



## CF SPOT RATES

Methodology Guide

Version: 12.0

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# 1 Version History

Version	Version Date	Changes to Previous
1	20 <sup>th</sup> June 2018	N/A
2	15 <sup>th</sup> August 2018	Addition of Parameters & Specifications for Bitcoin Cash
3	5 <sup>th</sup> June 2019	Amendment to Methodology Parameters for CF Bitcoin Cash-Dollar Spot Rate and CF Ripple-Dollar Spot Rate
3.1	2 <sup>nd</sup> July 2019	Removal of Bitfinex from CF Ripple-Bitcoin Spot Rate
3.2	16 <sup>th</sup> July 2019	Move constituent list to separate document
4	16 <sup>th</sup> July 2019	Rebrand for CF Benchmarks
5	11 <sup>th</sup> September 2019	Update legal text with BMR registration
6	2 <sup>nd</sup> December 2019	Change order size cap from static to dynamic
7	10 <sup>th</sup> February 2020	Change potentially erroneous data parameter
8	13 <sup>th</sup> May 2020	Addition of: <ul style="list-style-type: none"> <li>• CF EOS-Dollar Spot Rate</li> <li>• CF Stellar Lumens-Dollar Spot Rate</li> <li>• CF Tezos-Dollar Spot Rate</li> </ul> Update ticker symbols
9	20 <sup>th</sup> May 2020	Clarify use of orderbook price levels
10	31 <sup>st</sup> July 2020	Addition of sections concerning: <ul style="list-style-type: none"> <li>• Underlying Economic Reality</li> <li>• Expert Judgement</li> <li>• Methodology Review and Changes</li> </ul>
11	25 <sup>th</sup> August 2020	Addition of: <ul style="list-style-type: none"> <li>• CF PAX Gold-Dollar Spot Rate</li> <li>• CF Bitcoin-Euro Spot Rate</li> <li>• CF Ether-Euro Spot Rate</li> </ul>
12	14 <sup>th</sup> September 2020	Change to the implementation of the <b>Potentially Erroneous Data Parameter</b>

## 2 Overview

The CF Spot Rates have been specifically designed to serve as a transparent and representative indicator of the instantaneous price of a digital asset for the purposes of calculating margining requirements for orderly futures trading. No further applications of the CF Settlement Prices have been taken into consideration in its design.

This document covers the methodology for calculating the CF Spot Rates. A summary of specifications is provided in Section 7.

### **Underlying Economic Reality**

The CF Spot Rates are intended to measure the underlying economic reality of the exchange of the base asset for the quote asset and vice versa. This is accomplished by the use of order input data from Constituent Exchanges, the criteria for eligibility for which are available in the CF Constituent Exchange Criteria.

### 3 Definitions

**API:** Application programming interface.

**Calculation Time:** Any time as of which a CF Spot Rate is published.

**Constituent Exchange:** A cryptocurrency trading venue approved by CF management to serve as pricing source for the calculation of a CF Spot Rate

**Relevant Pair:** The cryptocurrency versus cryptocurrency or legal tender pair referenced by a CF Spot Rate, as defined in Section 6.

**Relevant Order Book:** The universe of the currently unmatched limit orders to buy or sell a unit of cryptocurrency versus cryptocurrency or legal tender on a Constituent Exchange in the Relevant Pair, aggregated by price, that is reported through its API to the Calculation Agent.

**Retrieval Time:** The time, as given by the server clock of the Calculation Agent, as of which the Relevant Order Book of a Constituent Exchange is requested by the Calculation Agent through the API of the Constituent Exchange.

## 4 Methodology and Rules

### 4.1 Methodology

#### 4.1.1 Qualitative Description

The CF Spot Rates are calculated in real time based on the Relevant Order Books of all Constituent Exchanges. An order book is a list of buy and sell orders with associated limit prices and sizes that have not yet been matched due to lack of supply or demand to trade at that price. It therefore informs about the price at which a trader can buy or sell a certain amount of cryptocurrency as of now. In line with existing cryptocurrency market practises, the "order size" refers to the aggregated sizes of all orders at the same price, the price/sizes tuples of buy orders ("bids") descend by price and the price/size tuples of sell orders ("asks") ascend by price.

