CCaR Model Guidelines

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1 Model purpose and scope

This document is the model documentation for Nasdaq Clearing's stress testing model (also referred to as the "Clearing Capital at Risk" or "CCaR" model). This document also covers the methodology to calibrate CCaR model parameters and how Nasdaq Clearing determines extreme but plausible historical and hypothetical stress scenarios.

1.1 Purpose of the CCaR model

The purpose of the CCaR model is to calculate clearing participants' stress losses beyond margin under extreme but plausible circumstances. This is required for the CCP in order to:

- Determine and monitor the appropriateness of the default fund and clearing capital for each clearing service which protects the CCP and its members in the event of one or multiple defaults.
- Evaluate and monitor the tail risk exposure of clearing members.
- Serve as input to the stress add-on calculation.

1.2 Scope and model application

The CCaR model applies to all clearing services and all clearing participants' portfolios which are active at Nasdaq Clearing, this means the Financial Markets, the Commodities and the Seafood clearing services.

2 Model overview

This section aims to provide a brief and high-level overview of the key model information.

2.1 Model overview – inputs, outputs and use

Model overview

The CCaR model consist of three main components:

- Single risk factor shock generation
- Portfolio risk calculation; and
- Stress loss calculation and aggregation.

The single risk factor shock generation is required to reflect extreme but plausible market conditions by Article 29 of EMIR 153/2013. For each of Nasdaq Clearing's Clearing Services, the CCaR model calculates the stress loss per clearing member given three different approaches:

- Historical scenarios, where historical extreme events are identified and used for stress shock generation
- Hypothetical stress, where the 99.9 percentile market move, estimated using Extreme Value Theory, of each individual risk factor is used for stress shock generation
- Narrative stress, where scenarios are defined top-down and risk-factor shocks, portfolio assumptions, default assumptions etc. are considered in line with the overall narrative (and can leverage hypothetical, historical or other risk factor shocks)

Portfolio risk calculation is the second largest component of the CCaR model, where the combinations of directions of the calibrated individual shocks are applied at portfolio level based on stressed correlation assessments. Product areas (PAs) are defined to group the risk factors which are expected to show similar behaviour in a tail event. Correlation between PAs is assumed to be either full, or negative, selecting the scenario that gives the worst result.

Finally, under each stress scenario and for each Margin Requirement Account (MRA), loss is defined as the difference in position value under stress compared to Initial Margin (calculated on the Margin Calculation Account level and aggregated to the Margin Requirement Account level) or the collateral available on the Margin Requirement Account, whichever is worst. Excess collateral is thus never considered, whereas a collateral shortfall compared to the margin requirement is considered.

Model input

Model input is historical market data for calibration of stress parameters ("CCaR parameters") applied and correlation assumptions employed as well as clearing member positions for each account for stress loss calculations. The calculation engine takes the calibrated stress parameters and correlation structure as input.

Model output

Currently, the model output presents the following results observed under the stressed market scenarios:

1. Default of the two members that has the largest loss.
2. Default of the member that has the largest loss.
3. Default of the member that has the second largest loss.
4. Default of the two members that has the second and third largest loss.
5. Individually worst loss over initial margin per member, allowing scenarios driving these figures to vary between members.
6. Loss over initial margin per member in each of the stress scenarios.

Model use

The model is used to calculate cover-1 and cover-2 stress losses for default fund sizing and for liquidity at risk calculation, to size the IM / CCaR ratio used in the stress IM add-on and for risk reporting, evaluation of model performance and governance (as detailed in Sections 6.1 and **Error! Reference source not found.**).

The following models are noted as upstream models:

- Margin models – OMS II, CFM and SPAN for calculation of stressed market value.
- The concentration margin models for Fixed Income, Equity and Commodities for several calculations related to stress components related to liquidation costs.

The following models are noted as downstream models:

- Liquidity at Risk – where liquidity stress from potential defaults is sized with CCaR
- Stress Margin add-on – where the "IM / CCaR" ratio is based on point 5 above

2.2 Materiality/importance of the model

As the model is used to size the default funds and clearing capital per clearing service, the materiality and importance of the model is deemed high.

2.3 Platforms/Software/Vendor systems used

The model is implemented in Genium INET, a proprietary Nasdaq software.

