CASAL2
Software Architecture

v2016.1

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Document History

Version	Description	Author	Date
1.0	*Initial version - Draft*	S.Rasmussen	13/06/2012
1.1	*Modification of diagrams, explanation of states*	S.Rasmussen	12/07/2012
1.2	*Updating diagram to show modifications to states*	S.Rasmussen	28/02/2013
	Updating Development environment		
1.3	*Update to show functionality created as part of phase 1*	S.Rasmussen	05/07/2013
V2016.1	*Update to reflect released version 1.0 of CASAL2*	S.Rasmussen	20/01/2016

CASAL2 Overview

CASAL2 is the successor to the CASAL modelling application that was developed approximately 10 years ago. It has been developed using modern technology and current best practice development techniques to ensure maintainability and integrity.

CASAL2's architect is based on the design mentality behind the Spatial Population Model (SPM - http://www.niwa.co.nz/fisheries/tools-resources/spm-spatial-population-model). The code base is highly modular with code developed in small light-weight objects that are easily recognisable and extensible.

The SPM code base was developed in 2007 and is still maintainable today as the code follows a well documented coding standard and a simplistic layout for objects. The techniques used to develop SPM are proven, and have been applied to the development of CASAL2.

Supported Operating Systems

CASAL2 is as a native 64 bit (x64) application with no 32 bit (x86) support.

The processor families supported are the Intel and AMD processors that conform to the AMD64 (x64) specification. PowerPC and ARM processors are not supported.

Operating Systems supported will be Windows 7/8/10 (64 bit) and Linux (64 bit). All other Operating System variants (BSD, Unix, OSX, Android, IOS) may work, but have not been tested.

Development Environment

CASAL2 will primarily be developed on:

Operating Systems

- Microsoft Windows 7 (x64)
- Microsoft Windows 10
- OpenSuSe 12.2 (Mantis x64)
- OpenSuSe Tumbleweed (bleeding edge rolling releases)
- Ubuntu 15.10

Development Environment

The environments listed below contain the compatable versions. Any versions of software not listed below are most likely not compatable with CASAL2.

The G++ compiler must be atleast version 4.8 to work. Anything newer than this should work fine.

Windows

- TDM-GCC 4.8.X (http://tdm-gcc.tdragon.net/)
- TDM-GCC 4.9.X (http://tdm-gcc.tdragon.net/)
- TDM-GCC 5.0.X (http://tdm-gcc.tdragon.net/)
- TDM-GCC 5.1.X (http://tdm-gcc.tdragon.net/)
- TDM-GFortran
- AQTime3 – Performance profiling
- Very Sleepy – Performance profiling

CASAL2 comes with components as part of it's build system. These are:

- Unix Utils - *nix command line applications for Windows
- Python 2.X
- CMake 2.8.X

Linux

- GCC/G++ 4.8.X
- GCC/G++ 4.9.X
- GCC/G++ 5.0.X
- GCC/G++ 5.1.X
- GCC/G++ Fortran
- Valgrind
- CMake 2.8.X+
- Python 2.X (not 3.X or 4.X)

- Python dateutil, datetime, re, distutils modules

Both

- Eclipse (http://www.eclipse.org/)

Coding Style

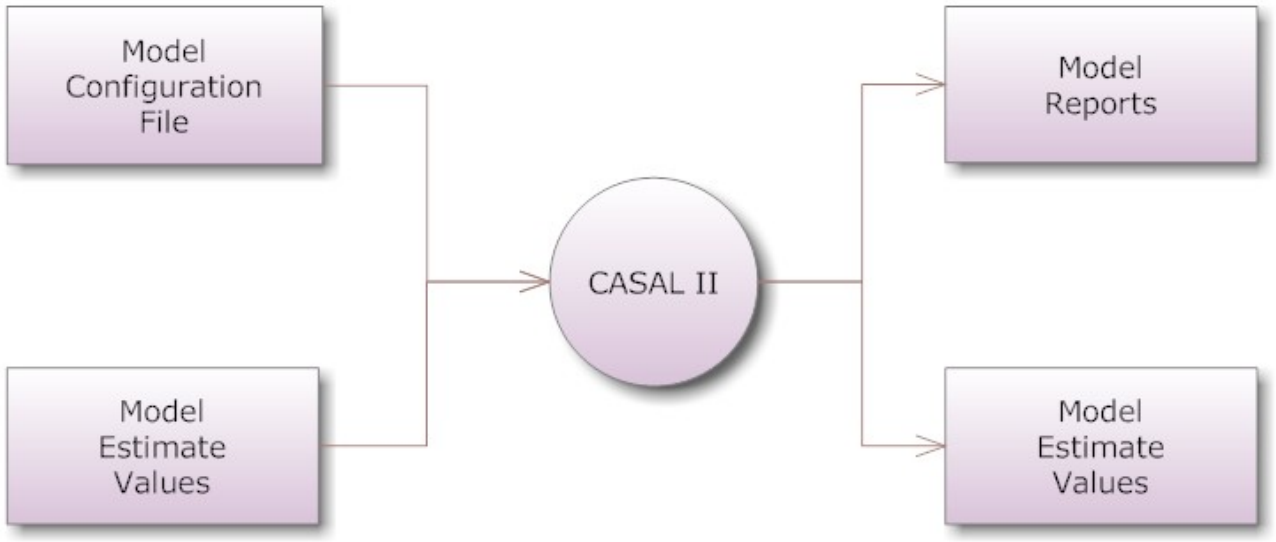
While it's going to be a step away from the style used for SPM, CASAL2 will use the Google Coding style (http://google-styleguide.googlecode.com/svn/trunk/cppguide.xml). Google provides a handy script to parse source code and highlight errors that do not match their coding style.

