OASIS Integration

HailAUS7

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EXECUTIVE SUMMARY

This document provides detailed documentation of the integration of Risk Frontiers' Australian hail model, codename HailAUS7, into the Oasis Loss Modelling Framework. This integration is achieved through the use of the newly released Complex Model MDK which support the integration of a custom loss engine into the Oasis framework. Here is a summary of the capabilities and features of the integrated HailAUS7 model.

- HailAUS7 is a national severe hailstorm model for Australia. It is fully integrated into OasisLMF using the Complex Model MDK.

- The event set contains simulated hail events for 50,000 years featuring around 90M individual hail storm footprints.

- It features both static and dynamic motor vulnerability models which can simulate seasonal car movements and covered car spaces in major cities in Australia.

- The integrated model supports Open Exposure Data (OED) input exposures with any combination of GNAF ID (address), Latitude/Longitude, Postcode, ICA Zone and Cresta geolocation.

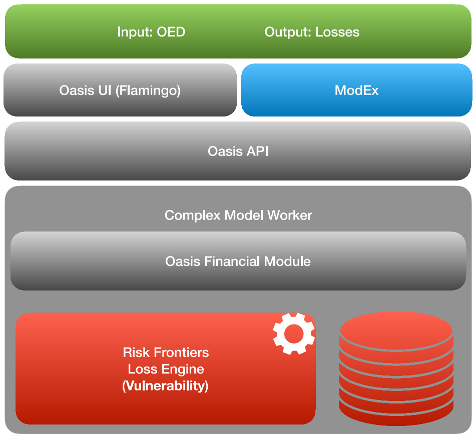
- All basic features and execution modes of Risk Frontiers Multi-Peril Workbench are supported. These include the Dynamic Motor execution mode, the Individual Risk Mode and the post amplification of losses using Demand Surge. In particular, it supports both the conventional single sample execution of Risk Frontiers models as well as the multi-sample requirement by the Oasis framework.

- The integration generates ground up losses that are validated to be practically indistinguishable from the Multi-Peril Workbench.

- Since this is an OasisLMF integration, we fully rely on the Oasis Financial Module and the validation of the integration is restricted to ground up losses.

GENERAL ARCHITECTURE

A general overview of the structure of the integration can be found in the following figure.



This is an implementation of the new Complex Model MDK from OasisLMF.

Oasis Loss Modelling Framework

The grey components are produced and maintained by the Oasis team. The Oasis UI is a web-based graphical interface providing visual access to the Oasis eco-system. The Oasis API is the main bridge between the frontend and backend components of the framework. The Complex Model worker is an instance of the oasis model worker responsible for performing loss sampling (via Monte Carlo simulation) and financial calculation. These are integrated into the ktools suite.

End user input/output

The green input and output are produced and consumed by the model end user. Only OED formatted inputs are currently supported.

ModEx Interface

The blue component is provided by ModEx as an alternative visual interface to the system. Note that a ModEx deployed installation is fully managed by the ModEx team.

Risk Frontiers model

Finally, the red loss engine and databases are provided and maintained by Risk Frontiers. They correspond to Risk Frontiers' dynamic vulnerability and stochastic event catalogue with associated metadata.

REQUIREMENTS

INSTALLATION

Deployment

To install the complex model integration of HailAUS 7, follow the following steps. Note that the integration has been tested on Ubuntu 18.04. The commands are exactly as follows for Debian system and they should work without any issue on any other flavor of Linux with appropriate modifications.

1. Install git, docker and docker-compose

```
sudo apt update && sudo apt install tree git docker docker-compose
```

2. Add `user` to the `docker` group and switch user to obtain a shell where `user` is actively a member of that group

```
sudo usermod -aG docker user
su - $USER
```

3. Clone the repository

```
git clone https://github.com/risk-frontiers/OasisComplexModel.git
```

4. **Optional**: change the user/password combination used to access the Oasis UI by chanding `OASIS_ADMIN_USER` and `OASIS_ADMIN_PASS` in `docker-compose.yml` if required.

