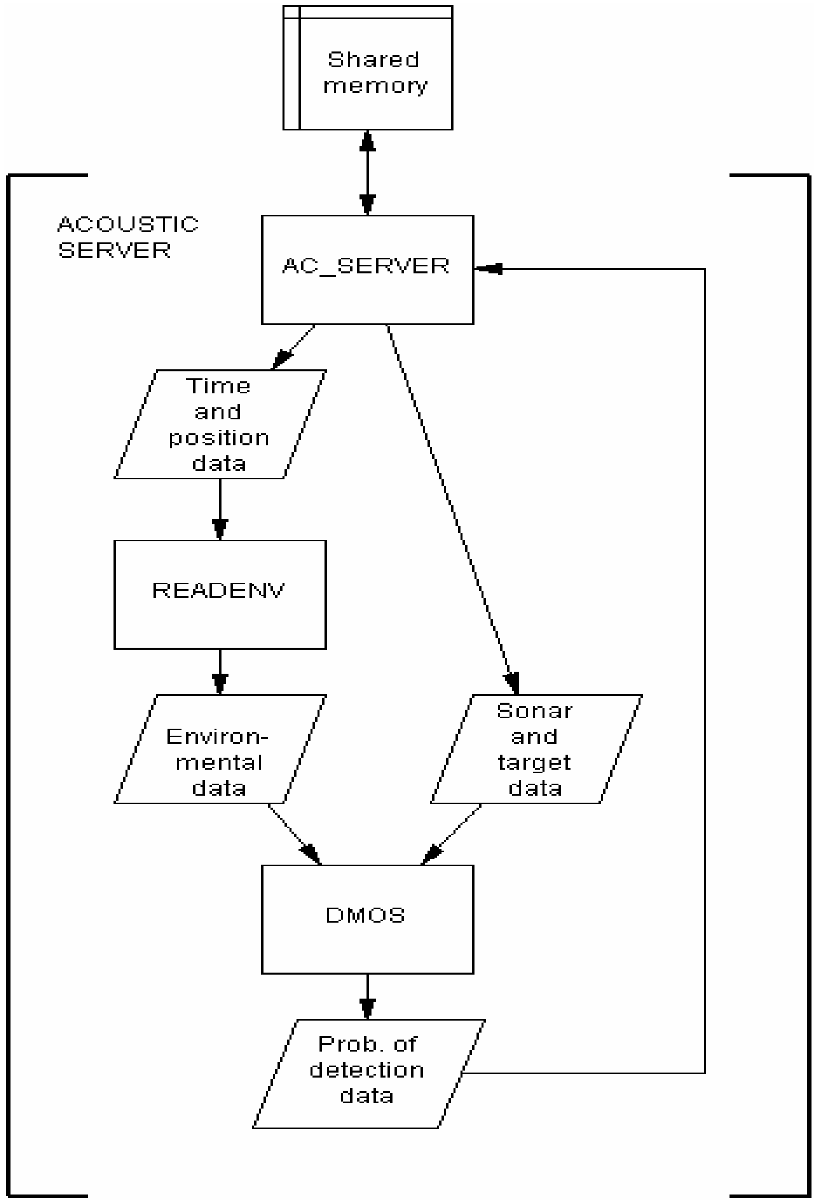

Figure 2. *Acoustic server processes*

Program AC_SERVER acts as a controller for the acoustic server. AC_SERVER retrieves sonar and target data from shared memory, and does some processing of the data. The resultant data are used to generate input files for the READENV and DMOS programs. AC_SERVER then runs READENV and DMOS. AC_SERVER reads the probability of detection data files created by DMOS, and writes the probability values to shared memory. Since the user does not interact directly with READENV or DMOS, they are effectively "invisible" to the user.

Given as input the time of year and position (latitude and longitude), program READENV outputs the following ocean environmental data: bathymetry, sound speed profile, and bottom loss data.

DMOS (DRDC Atlantic Model Operating System) is a suite of programs for sonar modelling (Theriault and Calnan [2]). The acoustic server uses DMOS to compute the probability of detection of the targets by the sonars.

DMOS

Which DMOS programs are run depends on whether an active or passive sonar is being modelled (figures 3 and 4). The active sonar case involves the extra step of reverberation calculations.

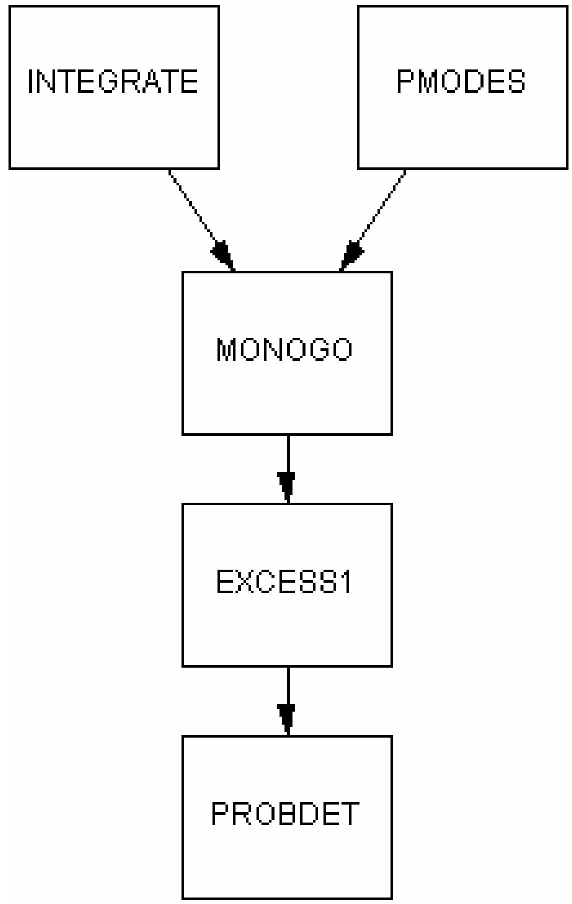

Figure 3. *DMOS processing flow for active sonar*

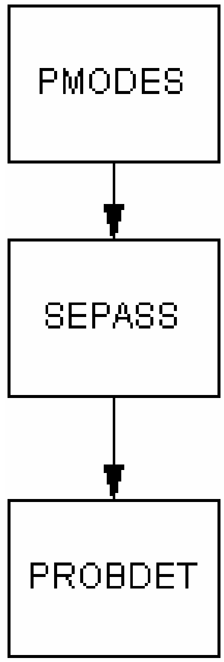

Figure 4. *DMOS processing flow for passive sonar*

The DMOS programs used are:

- INTEGRATE which generates transmitter and receiver specification files. It can be used for beam pattern integration, but it is not used for that purpose in the acoustic server.

