# DFS2420 - Smart Order Router

**Phase:** **Solution Definition**

**Module:** **System Delivery Specification (SDS)**

**1st Level WP:** **System Delivery Specification**

**2nd Level WP:** **Detailed Functional Specification**

**Internal / Confidential**

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| Author | B. Mallin |
| Owner | B. Mallin |
| Reviewers | M. Davis, N. Mukerjee, B. Hallnan, J. Palmer |
| Approvers | K. Rathi, R. Wieszczek |
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## Abstract

This document provides functional specifications for the Smart Order Router (SOR) for Project Optimise.SOR is a critical tradingcomponent that routesreal-time stock orders from Matching Engine (ME) for stock legs of stock-option complex orders and quotes to supported stock execution venues, which could be broker/dealers, alternative trading systems (ATS) or exchanges. SOR also processes execution reports from the stock execution venues, which include, but are not limited to,BNY ConvergEx Transaction Services (NTS) andBNY ConvergEx Millennium (NM). The scope of this document is the functionality that will be provided by SOR for OptimISE.Finally, the SOR is a key stock post-trade allocation (SPTA) component responsible for routing stock leg allocation requests and responses between the Trade Manager (TM) and the stock execution venues respectively.

This document details the functional specifications for the SOR.

## Keywords

ISE, ME, TM, OFI, FIX, BNY, ConvergEx, NTS, NM, Stock, Spreads, Equity

## Revision History

| Date | By | Version | Reason |
|---|---|---|---|
| 23/11/09 | R. Dultsin | 0.1 | First Draft |
| 25/11/09 | R. Dultsin | 0.2 | Updated with comments from B. Hallnan<br>Added reference to SRQ2410 (a.k.a. SRQ31xx) |
| 27/11/09 | R. Dultsin | 1.0 | Updated with comments from H. Zion and B. Hallnan |
| 16/03/10 | B. Hallnan | 1.0 | Changed name to 2410, per CPO. Updated references to SCD2400 – to SCD2410, per CPO. |
| 10/05/10 | R. Dultsin | 3.0 | Final |
| 21/01/11 | R. Dultsin | 3.1 | Miscellaneous Updates |
| 17/08/11 | R. Dultsin | 3.2 | Direct Ultra Messaging-based API Session |
| 21/11/11 | R. Dultsin | 3.3 | Conversion from EDS to a third-party ticker plant |
| 27/01/12 | R. Dultsin | 3.4 | Stock Venue Additions (Phase I) |
| 09/07/12 | B. Mallin | 3.5 | Modification to round robin. Also bust All or None or FOK orders that are partially filled. |
| 19/07/12 | B. Mallin | 3.6 | Add Cheevers stock venue |

# Table of Contents

# 1 Introduction

The Smart Order Router (SOR) system is a critical ISE trading and post-trade processing component that routes real-time stock orders and stock leg allocations that originate at the Matching Engine (ME), the Trade Manager (TM) or the ISE Applications (e.g. PrecISE, IORS) to supported stock execution venues and provides the stock execution / allocation data back to the ME, the TM or the ISE Applications.

Order and execution report traffic with the ME and the TM is handled by the Outbound Feed Interface (OFI), which DBS has developed. The OFI plays the role of middleman between the IBM WLLM bus, to which the ME and the TM will be publishing their stock orders and stock post-trade allocations, and the SOR.

Order and execution report traffic with the ISE Applications is handled via Informatica Ultra Messaging technology. Ultra Messaging Streaming Edition (a.k.a. LBM) is used for SOR-inbound orders and allocation requests as well as for SOR-outbound execution reports and allocation reports.

The high-level features of the SOR are:

- The SOR receives stock crosses (double-sided):
    - From the ME via the OFI
    - From the ISE Applications via LBM
- The SOR receives stock orders (single-sided) from the ME via the OFI
- The SOR routes orders and crosses to the NM, the NTS or other certified and enabled stock execution venues in round-robin fashion according to round robin logic in section 3.1.1, allowing tiers of venues.
- The SOR aggregates stock order executions and reports back
    - To the ME via the OFI
    - To the ISE Applications via LBM
- The SOR receives acknowledgement and reject responses from the ME via the OFI
- The SOR receives confirmation instruction from the ISE Applications via LBM
- The SOR busts execution reports as indicated by the reject responses from the ME
- The SOR notifies Operations via E-mail of urgent manual actions needed to be taken
- The SOR receives TM to SPTA Maintenance Request broadcasts from the TM via the OFI
- The SOR receives Allocation Instruction messages from the ISE Applications via the LBM
- The SOR sends Allocation Instruction FIX messages to the NM, the NTS or other certified and enabled stock execution venues that support SPTA
- The SOR receives Allocation Instruction Ack FIX message from stock execution venues
- The SOR sends SPTA to TM Maintenance Acknowledgement message to the TM
- The SOR receives TM to SPTA Maintenance Confirmation response from the TM
- The SOR sends Allocation Instruction Ack message to the ISE Applications via LBM
- The SOR auto-shuts off a stock execution venues which violatethe configurable terms of SLA
- The SOR informs the ME via the OFI when a stock execution venue has been auto-shutoff
- The SOR is scalable, redundant, and recoverable
- The SOR maintains minimal configuration settings in the configuration file and the rest in the configuration service
- The SOR loads the ~~NM~~Generic FIX Stock Venue and the NTS libraries as run-time plug-ins
- The SOR maintains file logs and performance counters

- The SOR is monitored by Operations Service
- The SOR is integrated with XTP, which provides underlying quotes