5. Extract the model data and copy your license.txt into the model_data root folder. You can use WinSCP to copy files from windows to linux.

6. Copy model_data inside OasisCompexModel. The folder structure should be as follows

```
user@ubuntu:/home/user$ tree -L 1 OasisComplexModel/
OasisComplexModel/
├── api_evaluation_notebook
├── complex_model <---------- this contains Risk Frontiers' executables
├── conf.ini
├── docker-compose.yml
├── Dockerfile.custom_model_worker
├── install.sh
├── model_data    <---------- model_data contains license.txt and Risk Frontiers' data
├── model_resource.json
├── OasisUI
├── README.md
├── requirements.txt
├── rf_install.sh <---------- Risk Frontiers complex model installation script
├── setup.py
└── tests
```

7. Run the deployment script

```
cd OasisComplexModel
./rf_install.sh
```

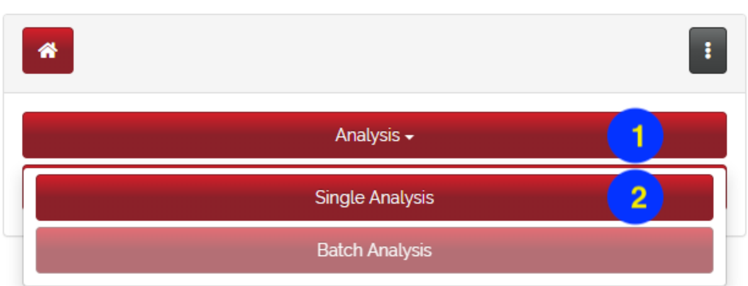
8. Open a web browser from a computer attached to the network and navigate to http://<server>:8080/app/BFE_RShiny to access the Oasis UI interface (<server> should be replaced with the IP address or hostname of the server where the complex integration was deployed.

Running the integrated model through Oasis UI

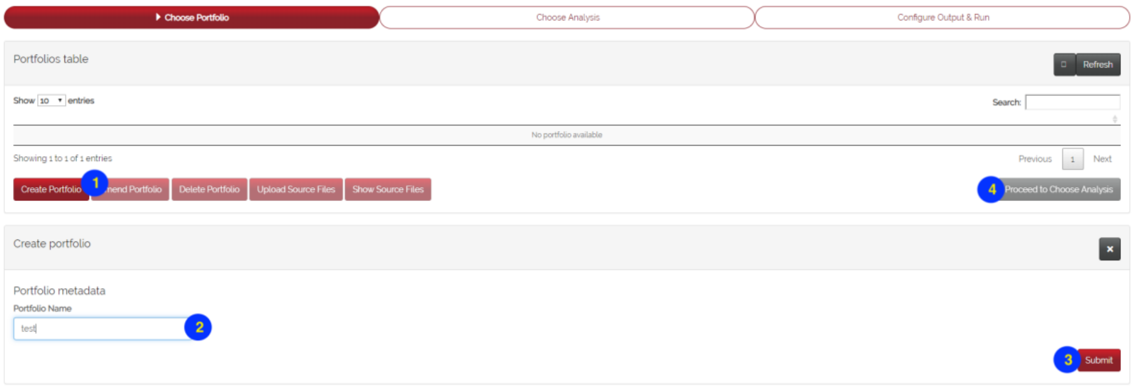
To use the integrated model through the Oasis UI, please follow the following steps. To start an analysis, you need at least an input location file formatted according to the Open Exposure Data specification. Our integration only accepts OED input files and a sample location file can be found in our repository.

1. Navigate to http://<server>:8080/app/BFE_RShiny and enter `admin:password` as the default admin and password (or use the combination set during deployment).