- PMODES which produces normal mode files for input to MONOGO, or transmission loss files for input to SEPASS. As part of its input, PMODES uses the environment data produced by program READENV.
  PMODES uses a normal mode propagation model, and is range independent. There is an alternate DMOS program, BellhopDMOS/Bellhop, that uses a ray theory (ray tracing) model, and is range dependent. PMODES was chosen over Bellhop primarily due to PMODES' faster speed. Moreover, Bellhop was a recent addition to DMOS, and had not been used/tested as much as PMODES had.

- MONOGO which performs monostatic reverberation calculations.

- EXCESS1 which computes signal excess for the active sonar case.

- SEPASS which computes signal excess from the passive sonar case.

- PROBDET which computes probability of detection from signal excess data.

Acoustic modelling

There are many forms of the sonar equations that quantify the passive or active detection of targets. Here we present a simplified form of the equations used in DMOS. Terms are in decibels.

For the passive sonar case:
$SE_P = SL - TL - (NL - AG_P) - DT$

For the active sonar case:
$SE_A = SL - 2TL + TS - (RL + NL - AG_A) - DT$

Where:
SE is the signal excess.
SL is the source level.
TL is the transmission loss.
TS is the target strength.
RL is the reverberation level.
NL is the noise level.
AG is the array gain.
DT is the detection threshold.

SL, TS, AG and DT are input to DMOS. A value for NL is either input to DMOS, or is computed by DMOS based on frequency, sea state, wind speed, and other input parameters (Weinberg [3]). TL and RL are computed by DMOS from the sonar and target positions, and from environment data.

Currently, program AC_SERVER computes a value for SL for the passive sonar case from:
$SL = 60 \log(K) + 9 \log(T) - 20 \log(F) + 34$
where K is the target speed in knots, T is the displacement tonnage of the target, and F is the frequency in kHz. (This equation was adopted from Urick [4], with reference distance converted from yards to metres.) The equation is for surface targets; for subsurface targets (submarines and sonobuoys), we assume a 20 dB lower source level. If the target has any transmitting active sonars attached to it, then SL will be adjusted to take into account the source levels of those sonars.

Target strength, TS, is defined to be 20 dB for a sound incidence angle within 15 degrees of broadside, and 0 dB for other angles.

Limitations

The number of normal modes, N, used in program PMODES is given by:
$N=hf/c$
where h is the water depth, f is the signal frequency, and c is the sound speed in water. There is a limit on the number of modes that the software can handle (currently 1000 modes for

passive sonar, 800 for active sonar). Therefore to reduce the number of modes, mode calculations are sometimes done at a lower frequency, whereas calculations of attenuation, surface scattering, and ambient noise are still based on the actual signal frequency. This approximation yields results that are often not the same as those obtained by using the actual signal frequency for all calculations. Consequently, the software gives best results for shallow water depths, where the approximation need not be used.

Ocean bottom loss data are most detailed around the North American coast, the area of interest in the MALO TDP.

Program AC_SERVER

This program reads MALO target and sonar data from shared memory. The data are processed, and are used to generate input files for the READENV and DMOS programs. AC_SERVER then runs READENV and DMOS. DMOS generates probability of detection files that are read by AC_SERVER, and AC_SERVER writes the probability values to shared memory.

The user starts the HLA interface program, and then AC_SERVER. AC_SERVER and the HLA interface program use a semaphore to control access to the shared memory. First AC_SERVER waits until it is signalled that the HLA interface program has placed target and sonar data in the shared memory. AC_SERVER then retrieves that data, and runs READENV and DMOS to process the data. The resultant probability of detection data are placed in shared memory for use by the HLA interface program. AC_SERVER then waits for the HLA interface to place the next set of target and sonar data in shared memory. Thus AC_SERVER loops endlessly, until the user types CTRL-C at the keyboard to stop the program.

The MALO federation does not provide all the data AC_SERVER requires to run READENV and DMOS. Hence, AC_SERVER also has built-in data, some of which can be over-ridden by command-line parameters and/or an optional environment input file.

Running the program

The environment variables ETOPO_PATH and DMOS should be set appropriately prior to running AC_SERVER. ETOPO_PATH should be point to the directory that holds some input data files, used by programs AC_SERVER and READENV. DMOS should point to the directory that contains the READENV and DMOS programs. If ETOPO_PATH or DMOS is not defined, it is assumed that the relevant files are in the current directory.

Examples:
export ETOPO_PATH=/data   (Linux bash shell)
export DMOS=/dmos/bin

setenv ETOPO_PATH /data   (Linux tcsh shell)
setenv DMOS /dmos/bin

When AC_SERVER is run, it creates a lot of files in the current directory. Therefore it is recommended that one create a special directory from which AC_SERVER is run.

To run AC_SERVER, enter:
ac_server [[-e] environment_file] [-t time_period] [-s sonar_name] [-d debug_flag]

(Note: AC_SERVER runs in an endless loop. To terminate the program gracefully, type CTRL-C.)

Table 1. *AC_SERVER command line arguments*

OPTION	MEANING
-e environment_file	If present, environment parameters will be read from the indicated file (see below). Note that this file is not assumed to be in the path indicated by ETOPO_PATH.
-t time_period	Time period for the model. 0=annual, 1-12 = month, 13-16=season (13=winter, January-March). This time period takes precedence the time period specified in the environment file ("-e" option).
-s sonar_name	The name of the single sonar that will be processed. (This is the name of the sonar as provided by the HLA interface program.) If the "-s" option is not used, all sonars will be processed.
-d debug_flag	The AC_SERVER program generates scripts to run the READENV and DMOS programs. The value of debug_flag controls the stdout and stderr from those scripts: =0, do not save stdout. ≠0, save READENV stdout plus stderr in the file renv_script.out, and DMOS stdout plus stderr in the file script.out. =2, print long, or verbose, output messages. =4, print extra debugging output messages. =6, print both long and debugging output messages. (Values 2,4 and 6 apply only to the DMOS programs.) Thus to save stdout and stderr, but without the long and debugging messages, one would use a value of 1 for debug_flag.