Calculation steps are as follows:

1. At the Effective Time, the Relevant Order Book of each Constituent Exchange is added to a joint list of order books.
2. The joint list of order books is aggregated into one consolidated order book. If the size of a bid or ask order price level exceeds the order size cap, it enters the consolidated order book with a size equal to the order size cap.
3. The cumulative bid price-volume curve, ask price-volume curve, mid price-volume curve and mid spread-volume curve are calculated from the consolidated order book at a granularity equal to the spacing parameter.
  - a. The bid price-volume curve maps transaction volume to the marginal price per cryptocurrency unit a seller is required to accept in order to sell this volume to the consolidated order book.
  - b. The ask price-volume curve maps a transaction volume to the marginal price per cryptocurrency unit a buyer is required to pay in order to purchase this volume from the consolidated order book.
  - c. The mid price-volume curve represents the average of the bid price-volume curve and the ask price-volume curve.
  - d. The mid spread-volume curve represents the percentage deviation of the ask price-volume curve from the mid price-volume curve.
4. The utilized depth is calculated as the maximum cumulative volume for which the mid spread-volume curve does not exceed a certain percentage deviation from the mid price. If this volume is less than the spacing parameter, the utilized depth is set to the spacing parameter.

5. The mid price-volume curve is weighted by the normalized probability density of the exponential distribution up to the utilized depth.
6. The CF Spot Rate is then given by the sum of the weighted mid price-volume curve obtained in the previous step.

#### 4.1.2 Mathematical Representation

The following table shows the symbols used in the mathematical representation of CF Spot Rates.

Symbol	Name	Description	Type
$T$	Effective time	The time at which a CF Spot Rate is calculated	Parameter, see Section 6
$C_T$	Order size cap	The size above which any excess size of a bid or ask order price level is discarded	Internal variable, see Section 4.1.3
$D$	Deviation from mid	The maximum percentage deviation of a limit order price level from the mid price-volume curve, until which that limit order price level is used for the calculation of a CF Spot Rate	Parameter, see Section 6
$\lambda$	Lambda	A parameter that determines the shape of the probability density function of the exponential distribution	Parameter, see Section 6
$s$	Spacing	The spacing granularity of a price-volume curve	Parameter, see Section 6
$v$	Volume	The independent variable of a price-volume curve	Internal variable
$A_T$	Ask orders	The ask order price levels of the consolidated order book as of the effective time, ordered ascending by price	Input
$a_{T,i}$ with $a_{T,i} = (ap_{T,i}, as_{T,i})$ , $a_{T,i} \in A_T, as_{T,i} = \min\{as_{T,i}, C_T\}$	Ask order	The $i$ th price/size ask order pair of the consolidated order book	Input
$B_T$	Bid orders	The bid order price levels of the consolidated order book as	Input

		of the effective time, ordered descending by price	
$b_{T,i}$ with $b_{T,i} = (bp_{T,i}, bs_{T,i})$ $b_{T,i} \in B, bs_{T,i} = \min\{bs_{T,i}, C_T\}$	Bid order	The $i$ th price/size bid order pair of the consolidated order book	Input
$NF$	Normalization factor	A parameter chosen such that $\frac{1}{NF} \sum_{v \in \{s, 2s, \dots, \bar{v}_T\}} \lambda e^{-\lambda v} = 1$	Output
$CCRTI_T$	CCRTI	The CF Spot Rate at time $T$	Output

Using the above notation, we define the ask price-volume curve,  $askPV_T$ , the bid price-volume curve,  $bidPV_T$ , the mid price-volume curve,  $midPV_T$ , and the mid spread-volume curve,  $midSV_T$ , in each case as of the effective time  $T$ , as:

$ask\widehat{PV}_T(v) = ap_{T,j+1}$ where $\sum_{i=1}^j as_{T,i} < v$ and $\sum_{i=1}^{j+1} as_{T,i} \geq v$	Eq. 1a
$bid\widehat{PV}_T(v) = bp_{T,j+1}$ where $\sum_{i=1}^j bs_{T,i} < v$ and $\sum_{i=1}^{j+1} bs_{T,i} \geq v$	Eq. 1b
$askPV_T(v) = ask\widehat{PV}_T\left(s \left\lfloor \frac{v}{s} \right\rfloor\right)$	Eq. 1c
$bidPV_T(v) = bid\widehat{PV}_T\left(s \left\lfloor \frac{v}{s} \right\rfloor\right)$	Eq. 1d
$midPV_T(v) = \frac{askPV_T(v) + bidPV_T(v)}{2}$	Eq. 1e
$midSV_T(v) = \frac{askPV_T(v)}{midPV_T(v)} - 1$	Eq. 1f