Spelling of variable names, classes etc will all be done using British English.

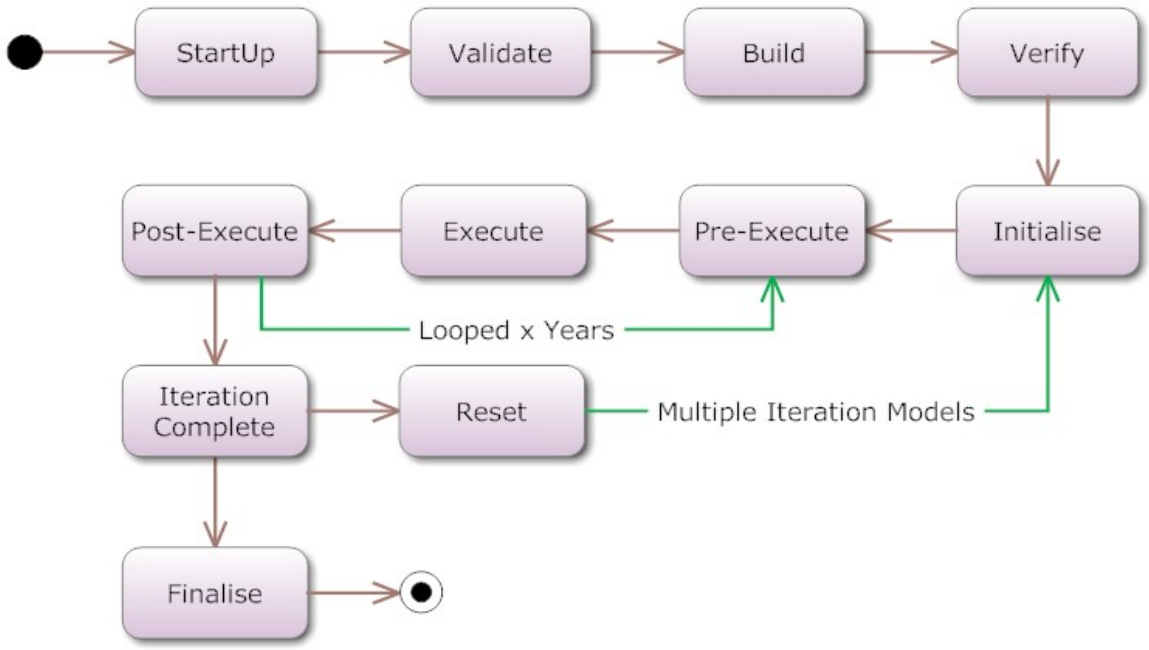
*Note: The only deviation from this style is the use of *.cpp instead of *.cc for filename extensions.*

High-Level Design

Level 0 Data-Flow-Diagram



State-Transition Diagram



State Descriptions

StartUp

The model is in the blank start and the configuration system is loading the configuration files and parsing any extra inputs.

Tasks completed:

- Parse command line
- Parse configuration file
- Load plugins
- Load estimate values from input files

Validate

All user configurations have been loaded at this point. Now the model will go through every object that has been created and check that the parameters given to them.

This step will ensure every object in the model has sufficient parameters to be executed without causing a system fault or error in the model.

This state will not check the values to ensure they are logical in relation to an actual model. They will only test that they exist and meet minimum requirements to execute a model.

At the end of the validate stage each object should be internally consistent. No lookups or external references are allowed to be formed during this stage.

Build

The build phase is where the system will build relationships between objects that rely on each other. Because validation has been completed, each object in it's self-contained configuration is ok.

This phase generally assigns values to pointers for objects so they don't need to do lookups of objects during execution phases.

Verify

At this point pre-defined configurations are checked against the model's current configuration to verify if the model makes sense logically. These are business rules being applied to the model to help ensure the output is not garbage.

Note: This state is not executed by default and must be defined as part of the model execution.

Note: This has not been implemented.

PreExecute

Pre-Execution happens at the beginning of a time step. This allows objects to calculate values based on the partition state before any of the other processes in the time step are executed.

Execute

This is the general work method of the model and where all of the processes will be run against the partition.

PostExecute

This is executed at the end of a time step after all of the processes and associated objects have been executed. This is typically used for things like reports and derived quantities.