2.4 Outline of risk factors

Key risk factors in the model are:

- Commodity (primarily Power) prices
- Interest rates
- Equity prices
- Implied volatilities across the above

- FX risk (for cleared exposures, note that collateral FX risk is handled by collateral haircuts)
- Liquidation cost under stressed market conditions

3 Stress exposure and risk factor identification

This chapter outlines the exposures covered by the CCaR model and the key risk factors.

3.1 Types of credit stress exposure faced by the CCP

3.1.1 Credit risk and credit concentration risk

The CCP is exposed to credit risk from its clearing members, and the risk can materialize if one of its clearing members defaults. The credit risk exposure depends on the composition of the clearing member's cleared portfolio(s) and any collateral held by Nasdaq Clearing against the portfolios. The credit risk exposure is captured in Nasdaq Clearing's model landscape through:

- Credit risk exposure due to value fluctuations of the cleared portfolio under normal market conditions is covered in the respective Initial Margin models deployed by Nasdaq Clearing
- Credit risk exposure due to value fluctuations of the cleared portfolio under extreme but plausible market conditions is covered in the CCaR model
- Credit risk exposure due to value fluctuations of collateral posted by the member are accounted for in the collateral haircuts employed by Nasdaq Clearing
- Credit risk exposure due to combined effects on cleared portfolio and collateral, e.g. wrong-way-risk, are further identified, mitigated and reported as part of narrative stress testing
- Concentration risk towards particularly large cleared portfolios in certain contracts compared to the overall market is covered both in the respective Initial Margin models and the CCaR model through add-ons

3.2 Risk factors covered in the model

Risk factor selection in the CCaR model is the same as for Nasdaq Clearing's Initial Margin models, and a brief overview is provided in this section. Notably, although the risk factors are the same, stresses applied, and methodologies may vary between IM and CCaR models.

Below table outlines the risk factors covered in CCaR:

Table 1: Overview of Risk Factors covered in the CCaR model

Asset class(es)	Risk factor	Coverage
Commodities, Equities	Price risk	CCaR parameter estimation
All	Implied volatility risk	IV-stress shocks
All	FX risk	FX-stress shocks
All	Market liquidity risk/ concentration risk	Base liquidation adjustment Knock-on adj. concentration add-on
Fixed income	Interest rate risk	CCaR parameter estimation
Fixed income	Duration risk	Principal component framework
Fixed income	Bond price risk	CCaR parameter estimation (for niche instruments without curve modelling)
All	Jump-to-default risk	Monitoring

4 Model input

The key model input for calculation of the CCaR for the model is clearing member positions, market data to calibrate stress scenarios and calibrated model parameters. The clearing member positions are the same as used for IM, so not assessed separately here. This section covers market data, and the following sections cover the calibrated model parameters.

4.1 Hypothetical scenarios input data

Hypothetical scenarios are derived using combinations of historical stress based on an extreme percentile of historical market data. This section outlines the data sources, data cleaning methodology, data quality assessment as well as proxy framework for these.

4.2 Historical scenarios input data

The historical scenarios leverage the same input data as the hypothetical scenarios; however, risk factor data is only used for the identified historical events and a short window of time surrounding these events.

4.3 Narrative scenarios input data

For narrative stress testing scenarios, the input data sources from previous scenario types are used, but often combined with further desk research. Due to the nature of narrative scenario design, data that may be used to quantify the narratives is:

- Risk factor data from other markets than those cleared by Nasdaq Clearing
- Desk research qualitative data, such as observed market patterns or reactions which may be applicable for Nasdaq Clearing
- Data on secondary risk factor drivers, e.g. Power demand and supply, power grid structure, etc. in the commodities market
- Input from relevant expert committees present at Nasdaq Clearing

5 Model methodology

The CCP's credit exposure towards clearing members under extreme but plausible market conditions is estimated by the CCaR model for each clearing member and each clearing service separately. This section describes the methodology underpinning the model, starting with an overview of the methodology and its logic, followed by a description of the three main blocks single risk factor stress estimation, portfolio risk calculation, and stress loss calculation and aggregation. Within each section, the specifics of the different types of stress scenarios (hypothetical, historical and narrative are considered).