Input environment file

This optional input file allows one to specify some environment parameters for the model. The following listing shows the contents of a sample environment file; the data values shown are the program defaults.

```
A sample AC_SERVER environment file
0 1 -1          ! 2) Time period, reverb single sum, max active modes
1.0 -1.0 35.0   ! 3) Water density, attenuation flag, salinity
1 -1.0          ! 4) Max. no. of bottom layers, min. layer thickness
11              ! 5) No. of computational layers
1 -999.0 4.0    ! 6) Surface scattering type, sea state, wind speed
0 5.0 -999.0    ! 7) Rain rate, shipping level, ambient noise
5.6             ! 8) Standard deviation for log normal distribution
```

Table 2. *Comments on AC_SERVER environment file*

DATA LINE	DATA LINE INFORMATION
1	A comment.
2	This line has three numbers: • The time period for the model. 0=annual, 1-12=month (1=Jan), 13-16=season (13=winter, January-March). • A flag indicating whether a single sum versus a double sum is to be used in MONOGO reverberation calculations (Ellis [5]). If zero, a double sum is used. Otherwise, a single sum is used. Using a single sum speeds up calculations. • The maximum number of normal modes to be used in active sonar calculations (program PMODES). Should be ≥ 10 and ≤ 800. If a value outside this range is specified, the program uses a value of 100 for single sum reverberation calculations, and 800 for double sum reverberation calculations. N.B. - Reducing the maximum number of normal modes speeds up calculations, but may reduce the accuracy of the results.
3	This line has three numbers: • The water density in gm/cm**3. • The water column attenuation flag. If this is ≥ 0.0 and ≤ 1.0, the value is used as the attenuation coefficient (dB/Hz-km) for the water column. If this = -1.0, then Thorpe volume attenuation is used. If this = -2.0, then Urick volume attenuation is used • The default water salinity (ppt). This is used only if no salinity data files are available, which should normally not occur.
4	This line has two numbers: • The maximum number of bottom layers, including the bottom half-space, as used by program readenv. If = 0, there will be a single layer whose properties are those of the surficial sediments. If = 1, the single layer will have the sediment properties as averaged over the sediment thickness (N.B. – A value ≠ 1 is not recommended for PMODES output, as the resultant data may cause program PMODES to abort.) • The minimum thickness of layers (other than the bottom half-space). The topmost sediment layer(s) will have this thickness. If ≤ 0, there will be at most two layers output.
5	The number of computational layers, as used by program PMODES. Must be ≤ 511. If ≤ 0, PMODES will use 251 computational layers.
6	This line has three numbers: • The type of surface scattering. 0 for Lambert, ≠ 0 for Chapman-Harris. N.B. - Chapman-Harris scattering requires a wind speed > 0.0. • Sea state, an integer from 0 to 6. If < 0, sea state is assumed to be undefined. • Wind speed in knots (floating-point number). If < 0.0, wind speed is assumed to be undefined.
7	This line has three numbers: • Rain rate, an integer from 0 to 3 (0=none, 1=intermediate, 2=moderate, 3=heavy). If < 0, rain rate is assumed to be undefined. • Shipping level, an integer from 1 to 9. If ≤ 0, shipping level is assumed to be undefined. • Ambient noise level in dB re 1 uPa**2/Hz. If a noise level of –999 is specified, the ambient noise will instead be calculated using frequency, sea state, wind speed, rain rate, and shipping level (Weinberg [3]).
8	Standard deviation (dB) to use for a log normal distribution. Used in computing probability of detection from signal excess values.

Input entity info file

The ASCII file entity_info.txt contains information regarding the platforms (targets) and sonars to be used in the model. The file should be in the directory specified by the environment variable ETOPO_PATH. The following listing shows the contents of a sample entity info file.

```
Test platform and sonar types
1 3 222 4 2 1 -1 7940.0         ! 2) C.I.S. Sovremenny destroyer
1 3 222 6 4 -1 -1 4200.0        ! 2) C.I.S. Neustrashimy frigate
1 4 222 3 8 -1 -1 8500.0        ! 2) C.I.S. AKULA class sub
1 3 39 4 1 -1 -1 5100.0         ! 2) Canada Tribal destroyer
1 3 39 6 1 -1 -1 4770.0         ! 2) Canada Halifax frigate
1 4 225 52 8 2 0 0.0156         ! 2) Active sonobuoy (SSQ 62E)
-1 0 0 0 0 0 0 0.0.0            ! 3) End of platform types
1  0 200.0 0.0 0.0 6.0 -1.0     ! 4) Passive sonobuoy (SSQ 53)
9  1 5000.0 220.0 6.0 6.0 40.0  ! 4) Active sonobuoy (SSQ 62E)
24 0 200.0 0.0 0.0 10.0 -1.0    ! 4) Passive hull mount (SQS 56)
27 0 200.0 0.0 0.0 20.0 -1.0    ! 4) Passive towed array (SQR 19)
45 1 5000.0 220.0 6.0 15.0 40.0 ! 4) Active hull mount (SQS 56)
-1 0 0.0 0.0 0.0 0.0 -1.0       ! 5) End of sonar types
```

__Table 3.__ Comments on AC_SERVER entity info file

DATA LINE	DATA LINE INFORMATION
1	A comment.
2	Line 2 appears multiple times, once for each type of platform (target). (Platforms that are not considered targets need not be included.) Each line has eight numbers; the first seven are DIS codes (SISO [6]) for the platform: • Kind (1 = platform). • Domain (3 = surface, 4 = subsurface). • Country. • Category. • Subcategory. If a negative number is given here, it is assumed that the subcategory does not matter (I.e., the negative number acts as a wildcard). • Specific entity definition. If a negative number is given here, it is assumed that the specific entity definition does not matter. • Extra entity definition. If a negative number is given here, it is assumed that the extra entity definition does not matter. • Displacement tonnage of the platform in long tons (2240 lbs.).
3	The end of platform type data is marked by a line resembling line 2, but with a negative “kind” value.
4	Line 4 appears multiple times, once for each type of sonar. Each line has seven numbers: • Enumeration/code for this sonar type. • Sonar mode (0 = passive, 1 = active and has a receiver, 2 = active but has no receiver). Note that a sonar operating in mode 2 cannot detect any targets by itself. • Frequency (Hz). • Source level (dB) for transmitter. This is ignored for passive sonars. • Gain factor (dB) for transmitter. This is ignored for passive sonars. • Gain factor (dB) for receiver. (The transmitter and receiver gain factors make up the array gain term in the sonar equations; see “Acoustic modelling” section above.). • Maximum detection range (kyds) for the sonar. This is ignored for passive sonars. A negative value indicates an unlimited detection range.
5	The end of sonar type is marked by a line resembling line 4, but with a negative “enumeration/code” value.

N.B.: The DIS codes specified on line 2 should match those used in the model by the MALO federation. Moreover, the sonar enumeration/code values specified on line 4 should match those used by the MALO federation. Mismatches between the entity info file codes and those used by the MALO federation will result in faulty or absent target detection.

Input geoid heights file

AC_SERVER requires a little-endian binary file (www15mgh.dos, NGA[7]) that contains a 15 minute grid of geoid heights. These heights are used when calculating depths below sea level from MALO geocentric xyz coordinates. The file should be in the directory specified by the environment variable ETOPO_PATH.