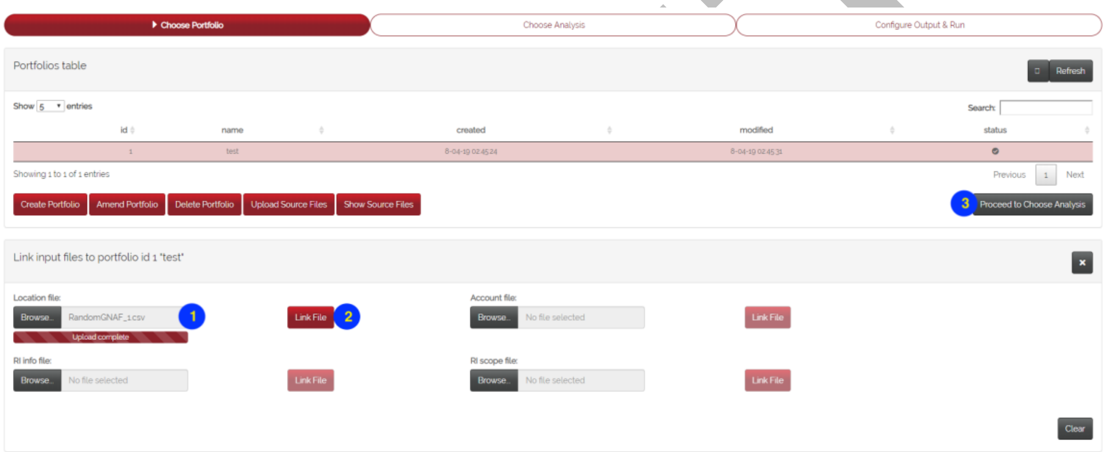
2. Create an analysis by selecting **Analysis** → **Single Analysis** on the left-hand side panel.



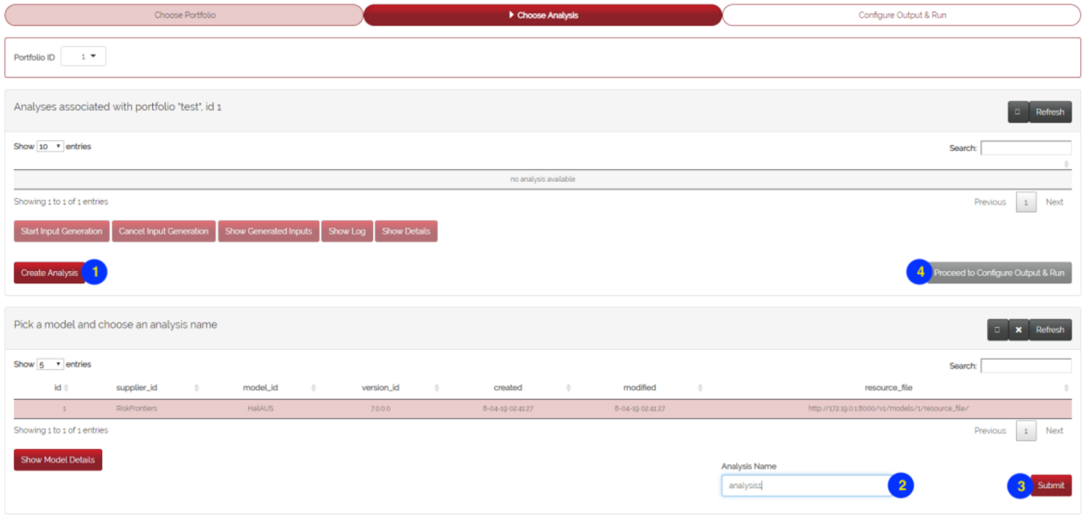
3. We now need to create a portfolio.



