ISA-95 Process Centric Messaging Working Group

Process Centric Events Proposal

Responsible Author: Bill Poole
Contributing Authors: Simon Chalmers, Van Zyl Kruger

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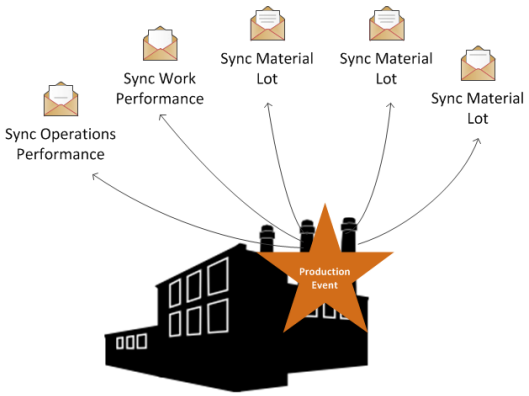
1 Background

The stated goals of ISA-95 (in Part 1) are to “increase uniformity and consistency of interface terminology and reduce the risk, cost, and errors associated with implementing these interfaces.” Part 1 states that “the standard can be used to reduce the effort associated with implementing new product offerings. The goal is to have enterprise systems and control systems that inter-operate and easily integrate.”

Although ISA-95 has made great strides towards achieving these goals, there is still opportunity for improvement. The current position within ISA-95 is focused around the concept of a data centric approach to system to system interaction. Information exchanges that utilise a data centric approach have been a stable approach to system integration for a long period of time. These offer the benefit of better visibility and response to data state changes. Unfortunately, this approach often suffers from data integrity issues and doesn’t integrate as effectively when more complex changes are required. Furthermore, there can sometimes be the perception into lost visibility into what has occasioned the change. One business process may cause multiple pieces of data to change and in order for downstream systems to process the change set correctly, they may need to understand the cause of the change in order to know what do in response to that event. Under normal circumstances this is straight forward to determine based on the data events. However under different and more complex situations this can be more difficult to determine.

One particular challenge is when a data event effects changes to data across multiple ISA-95 information models as Part 5 doesn’t currently provide a means to communicate all those changes in a single message. Although the transactions detailed in Part 5 apply each verb/action to a specific information model, this results in a data centric information exchange between systems, which has been sufficient for less complex architectures. However it is very common in practice for a single system transaction to update data spanning multiple ISA-95 information models in response to a single production event (illustrated below).

Figure 1 – Single Production Event Example Sync



This leaves receiving systems having to process each ‘part’ of the overall dataset (associated with that single real-world event) separately. This can result in the receiving system having to deal with inconsistent states of data internally (as messages are delivered separately and possibly out of order), or having to wait until all the ‘parts’ of the overall dataset have arrived before processing them (together) and the receiving system may not know which parts belong to which dataset. All receiving systems need to reflect the single real-world event in their datasets and must do so with atomicity and this is caused by the fact that Part 5 forces that data corresponding to a single real-world event must be published in multiple messages.

The above approach typically adds complexity to receiving applications and/or the integration components supporting those applications. It implies that the receiving system, or middleware infrastructure, is required to perform orchestration of the sent data events. For example, an Execution Management Function in ISA-95 might send a response to a schedule request containing a set of Job

Responses containing the work that has been performed. This function may also be required to send a list of Material Lots that pertains to the units of material that the work must be executed against. This would require the use of the B2MML Work Performance schema and the Material Lot schema to be sent as individual objects, assuming that end systems consuming this information will have the knowledge to reconstruct the context of both the Work Performance and related Material Lots into a set of useable data. Here is an example of what this data centric approach might look like:

- Step 1: Send the B2MML SYNC Add Work Performance objects
  <b2mml:WorkPerformance></b2mml:WorkPerformance>
- Step 2: Send the b2MML Sync Add Material Lot objects:
  <b2mml:MaterialLot></b2mml:MaterialLot>
- Step 3: Receiving systems start receiving sent messages and set aside those messages in a persistence store until all messages from the bundle have been received.
- Step 4: Once they have all been received, they are processed in such a manner that either all or none of them are processed.

The above example imposes a process centric problem in that the list of data SYNC add messages articulate what happened to cause those messages to be sent and highlights the level of complexity required to be implemented by consuming systems of B2MML data centric information exchanges. Part 5 also does not support a verb for notification of an event that has occurred as the contained event message many contain ISA-95 elements from different models relevant to the state of the activity when the event occurred. This paper is suggesting an approach which would reduce the above complexity in line with the stated goals of ISA-95.

This paper details BHP Billiton's proposed solution for the ISA-95 Process Centric Messaging Working Group and proposes that ISA-95 (Part 5) be expanded to support process centric information exchanges, supplementing and complementing the data centric information exchanges already supported.

2 Proposal

BHP Billiton proposes that a new set of transactions be added to ISA-95 (to Part 5) to support process centric event driven message exchanges between systems. The proposed solution is underpinned by two commonly used messaging patterns - process centric events and publish-subscribe[1] messaging. Publish-subscribe is a common messaging pattern which is evidenced by support from Manufacturing Operations Management software products and publish-subscribe standards such as MQTT[2] and AMQP[3].

This will leave all of the current ISA-95 transactions untouched, but allow organisations to take a process centric approach to integration if they wish. Process centric messages communicate that a business process or part of a business process has executed (and that a business/operations event has occurred) and includes all data relevant to that event. This ensures that one and only one message is sent that corresponds to each system transaction, rather than a message for each new or updated data entity.

This paper attempts to capture all of the business events relevant to all of the Level 4 and Level 3 ISA-95 functions and interactions. The proposal is for an individual message per business/operations event, containing a list of all the added, changed and/or deleted verbs or objects as is appropriate for that business/operations event.

2.1 Principles

The principles applied in the development of this paper were:

1. Describing process centric events as a notification that an event has occurred;
2. Minimising implementation cost and risk and minimise the impact to the standard by re-using all of the existing B2MML elements;
3. Maximising simplicity by adding B2MML elements to the process centric events through a minimalistic approach by starting incrementally and only adding new objects to the events as such uses are demonstrated as valid and appropriate;
4. Packaging multiple ISA-95 information models into single events without mixing the existing information models directly;
5. Preserving the existing ISA-95 information model (explained further in section 2.2 below);
6. Ensuring data consistency by prescribing that applications must be able to process B2MML messages and always remain in an internally consistent state;
7. Minimising the duplication of functionality between systems;
8. Maximising the use of Commercial Off The Shelf (COTS) products by ensuring a solution is implementable on COTS software by an organisation making use of the ISA-95 standards.

2.2 High Level Overview

A process centric ISA-95 transaction will package multiple ISA-95 information models into a single message, but will not mix the information models directly. For example, there will not be Material Lot elements embedded in Material Actual elements. There will be completely separate Operations Performance, Work Performance and Material Lot elements, bundled together (one after the other) into a single container message for transmission.

[1] Publish – subscribe is a messaging pattern where-by messages are sent by publishing systems to a queue or topic, and downstream systems can subscribe to these messages from the queue or topic. Publishing systems use a fire and forget approach with no consideration for receiving a confirmation from a subscribing system. This is performed asynchronously.