Input READENV related files

Since AC_SERVER runs program READENV, the data files used by READENV are required (see section below on READENV). These files should be in the directory specified by ETOPO_PATH.

Output files

When AC_SERVER is run, several files are created in the current directory. These files are created directly by AC_SERVER, or are indirectly produced when AC_SERVER runs program READENV and the DMOS programs. Normally these files are not of interest to the user. However if the acoustic server software does not appear to be working correctly, one may wish to examine the renv_script.out and script.out files to see if the READENV and DMOS programs encountered any errors.

Table 4. *Some AC_SERVER output files*

NAME	DESCRIPTION
check_env.script	Script used to check that the environment variables ETOPO_PATH and DMOS have been set properly.
readenv.script	Script used to run READENV.
renv_script.out	Stdout plus sterr resulting from running readenv.script. This file will be present only if a non-zero value has been assigned to the debug flag via the AC_SERVER "-d" command line option.
sonar.script	Script used to run the DMOS programs.
script.out	Stdout plus stderr resulting from running sonar.script. This file will be present only if a non-zero value has been assigned to the debug flag via the AC_SERVER "-d" command line option.

Program READENV

This program reads environmental data from the DRDC Atlantic Rapid Environmental Assessment (REA) database version 2 (Deveau [8]) and/or other data files. (When used by the MALO acoustic server, READENV does not access the REA database.) The data are processed and output to files for use by sonar modelling software.

Input files

Program READENV requires several little endian binary files. These are required even if the REA database is used, since the REA database lacks some data.

Table 5. *READENV input files*

NAME	CONTENTS
ETOPO2v2_LSB.RAW	ETOPO2 version 2 bathymetry data (two minute grid, cell-centered version) (NGDC / WDC MGG [9]).
Note: ETOPO2v2_LSB.RAW has superseded ETOPO2.dos.bin and ETOPO5.DOS. However, support for the latter two files has been retained in program READENV.	
ETOPO2.dos.bin	ETOPO2 version 1 bathymetry data (two minute grid) (NGDC / WDC MGG [10]). Optional - used only if ETOPO2v2_LSR.RAW isn't present. It is recommended that one use ETOPO2 version 2, rather than ETOPO2 version 1, since the former is more accurate.
ETOPO5.DOS	ETOPO5 bathymetry data (five minute grid) (NGDC / WDC MGG [11]). Optional – used only if neither ETOPO2v2_LSR.RAW nor ETOPO2.dos.bin are present.
sxxan1.dos	World Ocean Atlas 2001 salinity data (one degree grid) (NODC [12]). "xx" denotes the time period: 00 for annual, 13-16 for the seasons (13=winter, January-March), and 01-12 for the monthly files (01=January).
txxan1.dos	World Ocean Atlas 2001 temperature data (one degree grid) (NODC [12]). "xx" denotes the time period: 00 for annual, 13-16 for the seasons (13=winter, January-March), and 01-12 for the monthly files (01=January)
grainsiz.dos	Surficial sediment grain size data. For each latitude and longitude pair in the file, there are the mean grain size and/or the relative percentages of the sediment texture components (gravel, sand, silt, clay, and mud). The data were assembled from: • Geological Survey of Canada expedition database (NRCAN GSC [13]) • National Geophysical Data Center grain size database (NGDC / WDC MGG [14]) • U. S. Geological Survey's east coast sediment texture database (USGS [15]) • U. S. Geological Survey's usSEABED database (USGS [16], [17] and [18]) • Deep Sea Drilling Project grain size database (NGDC / WDC MGG [19) • Ocean Drilling Program smear slide/thin section data (NGDC / WDC MGG [20], IODP/TAMU [21]) • Integrated Ocean Drilling Program smear slide data (IODP/TAMU [22]) • Dalhousie University Scotian Shelf data (USGS [23]). Some data are from: • World Data Center for Marine Environmental Sciences (WDC-MARE [24]).
grainsiz_dir.dos	A directory for the grainsiz.dos file

seddist.dos	Genetic sediment types on the deep sea floor (global map; Wadsworth Group [25], Pinet [26])
seddist_indx.dos	An index for the seddist.dos file
sedmap.dos	Scripps Institution of Oceanography (SIO) sediment thickness data (depth to acoustic basement; one degree grid) (Laske [27]). Used in READENV for areas that are not in the sedthick.dos file.
sedthick.dos	National Geophysical Data Center (NGDC) sediment thickness data (depth to acoustic basement; two minute grid) (NGDC / WDC MGG [28]).

REA database

The REA database (Deveau [8]) is a collection of environmental data from DRDC Atlantic and other sources. In its first version (Deveau [29]), the database held only three types of data, all of which originated from DRDC Atlantic: Non-Acoustic Data Acquisition System (NADAS) files, Expendable Bathythermograph (XBT) data, and the Shallow Water Database (SWDB). When development of READENV started, the REA database was in its first version, so READENV was set up to access only the aforementioned three types of data from the REA database. A shortcoming of the REA data were their limited geographical coverage, which meant that READENV would have to fall back to its other input data files for the missing information.

Successive versions of the REA database have changed the format and content of its tables, and added more types of data. Rather than try to keep pace with the ongoing REA database changes, READENV (as used by AC_SERVER) uses only its own input data files. Current support of REA by READENV is limited: version 2 of the database is supported (currently the database is at version 3), and READENV uses only the three types of data that were in version 1 of the database.

Running the program

The environment variable ETOPO_PATH should be set to point to the directory which holds the input data files (other than the REA database). If ETOPO_PATH is not defined, it is assumed that the data files are in the current directory.

Examples:
export ETOPO_PATH=/data   (Linux bash shell)
setenv ETOPO_PATH /data   (Linux tcsh shell)

To run the program, enter:
readenv [-v] [-h hostname] [-U username] [-W password] [[-d] dbname]

Table 6. *READENV command line arguments*

OPTION	MEANING
-v	If present, causes some debugging output to be produced
-h hostname	The REA database server hostname. Can be specified by name or IP address. If not present, it is assumed that the database is on the current machine.
-U username	User name for REA database access. If not present, it is assumed that the user name is the current computer user name.
-W password	Password for REA database access.
-d dbname	Name of the REA database. If not present, it is assumed that the name is “readbv2”.

If the REA database is to be used, normally only the “hostname” option is required.

Program input (stdin) messages

If the user just presses <Enter> in response to a program message, the default parameter value shown in parentheses will be used.