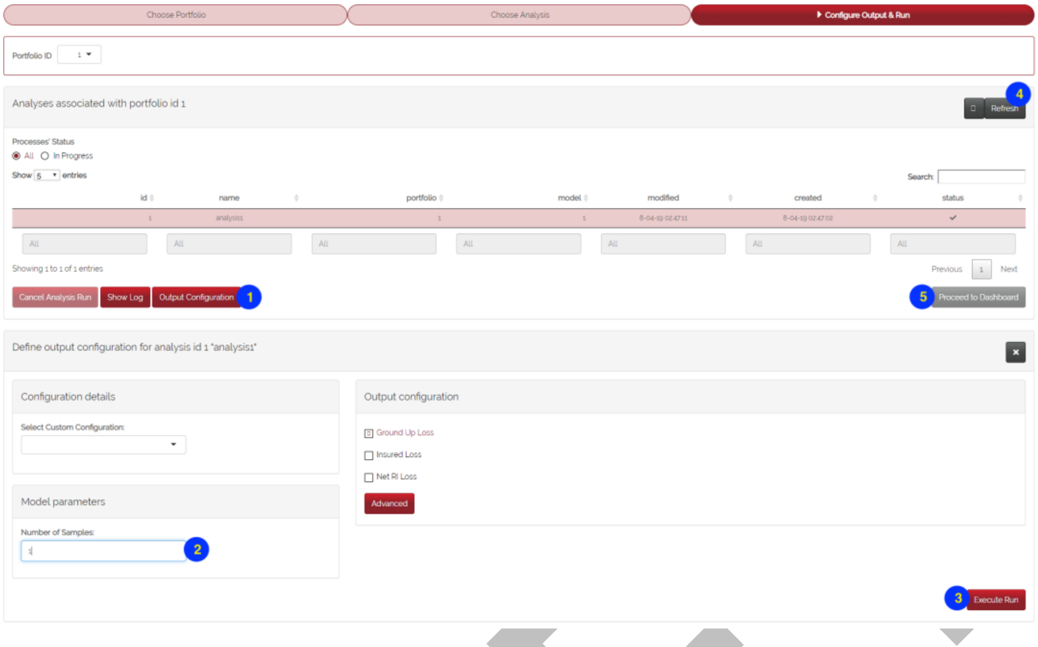
4. Upload the location, account and reinsurance files.



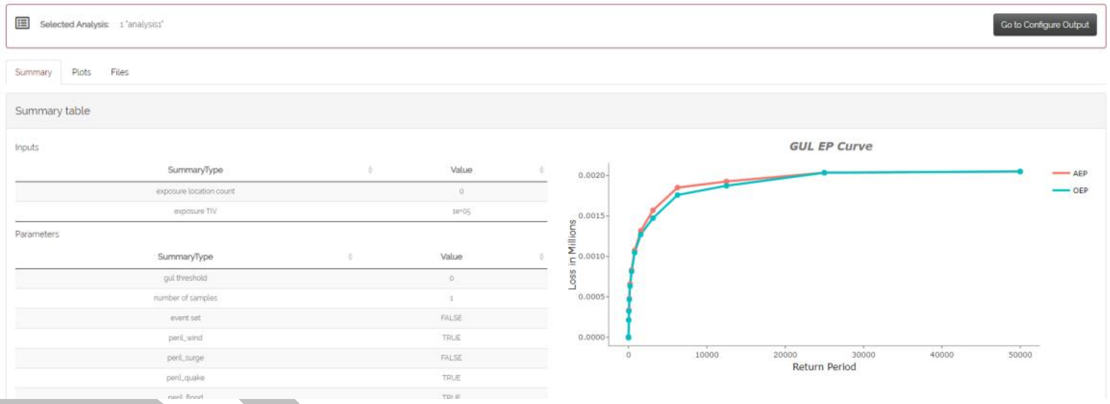
5. Create an analysis. This will generate input files by calling Risk Frontiers keys server. It might take a while especially if the locations are given at lat/lon level and without postcodes.



6. Configure the model run and then click **Execute**. Depending on the size of the portfolio and the model, it may take a while for the calculation to be performed.



7. Once the calculation has been performed, the button **Procced to Dashboard** will be enable. Click on it to download, analyse or visualize the output.



INPUT EXPOSURE

Open Exposure Data

Open Exposure Data, or OED, is an open source exposure data format that is specific to the Oasis framework. It provides a unified format for expressing exposure thus removing possible ambiguity from supporting multiple input formats. Moreover, OED was designed to specifically align with the Oasis financial module.