## 1.1 Abbreviations

Abbreviations used in this document are:

| | |
|---|---|
| AON | All-or-None |
| ATS | Alternative Trading System |
| BBO | Best Bid/Offer |
| BU | Business Unit |
| COPS | Computer Operations |
| CQS | Consolidated Quotation System |
| EDGA | EDGA Exchange, Inc. (a new stock exchange from Direct Edge pending approval from SEC) |
| EDGX | EDGX Exchange, Inc. (a new stock exchange from Direct Edge pending approval from SEC) |
| EMS | Enterprise Monitoring System |
| FIX | Financial Information eXchange |
| FOK | Fill-or-Kill |
| IOC | Immediate-of-Cancel |
| IORS | ISE Order Routing System |
| LBM | Latency Busters® Messaging |
| ME | Matching Engine |
| MOPS | Market Operations |
| MPID | Market Participant ID |
| ms | Milliseconds |
| NBBO | National Best Bid/Offer |
| NM | BNY ConvergEx Millennium ATS (formerly NYFIX Millennium) |
| NTS | BNY ConvergEx Transaction Services (formerly NYFIX Transaction Services) |
| NQDF | UTP Plan Quotation Data Feed |
| OFI | Outbound Feed Interface |
| RDCX | Reference Data Cache eXternal |
| UTP | Unlisted Trading Privileges |
| SEC | Securities and Exchanges Commission |
| SIAC | Security Industry Automation Corporation |
| SLA | Service Level Agreement |
| SPTA | Stock Post-Trade Allocation |
| TM | Trade Manager |
| WLLM | WebSphereMQ Low Latency Messaging |

| | |
|---|---|
| XTP | eXternal Ticker Plant |
| µs | Microseconds |
| QCC | Qualified Contingent Cross Orders |

## 1.2 Terminology

The matching engine can break up an order into many suborders. To distinguish between the two, the entire order will be referred to as the **matching order**, and each order that it sends to SOR will be referred to as a **matching attempt**. Similarly, SOR can break an order into many suborders. Each suborder will be referred to as an order slice.

## 1.3 Assumptions

The following sections list the functional and technical assumptions that support the functionality implemented in SOR.

### 1.3.1 Functional Assumptions

The functional assumptions are:

1. All message types defined in this document will be available with ME, TM and OFI in Optimise Core
2. The ME supports aggregated execution reports only from one stock execution venue
3. The eXternal Ticker Plant (XTP)supports query / subscription mechanism for providing BBO of specific exchanges used by SOR as stock execution venues (e.g. EDGA and EDGX) and NBBO
4. Enterprise logging, operational monitoring, performance monitoring, and reference data services are available
5. Reference data for business units supports multiple MPIDs (one per stock execution venue)
6. Stock venue fee structure and billing (e.g. maker/taker fees/rebates) are not considered by the SOR

### 1.3.2 Technical Assumptions

The technical assumptions are:

1. The OFI is available and provides functionality described for Optimise Core R2.0 or later
2. The ME is available and provides functionality described for Optimise Core R2.0 or later
3. The TM is available and provides functionality described for Optimise Core R2.0 or later
4. The XTPis available and provides functionality described in this document
5. Reference data (view on business units' MPIDs, product's lot sizes, etc.) is available and provides functionality described for Optimise Core R2.0 or later

## 1.4 Out of Scope

The following topics are out of scope in this document:

1. Technical design of SOR and its components

## 1.5 Related Documents

| |
|---|
| SRQ3180 – Stock Combinations in Complex Instruments.doc |

| |
|---|
| SRQ2400 – Smart Order Router v0.1.docx |
| DFS3610 Production Matcher v1.1 part D.doc |
| DFS3643 - Trade Capture and Management I6 Part B v11.doc |
| SCD2420 – Smart Order Router v3.3.docx |

## 2 SOR High Level Overview

At the highest level, the SOR can be described as system that processes stock orders and executions for the ME / ISE Applications and stock leg post-trade allocations for the TM / ISE Applications. The SOR architecture provides horizontal scaling. The SOR internal design provides a framework to easily add new stock execution venues.The SOR relies on the XTP for quotes from certain exchanges used as stock routing venues. Finally, the SOR uses Reference Data Cache eXternal (RDCX) for reference data including business units' stock-execution venues' recognized MPIDs and their entitlements reflecting agreements with stock execution venues that members have on file with ISE.

The OFI is the middleman component between the ME, the TM and the SOR. The OFI shields the SOR from complexities of a direct interaction with Core's IBM WLLM bus. The OFI adds a minimal latency to the stock trading process.

The OFI allows SOR instance(s) to login and to subscribe for stock orders and stock leg post-trade allocation requests for one or more partitions. No two instances of the SOR should subscribe for the broadcasts from the same partition. After the SOR finishes its operations, it gracefully logs out from OFI.

Communication between ISE Applications and the SOR takes place over Ultra Messaging (LBM). Both directions of messages – SOR-inbound and SOR-outbound – are not persisted and are sent via LBM.

Figure 1 shows the SOR architecture.

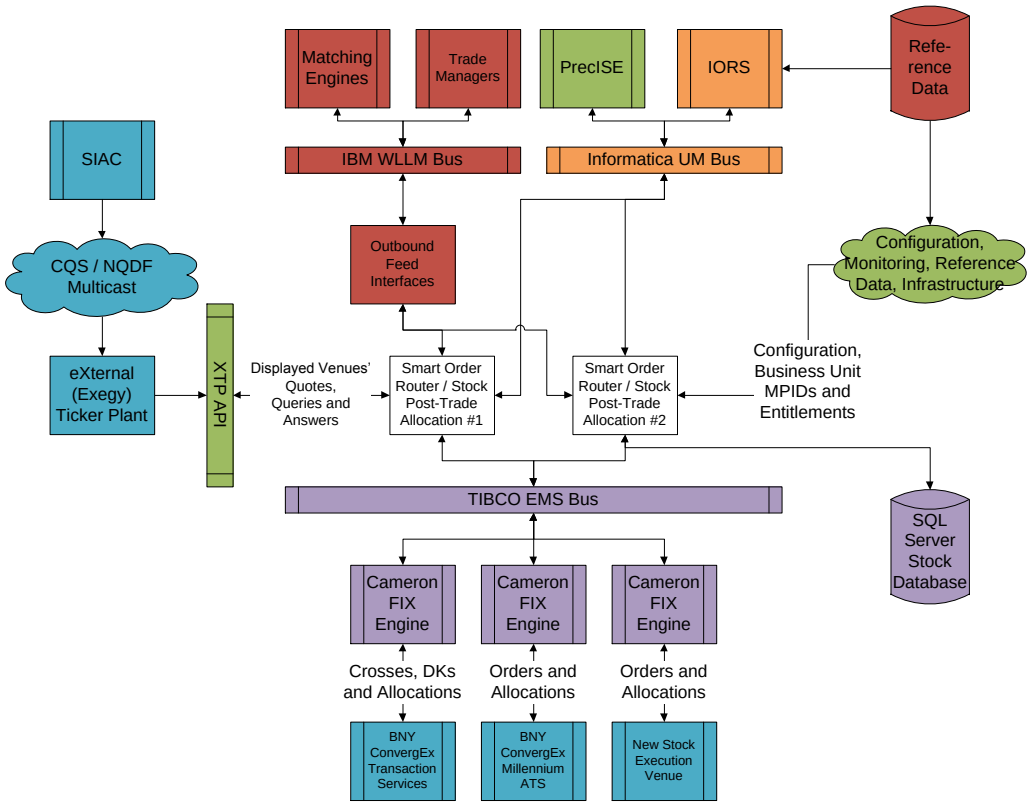



Figure 1 – SOR Architecture – High Level View

# 3 SOR Functionality

The functional requirements for the SOR include the following:

a. The SOR gets stock orders fromthe ME via the OFI:
   i. 2-sided orders (crosses) using SOR Cross Order Broadcast message type
   ii. 1-sided orders (legging-in and pinging orders) using SOR Order Broadcast message type
b. The SOR also gets stock orders from the ISE Applications:
   i. 2-sided orders (crosses) using New Order / Cross message type
c. The SOR either acknowledges SOR (Cross) Order Broadcast using SOR (Cross) Order Broadcast ACK or rejects it using SOR (Cross) Order Broadcast NAK. The SOR acknowledges New Order / Cross with a single (unlike official FIX protocol suggests) Execution Report (of type Acknowledgement) or rejects it using single Execution Report (of type Rejected).The rejection could be caused by reasons including, but are not limited to, the following:
   i. (For cross orders) buy and sell side don't have a common stock venue
   ii. No stock venue available for type of order (cross, leg-in or ping)
   iii. (For odd/mixed lots) no stock venue available supporting odd/mixed lots
   iv. (For limit orders) no stock venue available supporting given decimal precision in price
   v. The order cannot be split but exceeds notional value or notional size limits for any of the available stock venues
d. The SOR gets NBBOs and appropriate exchanges' BBOs from incoming equity data stream
e. The SOR gets reference data from the Reference Data Cache eXternal (RDCX)
f. The SOR routes FIX format orders to appropriate stock execution venues according to the following criteria:
   i. The SOR gets NBBOs and BBOs from configured exchanges (those used for stock trading)
   ii. The SOR uses Business unit MPIDs and entitlements reflecting agreements with stock execution venues
   iii. Based on i and ii, the SOR identifies one or more stock execution venues to submit an order to
   iv. Depending on the selected stock execution venues' configuration, which preference, support for odd/mixed lots, notional value order limits, order size limits, etc.), the SOR slices single-sided order as needed and submits to one (or more) stock venues for execution
   v. Stock venues are assigned to tiers via Stock Venues Configuration
   vi. A stock venue is picked for routing from the lowest-numbered available tier in randomly seeded fashion
g. A random sorting of stock venues within tiers is created for each matching attempt. See section 3.1.1 for round robin logic
h. The SOR receives order / order slice execution reports

i. For each ME match attempt, the SOR tracks the order slice execution, and re-tries orders / order slices multiple times until time runs out or order is fully executed. Until the occurrence of a first partial or full fill from a stock venue, SOR tries routing the order slice to the next available venue, however after the first fill all subsequent retry attempts will be routed to the same venue that provided the fill (see assumption #2 in Functional Assumptions).

j. The SOR aggregates order slice execution reports and calculates average price

k. The SOR sends the aggregated final order state to the ME (the SOR does not send intermediate order execution reports) by using either SOR (Cross) Trade Request when there is some filled quantity or by using SOR No (Cross) Trade whether there is no filled quantity received from stock venues.

l. The SOR sends the aggregated final order state to the ISE Applications (the SOR does not send intermediate order execution reports) by using either Execution Report (of type Fill) when there is some filled quantity or by using Execution Report (of type Unsolicited Cancel) whether there is no filled quantity received from stock venues.

m. If both members on a crossing order are not signed up at a common exchange, the SOR does not route a cross and sends SOR CrossOrder Broadcast NAK / Execution Report (of type Rejected) message back to the ME / ISE Application

n. The SOR sends SOR No (Cross) Trade / Execution Report (of type Unsolicited Cancel)if it the SOR doesn't receive a response from a stock venue within configuration period of time (i.e. timeout)

o. The SOR sends aggregated final SOR (Cross) Trade Request / Execution Report (of type Fill) to the ME / ISE Applications if the execution report arrives late (even after SOR No [Cross] Trade / Execution Report [of type Unsolicited Cancel]due to a response timeout has been sent). In this case, the ME will attempt to book the trade.

p. The SOR shuts off a stock execution venue if a stock execution venue does not respond for a configurable time period, and if the number of such incidents exceeds a configurable number of times
    i. The SOR notifies MOPS and COPS if this occurs
    ii. The SOR informs the OFI about the unavailability of the cross / leg-in / ping service depending only whether such shut-off makes no venue available for crossing, legging-in or pinging functionality

q. The SOR writes stock orders, execution reports and stock post-trade allocations to a database for the following reasons:
    i. Billing reconciliation
    ii. Failover / disaster recovery
    iii. Stock post-trade allocations
    iv. Reports

r. The SOR retrieves stock orders and fills from the database on a start-up

s. The SOR generates a unique outgoing identifier per order

t. The SOR provides the ability to easily plug-in new stock execution venues

u. The Generic FIX plug-in allows easily adding most of new stock execution venues with simple configuration changes, thus avoiding code changes

v. The SOR handles stock post-trade allocation requests sent by the TM via the OFI as TM to SPTA Maintenance Requests broadcasts and those sent by the ISE Applications via LBM as Allocation Instructions message

w. The SOR sends to the TM via the OFI results of stock post-trade operations as SPTA to TM Maintenance Acknowledgement requests

x. The SOR sends to the ISE Applications via LBM results of stock post-trade operations as Allocation Instruction Ack messages

y. The SOR processes stock post-trade allocation deal item ID sent by the TM via OFI as TM to SPTA Maintenance Confirmation responses

### 3.1.1 Symbol/SymbolSfx

In the outgoing FIX message to the stock venue, we put all symbols in tag 55 (Symbol), without the suffix