[2] MQTT (formerly MQ Telemetry Transport) is a publish-subscribe based "light weight" messaging protocol for use on top of the TCP/IP protocol. Refer http://mqtt.org

[3] The Advanced Message Queuing Protocol (AMQP) is an open standard application layer protocol for message-oriented middleware. Refer https://www.amqp.org

As an example, a “Performance Tracked” transaction will be defined (published from the Tracking Function) that indicates work that has been tracked. The B2MML process centric event will look something like:

Figure 2 – Event Example

In the “Performance Tracked” example above it is important to note that the ISA-95 information model is preserved in the structure of the Operations Performance and Work Performance, i.e. it would be invalid to have an a Work Response[4] outside a Work Performance, or an Operations Response outside an Operations Performance. A similar structure and prescription has been applied to all other process centric event messages in the detailed sections to follow.

The semantics of process centric events are subtly different than those of the SYNC messages defined in Part 5. Unlike SYNC messages, process-centric events don’t constitute a request to subscribing systems to ADD, CHANGE or DELETE data. Rather they constitute a notification that an event has occurred, and what data is pertinent to the event.

It is up to subscribing systems to determine what they will (or won’t) do with the data they receive in process centric event messages. In the above Performance Tracked example, the message isn’t requesting that receiving systems add, change or delete Work Performance or Material Lots or Sublots. It is notifying receiving systems that the Tracking function has tracked some work, and the message contains data describing the work that was tracked.

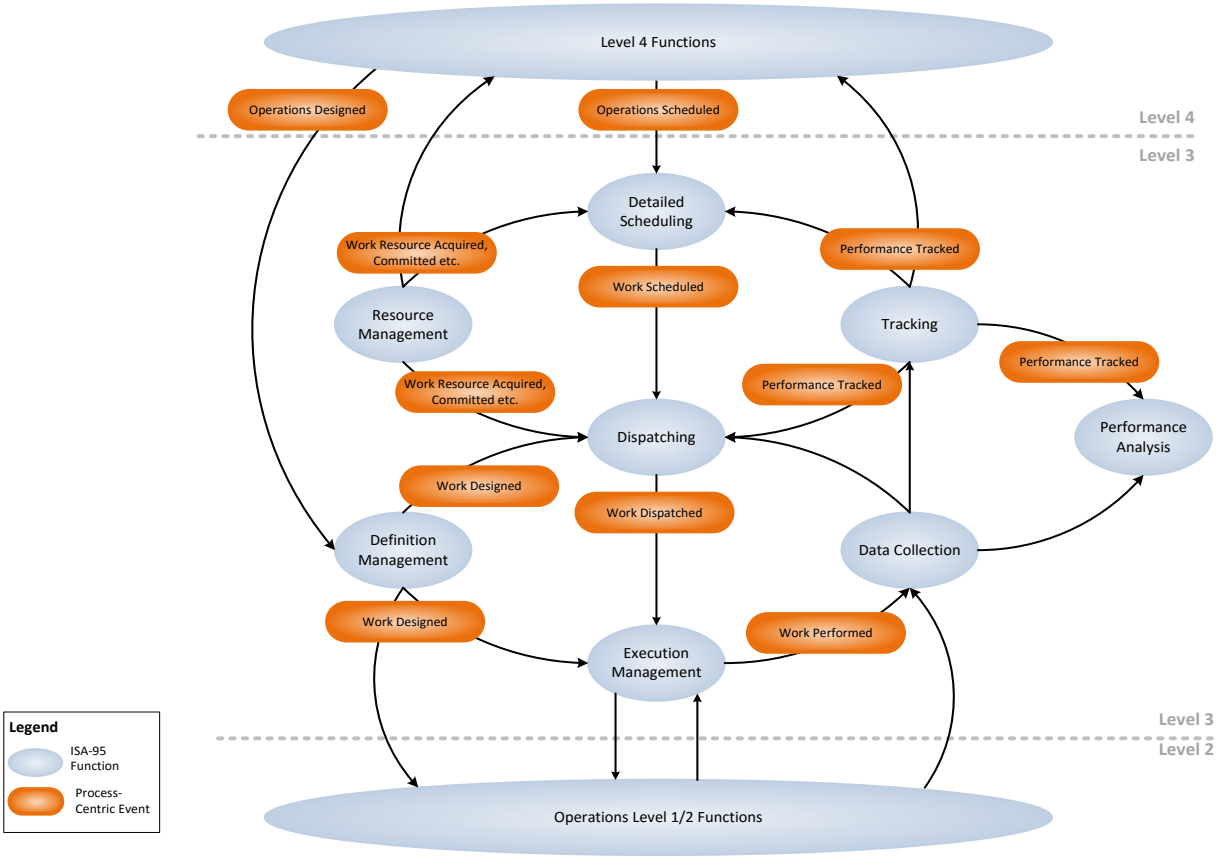
Furthermore with process centric events, each message and its contained data are context-specific to the particular ISA-95 function and associated systems’ plant/process meta-data representation that published it. An example is illustrated in Figure 2 on the following page that shows a key set of process centric events between Level 4 and Level 3 systems.

For example, the Execution Management function may create a new Material Lot, which is reported as Added in a Work Performed event. The Tracking function receives this event and creates a corresponding Material Lot (with the same ID), maps the event data into the tracking context of the plant process and publishes it in a Performance Tracked message (as described above) in the tracking systems contextualised form. The concern here is that this means the receiving system has no opportunity to publish a message to communicate that it did something in response to the message it received and there is limit benefit associated with a receiving system re-publishing the exact same message. This is a fundamental difference from the current data-centric approach of Part

[4] In the V06 B2MML Work Performance schema, a Work Response is nested underneath the Work Performance response structure.

5. The proposed process centric event message allows flexibility for organisations to choose a model that best suits their requirements whilst minimising risk, cost and complexity.

Figure 3 – ISA-95.03 Generic Activity Model: Sample Process Event Data Flow

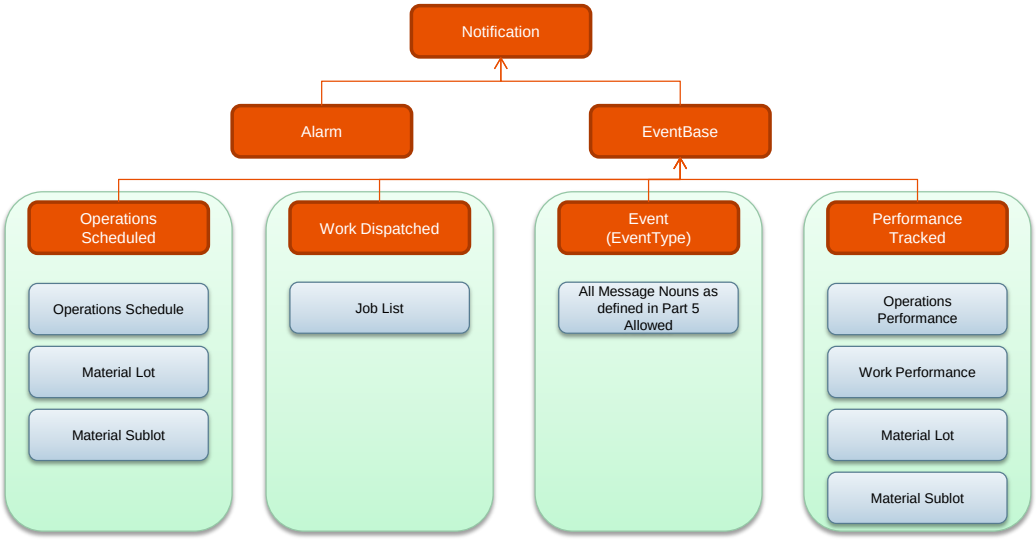


*This model illustrates only the key events between functions.