OED has four main components:

- **Location**: This table contains details relating to each location. This includes details relating to the value and type of asset (including primary and secondary modifiers), geographical information, the perils covered and the financial structures within the insurance contract relating to the location. Note that **one location can be represented by multiple rows.**

- **Account**: The account table contains details of the policies and accounts that exist within the import portfolios. Most of the fields in this table relate to financial structures, including special conditions. Note that **one policy may have multiple rows** in the account file.

- **Reinsurance info**: The reinsurance info table contains details of the reinsurance contracts that relate to the underlying portfolios, accounts and locations. There must be exactly one entry per reinsurance contract in this table.

- **Reinsurance scope**: The reinsurance scope file contains details of three different but related pieces of information: (a) the scope of the reinsurance contract: i.e. which portfolios, accounts, locations are covered by a particular reinsurance contract, (b) the risk level of the reinsurance contract: i.e. for reinsurance contracts with financial structures relating to a 'risk', the definition of what risk means, (c) the CededPercent for a surplus treaty: which can vary for each risk covered by the treaty.

Since the main role of Risk Frontiers is to provide the fundamental model to generate ground up losses, we will only discuss about the Location file and the interpretation of the data contained within that input when executed by Risk Frontiers' models. More information about the full OED specification can be found here. Please ensure that your input files are formatted according to that specification, in particular, regarding the presence and values of required and conditionally required fields.

Location file

The location file must be provided by user when running an analysis in the Oasis framework. It records the geographical, financial and physical features of the insured location. These features are recoded as columns within the OED format which is stored as a standard Comma Separated Value (CSV) file.

The following fields are the minimal required and conditionally required columns as per the OED specification. In fact, all that is required to generate ground up losses are the respective total insured values.

Field name	Description	Datatype
LocNumber	Location number	nvarchar(20)
AccNumber*	Account number	nvarchar(40)
PortNumber*	Portfolio number	varchar(20)
BuildingTIV	Building total insured value	float
OtherTIV	Other total insured value (including motor)	float
ContentsTIV	Contents total insured value	float
BITIV	Business interruption total insured value	float
CountryCode	Country code (based on ISO3166 alpha-2 codes)	char(2)
LocPerilsCovered	Location perils covered	nvarchar(250)
LocCurrency	Location currency	char(3)

* *These two fields are not specified as required in the OED specification but should be part of any location file as per the OED documentation pdf.*

Note that location must also have at least on specified geo-location, which can be an address id (GNAF), latitude/longitude pair, postcode, ICA zone or cresta. The following two tables specify these fields.

Field name	Description	Datatype
Latitude*	Latitude in degrees (-90.0 to +90.0)	float
Longitude*	Longitude in degrees (-180.0 to +180.0)	float
PostalCode	A 4 digits number representing an Australian postcode	int
AreaCode	At most 3 characters Australian state code	char(3)

* Please make sure that these are either empty or missing

GeogScheme	Interpretation	Example GeogName value	GeogName Datatype
XGNAF	Australiana GNAF ID	GATAS702557490	char(14)
CRL, CRH	ICA Zone code from 1 to 49	1	int
CRO	Cresta code from 1 to 49	5	int

OED fields and Risk Frontiers location features

Care should be taken regarding the following convention. The detailed correspondence between OED location fields and Risk Frontiers portfolio columns can be found in the appendix.

Field name	Description	Data Type
LocUserDef1	Assumed to hold Proportion of building built before 1981	float
YearBuilt	Assumed to hold the year when the location was built	int

Mapping between OED occupancy code and RF Line of Business

The following table records the correspondence between OED occupancy codes and Risk Frontiers Line of Businesses.

OED Occupancy Code Range	Broad Category of Occupancy	Risk Frontiers Line of Business
1000	Unknown	Residential
1050 – 1099	Residential	Residential
1100 – 1149	Commercial	Commercial
1150 – 1199	Industrial	Industrial
1200 – 3999	Unsupported	Unsupported

Mapping between OED construction code and RF construction type

This is currently not required for HailAUS 7.