Table 7. *READENV input messages*

NO.	MESSAGE	USER RESPONSE
1	REA database options (…) ?	A string of characters indicating what data are to be obtained from the REA database, if possible. “B”=bathymetry, “S”=sound speed profiles, “T”=bottom type, “N”=do not use REA database. Several options can be specified at once (e.g., “BST”). Specifying “N” indicates that the REA database is never to be used.
2	Output option (…) ?	An integer indicating the type of output file(s) to be produced: 0=none (program will stop). 1=general bathymetry, sound speed profile, and bottom loss files. 2=program PMODES environment file. General output (option 1) can be range dependent, whereas PMODES output (option 2) is range independent
3	Receiver latitiude (…) ?	Receiver latitude in degrees. Positive for north latitude.
4	Receiver longitude (…) ?	Receiver longitude in degrees. Positive for east longitude.
Messages 5 to 8 appear only if one asked for PMODES environment file output.		
5	Water density (g/cm**3) (…) ?	Water density in gm/cm**3.

6	Water column attenuation flag (…) ?	If this is ≥ 0.0 and ≤ 1.0, the value is used as the attenuation coefficient (dB/Hz-km) for the water column. If this = -1.0, then Thorpe volume attenuation is used. If this = -2.0, then Urick volume attenuation is used. If this is an integer ≥ 2, then the value is the number of attenuation coefficients.
Messages 7 and 8 appear only if one entered a value ≥ 2 for the water column attenuation flag.		
7	Depth increment (m) for attenuation coefficients (…) ?	The depth increment in metres between attenuation coefficient values.
Message 8 will be repeated N times, where N is the number of attenuation coefficients (≥ 2; see message 6).		
8	Attenuation coefficient no. j (dB/Hz-km) (…) ?	The jth attenuation coefficient for the water column in dB/Hz-km.
Messages 9 to 12 appear only if one asked for general file output.		
9	Radial bearing (degrees true) (…) ?	Bearing (in degrees true) of target relative to the receiver (degrees clockwise from north).
10	Maximum range (km) for bathymetry data (…) ?	Maximum range along the radial for which bathymetry data are to be output.
11	Number of bathymetry points to output (…) ?	Number of bathymetry points (≥ 1) to output, starting at the receiver's location.
12	Name of output bathymetry file (…) ?	Name of the file to which the bathymetry data will be written.
13	Round bathymetry to nearest metre (0=no, 1=yes) (…) ?	1 to round the bathymetry data to the nearest metre. (It is recommended that PMODES output be rounded.) 0 to not round the bathymetry data.
14	Please specify the time period for the sound speed profiles …. Time period (0 to 16) (…) ?	The time period for the output sound speed profiles [0=annual, 1-12 = month, 13-16=season (13=winter, January-March)].
15	Default salinity (ppt) (…) ?	The default salinity in ppt to be used in sound speed calculations. Used only if salinity data are not available.
Messages 16 to 18 appear only if one asked for general file output.		
16	Number of sound speed profiles to output (…) ?	The number of range dependent sound speed profiles (≥ 1) to output.
17	Name of output sound speed profiles file (…) ?	The name of the output sound speed profiles file.
18	Number of range dependent bottom loss sets (…) ?	The number of sets of bottom loss data (≥ 1) to be output
19	Maximum number of bottom layers (…) ?	The maximum number of bottom layers, including the bottom half-space. If = 0, there will be a single layer whose properties are those of the surficial sediments. If = 1, the single layer will have the sediment properties as averaged over the sediment thickness (N.B. – A value ≠ 1 is not recommended for PMODES output, as the

		resultant data may cause program PMODES to abort.)
20	Minimum thickness (m) of each bottom layer (…) ?	The minimum thickness of layers (other than the bottom half-space). The topmost sediment layer(s) will have this thickness. If ≤ 0, there will be at most two layers output.
Message 21 appears only if one asked for general file output.		
21	Name of output bottom loss file (…) ?	The name of the output bottom loss file
Message 22 appears only if one asked for PMODES environment file output.		
22	Name of output PMODES environment file (…) ?	The name of the output PMODES environment file.

Messages 2 to 22 are repeated until one specifies "no output" in response to message 2, or until an end-of-file is encountered (CTRL-D for Linux console input).

Processing of input data

READENV produces bathymetry, sound speed profiles, and bottom loss data for user-specified locations. These data are obtained as follows

Using the REA database

READENV tries to find bathymetry within ±0.5 degrees latitude and longitude of the desired location from the REA NADAS and XBT data. If data can be found, they are interpolated to obtain a bottom depth. Otherwise, READENV falls back to using the ETOPO data file to get bathymetry.

For sound speed profiles, READENV accesses the REA XBT data. It tries to find the closest temperature or sound speed versus depth profile within ±1.0 degree latitude and longitude of the desired location, at the specified time of year. If data are found, then they are despiked. Temperature data are converted to sound speeds using salinity data obtained from the WOA data files. The sound speed profiles are smoothed and decimated. If no data could be obtained from the REA database, sound speed profiles are computed from the WOA temperature and salinity data.

For bottom loss data, READENV uses the REA SWDB data. It tries to find the closest sediment type data within ± 1.25 degrees latitude and longitude of the desired location. If the sediment type data are found, then a mean grain size is computed from the data. Otherwise, mean grain size data is obtained from the grain size data file. Sediment thickness is obtained from the stand-alone sediment thickness data file. The sediment data are then used to calculate the bottom loss information.

Using stand-alone data files

Bathymetry data are obtained by interpolating data from the ETOPO file. For sound speed profiles, salinity and temperature profiles are obtained by interpolating data from the WOA salinity and temperature files for the requested time period. The resultant interpolated salinity and temperature data are used to compute the sound speed profile.

For bottom loss data, READENV tries to find the closest mean grain size data within ± 4 degrees of the desired latitude and longitude, using the grain size data file. (This range is larger than that used for the REA SWDB data, since the stand-alone grain size data file includes deep sea areas where samples are not as closely spaced.) If the data are not found, then the genetic sediment type for the location is determined from the genetic sediment type file (seddist.dos), and a mean grain size for that sediment type is chosen based on average data from Hamilton and Bachman [30]. Sediment thickness for the location is obtained by interpolating data from the sediment thickness file. The mean grain size and sediment thickness data are then used to compute bottom loss parameters (Hamilton and Bachman [30], Hamilton [31-36], Bachman [37-39], Mitchell and Folke [40], Bowles [41]).

General output files

General output files consist of separate ASCII files for bathymetry, sound speed profiles, and bottom loss data. The data may be range dependent.

Table 8. *General output bathymetry file*

RECORD	CONTENTS	DATA TYPE
1	Number of bathymetry points (say N).	Integer
2 to N+1	Range (km) and depth (m)	Two floating-point numbers

The data are stored in order of increasing range.