2.3 Generic Event Container

It is assumed that the prescribed process centric events in the following chapters may not represent an exhaustive list of all events for all organisations. As a result, this paper introduces the definition of a generic Event Type container within the Event Type Hierarchy that can be used to house information related to process centric events, specifically to allow organisations to define events beyond the specific events described in this paper. This is illustrated in the figure below:

Figure 4 – Event Type Hierarchy



The generic event message ('EventType') must contain an event name so that subscribing systems can identify the event, and must permit Added, Changed and Deleted verbs for any combination of the message nouns described in Section 4.3.4 of Part 5.

2.4 Message Structure

Similar to ISA-95 Part 5, the Process Centric Event messages will contain an Application Area and a Data Area. As per the example in Figure 2 on page 7, the message structure will also take into account the following:

- The Application Area is reused as per ISA95 Part 5;
- The Data Area will contain the Process Centric Event;
- The Data Area will include "Notify" as an initiating verb:
    - OAGIS "Notify" verb is used to inform the receiving party that an event has occurred or document has been created;
    - OAGIS "Notify" is currently not used in Part 5 and will be required to be added.
- The Added, Changed and Deleted verbs will be of their respective type, for example, under an "Operations Scheduled" event the Added element will be of type "OperationsScheduleType" thus allowing minimal modifications to B2MML.

An approach is needed to represent the event type hierarchy illustrated in Figure 4 above in XML Schema Documents (XSDs). The approach taken was to leverage the 'extension' keyword in XML Schema version 1.0 to allow a 'complex type' to 'inherit' from another. This results in a specific 'complex type' being defined for each process-centric event.

The following two alternative approaches were considered to represent the event type hierarchy in XML schema for process centric events:

1. The use of the 'alternative' keyword (taken from XML Schema version 1.1) in the schema definition, for example:

```
<Event name='ProcessCentricEvent'>
  ... (specific ProcessCentricEvent schema)
</Event>
```

   This format is not currently supported by Microsoft and was not adopted for this reason.
2. The usage of schema group element (i.e. <xsd:group>), which is just one of the patterns used in the current B2MML schemas. The group construct is just an inclusion of elements within a type and does not create true inheritance between types. This format was not adopted for this reason.

3 Definition & Resource Management

OVERVIEW:

The Definition Management Function is responsible for defining Operations Definitions and Work Masters, along with corresponding master data, including but not limited to Equipment, Equipment Classes, Material Definitions and Material Classes. The Resource Management Function activities monitor the usage of personnel, material, physical assets and equipment resources. This information is used by Detailed Scheduling, Business and Logistics Planning, Dispatching, Tracking and Execution.

An example of an operations design process includes the definition and maintenance of the Operations Definitions and Work Masters when the end-to-end supply chain and associated assets are configured in Level 4 and Level 3 systems. New Materials and Material Test Specifications are defined in this event in Level 4 Functions and supporting systems.

As shown in Figure 3, this paper makes a distinction between *Design Resources* and *Physical Resources*:

- *Design Resources* are those which form part of the description of the supply chain and plant/asset operations design; they are defined and maintained through the supply chain process and supporting asset operations management process. Design Resources include Equipment, Equipment Class, Material Definition, Material Definition Class, Physical Asset Class, and Personnel Class;
- *Physical Resources* (managed during day-to-day operations) are created and maintained during the execution of Operations (Level 4) where they are 'bought' or Work (Level 3) where they are 'made'. Physical Resources include Physical Assets, Personnel, Material Lots and Material Sub-lots. Unlike Design Resources which are defined as an output of a design process, Physical Resources and their associated Capabilities are acquired (either through procurement or manufacturing), used and then retired.

Design Resources may also be created and maintained during the definition of the Operations (Level 4) and the Work (Level 3) as a combined design process. The Design Resources are recognised and maintained using the Supply Chain Designed (Level 4 & Level 3) process centric event. This option exists to cater for the scenario whereby an organisation performs operations and work masters in a single step, a process and/or a single system. Ultimately, the Definition Management Function is responsible for managing design resources, while the Resource Management Function is responsible for managing physical resources.

Design or Physical Resources are committed for future operations execution use in the Detailed Scheduling (Operations Schedule) and Dispatch (Work Schedule) activities and their associated process events. The Operations and Work Acquired, Adjusted and Retired events manage the lifecycle of capability of a plant's resources by setting Total through to Unattainable capabilities of each resource and process. The resource commitment events, Operations Resource Committed and Work Resource Committed are an output notification of scheduling activities. The Resource usage events, Operations Resource Used and Work Resource Used, are an output notification of the actual execution of a job order to the Level 3 Work Schedule and Level 4 Operation Schedule. It is important to note that change and reconciliation of resource and process capability definitions occur in the Resource Management process for all resources and are reflected in the Resource Acquired, Adjusted and Retired events as output notifications.

The primary purpose of the proposed design with regards to Definition and Resource Management is to establish process centric events that are aligned with the business processes that a manufacturing organisation performs in order to design their supply chain and manage their resources. Refer to the Figure 3 diagram for a list of all process centric events specific to Definition and Resource Management.

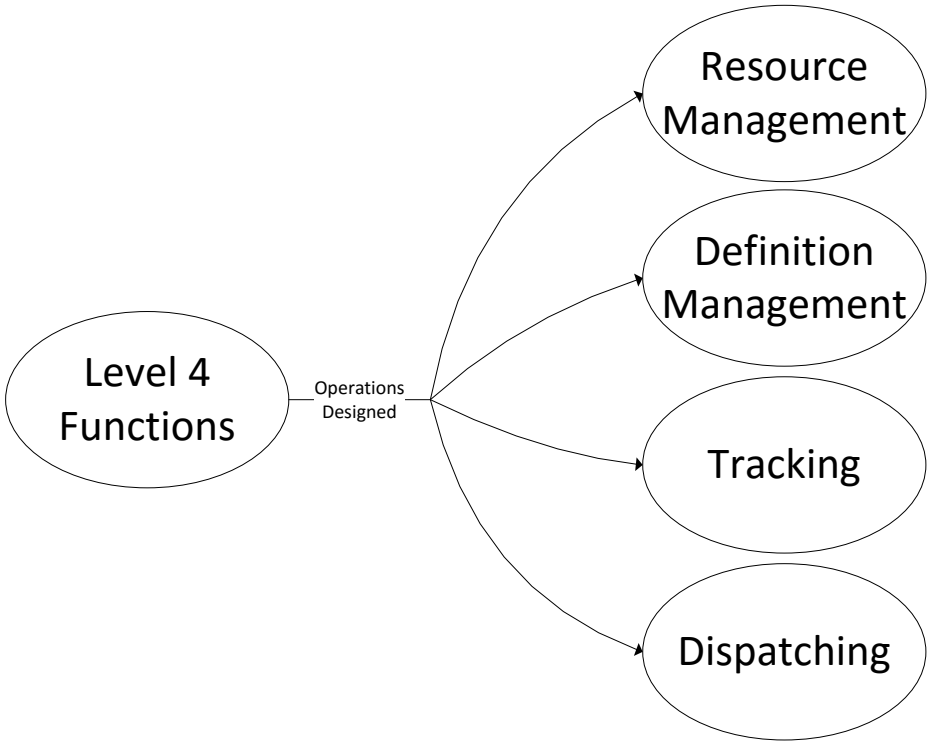
The event model proposed in this paper for the Resource Management function requires that each event message is able to communicate added, changed or deleted capability information for a specific resource for a specific Capability Type (Total, Unattainable, Committed, Available, Used and