The utilized depth,  $\bar{v}_T$ , is calculated as:

$\bar{v}_T = \max(v_i \text{ where } midSV_T(v_i) \leq D \text{ and } midSV_T(v_{i+1}) > D, s)$	Eq. 2
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The CF Spot Rate as of the effective time  $T$ ,  $CCRTI_T$ , is then given by:



$$CCRTI_T = \sum_{v \in \{s, 2s, \dots, \bar{v}_T\}} midPV_T(v) \frac{1}{NF} \lambda e^{-\lambda v}$$

Eq. 3

### 4.1.3 Dynamic Order Size Cap

Unless specified as a fixed value in Section 6, the order size cap is calculated from the uncapped consolidated order book. The following symbols are used in the calculation of the order size cap:

Symbol	Name	Description
$ac_T$	Ask sample size	The number of samples used for ask-side sizes
$bc_T$	Bid sample size	The number of samples used for bid-side sizes
$S_T = \{s_{T,1}, s_{T,2}, \dots, s_{T,n_T}\}$	Size sample set	The consolidated set of sizes, ordered by ascending size
$k$	Trimming / winsorizing size	The number of samples to trim or winsorize from $S_T$
$\bar{s}$	Trimmed mean	The trimmed mean of the sample set $S_T$
$S'_T = \{s'_{T,1}, s'_{T,2}, \dots, s'_{T,n_T}\}$	Winsorized sample set	The winsorized sample set of $S_T$
$\bar{s}'$	Winsorized mean	The mean of the winsorized sample set $S'_T$
$\sigma$	Winsorized sample standard deviation	The sample standard deviation of the winsorized sample set $S'_T$

Using the above notation, the dynamic order size cap is derived as follows:

$ac_T = \max \left( \max_{1 \leq i \leq  A_T } \{i \mid ap_{T,i} \leq 1.05ap_{T,1}\}, \min( A_T , 50) \right)$	Eq. 4a
$bc_T = \max \left( \max_{1 \leq i \leq  B_T } \{i \mid bp_{T,i} \geq 0.95bp_{T,1}\}, \min( B_T , 50) \right)$	Eq. 4b
$S_T = [bs_{T,1}, bs_{T,2}, \dots, bs_{T,bc_T}] \cup [as_{T,1}, as_{T,2}, \dots, as_{T,ac_T}]$ $S_T = [s_{T,1}, s_{T,2}, \dots, s_{T,n_T}] \text{ where } s_{T,1} \leq s_{T,2} \leq \dots \leq s_{T,n_T}$	Eq. 4c
$k = \lfloor 0.01n_T \rfloor$	Eq. 4d
$\bar{s} = \frac{1}{n_T - 2k} \sum_{i=k+1}^{n_T-k} s_{T,i}$	Eq. 4e
$s'_{T,i} = s_{T,k+1} \text{ if } i \leq k$ $s'_{T,i} = s_{T,n-k} \text{ if } i > n - k$ $s'_{T,i} = s_{T,i} \text{ otherwise}$	Eq. 4f
$\bar{s}' = \frac{1}{n_T} \sum_{i=1}^{n_T} s'_{T,i}$	Eq. 4g
$\sigma = \sqrt{\frac{1}{n_T - 1} \sum_{i=1}^{n_T} (s'_{T,i} - \bar{s}')^2}$	Eq. 4h

The order size cap as of the effective time  $T$ ,  $C_T$ , is then given by:

$C_T = \bar{s} + 5\sigma$	Eq. 5
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## 4.2 A Note on Properties

The CF Spot Rates reflect the instantaneous supply and demand of a given cryptocurrency and result in a robust, yet highly timely indication of the current price. This is achieved through the following design choices:

### Order Book Data

CF Spot Rates are calculated from order book data, as opposed to, for instance, trade data. Order book data is composed of unmatched limit orders to buy or sell cryptocurrency. The order books retrieved from the constituent exchanges are aggregated by price. They inform about the price at which a trader can buy or sell cryptocurrency now or in the future and are therefore forward-looking by nature. Further, absent retrieval constraints, order book data is always up to date. This is in

contrast to trade data, which is produced in stochastic intervals only and informs about the price at which the cryptocurrency has traded in the past.