IterationComplete

This is executed at the end of every model run. This is only useful when the model is in a multiple-iteration mode (e.g MCMC or Estimation). After every model iteration this state is triggered.

Reset

If the model has to run multiple iterations then the reset state is used to reset everything back in to a state where the model can be re-executed without any legacy data remaining.

This state allows us to run multiple iterations of the model without having to re-process the configuration information or de-allocate/re-allocate large amounts of memory.

Finalise

Finalise will happen after all iterations of the model have been completed.

Software Components

Utilities Library

Inside CASAL2 is a collection of re-usable methods for reading the command line, converting between types, using auto-differentiation types, logging, error handling, double comparison etc.

While not a stand-alone library these methods can easily be extracted for use within other NIWA projects.

Configuration File Parser

The configuration parser was developed from the ground up as a new component for CASAL2 using ideas inspired by the SPM implementation. While it's not a stand-alone component it is still in a state that allows it to be easily ported to other applications.

Some of the in-built functionality of the configuration file parser is a “parameters” architecture that allows for quick retrieval and validation of user supplied parameters with type-conversions and validations. The configuration parser also has the ability to track what file and line a particular parameter was defined to be used for error reporting.

Note: it is expected that SPM will move to the same coding standard as CASAL2 in the future and one of the first components that will make a migration back from CASAL2 will be the configuration parsing system.

Minimisers

CASAL2 supports multiple minimisers out of the box.

- ADOL-C (Auto Differentiation)
- BetaDiff (Auto-Differentiation)
- CppAD (Auto-Differentiation)
- GammaDiff / Numerical Differences
- DESolver – Differential Evolutionary Solver
- DLib

Adding new minimisers is quite simple. Adding new minimisers that are auto differentiation minimisers is significantly more complex, but still a relatively simple task.

Plugin Architecture

No plugin architecture has been developed. However adding the ability to have objects loaded from shared libraries at runtime would be a simple task. The main components of CASAL2 are already loaded like this, so there is a heap of template code in the FrontEnd application.

Dynamic-Library

Developers with enough competence in C++ will be able to develop and load their own plugins by building shared-libraries and specifying the location of these within their configuration files.

An expected inclusion section of someone's plugin would be:

```
#include <niwa/CASAL2/process.h>
#include <niwa/CASAL2/selecvity.h>

class myNewProcess : public niwa::CASAL2::process {
public:
 void validate() { }
 void build() { }
 void execute() { }
}
```

Difficulty for user to develop: High

Execution speed: Fast

Command-Line Executable

Some components of the application will be replacable with command line applications that take specific arguments and return a single result (e.g Selectivities/Layers).

A specification will be developed to allow people to build and specify stand-alone executable based plugins for specific functionality within CASAL2 II.

The upside to this approach is that the user can specify any type of executable they wish, developed in any language, including shell-scripts. The application will simply do an exec() call on that object and intepret the result.

Difficulty for user to develop: Low

Execution speed: Slow

Equation Parser

CASAL2 will have an inbuilt equation parser for handling equations specified natively in the configuration file.

A valid example equation would be: 3^x * 2

Where the user is able to bind 'x' to an internal parameter inside CASAL2 II.

Difficulty for user to develop: Low

Execution speed: Slow

Population Processes

CASAL2 supports a number of population processes. While there is a large number of individual processes the general purpose of these can be broken down in to a few different types.

Category shifting, recruitment, mortality and ageing/growth.

Category Shifting

These processes are responsible for moving part of the population from 1 category in to another.

Implemented in CASAL2 there is:

- Rate

Recruitment

These processes are responsible for the introduction of new population members.

Implemented in CASAL2 there is:

- Constant rate
- Beverton-Holt

Mortality

These processes are responsible for the removal of population members.

Implemented in CASAL2 there is:

- Constant rate
- Event

Ageing/Growth

These processes are responsible for moving population members up through ages/lengths. They work similar to category shifting except only work within a single category.

Implemented in CASAL2 there is:

- Ageing

Software Integrity

One of the key focusses in the CASAL2 development is the emphasis on software integrity. It's hugely important to ensure results coming from user models are consistent and correct.

As part of this we utilise unit tests to check individual components of the software and run entire models verifying results.

CASAL2 uses:

- Google testing framework
- Google mocking framework

As at 5th July 2013 the unit test output was:

```
[==========] Running 19 tests from 4 test cases.
[----------] Global test environment set-up.
[----------] 7 tests from BasicModel
[ RUN      ] BasicModel.Observation_Abundance
[       OK ] BasicModel.Observation_Abundance (3 ms)
[ RUN      ] BasicModel.Accessors_Cached_CombinedCategories
[       OK ] BasicModel.Accessors_Cached_CombinedCategories (1 ms)
[ RUN      ] BasicModel.Processes_Constant_Recruitment
[       OK ] BasicModel.Processes_Constant_Recruitment (1 ms)
[ RUN      ] BasicModel.Processes_Mortality_Event_No_Penalty
[       OK ] BasicModel.Processes_Mortality_Event_No_Penalty (1 ms)
[ RUN      ] BasicModel.Processes_Mortality_Constant_Rate
[       OK ] BasicModel.Processes_Mortality_Constant_Rate (1 ms)
[ RUN      ] BasicModel.Processes_Maturation_Rate_Constant_One_Selectivity
[       OK ] BasicModel.Processes_Maturation_Rate_Constant_One_Selectivity (1 ms)
[ RUN      ] BasicModel.Processes_Ageing
[       OK ] BasicModel.Processes_Ageing (1 ms)
[----------] 7 tests from BasicModel (10 ms total)

[----------] 1 test from PartitionAccessors
[ RUN      ] PartitionAccessors.Category
[       OK ] PartitionAccessors.Category (0 ms)
[----------] 1 test from PartitionAccessors (0 ms total)

[----------] 10 tests from Selectivities
[ RUN      ] Selectivities.LogisticProducing
[       OK ] Selectivities.LogisticProducing (0 ms)
[ RUN      ] Selectivities.Logistic
[       OK ] Selectivities.Logistic (0 ms)
```

```
[ RUN      ] Selectivities.KnifeEdge
[       OK ] Selectivities.KnifeEdge (0 ms)
[ RUN      ] Selectivities.InverseLogistic
[       OK ] Selectivities.InverseLogistic (0 ms)
[ RUN      ] Selectivities.Increasing
[       OK ] Selectivities.Increasing (0 ms)
[ RUN      ] Selectivities.DoubleNormal
[       OK ] Selectivities.DoubleNormal (0 ms)
[ RUN      ] Selectivities.DoubleExponential
[       OK ] Selectivities.DoubleExponential (1 ms)
[ RUN      ] Selectivities.Constant
[       OK ] Selectivities.Constant (0 ms)
[ RUN      ] Selectivities.AllValuesBounded
[       OK ] Selectivities.AllValuesBounded (0 ms)
[ RUN      ] Selectivities.AllValues
[       OK ] Selectivities.AllValues (0 ms)
[----------] 10 tests from Selectivities (2 ms total)

[----------] Global test environment tear-down
[==========] 18 tests from 4 test cases ran. (14 ms total)
[  PASSED  ] 18 tests.
```

A basic coverage of the currently implemented processes and selectivities has already been achieved.

As of 20th January 2016 the unit test output is:

Loading unit test DLL

```
[==========] Running 144 tests from 12 test cases.
[----------] Global test environment set-up.
[----------] 1 test from AdditionalPriors
[ RUN      ] AdditionalPriors.Beta
[       OK ] AdditionalPriors.Beta (0 ms)
[----------] 1 test from AdditionalPriors (0 ms total)

[----------] 72 tests from InternalEmptyModel
[ RUN      ] InternalEmptyModel.AgeLengths_Data_Mean_Mean
[       OK ] InternalEmptyModel.AgeLengths_Data_Mean_Mean (314 ms)
[ RUN      ] InternalEmptyModel.AgeLengths_Data_NearestNeighbour_Mean
[       OK ] InternalEmptyModel.AgeLengths_Data_NearestNeighbour_Mean (305 ms)
[ RUN      ] InternalEmptyModel.AgeLengths_Data_Mean_NearestNeighbour
[       OK ] InternalEmptyModel.AgeLengths_Data_Mean_NearestNeighbour (306 ms)
[ RUN      ] InternalEmptyModel.AgeLengths_Data_Mean_Interpolate
[       OK ] InternalEmptyModel.AgeLengths_Data_Mean_Interpolate (312 ms)
```

```
[ RUN      ] InternalEmptyModel.Asserts_Estimable
[       OK ] InternalEmptyModel.Asserts_Estimable (6 ms)
[ RUN      ] InternalEmptyModel.Asserts_Estimable_Throws_Exception
[ERROR] /home/zaita/CASAL2/CASAL2/source/Asserts/Children/Estimable.cpp(line: 88): Assert Failure: Estimable: process[Recruitment].R0 had actual value 997386 when we expected 1
[       OK ] InternalEmptyModel.Asserts_Estimable_Throws_Exception (5 ms)
[ RUN      ] InternalEmptyModel.Asserts_ObjectiveFunction
[       OK ] InternalEmptyModel.Asserts_ObjectiveFunction (6 ms)
[ RUN      ] InternalEmptyModel.Asserts_ObjectiveFunction_Throws_Exception
[ERROR] /home/zaita/CASAL2/CASAL2/source/Asserts/Children/ObjectiveFunction.cpp(line: 49): Assert Failure: Objective Function had actual value 13.8129 when we expected 1 with difference: 12
[       OK ] InternalEmptyModel.Asserts_ObjectiveFunction_Throws_Exception (5 ms)
[ RUN      ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_1
[       OK ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_1 (1 ms)
[ RUN      ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_2
[ERROR] /home/zaita/CASAL2/CASAL2/source/Categories/Categories.cpp(line: 128): At line 98 in /home/zaita/CASAL2/CASAL2/source/Categories/Categories.Test.cpp the parameter 'years' value 2000 has already been defined for the category male.immature.2000
[       OK ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_2 (0 ms)
[ RUN      ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_3
[       OK ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_3 (1 ms)
[ RUN      ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_4
[       OK ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory_4 (0 ms)
[ RUN      ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory
[       OK ] InternalEmptyModel.Categories_AssignSpecificYearsPerCategory (0 ms)
[ RUN      ] InternalEmptyModel.Categories_GetCategoryLabels
[       OK ] InternalEmptyModel.Categories_GetCategoryLabels (1 ms)
[ RUN      ] InternalEmptyModel.DerivedQuantities_Abundance
[       OK ] InternalEmptyModel.DerivedQuantities_Abundance (1 ms)
[ RUN      ] InternalEmptyModel.DerivedQuantities_Biomass
[       OK ] InternalEmptyModel.DerivedQuantities_Biomass (0 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Inverse
[       OK ] InternalEmptyModel.EstimateTransformations_Inverse (558 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds
[       OK ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds (499 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds_With_DLib_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds_With_DLib_Minimiser (6901 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds_With_DeSolver_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_Inverse_NoBounds_With_DeSolver_Minimiser (1301 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Log
[       OK ] InternalEmptyModel.EstimateTransformations_Log (509 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Log_NoBounds
[       OK ] InternalEmptyModel.EstimateTransformations_Log_NoBounds (990 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_Log_With_DLib_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_Log_With_DLib_Minimiser (6970 ms)
```

```
[ RUN      ] InternalEmptyModel.EstimateTransformations_Log_With_DeSolver_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_Log_With_DeSolver_Minimiser (1306 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_SquareRoot
[       OK ] InternalEmptyModel.EstimateTransformations_SquareRoot (697 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_SquareRoot_NoBounds
[       OK ] InternalEmptyModel.EstimateTransformations_SquareRoot_NoBounds (1205 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_SquareRoot_With_DLib_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_SquareRoot_With_DLib_Minimiser (3607 ms)
[ RUN      ] InternalEmptyModel.EstimateTransformations_SquareRoot_With_DeSolver_Minimiser
[       OK ] InternalEmptyModel.EstimateTransformations_SquareRoot_With_DeSolver_Minimiser (1301 ms)
[ RUN      ] InternalEmptyModel.Estimates_Beta
[       OK ] InternalEmptyModel.Estimates_Beta (79 ms)