Unused). Operations and Work Capability IDs must therefore be sufficiently specific to allow resource-related events to specifically target added, changed or deleted capability information for a single resource for a single Capability Type.

Figure 5 – Common Definition & Resource Management Process Centric Events

3.1 Operations Designed

INFORMATION FLOW:

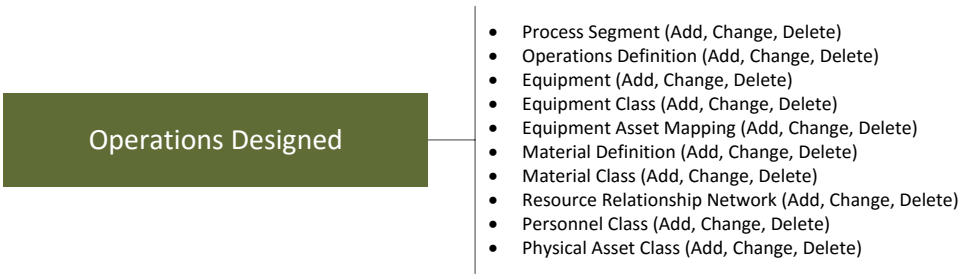


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

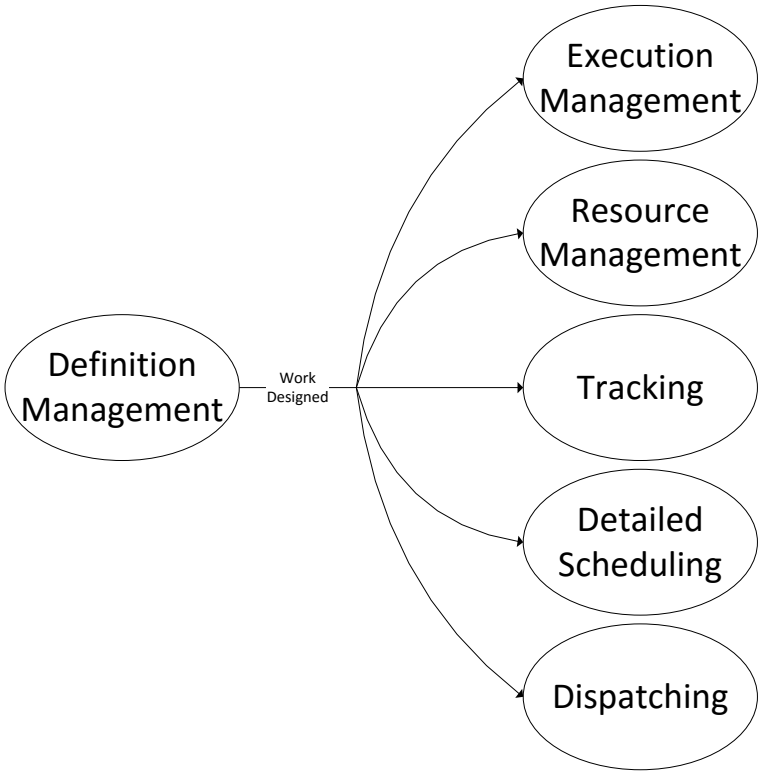
The key focus of the Level 4 supply operations chain design process (as design time as opposed to run time construct) is the Operations Definitions and the Process Segments to align Level 4 Planning with an asset's Level 3 activities. At any point when Operations are designed (Operations Definition or Process Segment) it will potentially result in the addition of new or change to existing Equipment, Equipment Classes, Material Definition, Material Classes, Personnel Classes and Physical Asset Classes. Capabilities of design resources are managed by the Resource Management function.

Added, Changed and Deleted verbs are provided because supply chain processes can be introduced, updated or removed as a consequence of updating the supply chain operations design. The creation, addition or change of an Operations Definition could potentially result in the creation, addition or change to the related Process Segments.



3.2 Work Designed

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

At any point when work is designed (Work Master) Work Designed potentially results in the addition of new or change to existing Equipment, Equipment Classes, Material Definition, Material Classes, Personnel Classes and Physical Asset Classes.

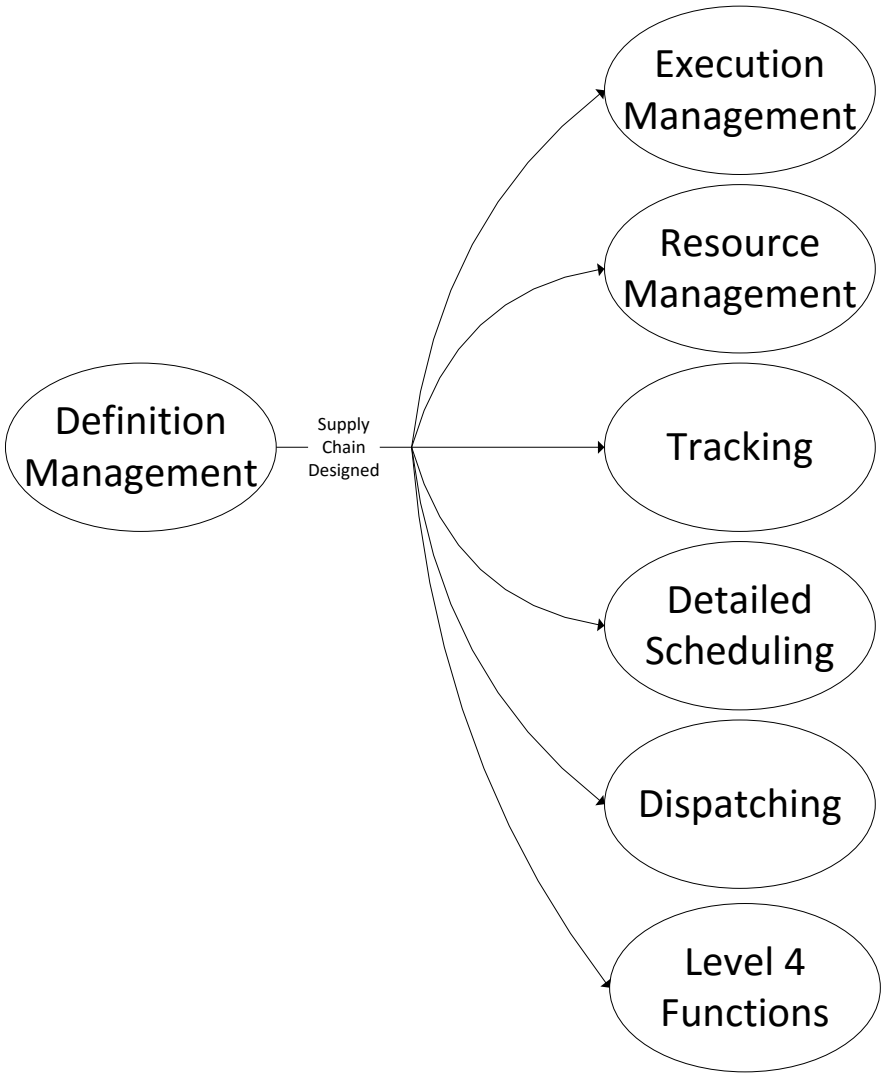
As design-time processes, Added, Changed and Deleted verbs are provided because supply chain processes can be introduced, updated or removed as a consequence of updating the supply chain design. Added, Changed and Deleted verbs are also provided against Resource Relationship Networks as an expression of the relationships between two or more physical resources.