### Mid Price Volume Curve

The mid price volume curve represents the average of the marginal price at which a certain amount of cryptocurrency can be sold and bought. By averaging across the mid price volume curve, CF Spot Rates Indices represent a blend of such (hypothetical) transactions at various transaction sizes.

### Utilized Depth

CF Spot Rates are calculated from the section of the mid price volume curve for which ask limit order price levels at a certain depth diverge by no more than a certain percentage from the mid price at that depth. It therefore reflects a significant portion of the top of the consolidated order book (as opposed to, for instance, the best bid and ask prices only) but discards limit order price levels that are less likely to be matched. This makes it a meaningful representation of true liquidity and robust to local changes in order books.

Note that utilized depth will always include any crossing section of the consolidated order book, as well as the non-crossing section with limit orders up to a certain percentage away from the crossing point. If zero size resides in both these sections, utilized depth is set to the spacing parameter. The CF Spot Rate is then effectively equal to the mid price of the consolidated order book.

### Exponential Weighting

The mid price-volume curve is weighted by the normalized probability density of the exponential distribution. The exponential distribution and its first derivative are monotonically decreasing, resulting in a higher emphasis on the initial section of the mid price-volume curve, i.e. bid and ask prices that are closest to the global best bid and ask price.

### Markov Process and Martingale

Indices are frequently based on historical data, such as recent trade prices or volumes. This can result in certain predictability, for instance due to the expectation that stale prices will be updated or that a price will drop out of a weighting window.

By relying solely on order book data, CF Spot Rates are both a Markov process and a martingale. A Markov process is a stochastic process with a probability distribution that depends only on the current information set, not on historical information sets. The martingale property implies that the best prediction of the next CF Spot Rate value is its current value:

$$E(CCRTI_{t+1} | CCRTI_1, CCRTI_2, \dots, CCRTI_t) = CCRTI_t$$

This makes CF Spot Rates fit for its primary application of facilitating orderly futures trading.

## 5 Contingency Calculation Rules

### 5.1 Delayed Data

Delayed data is treated according to the following rules:

1. If the Retrieval Time of the Relevant Order Book of a Constituent Exchange is at least 30 seconds older than the Calculation Time, the Constituent Exchange is disregarded in the calculation of the CF Spot Rate for that Calculation Time.

If the Retrieval Times of the Relevant Order Books of all Constituent Exchanges are each at least 30 seconds older than the Calculation Time, a CF Spot Rate calculation failure occurs for that Calculation Time (see Section 5.5).

### 5.2 Erroneous Data

#### 5.2.1 Erroneous Books

All Relevant Order Books are subject to an automated screening for erroneous data according to the following rules:

1. If the format of a Relevant Order Book deviates from the expected format such that it cannot be parsed, it is flagged as erroneous.
2. If the Relevant Order Book contains no bid orders or no ask orders, it is flagged as erroneous.
3. If the Relevant Order Book crosses, it is flagged as erroneous.

Relevant Order Books flagged as erroneous for a given Calculation Time are disregarded in the calculation of the CF Spot Rate for that Calculation Time.

If the Relevant Order Books of all Constituent Exchanges are flagged as erroneous for a given Calculation Time, a CF Spot Rate calculation failure occurs for that Calculation Time (see Section 5.5).

#### 5.2.2 Erroneous Prices

All Relevant Order Books are subject to an automated filtering process according to the following rule.

1. If a Relevant Order Book contains any entries with a non-numeric or non-positive limit price or size then any such entries are flagged as erroneous.

All entries in a Relevant Order Book which are flagged as erroneous for a given Calculation Time are disregarded in the calculation of the CF Spot Rate for that Calculation Time.