Mapping between OED and RF physical asset properties

This is currently not required for HailAUS 7.

IMPLEMENTATION DETAILS

Technology

Portable engine via .Net Core 2.2

The main technology that enables the embedding of Risk Frontiers loss engine into the oasis platform is **.Net Core 2.2**. This permits us to maintain the exact same code base for Risk Frontiers Multi-Peril Workbench and its OasisLMF integration counterpart. It also allows the loss engine to run on multiple platform as the .Net Core technology is platform agnostic.

SQLite as backend database

One main technical difference between the Multi-Peril Workbench and the Oasis complex model is the backend database used by the loss engine. In this integration, we are using **SQLite** databases to store hazard, exposure, loss and auxiliary data.

The main implication is that there are limitation to using embedded relational databases such as SQLite compared to a full blown SQL server. In particular, this is particularly acute in terms of performance.

There are also some subtle differences in accuracy as SQLite does not support 4-bytes integer. Therefore, the loss output from the complex model and the Multi-Peril Workbench are not exactly the same in terms of decimal number representation. For more information regarding this challenge, please read the Validation section.

Detailed architecture

Input generation: `uni_exposure` creation

Output generation: gulcalc output stream

1	2	3	4	5	6	7	8
0x01	stream_type:0x02			num_samples:int32			
event_id:int32				item_id:int32			
sidx:int32				loss:float32			
sidx:int32				loss:float32			
0x0000000000000000							
event_id:int32				item_id:int32			
sidx:int32				loss:float32			

Analytical Mean and Standard deviation

We use the following formulae to compute analytical mean and variances

Sum and product of independent random variables

All random variables used in HailAUS 7 are independent and the analytical mean and variances of their linear combinations and products are computed using the following identities

$E[aX + bY] = aE[X] + bE[Y]$

$E[XY] = E[X]E[Y]$

$Var(X) = E[X^2] + E[X]^2$

$Var(aX + bY) = a^2Var(X) + b^2Var(Y)$

$Var(XY) = Var(X)Var(Y) + E[X]^2Var(Y) + Var(X)E[Y]^2$

Uniform distribution

The uniform distribution $X \sim unif(a, b)$ is used as a source of uncertainty in the HailAUS 7 implementation. Its analytical mean and variance are

$E[X] = \frac{(a+b)}{2}$ and $Var[X] = \frac{(E[X]-a)^2}{12}$

Exponential of the normal distribution

The normal distribution $X \sim N(0, \sigma)$ is used as a source of uncertainty in the HailAUS 7 implementation. It is furthermore transformed by the exponential function so that the analytical mean and variance are

$E[e^X] = e^{\sigma^2}$ and $Var[e^X] = E[X]^2(E[X]^2 - 1)$

Note that the normal distribution in the implementation was truncated. Computing an analytical formula for the exponential of that distribution is extremely difficult so we have approximated it with the un-truncated version. This implies that the analytical variance is more generous.

VALIDATION

Methodology

The validation of the OASISLMF integration of Risk Frontiers HailAUS 7 model is achieved through an exact ground-up loss comparison between the OASISLMF implementation with the Multi-Peril Workbench output. Thus, this validation phase takes results from the Multi-Peril Workbench as ground truth whose validation can be in turn found in the official manual. The losses were generated from within the worker docker only as, at the time of this validation, few issues prevented us from executing large analysis from the Oasis UI.

The comparison uses both absolute and relative differences. Absolute difference looks at the different between two number while relative difference looks at the ratio between the absolute difference and the expected output. Relative difference is particularly useful when comparing results that are very large or very small as the floating-point representation of real number introduces inaccuracies.

Important note: we are only validating the ground-up loss produced by the OASISLMF integration of HailAUS 7 and do not perform any formal check on the correctness of losses after the application of the OASISLMF financial module. We assume that that financial module is correct, and its validity is ensured by the OASISLMF development team.