For Nasdaq, we put the suffix including the delimiter in tag 65 (SymbolSfx)
For everything else, we put the suffix minus delimiter in tag 65

The delimiter is the first non letter encountered

Ex) Symbol = ABC.D

Nasdaq: Tag 55=ABC
65=.D

Everything else
Tag 55=ABC
65=D

Ex) Symbol = ABC1
Nasdaq: Tag 55=ABC
65=1

Everything else
Tag 55=ABC
65=<blank>

### 3.1.2 Round Robin Logic

For each matching order a key will be generated consisting of the exchange order id, clearing account and product id. This key will then be used to build a list of tiered stock venues where each tier's venues are randomized. SOR will cycle through each venue in this list as described below. The following use cases should cover all of the scenarios the round robin logic will be exposed to. Let's assume there are 6 venues, 3 on each tier. A randomized list is built so that the first three on the list are stock venues 1, 2, and 3 in randomized order followed by 4, 5, and 6 in randomized order. Note that this list could be pruned due to various reasons such as venue not supporting the quantity, volume, or odd lots if this is an odd lot order. See section 3.7 for more details.

a. **Match attempt is filled entirely**. In this case we continue cycling to the next venue if the venue is at the lowest tier, if not we reset back to the first venue on the lowest tier. In the past when a new matcher attempt with the same key came in, we would have cycled to the next venue, even if that venue was at a higher tier.

b. **Order slice filled, but matcher attempt not filled**. Due to matcher engine limitations, all subsequent order slices will be sent to the venue that the first slice was filled at. This will continue until the entire matcher attempt is filled or timeout.

c. **Order slice rejected or cancelled**. We cycle through all the available venues removing the venue as a candidate if its maximum retries has been exceeded. In production, max retries is set to one therefore once we reach the end of the list, this indicates that we have tried all venues and they have all failed and therefore the list will now be empty. We send a nak over to the matching engine in this case.

## 3.1 Message Types

### 3.1.1 Optimise Core

The OFIuses the following message types to communicate to the SOR:

- SOR Cross Order Broadcast
- SOR Cross Trade Event
- SOR Cross Trade Failure
- SOR Order Broadcast
- SOR Trade Event
- SOR Trade Failure
- TM to SPTA Maintenance Request (Broadcast)
- TM to SPTA Maintenance Confirmation (Response)

The SOR uses the following message types to communicate back to the OFI:

- Logon
- Subscribe
- SOR Cross Order Broadcast ACK
- SOR Cross Order Broadcast NAK
- SOR Cross Trade Request
- SOR No Cross Trade
- SOR Order Broadcast ACK
- SOR Order Broadcast NAK
- SOR Trade Request
- SOR No Trade
- SPTA to TM Maintenance Acknowledgement (Request)
- Stock Type Matching Status for each of type of matching (cross, legging-in, and pinging) with one of the following statues:
    - Open
    - Closed (i.e., disabled via configuration or auto-shutoff during trading)
- Unsubscribe
- Logout

### 3.1.2 ISE Applications

The ISE Applications use the following message types to communicate to the SOR:

- New Order / Cross
- Trade Cross Confirmation
- Allocation Instruction TM to SPTA Maintenance Request (Broadcast)

The SOR uses the following message types to communicate back to the ISE Applications:

- Execution Report of type
    - Acknowledgement
    - Fill
    - Unsolicited Cancel
    - Rejected
    - Bust
    - Timeout
- Allocation Instruction Ack

## 3.2 Start-up and Shut-down

On a start-up the SOR checks its stock database for any filled orders that have not been reported to ME and attempts to break them. MOPS are alerted to such activity.

When an SOR instance starts up, it sends Logon message to OFI. The Subscribe message communicates to OFI which partitions are covered by this instance of SOR. Additionally, the instance notifies the ME of the appropriate statesfor all types of stock type matching.Finally, SOR starts listening to partition-based request topics via LBM and pre-allocations business unit (BU) id-based response topics for those BU's that have an MPID assignment in the Reference Data.

Upon shut-down, the SOR notifies the ME of closed states of appropriate stock order types (cross, legging-in and pinging). Additionally, the SOR sends the Unsubscribe message to the OFI followed by the Logout message.

## 3.3 Configuration

The SOR has the following configuration settings controlling its behaviour:

- For each session (SOR, SPTA or API)
    - Partitions covered
    - (Only for SOR and SPTA) OFI-related configuration
    - Total amount of time (in ms) the SOR is allowed to work on each order type:
        - Cross (two-sided)
        - Leg-in / ping (single-sided)
- Dual-configuration Failover Manager configuration section
- ISE internal E-mail recipient list for alerts (e.g. SORAlert@ise.com)
- SQL Server-related configuration section
- TIBCO EMS-related configuration section
- Exegy Wrapper API-related configuration section
- Stock execution venue tiersper order type:
    - Cross (two-sided)
    - Leg-in (single-sided)

    - Ping (single-sided)
- MPID's tier overrides per type of order (if different from above)
- For each execution venue:
    - Plug-in name and path
    - Trading desk support E-mail recipient list for trade bust requests (e.g. TransactionSupport@convergex.com)
    - Time (in ms) to complete order as specified in SLA
    - Minimum notional order value (in U.S. dollars)
    - Maximum notional order value (in U.S. dollars)
    - Minimum order size (in shares)
    - Maximum order size (in shares)
    - Flag indicating support for odd / mixed lots
    - Number of price decimal places supported for limit orders
    - Threshold interval (in ms) after which a stock order is considered to be timed out
    - Maximum number of timeout violations, after reaching of which, the stock execution venue is auto-shutoff
    - Maximum number of retries, after reaching which, the stock execution venue is no longer considered for routing by the retry logic
    - XTP exchange code (should be specified for displayed markets only)
    - Flag indicating whether the venue should only be used for QCC orders
    - FIX tag to use for AON orders:
        - None (i.e. AON is not supported)
        - TimeInForce [tag 59] = FOK
        - TimeInForce [tag 59] = IOC and MinQty [tag 110] = OrderQty [tag 38]
    - FIX tag to use for MPID:
        - ClientID [tag 109]
        - OnBehalfOfCompID [tag 115]
    - FIX value to use for ExecInst [tag 18]:
        - None (i.e. don't provide ExecInst tag-value pair)
        - 1 = Not Held
    - FIX value to use for Rule80A [tag 47]
        - None (i.e. don't provide Rule80A tag-value pair)
        - A = Agency
    - FIX value to use for LocateReqd [tag 114], when selling short or short exempt
        - None (i.e. don't provide LocateReqd tag-value pair)
        - N = Broker not required to locate
    - FIX value (free text) to use for ExDestination [tag 100]:
        - Blank (i.e. don't provide ExDestination tag-value pair)
        - Text (e.g. KM, SMART)
    - FIX value to use for ShortSaleExemptionReason [tag 1688]:
        - None (i.e. don't provide ShortSaleExemptionReason tag-value pair)
        - 0 = Exemption Reason Unknown
        - 1 = Incoming Short Sale Exempt