__Table 9.__ General output sound speed profiles file

RECORD	CONTENTS	DATA TYPE
1	Number of range dependent sound speed profiles (N)	Integer
Following the above record are N sets of sound speed profile data. (The following record numbers are for the first such set. Records 2 to 3+(J-1) are repeated for each set.)		
2	Range (km) and number of sound speed profile points (say J).	Floating-point, integer
3 to 3+(J-1)	Depth (m) and sound speed (m/s)	Two floating-point numbers

Data are stored in order of increasing range. For a particular range, data are stored in order of increasing depth.

__Table 10.__ General output bottom loss file

RECORD	CONTENTS	DATA TYPE
1	Number of range dependent bottom loss sets (N)	Integer
Following the above record are N sets of bottom loss data. (The following record numbers are for the first such set. Records 2 to 3+(J-1) are repeated for each set.)		
2	Range (km) and number of bottom loss points (say J).	Floating-point, integer
3 to 3+(J-1)	Layer thickness (m), density (g/cm**3), compressional sound speed (m/s), attenuation (dB/KHz-m). The final layer thickness of –1 indicates the bottom half-space.	Four floating-point numbers

Data are stored in order of increasing range. For a particular range, data are stored in order of increasing depth.

Output PMODES environment file

This file contains a subset of the information present in a program PMODES environment file (section 5.11 of Theriault and Calnan [2]).

Table 11. *Output PMODES environment file*

RECORD	CONTENTS	DATA TYPE
1	Depth (m), water density (gm/cm**3), and attenuation flag. The attenuation flag is defined as follows: If it is ≥ 0.0 and ≤ 1.0, the value is used as the attenuation coefficient (dB/Hz-km) for the water column. If it = -1.0, then Thorpe volume attenuation is used. If it = -2.0, then Urick volume attenuation is used. If it is an integer ≥ 2, then the value is the number of attenuation coefficients.	Three floating-point numbers
Record 2 is present only if the attenuation flag value in record 1 is ≥ 2.		
2	Depth increment (m), followed by as many attenuation values in dB/Hz-km as are specified by the value of the attenuation flag in record 1.	Three or more floating-point numbers
Record 3 is repeated N times, once for each sound speed profile pair.		
3	Water depth (m), compressional sound speed (m/s).	Two floating-point numbers
4	The end of sound speed profile is marked by a record resembling record 3, but with a negative “sound speed” value.	Two floating-point numbers
5	Shear speed and attenuation. These are unused by PMODES, and are set to 0.0 by READENV.	Two floating-point numbers
Record 6 is repeated K times, once for each bottom layer. The layers are specified from the surface downwards.		
6	Layer thickness (m), layer density (g/cm**3), layer compressional sound speed (m/s), layer attenuation (dB/Hz-km). The final layer (the bottom half-space) has a layer thickness of –1.0.	Four floating-point numbers
7	Surface and bottom RMS roughness. These are unused by PMODES, and are set to 0.0 by READENV.	Two floating-point numbers

DMOS changes

DMOS (DRDC Atlantic Model Operating System, Theriault and Calnan [2]) is a suite of programs for modelling reverberation, transmission loss, signal excess, and probability of detection for sonars. Several changes were made to DMOS, partly in order to use it with the MALO acoustic server. The major changes were:

1. The option to compute ambient noise based on frequency, wind speed, shipping level, and other environment parameters was added.

2. A new version of Bellhop (McCammon [42]) was added.

3. The maximum allowable number of normal modes for active sonar calculations was increased.

4. To get around limits on the number of modes the software can handle, mode calculations can now be optionally done at a lower frequency, whereas calculations of attenuation, surface scattering, and ambient noise are still based on the actual signal frequency. (This stratagem is possible because the number of normal modes used in calculations is directly proportional to the signal frequency.)

5. MONOGO was modified to allow the option of performing normal mode reverberation calculations using a single sum, as opposed to the former double sum (Ellis [5]). Using a single sum speeds up calculations.

6. A new program, SEPASS, to calculate signal excess for passive sonars was added.

Details of the changes to the DMOS programs are given in the following sections.

Environment description (.des) file

This file provides an environment description for use by the DMOS programs Bellhop, MONOGO, EXCESS1 and TSPREAD1. Some optional parameters (rain rate and shipping level) were added to this file for use in ambient noise calculations. The following listing shows the revised contents of a sample environment description file (compare with listing 25 in section 5.15 of Theriault and Calnan [2]); note the new optional lines 4g and 4h:

```
BASE 04 test run
36.3057  15.7192  66.0  018.0          !2) Transmitter data
36.3057  15.7192  66.0  018.0  060.0   !3) Receiver data
Gradient slope                         !4a)
Gradient flat                          !4b)
Gradient FILE = bathy_0600.data        !4c)
SURFACE SCATTERING = chapman           !4d)
SURFACE SCATTERING = lambert           !4e)
SEA STATE=3                            !4e)
WIND SPEED=15                          !4f)
RAIN RATE=0                            !4g)
```

```
SHIPPING LEVEL=1                        !4h)
Radial Information                      !5) PMODES line
Radial Information eigenray             !5) Bellhop line
....
```

Table 12. *Comments on environment description (.des) file*

DATA LINE	DATA LINE INFORMATION
4	Lines 4g) and 4h) are optional. 4g) contains the strings “RAIN” and “RATE” separated by one blank space. The strings must be followed by the “=” character, which is followed by an integer from 0 to 3 for the rain rate: 0=none, 1=intermediate, 2=moderate, 3=heavy. 4h) contains the strings “SHIPPING” and “LEVEL” separated by one blank space. The strings must be followed by the “=” character, which is followed by an integer from 1 to 9 for the shipping level.

Program Bellhop version 1

This program was previously incorporated in DMOS under the name BellhopDMOS (Calnan [43]). We now call this program BellhopDMOS1. BellhopDMOS1 is a wrapper program that runs program bellhopDRDC_S (McCammon [44]).

Program Bellhop version 2

This updated version of the Bellhop program has been added to DMOS under the name BellhopDMOS2. BellhopDMOS2 is a wrapper program that runs program bellhopDRDC_2 (McCammon [42]). Note that Bellhop version 2 uses a different format for the bottom loss description file, bottomloss.inp, than that used in Bellhop version 1. Otherwise, the Bellhop v2/BellhopDMOS2 input files are the same as the Bellhop v1/BellhopDMOS1 input files. In BellhopDMOS2, the data in output arrival files have been written with more digits to improve accuracy.

Program PMODES

The PMODES stdin and output transmission loss files have been changed.