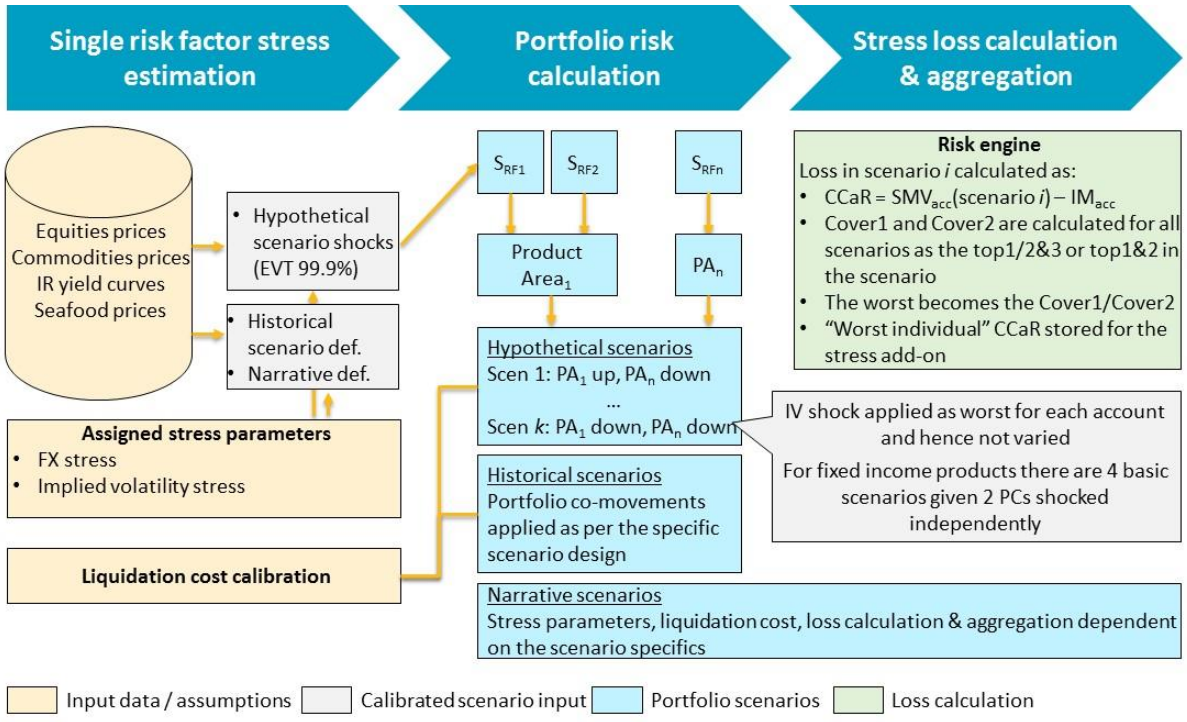
5.1 Overview of model methodology and logic

The CCaR model can broadly be divided into three main blocks:

- Single risk factor stress estimation,
- Portfolio risk calculation, and
- Stress loss calculation and aggregation

Figure 1 below provides a visual overview of the model and the three main blocks, which are respectively described in more detail in the three following sections.

Figure 1: Overview of CCaR Calculation



5.2 Single risk factor stress estimation

The purpose of the single risk factor stress estimation is to in isolation estimate the market movements expected under extreme but plausible scenarios for each risk factor included in the model scope. Material risk factors per asset class are used to derive the stress levels to consequently be utilized in the portfolio stress calculation. For each of the asset classes (Commodities, Equities and Fixed income), the risk factor stress levels are estimated depending on scenario type:

- Hypothetical scenarios: the 99.9 percentile return derived through extreme value theory (if possible), of each individual risk factor forms the single risk factor stress
- Historical scenarios: the returns occurring during the historical extreme events are identified, extrapolated and used as the single risk factor stress
- Narrative scenarios: the relevant returns for the respective risk factors as estimated for the scenarios are used as the single risk factor stress

In the following sub sections below, the methodology for generating the single risk factor shocks is described, starting with the hypothetical scenarios. In the final section, stress parameters which are common across the scenario types are outlined (stress to implied volatility, FX and stressed liquidation cost.

5.2.1 Generating hypothetical scenario single risk factor stress

The approach for generating the hypothetical scenario single risk factor stresses can be summarized in the below four steps:

A. **Return computation:** Historical returns are calculated over the relevant liquidation period
B. **Stress parameter estimation:** The stress parameter for the risk factor is calculated using:
   – Extreme Value Theory estimation,
   – Proxy application, or
   – Fallback value
C. **Conservative floor application:** The stress parameter estimates are compared against conservative floors, defined per asset class, to ensure prudent calibration

5.2.2 Generating historical scenario risk factor stress

The historical stress scenarios are historical market replays that replicate extreme market stresses observed historically. This section describes the methodology behind the historical stress scenarios, divided into:

A. Selection of historical events
B. Calibration of historical stress
C. Application of proxies and adjustments

A. Selection of historical events

The historical events should represent periods in which risk factors to which Nasdaq Clearing has large exposure demonstrate significant volatility. The selection of historical events is in a first step

based on inclusion of known market periods of stress, and as markets for different products have faced stress during different times, these vary with asset class. To ensure that the considered events represent extreme market movements, and that no other events with significant stress are missed out, the historical return series of the risk factors are investigated.