        - 2 = Above National Best Bid (Broker Dealer Provision)
        - 3 = Delayed Delivery
        - 4 = Odd-Lot
        - 5 = Domestic Arbitrage
        - 6 = International Arbitrage
        - 7 = Underwriter or Syndicate Distribution
        - 8 = Riskless Principal
        - 9 = VWAP
    - FIX value to use for SecurityType [tag 167]
        - None (i.e. don't provide SecurityType tag-value pair)
        - CS = Common Stock

## 3.4 Receiving Stock Orders

The SOR receives two types of stock orders with limit pricesfrom ME through OFI – two-sided stock orders (crosses) and single-sided stock orders (legging-in and pinging orders). The SOR Order Broadcast message type is used for single-sided orders, while the SOR Cross Order Broadcast message type is used for two-sided crosses.

The SOR receives one type of stock order with limit prices from ISE Applications via LBM – two-sided stock orders (crosses). The New Order / Cross message type is used for two-sided crosses.

## 3.5 Reference Data

The SOR accesses reference data for MPIDs of business unit for each stock execution venue. Absence of such value indicates that business unit does not have an agreement with a stock execution venue on file with ISE. The SOR also accesses reference data for round lot sizes for each underlying.

The SOR handles intraday changes to the above-mentioned reference data.

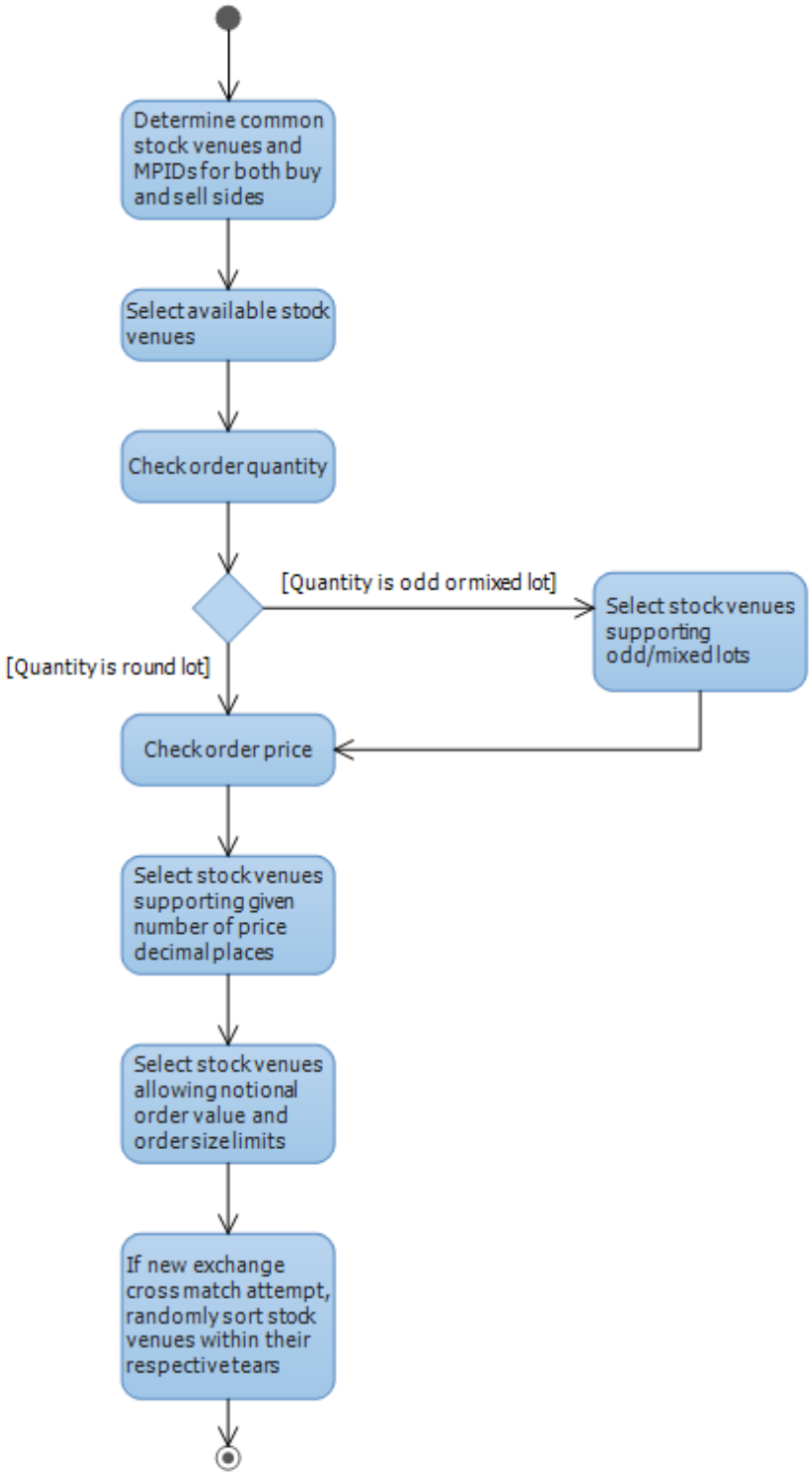
## 3.6 Routing Stock Orders

The SOR is responsible for routing stock orders to proper destination(s). SOR takes into account the following information when picking a stock execution venue:

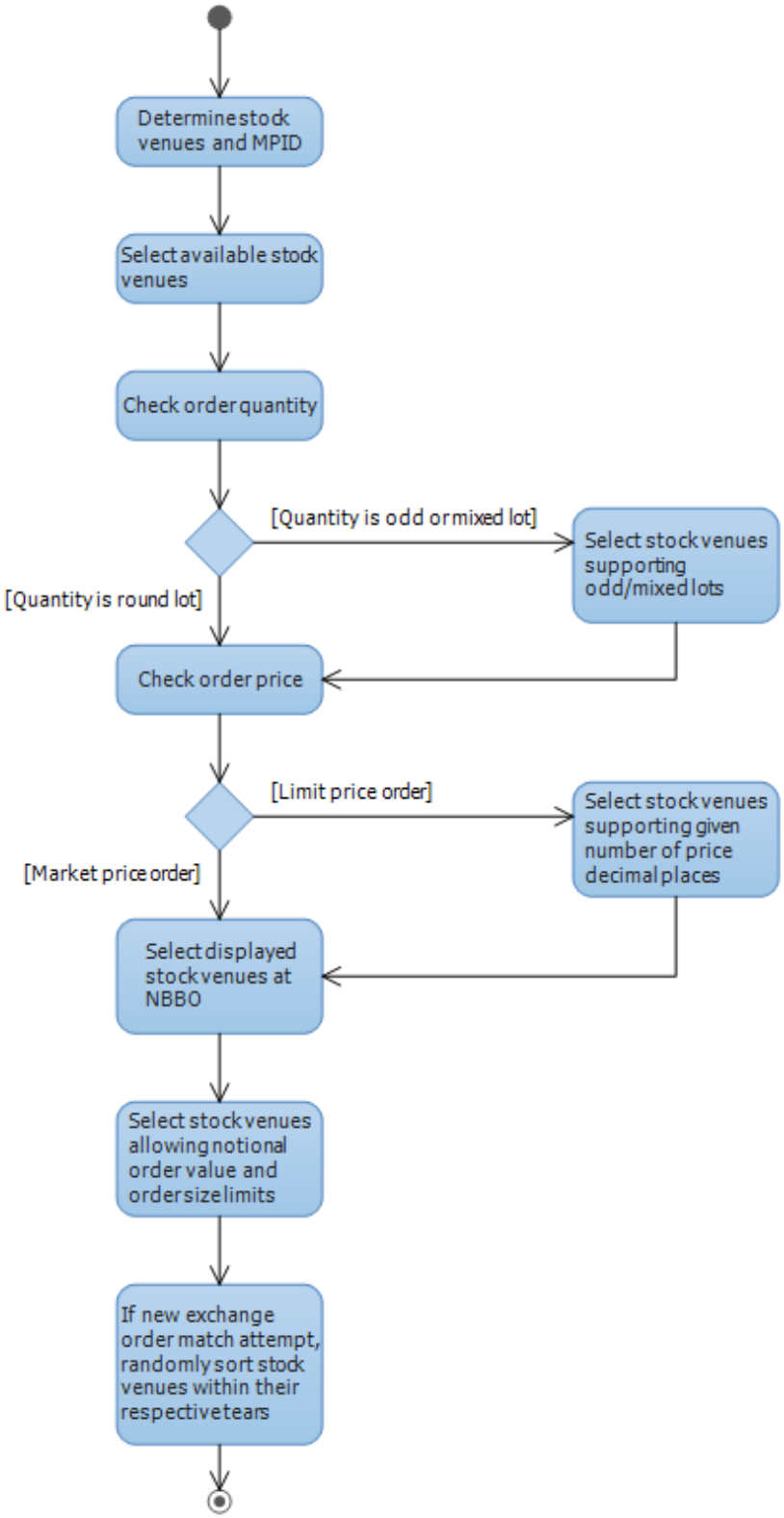
- (For orders with no stock give-up specified only ) Availability of member(s) agreement on file with ISE between member(s) and stock execution venues as represented by MPID entries for business unit(s) in reference data for those particular stock execution venues
- (For orders with stock give-up specified) Availability of member(s) agreement on file with ISE between member(s) and stock execution venues as represented by MPID entries for MPID(s) in reference data for those particular stock execution venues
- Stock execution venue state
- (For odd and mixed lot orders only) Stock execution venue's support for odd / mixed lot orders
- (For limit orders only) Stock execution venue's support for given number of price decimal places
- Stock execution venue's notional order value limits and order size limits
- (For legging-in to exchanges only) Stock execution venue's BBOrelative to NBBO (i.e. displayed market gets the order first if on NBBO, otherwise doesn't get it at all)

- Stock venue tier assignment from Stock Venues Configuration
- Randomness of sorting stock execution venues within tiers based on conditions described in section 3.1.1
- Is the QCC only flag set? If so the venue will be excluded for non-QCC orders. Currently the only venue that will have this flag set is Cheevers, a new venue configured to process QCC orders only.
- For orders routed through the stock API, the venue will now be specified in the incoming message.