### 5.3 Potentially Erroneous Data

All Relevant Order Books are subject to an automated screening for potentially erroneous data according to the following rules:

1. For each Constituent Exchange individually, the current mid price is calculated as the average of the highest bid price and the lowest ask price of the Relevant Order Book.
2. For each Constituent Exchange, the absolute percentage deviation of the mid price, as calculated in the previous step, from the median of the mid prices of all Constituent Exchanges is calculated.
3. If for any Constituent Exchange the absolute percentage deviation, as calculated in the previous step, exceeds the Potentially Erroneous Data Parameter for the respective Spot Rate represented in the Spot Rate Parameters (section 6) then the Relevant Order Book of that Constituent Exchange for the affected Spot Rate is flagged as potentially erroneous.
4. Upon an orderbook of a Constituent Exchange having been disregarded in the calculation as described in the previous step, its orderbook shall continue to be disregarded from the calculation of the affected index until the absolute deviation of the mid-price of its orderbook as calculated in step 2 is less than 50% of the Potentially Erroneous Data Parameter. At this point it shall be re-instated to the calculation for that Calculation Time and all subsequent Calculation Times unless it is removed from the calculation for any of the reasons as described in section 5.

Relevant Order Books flagged as potentially erroneous for a given Calculation Time are disregarded in the calculation of the CF Spot Rate for that Calculation Time. The occurrence of any such flag is reported to the Oversight Function.

If the Relevant Order Books of all Constituent Exchanges are flagged as potentially erroneous for a given Calculation Time, a CF Spot rate Calculation Failure occurs for that Calculation Time (see Section 5.5).

### 5.4 Expert Judgement

The Administrator does not utilise expert judgment in the day to day calculation of the Spot Rates. In extraordinary circumstances Expert Judgement may be exercised by the

Administrator in accordance with its codified policies and processes which are available upon request.

## 5.5 Calculation Failure

If a CF Spot Rate cannot be calculated for a given Calculation Time, for instance because:

- the Retrieval Times of the Relevant Order Books of all Constituent Exchanges are each at least 30 seconds older than the Calculation Time, or
- all Relevant Order Books are flagged as erroneous or potentially erroneous (see Section 5.2); or
- any other reason or circumstance that prevents the orderly calculation of a CF Spot Rate,

then the CF Spot Rate for that Calculation Time is not published. The occurrence of any CF Spot Rate calculation failure is reported to CF management and persistent failure will lead to a review of the methodology.

## 6 Spot Rate Parameters

The following table summarizes the parameters for the currently supported CF Spot Rates:

	CF Litecoin-Dollar Spot Rate	CF Ripple-Dollar Spot Rate	CF Ripple-Bitcoin Spot Rate	CF Bitcoin Cash-Dollar Spot Rate
<b>Effective Time (<math>T</math>)</b>	Approximately every second of each day for the entire year including weekends and holidays.			
<b>Spacing (<math>s</math>)</b>	50	10,000	10,000	10
<b>Deviation from Mid (<math>D</math>)</b>	1%	1%	1%	1%
<b>Lambda (<math>\lambda</math>)</b>	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$
<b>Potentially Erroneous Data Parameter</b>	10%	10%	10%	10%
<b>Order Size Cap (<math>C_T</math>)</b>	Dynamic	Dynamic	Dynamic	Dynamic



	CF EOS-Dollar Spot Rate	CF Stellar Lumens-Dollar Spot Rate	CF Tezos-Dollar Spot Rate	CF PAX Gold-Dollar Spot Rate
<b>Effective Time (<math>T</math>)</b>	Approximately every second of each day for the entire year including weekends and holidays.			
<b>Spacing (<math>s</math>)</b>	1,000	100,000	1,000	1
<b>Deviation from Mid (<math>D</math>)</b>	1%	1%	1%	2%
<b>Lambda (<math>\lambda</math>)</b>	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$
<b>Potentially Erroneous Data Parameter</b>	25%	25%	25%	25%
<b>Order Size Cap (<math>C_T</math>)</b>	Dynamic	Dynamic	Dynamic	25