The events are selected based on the severity, i.e. the size of the observed risk factor movements and the impact on Nasdaq Clearing. Below, the general approach to select the events is described per asset class, starting with Equities.

Equities

The equity derivatives market is dominated by the OMXS30 index derivatives in terms of equity risk exposure for the CCP (~70-80% of IM). Remaining exposure is largely to single names included in the OMXS30 index. As such, known periods of stress for the OMXS30 are therefore representable for the historical extreme events within the Equities asset class.

Fixed income

The Swedish Swap Curve is the largest exposure within the Fixed income derivatives asset class. From a materiality perspective it is therefore deemed reasonable to define the historical extreme events as the periods for which the SEK Swap curve has faced extreme movements. As more than 90% of IM is Swedish rates, which are highly correlated, this is expected to cover the most severe stresses relevant to Nasdaq Clearing's exposures. Note that as equities and fixed income belong to the same clearing service, any scenario used for fixed income will also include the historically observed stresses for equities and vice versa.

Commodities

The largest exposure in Commodities is Nordic Power. As such, the historical extreme events for the Commodity derivatives asset class are derived from extreme periods of stress observed in Nordic Power. Nordic Power and EPADs (area differential contracts) represent over 90% of Commodities IM.

Seafood

With only one product, the historical stress events for the Seafood asset class are naturally derived from the most extreme events observed on the market for the Fresh Salmon risk group.

Generally, across the different asset classes, there are typically a few events constituting the most severe stress, and as such, selecting a large number of events means that many will have no impact on the CCaR model calculation outcome. Therefore, the historical events are kept to a limited number, yet capturing the key historical stresses observed.

In the table below, the historical events currently used by Nasdaq Clearing are displayed.

Table 2: Overview of historical events

Asset class	Date	Event	Market movement
Equities	1987-10-29[1]	Stock market crash	Equities down

[1] Note that an additional event constituting the 1987 stock market crash, but with OMXS30 stress increased to 15% is tested based on a request from the SFSA

	1998-10-12	Recovery from Russian crisis	Equities up
	2008-10-07	Post Lehman unrest	Equities down
	2008-12-09	Post Lehman unrest	Equities up
	2020-03-12	COVID-19 outbreak	Equities down
Fixed income	1987-10-29	Stock market crash	Rates down
	1994-08-11	Swedish financial crisis	Rates up
	1994-08-22	Swedish financial crisis unrest	Rates down
	2008-12-09	Post Lehman unrest	Rates up
	2008-12-17	Post Lehman unrest	Rates down
	2012-06-07	Euro crises aftermath	Rates up
Commodities	2006-04-26	Allowances and power market crash	Power, allowances down
	2008-04-04	Bullish fuel prices	Power, allowances, fuel oil, freight up
	2012-07-20	Sharp decline in power prices	Power down
	2018-09-10	German and Nordic Power spread event	German power up Nordic power down
Seafood	2011-06-21	Sharp decline in salmon prices	Seafood down
	2016-06-29	Sharp increase in seafood prices	Seafood up

Nasdaq Clearing regularly reviews the set of historical events and if any new stress events should be included.

B. Stress level calibration

The historical stress shock is calibrated for each risk factor separately, based on the date set given the observed stress in the main risk factor of the asset class. As there may be idiosyncratic differences between different risk factors affecting the exact date for which the stress is observed, a range of dates around the specific event date is considered (for other risk factors than the main risk factor). Specifically, the observation with the greatest stress seven days before or after the event reference date is used. The direction of the stress is fixed, so only the maximum observed stress in the relevant direction is captured (e.g. if equities had negative shocks in the historical events, the shock per equity risk factor will be the worst observed negative shock within a time span of seven days before or after the event). This leads to more severe shocks in the scenarios than if the same day were used.