[ RUN      ] InternalEmptyModel.Estimates_Lognormal
[       OK ] InternalEmptyModel.Estimates_Lognormal (74 ms)
[ RUN      ] InternalEmptyModel.Estimates_Normal
[       OK ] InternalEmptyModel.Estimates_Normal (75 ms)
[ RUN      ] InternalEmptyModel.Estimates_Normal_By_Stdev
[       OK ] InternalEmptyModel.Estimates_Normal_By_Stdev (75 ms)
[ RUN      ] InternalEmptyModel.Estimates_Normal_Log
[       OK ] InternalEmptyModel.Estimates_Normal_Log (75 ms)
[ RUN      ] InternalEmptyModel.Estimates_Uniform
[       OK ] InternalEmptyModel.Estimates_Uniform (76 ms)
[ RUN      ] InternalEmptyModel.Estimates_Uniform_Log
[       OK ] InternalEmptyModel.Estimates_Uniform_Log (74 ms)
[ RUN      ] InternalEmptyModel.Estimates_Single_Target
[       OK ] InternalEmptyModel.Estimates_Single_Target (81 ms)
[ RUN      ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_Vector
[       OK ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_Vector (2472 ms)
[ RUN      ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_Unsigned_Map
[       OK ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_Unsigned_Map (39 ms)
[ RUN      ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_String_Map
[       OK ] InternalEmptyModel.Estimates_Multiple_Defined_Targets_String_Map (33 ms)
[ RUN      ] InternalEmptyModel.Estimates_All_Targets_Vector
[       OK ] InternalEmptyModel.Estimates_All_Targets_Vector (367 ms)
[ RUN      ] InternalEmptyModel.Estimates_All_Targets_Unsigned_Map
[       OK ] InternalEmptyModel.Estimates_All_Targets_Unsigned_Map (75 ms)
[ RUN      ] InternalEmptyModel.Estimates_All_Targets_String_Map
[       OK ] InternalEmptyModel.Estimates_All_Targets_String_Map (34 ms)
[ RUN      ] InternalEmptyModel.Observation_Process_Abundance
[       OK ] InternalEmptyModel.Observation_Process_Abundance (6 ms)
[ RUN      ] InternalEmptyModel.Observation_Process_Biomass
[       OK ] InternalEmptyModel.Observation_Process_Biomass (6 ms)
[ RUN      ] InternalEmptyModel.Observation_Process_Proportions_At_Age_Single
[       OK ] InternalEmptyModel.Observation_Process_Proportions_At_Age_Single (6 ms)
```

```
[ RUN      ] InternalEmptyModel.Observation_Process_Proportions_At_Age_Double
[       OK ] InternalEmptyModel.Observation_Process_Proportions_At_Age_Double (6 ms)
[ RUN      ] InternalEmptyModel.Observation_Process_Proportions_At_Age_for_fishery_Single
[       OK ] InternalEmptyModel.Observation_Process_Proportions_At_Age_for_fishery_Single (11 ms)
[ RUN      ] InternalEmptyModel.Observation_Proportions_At_Length_for_fishery_Single
[       OK ] InternalEmptyModel.Observation_Proportions_At_Length_for_fishery_Single (3 ms)
[ RUN      ] InternalEmptyModel.Observation_Biomass
[       OK ] InternalEmptyModel.Observation_Biomass (6 ms)
[ RUN      ] InternalEmptyModel.Observation_Proportions_At_Age_Single
[       OK ] InternalEmptyModel.Observation_Proportions_At_Age_Single (5 ms)
[ RUN      ] InternalEmptyModel.Observation_Proportions_At_Age_Double
[       OK ] InternalEmptyModel.Observation_Proportions_At_Age_Double (6 ms)
[ RUN      ] InternalEmptyModel.Observation_Proportions_At_Length_Single
[       OK ] InternalEmptyModel.Observation_Proportions_At_Length_Single (3 ms)
[ RUN      ] InternalEmptyModel.Observation_Proportions_At_Length_Double
[       OK ] InternalEmptyModel.Observation_Proportions_At_Length_Double (0 ms)
[ RUN      ] InternalEmptyModel.Processes_Mortality_Instantaneous_Simple
[       OK ] InternalEmptyModel.Processes_Mortality_Instantaneous_Simple (8 ms)
[ RUN      ] InternalEmptyModel.Processes_BevertonHolt_Recruitment
[       OK ] InternalEmptyModel.Processes_BevertonHolt_Recruitment (11 ms)
[ RUN      ] InternalEmptyModel.Processes_BevertonHolt_Recruitment_AutoSSBOffset
[       OK ] InternalEmptyModel.Processes_BevertonHolt_Recruitment_AutoSSBOffset (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Tag_By_Age
[       OK ] InternalEmptyModel.Processes_Tag_By_Age (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Tag_By_Age_With_Loss_Rate
[       OK ] InternalEmptyModel.Processes_Tag_By_Age_With_Loss_Rate (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Tag_By_Age_With_Loss_Rate_Selectivities
[       OK ] InternalEmptyModel.Processes_Tag_By_Age_With_Loss_Rate_Selectivities (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Tag_By_Age_With_Selectivities
[       OK ] InternalEmptyModel.Processes_Tag_By_Age_With_Selectivities (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Tag_By_Age_With_Proportions_Table
[       OK ] InternalEmptyModel.Processes_Tag_By_Age_With_Proportions_Table (1 ms)
[ RUN      ] InternalEmptyModel.Processes_Transition_Category_By_Age
[       OK ] InternalEmptyModel.Processes_Transition_Category_By_Age (3 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex1_BasicRun
[       OK ] InternalEmptyModel.Model_CasalComplex1_BasicRun (11 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex1_Estimation
[       OK ] InternalEmptyModel.Model_CasalComplex1_Estimation (2556 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex1_Simulation