	CF Bitcoin-Euro Spot Rate	CF Ether-Euro Spot Rate
<b>Effective Time (<math>T</math>)</b>	Approximately every second of each day for the entire year including weekends and holidays.	
<b>Spacing (<math>s</math>)</b>	1	25
<b>Deviation from Mid (<math>D</math>)</b>	0.5%	1%
<b>Lambda (<math>\lambda</math>)</b>	$\frac{1}{0.3\bar{v}_T}$	$\frac{1}{0.3\bar{v}_T}$
<b>Potentially Erroneous Data Parameter</b>	10%	10%
<b>Order Size Cap (<math>C_T</math>)</b>	Dynamic	Dynamic

## 7 Spot Rate Specifications

The following table summarizes the specifications for the currently supported CF Spot Rates:

	<b>CF Litecoin-Dollar Spot Rate</b>	<b>CF Ripple-Dollar Spot Rate</b>	<b>CF Ripple-Bitcoin Spot Rate</b>	<b>CF Bitcoin Cash-Dollar Spot Rate</b>
<b>Ticker Symbol</b>	LTCUSD_RTI	XRPUSD_RTI	XRPXBT_RTI	BCHUSD_RTI
<b>Administrator</b>	CF Benchmarks Ltd			
<b>Calculation Agent</b>	CF Benchmarks Ltd			
<b>Description</b>	Instantaneous U.S. Dollar price of one Litecoin	Instantaneous U.S. Dollar price of one XRP	Instantaneous Bitcoin price of one XRP	Instantaneous U.S. Dollar price of one Bitcoin Cash
<b>Calculation Methodology</b>	Real time aggregation of order book data of Constituent Exchanges			
<b>Dissemination Time</b>	Approximately every second of each day for the entire year including weekends and holidays.			
<b>Dissemination Precision</b>	0.01 U.S. Dollars	0.00001 U.S. Dollars	0.00000001 Bitcoin	0.01 U.S. Dollars

	<b>CF EOS-Dollar Spot Rate</b>	<b>CF Stellar Lumens-Dollar Spot Rate</b>	<b>CF Tezos-Dollar Spot Rate</b>	<b>CF PAX Gold-Dollar Spot Rate</b>
<b>Ticker Symbol</b>	EOSUSD_RTI	XMLUSD_RTI	XTZUSD_RTI	PAXGUSD_RTI
<b>Administrator</b>	CF Benchmarks Ltd			
<b>Calculation Agent</b>	CF Benchmarks Ltd			
<b>Description</b>	Instantaneous U.S. Dollar price of one EOS	Instantaneous U.S. Dollar price of one Stellar Lumen	Instantaneous U.S. Dollar price of one Tezos	Instantaneous U.S. Dollar Price of one PAX Gold token
<b>Calculation Methodology</b>	Real time aggregation of order book data of Constituent Exchanges			
<b>Dissemination Time</b>	Approximately every second of each day for the entire year including weekends and holidays.			
<b>Dissemination Precision</b>	0.001 U.S. Dollars	0.00001 U.S. Dollars	0.0001 U.S. Dollars	0.01 U.S. Dollars

	<b>CF Bitcoin-Euro Spot Rate</b>	<b>CF Ether-Euro Spot Rate</b>
<b>Ticker Symbol</b>	XBTEUR_RTI	ETHEUR_RTI
<b>Administrator</b>	CF Benchmarks Ltd	
<b>Calculation Agent</b>	CF Benchmarks Ltd	
<b>Description</b>	Instantaneous Euro price of one Bitcoin	Instantaneous Euro price of one Ether
<b>Calculation Methodology</b>	Real time aggregation of order book data of Constituent Exchanges	
<b>Dissemination Time</b>	Approximately every second of each day for the entire year including weekends and holidays.	
<b>Dissemination Precision</b>	0.01 Euros	0.01 Euros

## 8 Methodology Review and Changes

This methodology is subject to internal review by the Administrator and the CF Oversight Function at least annually.

Any changes to this methodology are overseen by the CF Oversight Function, and in accordance with EU BMR Article 13.

All *material* changes to the methodology shall only be implemented after a consultation process with users and relevant stakeholders that shall be conducted according to the Administrator's policies and overseen by the CF Oversight Function.

Should the Administrator deem it necessary to cease providing any of the Spot Rates it shall only do so after a consultation process with users and relevant stakeholders that shall be conducted according to the Administrator's policies and overseen by the CF Oversight Function.

## Contact Information

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