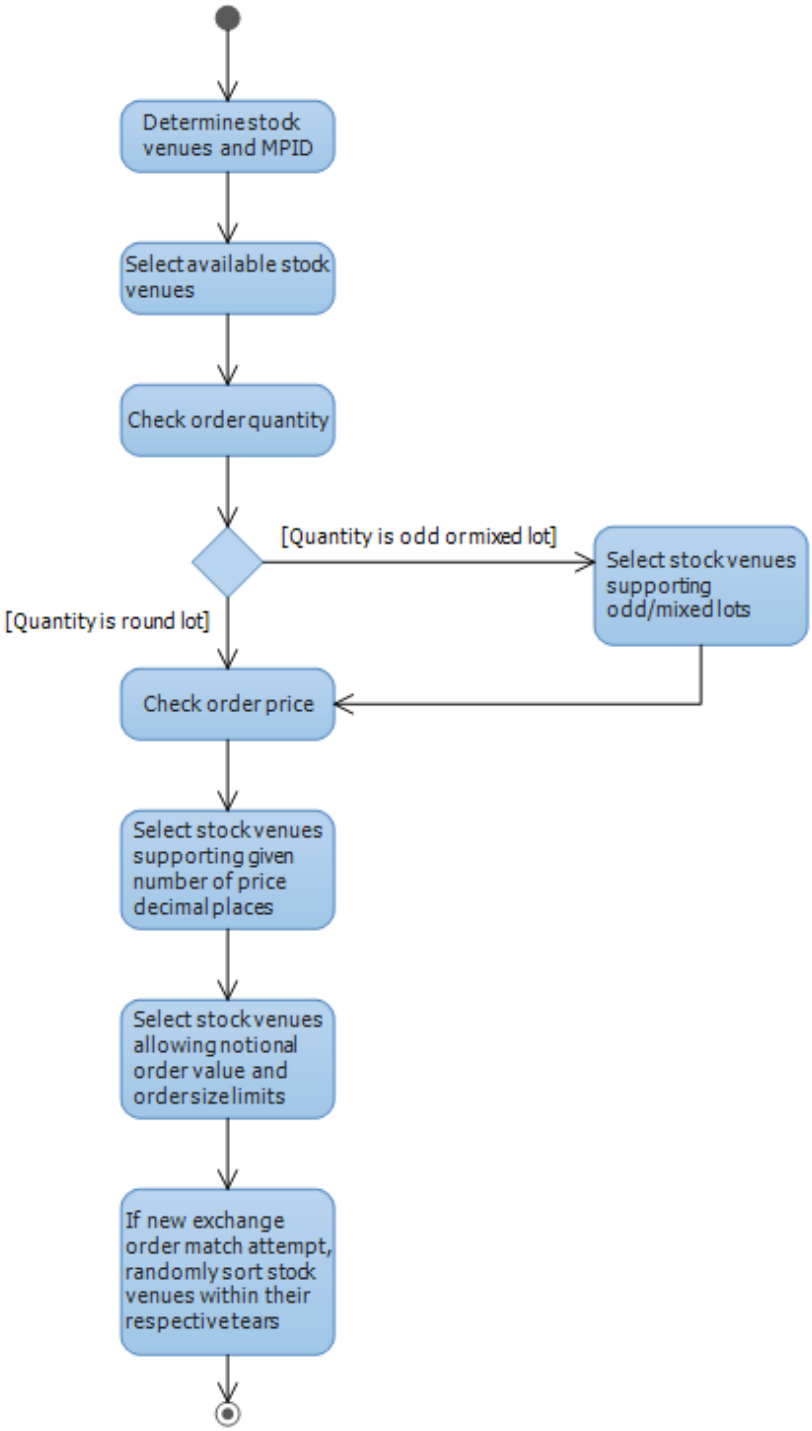
- The following activity diagram represents selection of stock venue for a **cross** order, which is a two-sided equity order destined for printing at an appropriate tape facility:



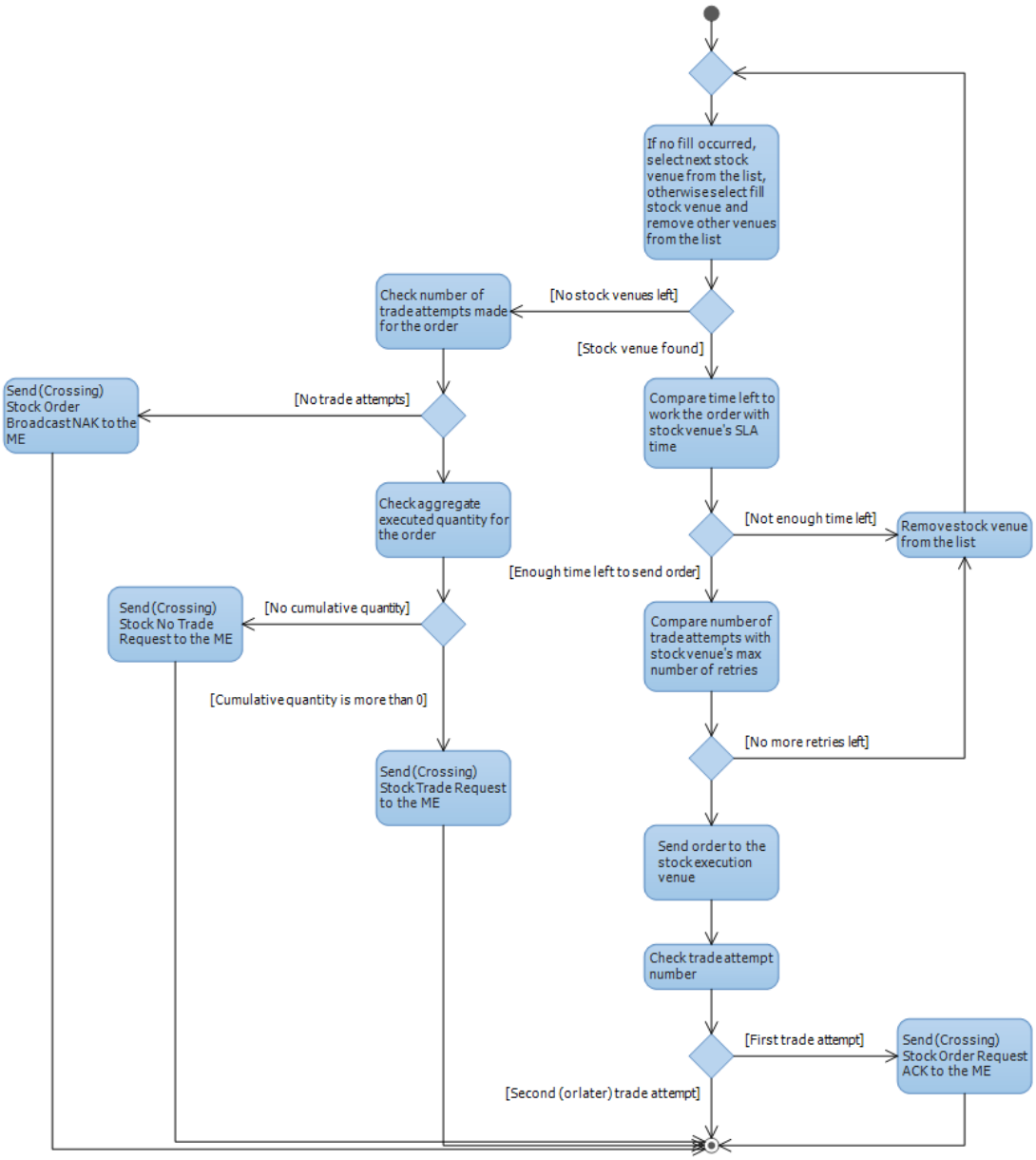
The following activity diagram represents selection of stock venue for a **lit** order, which is single-sided marketable equity order destined to a displayed stock market for execution:



The following activity diagram represents selection of stock venue for a **dark** order, which is single-sided unmarketable equity order destined to a dark pool for an execution attempt:



The following activity diagram represents generation of orders:



The SOR might attempt to slice off and execute a part of a single-legged order based on stock execution venue's order value limits (if such order allows partial fills). The SOR might attempt to execute same order in its entirety or in slices multiple times with the same stock execution venue only if there is enough time left. The SOR might shop a single-legged stock order at multiple stock execution venues however only if there is enough time left.