[       OK ] InternalEmptyModel.Model_CasalComplex1_Simulation (11 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex2_BasicRun
[       OK ] InternalEmptyModel.Model_CasalComplex2_BasicRun (14 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex2_Estimation
[       OK ] InternalEmptyModel.Model_CasalComplex2_Estimation (12106 ms)
```

```
[ RUN      ] InternalEmptyModel.Model_CasalComplex3_BasicRun
[       OK ] InternalEmptyModel.Model_CasalComplex3_BasicRun (15 ms)
[ RUN      ] InternalEmptyModel.Model_CasalComplex3_Estimation
[       OK ] InternalEmptyModel.Model_CasalComplex3_Estimation (9350 ms)
[ RUN      ] InternalEmptyModel.Model_TwoSex_BasicRun
[       OK ] InternalEmptyModel.Model_TwoSex_BasicRun (9 ms)
[ RUN      ] InternalEmptyModel.Model_TwoSex_Estimation
[       OK ] InternalEmptyModel.Model_TwoSex_Estimation (455 ms)
[ RUN      ] InternalEmptyModel.Model_TwoSex_Foward_Projection
[       OK ] InternalEmptyModel.Model_TwoSex_Foward_Projection (9 ms)
[----------] 72 tests from InternalEmptyModel (55361 ms total)


[----------] 9 tests from AgeLengths
[ RUN      ] AgeLengths.Schnute
[       OK ] AgeLengths.Schnute (4 ms)
[ RUN      ] AgeLengths.Schnute_BuildCV_ByLength_Proportion
[       OK ] AgeLengths.Schnute_BuildCV_ByLength_Proportion (4 ms)
[ RUN      ] AgeLengths.Schnute_BuildCV_ByLength_ProportionAndTimeStep
[       OK ] AgeLengths.Schnute_BuildCV_ByLength_ProportionAndTimeStep (5 ms)
[ RUN      ] AgeLengths.Schnute_BuildCV_LinearInterpolation
[       OK ] AgeLengths.Schnute_BuildCV_LinearInterpolation (0 ms)
[ RUN      ] AgeLengths.VonBertalanffy_CummulativeNormal
[       OK ] AgeLengths.VonBertalanffy_CummulativeNormal (0 ms)
[ RUN      ] AgeLengths.VonBertalanffy_CummulativeNormal_2
[       OK ] AgeLengths.VonBertalanffy_CummulativeNormal_2 (0 ms)
[ RUN      ] AgeLengths.VonBertalanffy_CummulativeNormal_3
[       OK ] AgeLengths.VonBertalanffy_CummulativeNormal_3 (0 ms)
[ RUN      ] AgeLengths.VonBertalanffy_DoAgeLengthConversion
[       OK ] AgeLengths.VonBertalanffy_DoAgeLengthConversion (0 ms)
[ RUN      ] AgeLengths.VonBertalanffy_DoAgeLengthConversion_plusGrp
[       OK ] AgeLengths.VonBertalanffy_DoAgeLengthConversion_plusGrp (0 ms)
[----------] 9 tests from AgeLengths (14 ms total)


[----------] 6 tests from Object
[ RUN      ] Object.Standard_Double_Estimable
[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple
[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()
[       OK ] Object.Standard_Double_Estimable (0 ms)
[ RUN      ] Object.Vector_Double_Estimable
[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple
[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()
[       OK ] Object.Vector_Double_Estimable (0 ms)
```

```
[ RUN      ] Object.StringMap_Double_Estimable

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()

[       OK ] Object.StringMap_Double_Estimable (1 ms)

[ RUN      ] Object.UnsignedMap_Double_Estimable

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()

[       OK ] Object.UnsignedMap_Double_Estimable (0 ms)

[ RUN      ] Object.UnnamedVectorMap_Double_Estimable

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()

[       OK ] Object.UnnamedVectorMap_Double_Estimable (0 ms)

[ RUN      ] Object.UnnamedVectorMap_Double_Estimable_with_plus

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 218): Unable to find the
estimable type with the label: apple

[CODE_ERROR] /home/zaita/CASAL2/CASAL2/source/BaseClasses/Object.cpp(line: 103):
estimable_types_.find(apple) == estimable_types_.end()

[       OK ] Object.UnnamedVectorMap_Double_Estimable_with_plus (0 ms)

[----------] 6 tests from Object (1 ms total)


[----------] 26 tests from ConfigurationLoader

[ RUN      ] ConfigurationLoader.HandleOperators_1

[       OK ] ConfigurationLoader.HandleOperators_1 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_2

[       OK ] ConfigurationLoader.HandleOperators_2 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_3

[       OK ] ConfigurationLoader.HandleOperators_3 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_4

[       OK ] ConfigurationLoader.HandleOperators_4 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_5

[       OK ] ConfigurationLoader.HandleOperators_5 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_6

[       OK ] ConfigurationLoader.HandleOperators_6 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_7

[       OK ] ConfigurationLoader.HandleOperators_7 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_8

[       OK ] ConfigurationLoader.HandleOperators_8 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_9

[       OK ] ConfigurationLoader.HandleOperators_9 (0 ms)

[ RUN      ] ConfigurationLoader.HandleOperators_10

[       OK ] ConfigurationLoader.HandleOperators_10 (0 ms)
```

```
[ RUN      ] ConfigurationLoader.HandleOperators_11
[       OK ] ConfigurationLoader.HandleOperators_11 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_12
[       OK ] ConfigurationLoader.HandleOperators_12 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_13