C. Proxies and adjustments

Cleared products with data limitations during a specific historical scenario (e.g. no data availability), are proxied.

5.2.3 Generating narrative scenario risk factor stress

Narrative stress testing offers a greater freedom in terms of defining the risk factor level stress applied. This applies both for risk exposure to single risk factor market movements on the exposure and the collateral side. Examples of how narrative stress scenario shocks are generated are:

- Application of historically observed maximum in the affected market(s)
- Application of unprecedented stress, e.g. derived from neighboring markets or underlyings
- Application of stress levels inferred through analysis of scenario determined effects on other factors (e.g. the credit rating of a government)

5.2.4 Common stress parameters across scenario types

This section outlines the stress parameters which are applied across different scenario types, and hence are not differentiated in calibration between historical and hypothetical scenarios. As narrative scenario design depends on the narrative, there may be differentiation between these risk factors compared to the standard CCaR approach (for historical and hypothetical scenarios).

A. **FX stress:** FX risk can arise for cleared positions where the exposure currency (the cleared instrument) is denoted in a different currency than the margin requirement and/or default fund of the relevant clearing service

B. **Implied volatility stress:** As the valuation engine in CCaR is common with the respective margin models, volatility stress is applied in a similar manner in CCaR as for IM

A. FX stress

To hold up against the risk arising from converting derivatives exposures denoted in a different currency than IM and default fund requirements for the exposure, a currency risk stress is applied to each individual member's exposure in such a currency. The stress is calibrated to withstand extreme but plausible market conditions for the relevant currency pairs for which Nasdaq Clearing has material exposure to with regards to the CCaR model. The relevant currency pairs can be found in the table below, for which SEK-EUR constitutes the largest exposure for Commodities, DKK-SEK for Financial markets and NOK-EUR for Seafood.

Table 3: FX pairs relevant for the CCaR model

FX pair
SEK-NOK
NOK-EUR
SEK-DKK
USD-EUR
SEK-EUR
SEK-USD
GBP-EUR
DKK-EUR

Note: The FX stress also applies to the inverted pair

More specifically, stress is calibrated per relevant currency pair as the 99.9 empirical exclusive percentile of observed daily relative return in rates (absolute sign) over the lookback period, scaled by the square root of five to hold up against risk from products with a liquidation period of five days.

5.3 Portfolio risk calculation

Once the individual stress parameters have been derived, a set of scenarios are generated to aggregate the calculated stress across product areas and each default fund. The scenario design, and thus the direction and correlation of the stressed shocks are based on different assumptions for historical, hypothetical and narrative scenarios, as described below:

- **Historical scenarios**: Scenarios reflect the observed underlying historical correlations, i.e. the actual direction of the historical stress events

- **Hypothetical scenarios:** Scenarios are built assuming the individual stress shocks will occur on the same day, for instruments within the same Product Area the shocks occur in the same direction, whereas between other products no certain dependency is assumed and hence all possible combinations of directionality are applied
- **Narrative scenarios:** Scenarios are built with hypothetical scenario design as a starting point, however the scenario build is tailored freely to fit the specific narrative

5.3.1 Historical scenario design

As the historical scenarios are designed as actual replays of the historical stress events[2] identified, applied to each of the current portfolios, the scenario design is simplistic. The scenarios are constructed by applying the observed historical stress for each risk factor per event, with the implied volatility stress in positive direction, and as such the number of historical scenarios is equal to the number of historical events selected. The implied volatility is always stressed upwards for historical events, as during times of extreme market movements it can be assumed that high (positive) volatilities are observed (this general rule is however broken in hypothetical scenarios, see below).

Note that currency stress is applied independently between the scenarios in the unfavourable direction should any FX risk exist for a portfolio, see next section for further description.

5.3.2 Hypothetical scenario design

The hypothetical scenarios are generated in two steps, namely via:

A. **Basic scenarios** – scenarios within Product Areas, for which individual risk factor shocks are applied simultaneously for all instruments in a certain direction – these scenarios are the building blocks of the "final scenarios"
B. **Final scenarios** – scenarios across Product Areas, taking all possible combinations of the basic scenarios (Not imposing any statistical dependency between different Product Areas)

Below, the two scenarios are described further.