Work Designed

- Work Master (Add, Change, Delete)
- Equipment (Add, Change, Delete)
- Equipment Class (Add, Change, Delete)
- Equipment Asset Mapping (Add, Change, Delete)
- Material Definition (Add, Change, Delete)
- Material Class (Add, Change, Delete)
- Personnel Class (Add, Change, Delete)
- Physical Asset Class (Add, Change, Delete)
- Resource Relationship Network (Add, Change, Delete)
- Work Alert Definition (Add, Change, Delete)
- Workflow Specification (Add, Change, Delete)

3.3 Supply Chain Designed

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

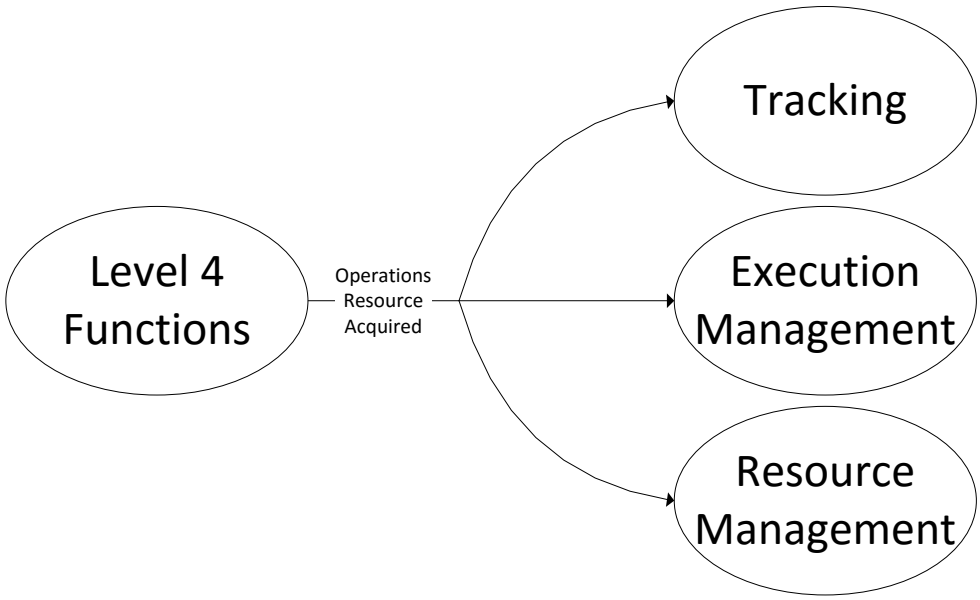
Triggered when the level 4 and level 3 supply chain operations are designed as a single activity or combined business process, the content of the Supply Chain Designed message is a union of the contents of the Operations Designed (Section 3.1 above) and the Work Designed (Section 3.2 above) messages

Supply Chain Designed

- Process Segment (Add, Change, Delete)
- Operations Definition (Add, Change, Delete)
- Work Master (Add, Change, Delete)
- Equipment (Add, Change, Delete)
- Equipment Class (Add, Change, Delete)
- Equipment Asset Mapping (Add, Change, Delete)
- Material Definition (Add, Change, Delete)
- Material Class (Add, Change, Delete)
- Personnel Class (Add, Change, Delete)
- Physical Asset Class (Add, Change, Delete)
- Resource Relationship Network (Add, Change, Delete)
- Work Alert Definition (Add, Change, Delete)
- Workflow Specification (Add, Change, Delete)

3.4 Operations Resource Acquired

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

Triggered when operations resources are designed, procured, hired, discovered (e.g. through exploration) or made (i.e. through planned or unplanned manufacturing work). Operations Resource Acquired contains Added, Changed and Deleted verbs for all the Equipment, Physical Assets, Material Lots/Sublots, Material, Personnel and Operations Capabilities (Total, Unattainable and Available). The supply chain operations event notifies plants and assets upstream and downstream of change to dependent resources and operations that are being scheduled or rescheduled locally and across the supply chain.

When Operations Resources are procured ('bought') or 'made', Capability Type (Total, Unattainable, Committed and Available) of each Operation are added to reflect the additions imposed by the business event. Committed capability needs to be included because when a resource is first created in a schedule (i.e. a Material Lot or Sublot) it is created with existing committed capability.