Validation Input Exposure

The input exposure used in the validation is built from market portfolios, which are split into two major categories:

1. Building, Contents and Business Interruption coverages: the market portfolios are built from the Nexis 2016 dataset.
2. Motor coverage: the market portfolio is built from the Red Book data set.

These market portfolios were converted into RF's exposure format and the Open Exposure Data (OED) format ensuring that we execute both implementations on the exact same inputs. More details regarding the input exposures are given in tables below.

Validation Accuracy

We have performed an end-to-end validation of the OasisLMF worker implementation. That is, losses were generated on a Linux platform where the integration was run. The ground up losses were in the form of binary files, which were converted into csv using the `gultocsv` tool and then imported into a SQL server and compared with the corresponding losses generated by the Multi-Peril Workbench. Run from the above input exposure shows that the OASISLMF implementation produces losses that are practically the same as the Multi-Peril Workbench. Some very small fluctuations were observed (absolute differences well below 10^{-6}) which are expected due to numerical conversion and slight difference in the implementation.

Note: The seed for the random sampling must match for both the OasisLMF implementation and the Multi-Peril Workbench execution to obtain accuracy at the loss per location and event level. To achieve this, the input portfolio in the Multi-Peril Workbench must contain a location_id field that is set to the line number for each row. (This convention is used in the OasisLMF implementation.) This field forms part of the seed for any random sampling.

Validation Results

Exposure at latitude/longitude level

For this test we have selected random 200 GNAF points around Australia and built a small test portfolio for each of the combination shown in the tables below. These results also apply to larger portfolios.

The following table shows the maximum ***absolute differences*** between the output losses, **per event and location (EL)**, from the Multi-Peril Workbench and the OASISLMF integration. As expected, the results are extremely close and the only observed fluctuations are strictly below E-06 which is due to various numerical conversion and difference in data storage. Motor 0 to 4 corresponds to a motor exposure with age group 0 to 4 (0 being unknown and 4 for most recent cars).

EL Loss	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	5.00E-07	5.00E-07		5.00E-07	5.00E-07	5.00E-07	5.00E-07	5.00E-07
Commercial	5.00E-07	5.00E-07	5.00E-07					
Industrial	5.00E-07	5.00E-07	5.00E-07					

Since the losses are practically similar at event and location level, the **Exceedance Probability** curves and **Annual Losses** are also very close through the floating-point errors are compounded. The following tables shows the maximum ***relative difference*** between the Average Annual Losses (AAL) and losses at Return Interval of 200 produced by the Multi-Peril Workbench and the OASISLMF integration.

The following table shows that the AAL are matching up to a variation of less than 0.0008%. That slightly visible fluctuation is due to having a small portfolio size. Practically, this variation is negligible.

AAL	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	0.0004%	0.0007%		0.0001%	0.0002%	0.0001%	0.0001%	0.0001%
Commercial	0.0005%	0.0001%	0.0001%					
Industrial	0.0008%	0.0002%	0.0001%					

The following table shows that at ARI 200, the outputs are practically the same.

ARI 200	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	0.0000%	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Commercial	0.0000%	0.0000%	0.0000%					
Industrial	0.0000%	0.0000%	0.0000%					

Exposure at Postcode level

For this test, we have selected a market portfolio built from the Nexis and Red Book data set. The exposure is uniformly at Postcode level. The tables only show maximum ***relative differences*** as we are approaching large losses and the representation inaccuracies become apparent.

EL Loss	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	0.1614%	0.0783%		0.0013%	0.0004%	0.0005%	0.0012%	0.0020%
Commercial	0.7575%	0.4445%	4.0963%					
Industrial	0.0034%	0.0022%	0.0133%					

In the yellow cell, the relative differences seem to be high. Note however that these are the maximum differences and the average difference is much smaller than E-06 (with a standard deviation of less than E-04). The maximum 4% difference is attached to a loss in the order of E-05.