A. Basic scenarios

The basic scenarios are the stress scenarios that take place within a certain Product Area. For example, a basic scenario can be that the underlying price is stressed up for all products within the Product Area. The magnitude of stress for the individual instruments is different and depends on the single risk factor stress estimation, but the directionality is consistent within the Product Area in the basic scenario. The number of basic scenarios per product area varies with the number of risk factors and per asset class:

- **For Equity and Commodity underlying prices** there are two basic scenarios: price shock up and down

[2] Note that the exact date representing one historical event could slightly differ between risk factors, as described in section 5.2.2, which although is more conservative

- **For Fixed income products** there are four basic scenarios due to the use two principal components (PC1, PC2); (up, up), (up, down), (down, up), (down, down)

The logic behind the basic scenarios is displayed in the table below. Note that per Margin Calculation Account (where IM calculations and Stressed Market Value calculations are compared to generate the CCaR or stress loss beyond margin per account) the implied volatility is shocked in the way which maximizes the CCaR value – hence it is not scenario consistent between different accounts. This assumption reduces the dimensionality of scenario generation and is conservative.

Table 4: Illustration of basic scenarios
UL = underlying, IV = implied volatility, PC = principal component

CCaR PA	Basic scenario 1	Basic scenario 2	Basic scenario 3	Basic scenario 4
Nordic stocks	UL up, worst of IV up/unchanged/down	UL down, worst of IV up/unchanged/down	N/A	N/A
Nordic bonds	PC1 up, PC2 up, worst of IV up/ unchanged/down	PC1 up, PC2 down, worst of IV up/ unchanged/down	PC1 down, PC2 up, worst of IV up/unchanged/down	PC1 down, PC2 down, worst of IV up/unchanged/down
ENOINT (Nordic Power)	UL up, worst of IV up/unchanged/down	UL down, worst of IV up/unchanged/down	N/A	N/A

B. Final scenarios

Final scenarios are the hypothetical scenarios covering all Product Areas. Since there is no dependency assumed between different Product Areas, the final scenarios are derived by taking all possible combinations of basic scenarios for all different Product Areas within a default fund.

The number of final scenarios is thus dependent on the number of Product Areas, and the number of basic scenarios per Product Area. For example, if there would be only two Product Areas and two different basic scenarios per Product Area, then 4 final scenarios would be created. A configuration with ten Product Areas and two basic scenarios per Product Area would yield 2^10 = 1024 final scenarios, and a configuration with ten Product Areas with four basic scenarios per Product Area would lead to 4^10 = 1048576 final scenarios. Given the approach where full independence is given between different Product Areas, the number of basic scenarios and Product Areas employed is an important consideration for computational efficiency. The table below illustrates the construction of final scenarios.

Table 5: Illustration of final scenarios for two Product Areas with two basic scenarios each

Final scenario #	PA 1	PA 2
1	Basic scenario 1	Basic scenario 1
2	Basic scenario 1	Basic scenario 2
3	Basic scenario 2	Basic scenario 1
4	Basic scenario 2	Basic scenario 2

Final scenario “stressed market value” – i.e. P&L impact of the scenario on the portfolio (MCA), is then compared with the IM for the portfolio to calculate the CCaR per MCA.

The CCaR per MCA is calculated in the instrument currency for Financials, but in the “margin currency” for the COM and SF clearing services. The next steps, applying FX risk per collateral

account (MRA) and aggregating all account losses to clearing member level, are outlined in Section 5.4.

5.3.3 Portfolio liquidation cost

Before proceeding in this section, it is useful to note that the concentration add-ons included as part of initial margin are reflected as part of the calculated stress loss as well. A portfolio that has a concentration add-on (in the Initial Margin sense) assigned to it, also has a corresponding liquidation cost (in the CCaR/stressed sense) assigned to it of the same magnitude, causing the two quantities to effectively cancel from the loss-beyond-margin calculations. The rationale behind this is that the liquidity haircuts used in the calculation of the concentration add-on are calibrated to represent the cost to liquidate concentrated positions under stressed conditions.

The base liquidation cost (i.e. bid/ask spread margin component) applied as part of the Initial Margin is also included as part of the SMV component in the stress loss calculation in the CCaR model, hence this component also cancel in the loss-beyond-margin calculation.