[       OK ] ConfigurationLoader.HandleOperators_13 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_14
[       OK ] ConfigurationLoader.HandleOperators_14 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_15
[       OK ] ConfigurationLoader.HandleOperators_15 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_16
[       OK ] ConfigurationLoader.HandleOperators_16 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_17
[       OK ] ConfigurationLoader.HandleOperators_17 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_18
[       OK ] ConfigurationLoader.HandleOperators_18 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_19
[       OK ] ConfigurationLoader.HandleOperators_19 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_20
[       OK ] ConfigurationLoader.HandleOperators_20 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_21
[       OK ] ConfigurationLoader.HandleOperators_21 (0 ms)
[ RUN      ] ConfigurationLoader.HandleOperators_22
[       OK ] ConfigurationLoader.HandleOperators_22 (0 ms)
[ RUN      ] ConfigurationLoader.HandleAssignment_1
[       OK ] ConfigurationLoader.HandleAssignment_1 (0 ms)
[ RUN      ] ConfigurationLoader.HandleAssignment_2
[       OK ] ConfigurationLoader.HandleAssignment_2 (0 ms)
[ RUN      ] ConfigurationLoader.RangeSplit
[       OK ] ConfigurationLoader.RangeSplit (0 ms)
[ RUN      ] ConfigurationLoader.RangeSplit_Reverse
[       OK ] ConfigurationLoader.RangeSplit_Reverse (0 ms)
[----------] 26 tests from ConfigurationLoader (1 ms total)

[----------] 2 tests from LengthWeights
[ RUN      ] LengthWeights.Basic
[       OK ] LengthWeights.Basic (0 ms)
[ RUN      ] LengthWeights.Basic2
[       OK ] LengthWeights.Basic2 (0 ms)
[----------] 2 tests from LengthWeights (0 ms total)

[----------] 7 tests from Likelihood
[ RUN      ] Likelihood.Binomial
[       OK ] Likelihood.Binomial (0 ms)
```

```
[ RUN      ] Likelihood.BinomialApprox
[       OK ] Likelihood.BinomialApprox (0 ms)
[ RUN      ] Likelihood.Dirichlet
[       OK ] Likelihood.Dirichlet (0 ms)
[ RUN      ] Likelihood.LogNormal
[       OK ] Likelihood.LogNormal (0 ms)
[ RUN      ] Likelihood.LogNormalWithQ
[       OK ] Likelihood.LogNormalWithQ (0 ms)
[ RUN      ] Likelihood.Multinomial
[       OK ] Likelihood.Multinomial (0 ms)
[ RUN      ] Likelihood.Normal
[       OK ] Likelihood.Normal (0 ms)
[----------] 7 tests from Likelihood (0 ms total)

[----------] 7 tests from BasicModel
[ RUN      ] BasicModel.Observation_Abundance
[       OK ] BasicModel.Observation_Abundance (1 ms)
[ RUN      ] BasicModel.Accessors_Cached_CombinedCategories
[       OK ] BasicModel.Accessors_Cached_CombinedCategories (0 ms)
[ RUN      ] BasicModel.Processes_Ageing
[       OK ] BasicModel.Processes_Ageing (0 ms)
[ RUN      ] BasicModel.Processes_Mortality_Constant_Rate
[       OK ] BasicModel.Processes_Mortality_Constant_Rate (0 ms)
[ RUN      ] BasicModel.Processes_Mortality_Event_No_Penalty
[       OK ] BasicModel.Processes_Mortality_Event_No_Penalty (1 ms)
[ RUN      ] BasicModel.Processes_Constant_Recruitment
[       OK ] BasicModel.Processes_Constant_Recruitment (0 ms)
[ RUN      ] BasicModel.Processes_Transition_Category_Constant_One_Selectivity
[       OK ] BasicModel.Processes_Transition_Category_Constant_One_Selectivity (0 ms)
[----------] 7 tests from BasicModel (2 ms total)

[----------] 1 test from PartitionAccessors
[ RUN      ] PartitionAccessors.Category
[       OK ] PartitionAccessors.Category (0 ms)
[----------] 1 test from PartitionAccessors (0 ms total)

[----------] 11 tests from Selectivities
[ RUN      ] Selectivities.AllValues
[       OK ] Selectivities.AllValues (0 ms)
[ RUN      ] Selectivities.AllValuesBounded
[       OK ] Selectivities.AllValuesBounded (0 ms)
[ RUN      ] Selectivities.Constant
[       OK ] Selectivities.Constant (0 ms)
[ RUN      ] Selectivities.DoubleExponential
```

```
[       OK ] Selectivities.DoubleExponential (0 ms)
[ RUN      ] Selectivities.DoubleNormal
[       OK ] Selectivities.DoubleNormal (1 ms)
[ RUN      ] Selectivities.Increasing
[       OK ] Selectivities.Increasing (0 ms)
[ RUN      ] Selectivities.InverseLogistic
[       OK ] Selectivities.InverseLogistic (0 ms)
[ RUN      ] Selectivities.KnifeEdge
[       OK ] Selectivities.KnifeEdge (0 ms)
[ RUN      ] Selectivities.Logistic
[       OK ] Selectivities.Logistic (0 ms)
[ RUN      ] Selectivities.Logistic_length_normal
[       OK ] Selectivities.Logistic_length_normal (0 ms)
[ RUN      ] Selectivities.LogisticProducing
[       OK ] Selectivities.LogisticProducing (0 ms)
[----------] 11 tests from Selectivities (1 ms total)

[----------] 1 test from RandomNumberGenerator
[ RUN      ] RandomNumberGenerator.Reset
[       OK ] RandomNumberGenerator.Reset (0 ms)
[----------] 1 test from RandomNumberGenerator (0 ms total)

[----------] 1 test from Utilities
[ RUN      ] Utilities.String
[       OK ] Utilities.String (0 ms)
[----------] 1 test from Utilities (0 ms total)

[----------] Global test environment tear-down
[==========] 144 tests from 12 test cases ran. (55380 ms total)
[  PASSED  ] 144 tests.
```