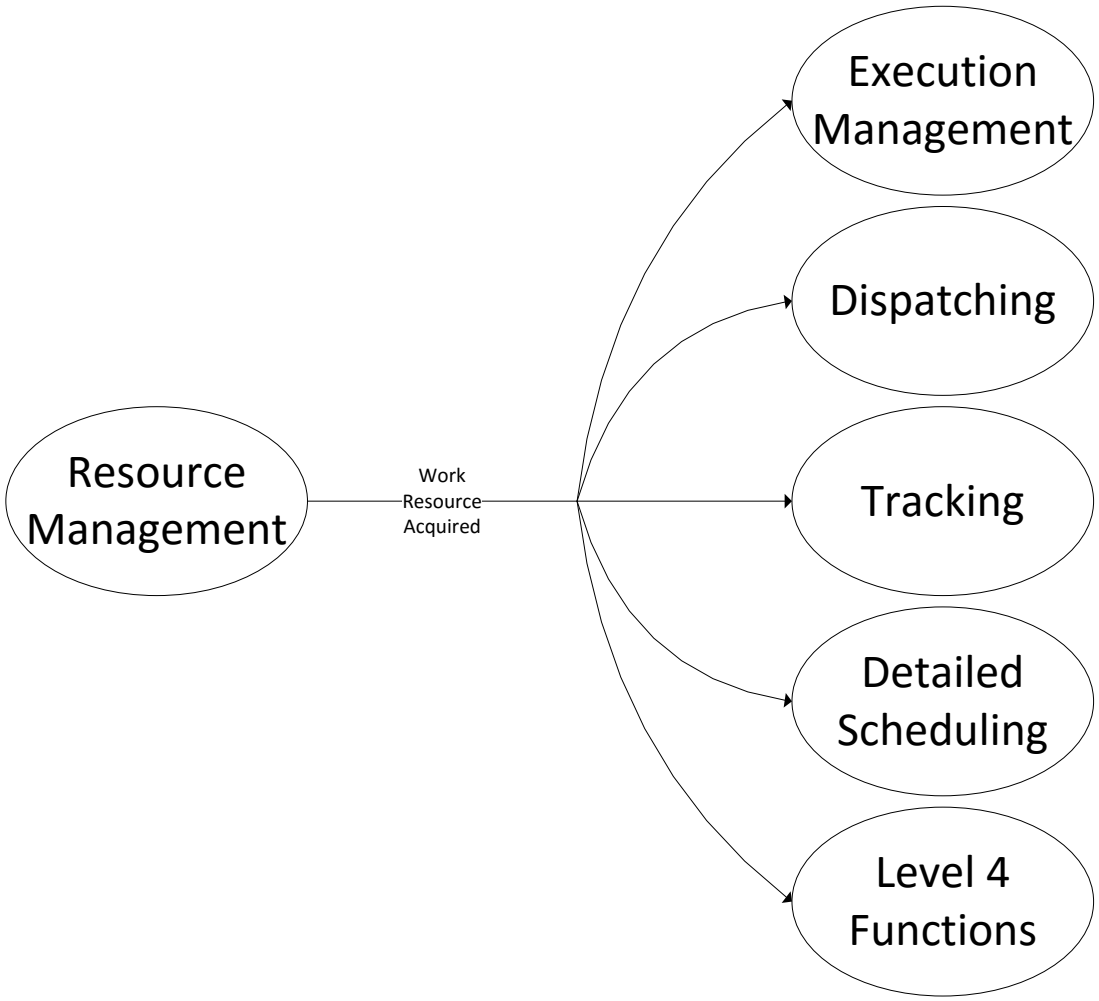
Similarly, Available Capability needs to be included because Available Capability = Total Capability – Unattainable Capability – Committed Capability, so Available Capability changes with total, unattainable, committed or available capability.

The Equipment Asset Mappings have been omitted from the Operations and Work Resource Acquired events and are included in the Operations and Work Resource Adjusted events, as the mappings will be established upon commissioning (i.e. the adjustment) of the Physical Assets rather than when they are procured (i.e. the acquisition).

Operations Resource Acquired	• Equipment, Physical Asset, Material, Material Lot/Sublot, Personnel (Add) • Operations Capability (Total, Unattainable, Available & Committed for any/all of the above), (Add)

3.5 Work Resource Acquired

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

Triggered when work resources are designed, procured, hired, discovered (e.g. through exploration) or made (i.e. through planned or unplanned manufacturing work). Work Resource Acquired contains Added verbs for all the Equipment, Physical Assets, Material Lots/Sublots, Material, Personnel and Resource Relationship Networks and Work Capabilities (Total and Unattainable).

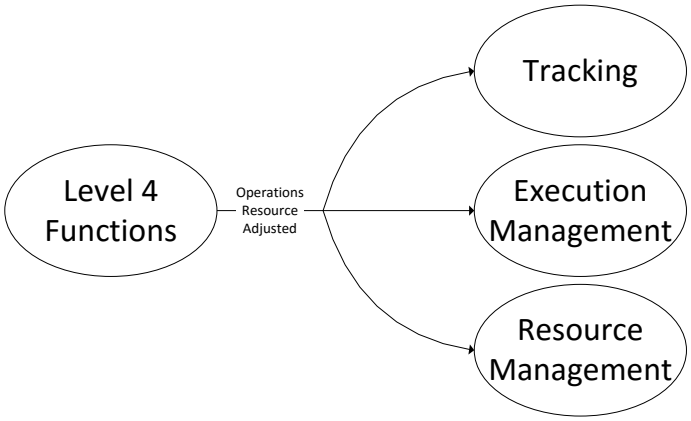
When Work Resources are procured ('bought') or 'made', Total, Unattainable, Committed and Available Work Capabilities are added here to reflect the additions imposed by the business event. Committed capability needs to be included because when a resource is first created in a detailed schedule (i.e. a Material Lot or Sublot) it is created with existing committed capability.

Similarly, Available Capability needs to be included because Available Capability = Total Capability – Unattainable Capability – Committed Capability, so Available Capability changes with total, unattainable, committed or available capability.

Work Resource Acquired	• Equipment, Physical Asset, Material, Material Lot/Sublot, Personnel (Add) • Resource Relationship Network (Add, Change, Delete) • Work Capability (Total, Unattainable, Available & Committed for any/all of the above), (Add)

3.6 Operations Resource Adjusted

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

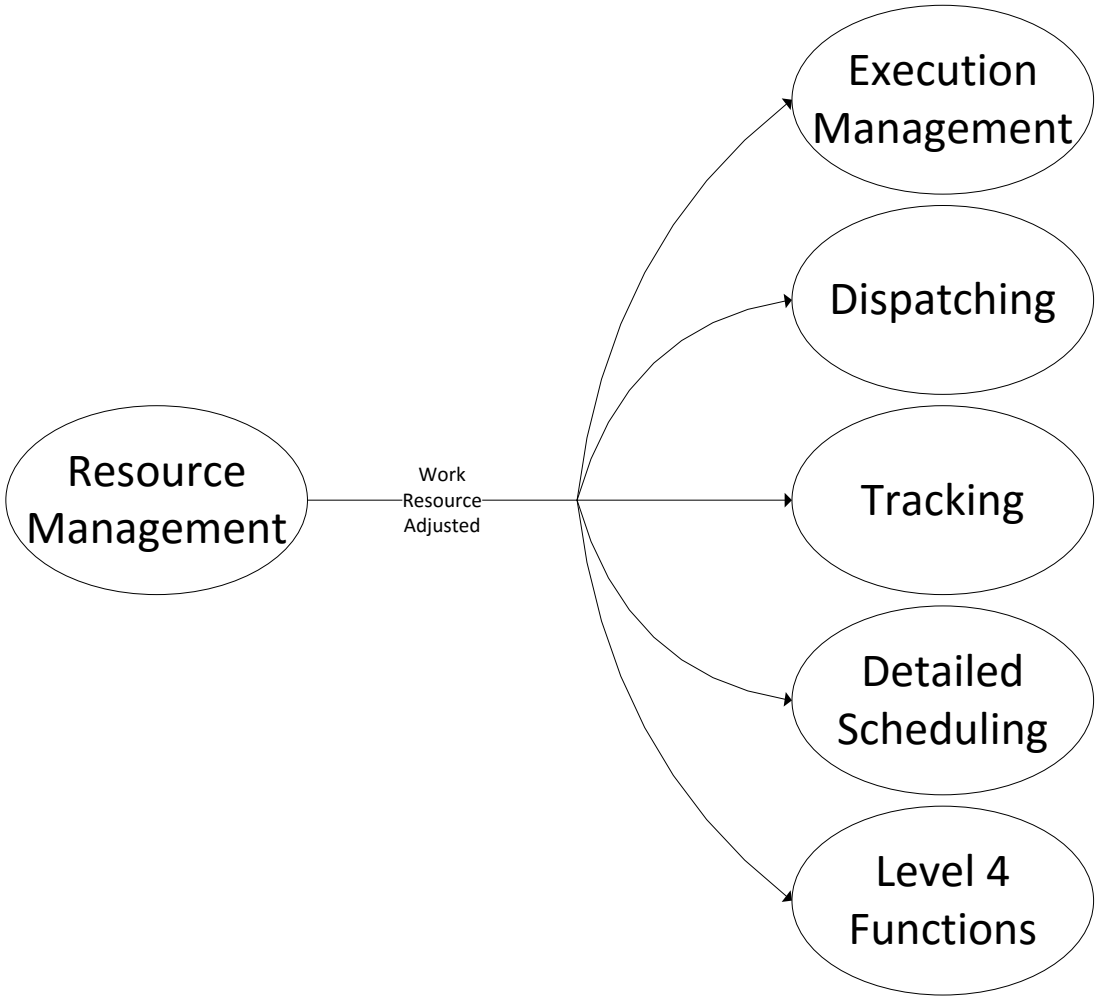
DESCRIPTION:

This event is triggered when a change occurs to an Operations Resource (e.g. commissioning of a Physical Asset), including any change to its Total or Unattainable Capabilities. This event may contain changes to Committed Capabilities because the event may be raised in response to a change to a Material Resource surfaced during Operations Scheduling – in which case the Material Resource is changed along with its Committed Capability.

Operations Resource Adjusted	• Equipment, Physical Asset, Material, Material Lot/Sublot, Personnel (Change) • Equipment Asset Mapping (Add, Change, Delete) • Operations Capability (Total, Unattainable, Available & Committed for any/all of the above), (Change)

3.7 Work Resource Adjusted

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

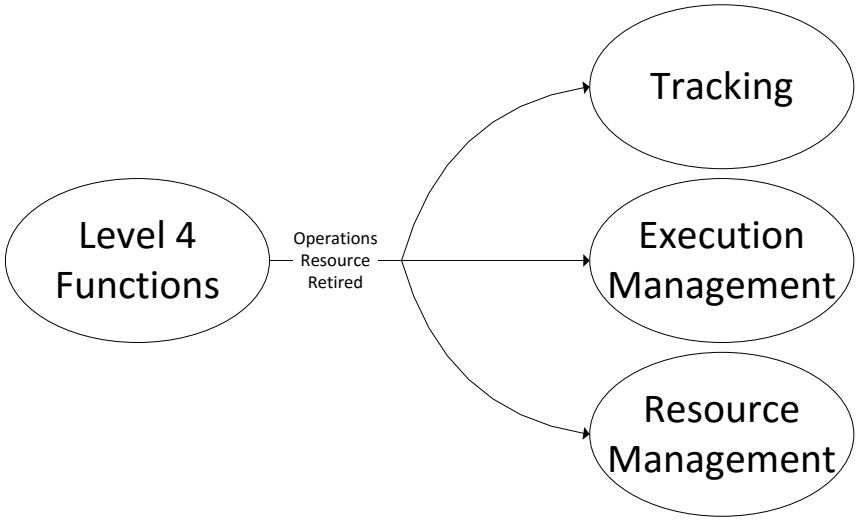
This event is triggered when a change occurs to a Work Master (e.g. commissioning of a Physical Asset), including any change to its Total or Unattainable Capabilities. This event may contain changes to Committed Capabilities because the event may be raised in response to a change to a Material Resource surfaced during Detailed Scheduling – in which case the Material Resource is changed along with its Committed Capability.

Work Resource Adjusted

- Equipment, Physical Asset, Material, Material Lot/Sublot, Personnel (Change)
- Equipment Asset Mapping (Add, Change, Delete)
- Resource Relationship Network (Add, Change, Delete)
- Work Capability (Total, Unattainable, Available & Committed for any/all of the above), (Change)

3.8 Operations Resource Retired

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

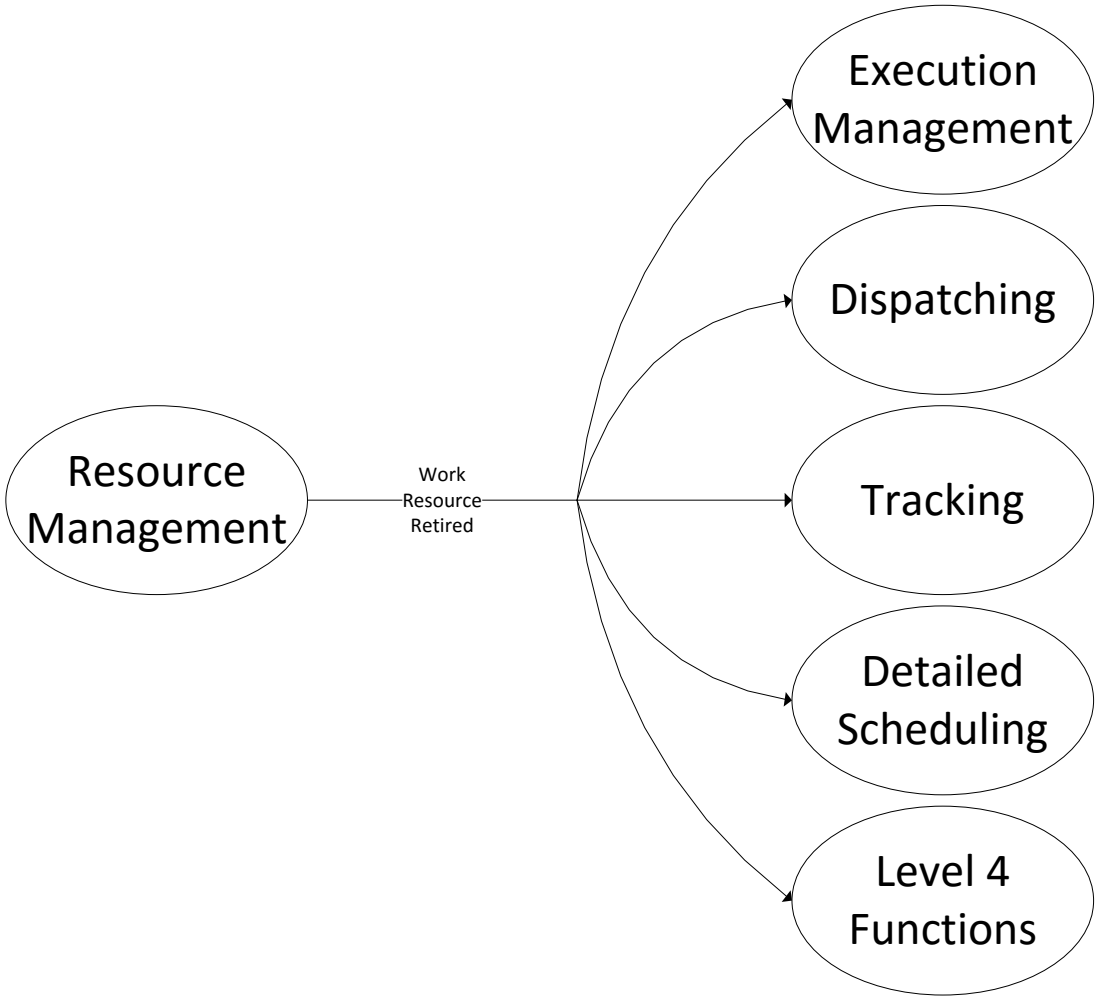
DESCRIPTION:

When a resource capability (Operations Capability) is removed or retired in a schedule, when Physical Assets are scrapped or sold on the second hand market, when Personnel leave or retire from an organisation and when Material is distributed to customers it will result in a delete of the associated Operations Capability (Total, Unattainable Available, Committed, Used and Unused) for Equipment, Physical Assets, Material Lots/Sublots, Material and Personnel.