There are two other mechanisms by which liquidation cost is accounted for in the CCaR model, in order to capture the potentially increased liquidation cost faced during close-out of a portfolio under extreme but plausible market conditions:

- “Stressed Base Liquidation Cost” (SBLC) – to ensure that all positions, in stress loss calculations, at minimum are charged a liquidation cost equivalent to the lowest level of liquidity haircut used in the concentration margin calculation. For positions where the concentration margin add-on (charged as part of Initial Margin) is either zero or below the liquidation cost corresponding to the lowest level of liquidity haircut, the SBLC will be greater than the concentration add-on and thus, for these positions, this will have an impact on the loss-beyond-margin calculation. Note however that positions that are classified as concentrated in the concentration margin add-on calculation, and receive a liquidation cost at least corresponding to the lowest level of liquidity haircut, will be considered as equally concentrated in the stress loss calculation. As stated in the introduction to this section, for such positions, the liquidation cost will effectively cancel in the loss-beyond-margin calculation (accomplished by setting the SBLC component in the stress loss calculation equal to the concentration margin add-on).
- "Knock-on Adjustment” (KO-adj) – an additional portfolio liquidation cost, conceptually applied as a “knock-on” to the concentration add-on, to account for increased liquidation cost given a lower risk warehousing capacity of the market following a default, in an event with multiple defaults.

5.4 Stress loss calculation and aggregation

This section describes how the stress losses are calculated and aggregated, followed by an overview of the specific stress loss CCaR outcomes generated.

5.4.1 Stress loss aggregation logic

The stress loss is calculated on all current portfolios (Margin Calculation Accounts) as outlined in Section 5.3 for all clearing counterparties. The estimated loss beyond initial margin (CCaR value) is derived as the market value change of a portfolio under stress, less the initial margin (or haircutted collateral, whichever is worst). The portfolio market value change under stress is sometimes referred to as the Stressed Market Value (SMV), which is calculated in each scenario given the risk factor movements specific to the scenario.

Under each stress scenario and for each Margin Requirement Account (MRA), loss is defined as the sum of losses for all underlying MCAs. As collateral is required on this level (MRA), this is where the CCaR is calculated as the scenario loss on MRA level less the initial margin requirement or the available (haircut) collateral, whichever is worst. CCaR is then the loss beyond margin, combining the stress losses with the collected collateral.

Excess collateral is not considered, whereas a collateral shortfall compared to the margin requirement is considered (and will reduce the collateral against which the SMV is compared, a shortfall is only expected in unusual circumstances when there has been delays in posting collateral from the clearing member for e.g. operational reasons, or if the value of the collateral has changed during the day).

The formula is hence (assuming all quantities are expressed with a negative sign):

$$CCaR_{MRA} = \sum_{MCA} Stress - \max\left(initial\ margin, available\ haircutted\ collateral\right),$$

where

$Stress_{MCA}$ includes stressed liquidation component

$initial\ margin$ includes base liquidation cost

However, the above also takes into account the aggregation rules with regards to mixing customer funds. This means that if the calculated SMV is a gain, not a loss, then while losses are always propagated, gains are only propagated when doing so would not result in shifting profits from one customer to another, or to the house account. More details are described below, when the same logic is applied for propagation beyond the MRA level.

From the losses calculated on the Margin Requirement Account level, further aggregation is done to the level of the Legal Entity that is a clearing member, and then to the Legal Entity Group (spanning any additional memberships of the Group). This means that all Legal Entities belonging to the same Group are assumed to go into a default simultaneously, not only one subsidiary.

Note that the aggregation of losses beyond the MRA level considers the default management rules with respect to transfer of gains: If a stressed scenario contains a gain on the house account, that surplus can be used to cover losses on client accounts. Gains on client accounts can however not offset losses on other client accounts, or losses on the house account. The aggregation rules will thus set gains under a specific scenario on any client MRA account to zero. Below, the formula is outlined for how the CCaR component for a legal entity under a specific scenario, i, is calculated.

$$CCaR_{LEI,i} = \sum_{House\ account(s)} CCaR_{MRA,i} + \sum_{Client\ account(s)} \min\left(CCaR_{MRA,i}, 0\right)$$

Losses are expressed with negative sign, gains with positive sign. The Legal Entity level CCaR aggregation to Group level does not transfer any potential gains in scenario i between the legal entities, these are set to zero similarly to the client accounts. A worst case for the largest Legal Entity Group would then form part of the Cover 1 test, whereas the worst-case scenario involving two Legal Entity Groups would form the Cover 2 test.