PMODES stdin file

The following listing shows the revised contents of the sample PMODES stdin file (compare with listing 2 in section 5.1.2 of Theriault and Calnan [2]); note the changes to line 1 and the new line 14b.

```
LTOF              !  1) Processing options
1000              !  2) Range minimum (m)                           [T]
1000              !  3) Range increment (m)                         [T]
...
9                 ! 14) Number of computational layers              [O]
5000.0            ! 14b) Frequency for attenuation calculations     [F]
Pek80.tls         ! 15) Transmission loss output file               [T]
Pek100.env        !  6) Environment input file                      [O]
Pek100.bin        !  7) Mode output file
Pek100.tls        ! 15) Transmission loss output file               [T]
Pek120.env        !  6) Environment input file                      [O]
....
```

Table 13. *Comments on PMODES stdin file*

DATA LINE	DATA LINE INFORMATION
1	The processing options, which have the new features: F – specify frequency for attenuation calculations (see line 14b). S – print short output messages.
14b	The frequency (Hz) to be used for attenuation calculations, which is only needed once since it is used for all environments. This line must be here only if option "F" was chosen.

PMODES output transmission loss (.tls) file

The following listing shows the revised contents of the sample PMODES output transmission loss file (compare with listing 21 in section 5.13.1 of Theriault and Calnan [2]); note the additional comments at the start of the file.

```
TYPE: Transmission loss
TITLE: Pekeris model -- 100 m - Last Revision: 28 June 95
COMMENTS: 4
PMODES OUTPUT
Sources:     1
Receivers:     1
Pairs:     1
DATA START
  0.1000000E-02   18.65814       18.78053
   1.001000       51.62262       49.34980
   2.001000       62.09769       52.52219
. . .
```

The three columns in the output file contain:
range in km
coherent transmission loss in dB
incoherent transmission loss in dB

The "Pairs" comment refers to the number of source-receiver pairs in the file. If there is more than one pair, the data are ordered by increasing range, and then by pair. Thus if there were two pairs, the data would be like:

```
TYPE: Transmission loss
TITLE: Pekeris model -- 100 m - Last Revision: 28 June 95
COMMENTS: 4
PMODES OUTPUT
Sources:     1
Receivers:     2
Pairs:     2
DATA START
  0.1000000E-02   18.65814       18.78053
  0.1000000E-02   20.56231       20.66794
   2.001000       62.09769       52.52219
   2.001000       64.79627       54.32957
. . .
```

Program MONOGO

The following listing shows the revised contents of the sample MONOGO stdin file (compare with listing 3 in section 5.1.3 of Theriault and Calnan [2]); note the change to line 2 and the new line 11.

```
Test - omni transmit/receive
LDFS                     !  2) Processing options
EX4d_0456.des            !  3) Input environmental description
working/temp             !  4) Directory for some files      [D]
EX4d_0456.sys            !  5) Input system file
EX4d_0456_ngv.rev        !  6) Output no-group reverb file
EX4d_0456_gv.rev         !  7) Output reverb file inc GV
1                        !  8) Minimum time (s)
100                      !  9) Maximum time (s)
0.5                      ! 10) Time increment (s)
5000.0                   ! 11) Frequency (Hz) for surface scattering
```

Table 14. *Comments on MONOGO stdin file*

DATA LINE	DATA LINE INFORMATION
1	The processing options, which have the new features: F – specify frequency for surface scattering calculations (see line 11). S – use single sum rather than double sum for reverberation calculations (Ellis [5]).
11	The frequency (Hz) to be used for surface scattering calculations. This line must be here only if option "F" was chosen.

Program EXCESS1

Target depths that are at or below the bottom depth are changed to be above the bottom as follows. If the bottom depth is ≥ 15 metres, the target depth is set 10 metres above the bottom. If the bottom depth is < 15 metres, the target is set to be half the bottom depth.

The EXCESS1 stdin file has been changed, and an optional MALO output file has been added.

EXCESS1 stdin file

The following listing shows the revised contents of the sample EXCESS1 stdin file (compare with listing 5 in section 5.1.5 of Theriault and Calnan [2]); note the changes to lines 1, 10 and 17, and the new lines 9b and 18.

```
EX4d - vla transmit/vla receive
LTSEDFX            !  2) Processing options
RD_rad40.des       !  3) Input environ. Description
somefiles/here     !  4) Directory for some input files  [D]
EX4d_0400.sys      !  5) Input system file
Target.des         !  6) Input target file
EX4d_0400.tls      !  7) Output TL file                  [T]
EX4d_0400.sex      !  8) Output SE file              [E] [S]
EX4d_0400.eco      !  9) Output echo level file          [E]
EX4d_0400.mal      !  9b) Output MALO file               [X]
EX4d_gv.rev        ! 10) Input reverb file       [X] [E] [S]
1.0                ! 11) Range minimum (km)
1.0                ! 12) Range increment (km)
60                 ! 13) Number of range points
90.0               ! 14) Sub-radial minimum (deg)
5.0                ! 15) Sub-radial increment (deg)
3                  ! 16) Number of radial points
-999               ! 17) Equiv. omni noise       [X] [E] [S]
5000.0             ! 18) Freq for noise calc [F] [X] [E] [S]
```

Table 15. *Comments on EXCESS1 stdin file*

DATA LINE	DATA LINE INFORMATION
1	The processing options, which have the added features: M – list mode details. (This is not a new feature, but the option is not mentioned in Theriault and Calnan [2]).) F – specify frequency for surface scattering calculations (see line 18). X – create a MALO output file.
9b	The name of the output MALO file. This line must be in the file only if option “X” was chosen. The file is described below.
10	The name of a reverberation input file. This line must be in the file if option “E”, “S” or “X” was chosen.
17	The equivalent omni-directional noise level in dB re 1 uPa**2/Hz. This line must only be in the file if option “E”, “S” or “X” was chosen. If a noise level of –999 is specified, the ambient noise will instead be calculated using frequency, wind speed, rain rate, and other environmental parameters. (The environmental parameters are given in the environmental description file, which is described above in this report.)
18	The frequency (Hz) to be used for ambient noise calculations This line should only be in the file if option “E”, “S” or “X” was chosen, option “F” was chosen, and a noise level of -999 was specified on line 17.

EXCESS1 MALO output file

This optional ASCII output file was introduced to satisfy preliminary requirements for the MALO project. (This file is currently not used by the MALO acoustic server.) The file has three sections. Each section has table headings, followed by columns of numbers.

1. Main active table:
   For PMODES output, this table contains these columns: Frequency, Echo Time, Latitude (source), Longitude (source), Depth (source), Depth (target), Range (target), Receiver Heading, Radial Bearing, Subradial Bearing, Beam, and Signal Excess.
   For Bellhop output, this table contains these columns: Frequency, Minimum Time, Maximum Time, Latitude (source), Longitude (source), Depth (source), Depth (target), Range (target), Receiver Heading, Radial Bearing, Subradial Bearing, Beam, and Signal Excess.