## 3.7 Handling Execution Reports

The SOR receives execution reports from applicable stock execution venues and aggregates them appropriately. Its purpose is to notify the ME / ISE Applications only of a final state of a stock order, not of intermediate states. Aggregated execution reports can only contain fills from one stock execution venue.

Should late fills arrive after a timed out execution report has been sent to the ME / ISE Applications, the SOR would sent aggregated fill execution report to the ME / ISE Applications. Once a fill has been reported to the ME / ISE Applications, the SOR temporarily assumes that reports made it all the way to the ME / ISE Applications and won't attempt to break the fill unless either explicitly instructed so by the ME (electronic busting of stock legs from ISE Applications won't be supported) or on a restart/failover when uncompleted stock trades are discovered. When option legs(s) tied to stock are busted, Market Operations call up stock venues on the phone and request a bust of the stock legs' execution.

## 3.8 Breaking Trades

The SOR instructs stock execution venues to break stock trades as specified by the ME in the SOR (Cross) Order Broadcast NAK message type. Additionally, on the start-up the SOR breaks stock fills, which haven't been reported to the ME / ISE Applications. MOPS are alerted to any trade break activity.

## 3.9 Stock Post-Trade Allocation

The SOR handles stock post-trade allocation requests sent by the TM via the OFI as TM to SPTA Maintenance Requests broadcasts. The SOR sends to the TM via the OFI results of stock post-trade operations as SPTA to TM Maintenance Acknowledgement requests. The SOR processes stock post-trade allocation deal item ID sent by the TM via OFI as TM to SPTA Maintenance Confirmation responses.

The SOR handles stock post-trade allocation requests sent by the ISE Applications via LBM as Allocation Instructions messages. The SOR sends to the ISE Applications via LBM results of stock post-trade operations as Allocation Instruction Ack messages.

The SOR would make extensive use of the stock execution and allocation database for stock post-trade allocation. The information sent from the TM (via the OFI) / ISE Applications (via LBM)and the data stored in the database would allow the SOR to deterministically determine the stock venues' executions / allocations in need of modifications.

If the SOR received a late response from stock venue, it would try sending it to the TM / ISE Applications.

In cases where stock post-trade allocation operation would fail, the SOR would send to the TM (via the OFI) / ISE Applications (via LBM)a human-readable error message text, which would include, but not be limited to, errors received from stock venue and errors encountered the SOR itself.

## 3.10 Service Announcements

SOR will announce its cross / leg-in / ping services' availability as follows:

- On start-up (including intraday restarts)

- On shut-downs (including disaster shutdown used to initiate SOR failover)
- On detected change in service availability
- On operator's command to override to service availability
- On GTS API failover of its connection from one OFI to another
- On SOR failover when going into "hot" (i.e. primary) mode from a "warm" (i.e. secondary) mode

## 3.11 Stock Execution Venue Auto-Shutoff

If a stock execution venue doesn't respond for a configurable amount of time and should the number of such incidents exceeda configurable number of times, the SOR automatically shuts off the stock execution venue. Auto-shutoffs can also occur if a trade requires manual busting.Upon such action MOPS and COPS arealerted. The ME is notified via the Stock Matching Type Status message whenever all stock execution venues for a particular matching type – cross, legging-in or pinging – areauto-shutoff. The stock execution venue auto-shutoff can be overridden from operator's application called $CombEX_{ST}$ Control Panel.

## 3.12 Stock Database

The SOR application uses a database for several purposes:

- To generate a unique order identifier across multiple stock order routing applications
- To store stock orders' and fills' information(including executing broker)for billing reconciliation and reports
- To access open stock orders in case of a failover or a disaster recovery

## 3.13 Failover and Disaster Recovery

The SOR is running in the "hot-warm"failover mode at the primary data center. Should a primary (hot) instance of application go down, a respective secondary application instance (warm) shall take over as primary. Should a secondary instance go down, a respective primary application instance shall continue to function uninterrupted. A failed or shut-down instance of SOR can be brought back up as secondary (warm) intraday to restore full redundancy.

Other components used by the SOR utilize the following failover features making the whole system completely redundant:

- Date in the database is replicated from the primary database to the secondary
- Bus uses self-recoverable cluster
- FIX engines take advantage of high-availability adapter (comparable to hot-warm failover mode of SOR)

Disaster recovery of the SOR at the secondary data center is manual, where the SOR is installed but is not running by default.

## 3.14 Monitoring and Performance

The SOR integrates with the OptimISE Operations Services for daily operations monitoring. The SOR monitoring features provide component status and statistics. The SOR monitoring features provide alerts to notify operators when errors or failures occur.

The detailed implementation of these requirements is described in *SCD2420 – Smart Order Router.*

## 3.15 Logging

The SOR uses the standard Enterprise Logging mechanism for application logging. Errors are logged in both a log file and the Windows application event log. Warnings are logged in log file only.

## 3.16 Configuration

The SOR integrates with Configuration Service for all of its configuration setting. The SOR application configuration file is only used to configuration Enterprise Logging and to point the application to where Configuration Service resides.

## 3.17 Scalability

The most granular level of SOR's scalability is by partitions. The SOR cannot be scaled by products. Partition specified in the application configuration of the SOR must exist in the reference database.

## 3.18 Performance Metrics

The SOR provides Windows performance counters so that all performance-related data can be captured and analyzed for certifying the SOR performance.

## 3.19 Security

The SOR adheres to the ISE security standards as described in SCD2420. The potential security vulnerabilities include interaction with outside parties via external interfaces.