To account for wrong-way risk when calculating the losses in the event of a simultaneous default of two members with the worst stress loss (cover 2), instruments posted as collateral by both of the two defaulters that is connected to the other defaulting party in the Cover 2 test is given an additional haircut to account for the concentration of wrong-way risk. Selection of defaulting counterparties is done without the WWR adjustment, and the WWR adjustment is applied afterwards by recalculating the CCaR value. The reason for this is because it is not regarded as computationally feasible to, for all joint default candidates across all tests, calculate a WWR-adjusted CCaR and compare it (note the difference between the Knock-on Adjustment, as the Knock-on effect is independent of the exact defaulting pair).

5.4.2 CCaR output generation

After aggregating the stress losses to Clearing Member (Group) level, the CCaR model calculates and generates its three main outputs (outputs on sub-levels outlined above are also stored), namely:

- Cover-1
- Cover-2
- Worst individual stress loss, per Clearing Member (Group) and per MRA

The below table provides an overview and describes each of these, including the selection of market scenario and application of liquidation cost. `

Table 6: Overview CCaR output

Output	Purpose	Calculation level	Defaulting CMs (rank in CCaR)	Selection of market scenario	Market scenario independent add-ons
Cover-1	Default fund sizing	Legal Entity Group	Top 1, or Top 2 & 3	Scenario generating worst individual CCaR (Top 1), Scenario generating worst combined loss of 2nd and 3rd member (Top 2 & 3)	• Base liquidation cost • Knock-on adjustment factor solely for scenario of Top 2 & 3
Cover-2	Clearing capital sizing	Legal Entity Group	Top 1 & 2	Scenario generating worst combined loss of 1st and 2rd member	• Base liquidation cost • Knock-on adjustment factor
Worst individual	Stress IM add-on	MRA	N/A	Worst scenario chosen for each (i.e. results not scenario consistent)	• Base liquidation cost
Worst individual	Reporting, analyses in narrative, etc.	Legal Entity Group	N/A	Worst scenario chosen for each (i.e. results not scenario consistent)	• Base liquidation cost

Note: The knock-on adjusted concentration add-on is solely applied if two members default simultaneously, as the concentration add-on in IM is clearing member specific and does not consider a potential additional default.

6 Model use

The primary use of the CCaR model is to calculate cover-1 and cover-2, which have downstream dependencies in sizing the default waterfall at Nasdaq Clearing (for details, please refer to the Default Fund Policy) and is being used to ensure that Nasdaq Clearing has sufficient liquid resources as part of the Liquidity at Risk framework. In addition, CCaR model output is used in the stress add-on, for stress testing reports and to inform potential changes or re-calibration of the IM models.

The testing of the CCaR model, referred to as the "model stress testing", involves increasing the number of defaults assumed, increasing the liquidation period of cleared portfolios, breaking assumed correlations and increasing the stress parameter levels. Should any of these model testing areas generate concerning results (e.g. coverage breaches, excessive stress losses for single members in specific scenarios, high model sensitivity to specific parameter changes in reverse stress testing, etc.), this triggers a review of the CCaR model or any other model methodologies and assumptions as relevant.

6.1 Intended model use

- Calculation of cover 1 and cover 2 for default waterfall sizing and input to liquidity at risk estimation
- Calculation of worst individual stress loss for e.g. use in the stress IM add-on
- Generation of regular stress test reports
- Informing potential enhancements to IM or other CCP risk models
- Informing CCP senior management on wider risks (primarily narrative stress test scenarios)

6.2 Model output and reports

- Regular stress testing report provided to internal and external risk committees
- Worst individual CCaR per clearing member
- CCaR per clearing member and scenario
- Cover-1 and Cover-2 figures per clearing service
- "Model stress testing" results – e.g. impact of multiple defaults, increased stress parameters, further correlation breakdowns

6.3 Re-calibration

The CCaR Parameters, i.e. the single risk factor shocks deployed, for all clearing services are re-calibrated as part of the regular monthly parameter reviews. All new available data since the last month's update is considered, the parameters are re-estimated, and then implemented in Genium INET.

At least yearly model reviews are performed to review and update all other model parameters (e.g. product area allocations) as well as to identify if there are any new historical or narrative scenarios to be added to the stress testing. Product areas are also monitored with regards to the share of IM of constituents compared to the whole. If a product area has a significant change in composition, an extraordinary review of the product area composition is launched.

Moreover, if market news or daily monitoring (such as backtesting) indicates a need to update the parameters more often, extra-ordinary updates are carried out. Such updates can be deployed within a few hours if necessary and are typically done during times of market turmoil.