The following table shows that the AAL are practically indistinguishable. In contrast, to the lat/lon validation, the AAL produced by the OASISLMF integration is much closer to the output of the Multi-Peril Workbench as we have considerably more risk points in the market portfolio.

AAL	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	0.0000%	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Commercial	0.0000%	0.0000%	0.0000%					
Industrial	0.0000%	0.0000%	0.0000%					

The following table shows that at ARI 200, the outputs are practically the same.

ARI 200	Building	Contents	BI	Motor 0	Motor 1	Motor 2	Motor 3	Motor 4
Residential	0.0000%	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
Commercial	0.0000%	0.0000%	0.0000%					
Industrial	0.0000%	0.0000%	0.0000%					

APPENDIX

Correspondence between OED location and RF portfolio input format

OED Field name	Req	RF Field Name/usage	Description	Type [default]
LocUserDef1	O	address_id	GNAF id	String []
Latitude	O	latitude	Location latitude	Decimal [0]
Longitude	O	longitude	Location longitude	Decimal [0]
PostalCode	O	postcode	Location postcode	Integer [0]
LowResCresta	O	cresta	Cresta code	Integer [0]
HighResCresta	O	Ica_zone	ICA Zone	Integer [0]
AreaCode	O	state	State	Char(3) []
CountryCode	R	country_code	Country code	Char(2) [AU]
LocCurrency	R	currency	Location currency	Char(3) [AUD]
LocPerilsCovered	R			Integer [0]
OccupancyCode	R	line_of_business	OED occupancy code	Integer [1050]
ConstructionCode	O	construction_type_id	OED construction code	Integer [5000]
LocationNumber	R	loc_id	Location ID	Integer
BuildingTIV	R	building_sum_insured	Building sum insured	Decimal [0]
OtherTIV	R	motor_sum_insured	Motor sum insured	Decimal [0]
ContentsTIV	R	contents_sum_insured	Contents sum insured	Decimal [0]
BITIV	R	business_interruption_sum_insured	BI sum insured	Decimal [0]
FirstFloorHeight	O	floor_height	Floor height	Decimal [0]
FirstFloorHeightUnit	O		Floor height unit	String [m]
NumberOfStories	O	Combined to infer building_type_id, high_rise	Number of stories	Integer [0]
BaseFloodElevation	O		Building elevation	Decimal [0]
BaseFloodElevationUnit	O		Building elevation unit	String [m]
YearBuilt	O	year_num	Year built	Integer [0]
LocUserDef2	O	Pre_post_ratio	Proportion of building built before 1981	Decimal [-1]
LocDed1Building	CR	building_deductible	Building deductible	Decimal [0]
LocDedType1Building	O	deductible_type*	Building ded. type	Integer [0]
LocDed2Other	CR	motor_deductible	Motor deductible	Decimal [0]
LocDedType2Other	O	deductible_type*	Motor deductible type	Integer [0]
LocDed3Contents	CR	contents_deductible	Contents deductible	Decimal [0]
LocDedType3Contents	O	deductible_type*	Contents ded. type	Integer [0]
LocDed4BI	CR	business_interruption_deductible	BI deductible	Decimal [0]
LocDedType4BI	O	deductible_type*	BI deductible type	Integer [0]
LocLimit1Building	CR	building_limit	Building limit	Decimal [0]
LocLimitType1Building	O	limit_type*	Building limit type	Integer [0]
LocLimit2Other	CR	motor_limit	Motor limit	Decimal [0]
LocLimitType2Other	O	limit_type*	Motor limit type	Integer [0]
LocLimit3Contents	CR	contents_limit	Contents limit	Decimal [0]
LocLimitType3Contents	O	limit_type*	Contents limit type	Integer [0]
LocLimit4BI	CR	business_interruption_limit	BI limit	Decimal [0]
LocLimitType4BI	O	limit_type*	BI limit type	Integer [0]

O: optional, R: required, CR: conditionally required