2. Target table:
   This table contains the columns Frequency and Target Strength.

3. System table:
   This table contains the columns Frequency, Net System Gain, and Detection Threshold.

Program SEPASS

Given range dependent transmission loss data as output by programs Bellhop and PMODES, SEPASS calculates signal excess values for passive sonars. SEPASS was modelled after program EXCESS1, which calculates signal excess for active sonars.

SEPASS stdin file

The following listing shows the contents of a sample SEPASS stdin file.

```
Test - passive sonar
L                  ! 2) Processing options
passive.dat        ! 3) Passive sonar parameters file
Y                  ! 4) Process incoherent TL (Y/N)?
input.tls          ! 5) Input transmission loss file
output.sex         ! 6) Output signal excess file
```

Table 16. *Comments on SEPASS stdin file*

DATA LINE	DATA LINE INFORMATION
1	Program run’s title, used in output files as an identifier.
2	The processing options, which for this program are: B – list known bugs related to SEPASS in the file bug_report.txt. C – list all known DMOS bugs in the file bug_report.txt. L – print long, or verbose, output messages. O – print extra debugging output messages. U – list update notes related to SEPASS in the file update_report.txt. V- list update notes related to DMOS in the file update_report.txt. If bug_report.txt and/or update_report.txt don’t exist in the current working directory, then the options that require them won’t be able to be performed, and a message will be written to that effect.
3	The name of an input file containing the passive sonar parameters.
4	Indicates if incoherent transmission loss (TL) data are to be processed: “Y” to process incoherent TL data, “N” to process coherent TL data.
5	The name of an input transmission loss file as produced directly by either Bellhop or PMODES. This is not a transmission loss file as produced by EXCESS1.
6	The name of the output signal excess file. This file is described below.

SEPASS input passive sonar parameters file

The following listing shows the contents of a sample passive sonar parameters file.

```
200 1 134.8          ! 1) Frequency, bandwidth, source level
0 -20                ! 2) Detection threshold, system loss
1                    ! 3) No. of receivers
0 -300               ! 4) Array gain, self noise
-999 4               ! 5) Sea state, wind speed
0 5                  ! 6) Rain rate, shipping level
-999                 ! 7) Omni noise level
```

Table 17. *Comments on SEPASS passive sonar parameters file*

DATA LINE	DATA LINE INFORMATION
1	This line contains three items: • Frequency (Hz) to be used in ambient noise calculations. • Receiver bandwidth (Hz). • Signal source level (dB).
2	This line contains two items: • The detection threshold (dB) for all receivers described in this file. • The system loss (dB) for all receivers described in this file.
3	The number of receivers (say N) described in this file.
4	The line is repeated N times, once for each of the receivers. The line contains two items: Array gain in dB re 1 Hz bandwidth. Self noise in dB.
5	This line contains two items: • The sea state, an integer from 0 to 6. If < 0, sea state is assumed to be undefined. • The wind speed (knots). If < 0.0, wind speed is assumed to be undefined.
6	This line contains two items: • The rain rate, an integer from 0 to 3 (0=none, 1=intermediate, 2=moderate, 3=heavy). If < 0, rain rate is assumed to be undefined. • The shipping level, an integer from 1 to 9. If < 0, shipping level is assumed to be undefined.
7	The equivalent omni-directional noise level in dB re 1 uPa**2/Hz. If a noise level of –999 is specified, the ambient noise will instead be calculated using frequency, sea state, wind speed, rain rate, and shipping level.

SEPASS output signal excess (.sex) file

The following listing shows the contents of a sample ASCII signal excess file.

```
TYPE: Signal Excess
TITLE: SEPASS
X-AXIS: Range (km)
Y-AXIS: Signal Excess (dB)
COLUMNS:     3
```

```
Beam     1
Beam     2
Beam     3
Frequency:    200.000 Hz
Source level:   134.864 dB re 1 uPa
DATA START
    0.3333    -9.1551    -8.3752   -10.4871    -8.3762
    0.6667   -16.7450    -9.4855   -10.5635    -9.4855
    1.0000   -11.9485   -10.5643   -10.2507   -10.2507
....
```

In the data portion of this file, column 1 is the range in km, and all but the last column has one of the beams' signal excess values in dB. The last column contains the maximum of the beams' signal excess values for that range. If there is only one beam, then only the range and that beam's results are listed; no maximum value column is created.

If there are more than five beams, then the signal excess values are created as an ASCII header file and a binary data file. A sample header file is:

```
TYPE: Signal Excess
TITLE: SEPASS
X-AXIS: Range (km)
Y-AXIS: Signal Excess (dB)
COLUMNS:     7
Beam     1
Beam     2
Beam     3
Beam     4
Beam     5
Beam     6
Beam     7
Frequency:    200.000 Hz
Source level:   134.864 dB re 1 uPa
BINARY DATA
```

The binary data file contains the range and signal excess data (including the maximum beam value) as per an ASCII data file. (The same data units are used for both ASCII and binary files.) If the SEPASS stdin file specified B04_1080.sex as the output signal excess file, then the ASCII header file would be named B04_1080.sex, and the corresponding binary data file would be called B04_1080B.sex.

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List of symbols/abbreviations/acronyms/initialisms

ACE	Aerospace and Cognitive Engineering
DMOS	DRDC Atlantic Model Operating System
DMSO	Defense Modeling and Simulation Office
DRDC	Defence Research and Development Canada
DSDP	Deep Sea Drilling Project
ED	Expedition database
GSC	Geological Survey of Canada
HLA	High Level Architecture
IODP	Integrated Ocean Drilling Program
MALO	Maritime Air Littoral Operations
NADAS	Non-Acoustic Data Acquisition System
NASA	National Aeronautics and Space Agency
NCCOSC	Naval Command and Control Ocean Surveillance Center
NGA	National Geospatial-Intelligence Agency
NODC	National Oceanographic Data Center
NRCAN	Natural Resources Canada
ODP	Ocean Drilling Program
ppt	Parts per thousand
Prob.	Probability
REA	Rapid Environmental Assessment
RMS	Root mean square
SIO	Scripps Institution of Oceanography
SISO	Simulations Interoperability Standards Organization

SWDB	Shallow Water Database
TAMU	Texas A & M University
TDP	Technology Demonstrator Project
USGS	United States Geological Survey
WDC-MARE	World Data Center for Marine Environmental Sciences
WDC MGG	World Data Center for Marine Geology and Geophysics
WOA	World Ocean Atlas
XBT	Expendable bathythermograph

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