Operations Resource Retired	• Equipment, Physical Asset, Material, Material Lot/Sublot, Personnel (Delete) • Operations Capability (Total, Unattainable, Available, Committed, Used & Unused for any/all of the above), (Delete)

3.9 Work Resource Retired

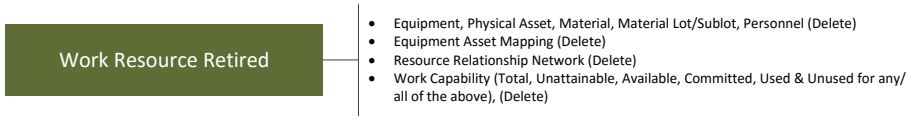
INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

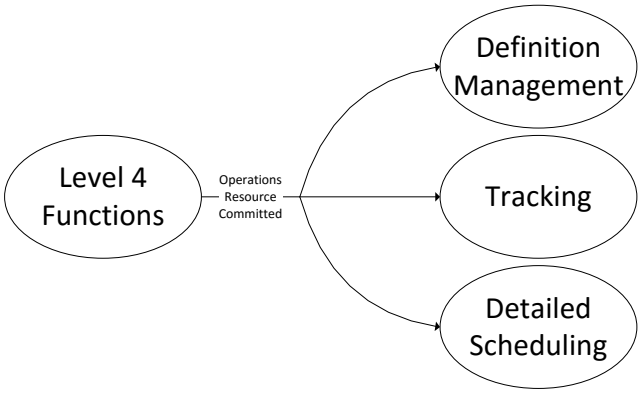
DESCRIPTION:

When a Work Capability is removed or retired in a schedule, when Physical Assets are scrapped or sold on the second hand market, when Personnel leave or retire from an organisation and when Material is distributed to customers it will result in a delete of the associated Operations Capability (Total, Unattainable Available, Committed, Used and Unused) for Equipment, Equipment Asset Mapping, Physical Assets, Material Lots/Sublots, Material and Personnel



3.10 Operations Resource Committed

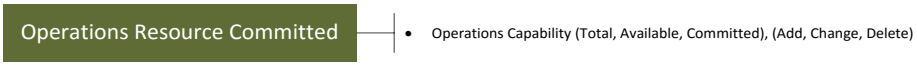
INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

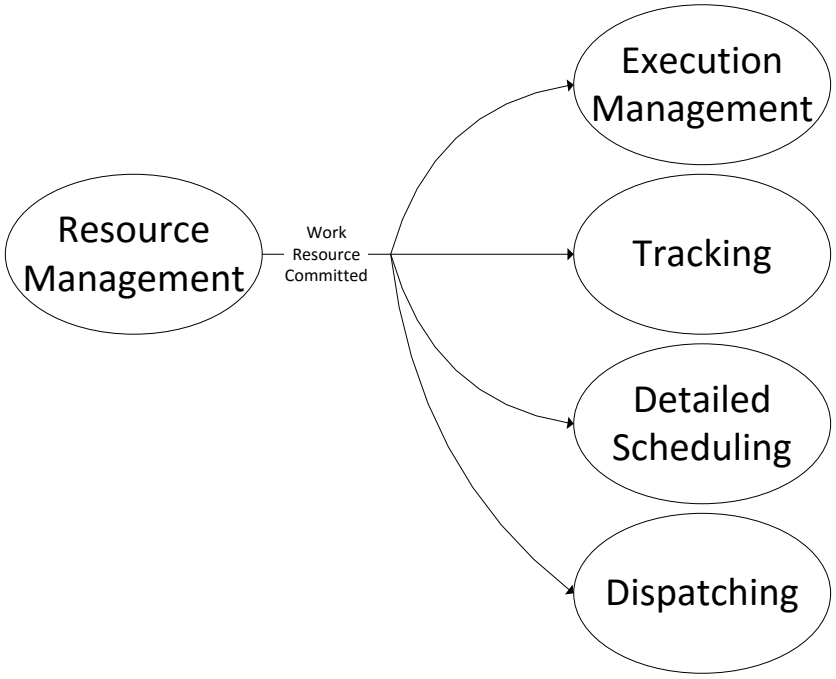
DESCRIPTION:

When a resource is committed in an Operations schedule it will result in an added, changed and/or deleted of the associated Operations Capability (Total, Available and Committed).



3.11 Work Resource Committed

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

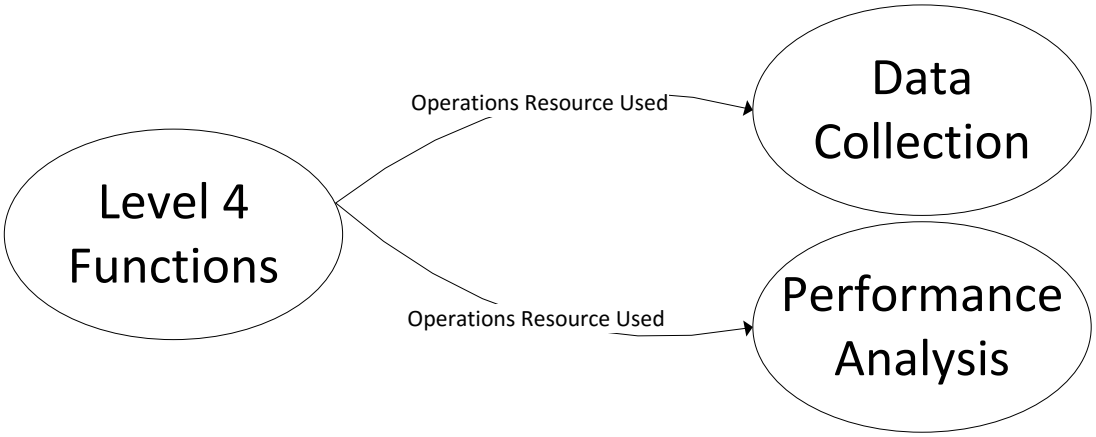
DESCRIPTION:

When a resource is committed in a Work Schedule it will result in an added, changed and/or deleted of the associated Work Capability (Total, Available and Committed).


Work Resource Committed
Work Capability (Total, Available, Committed), (Add, Change, Delete)

3.12 Operations Resource Used

INFORMATION FLOW:



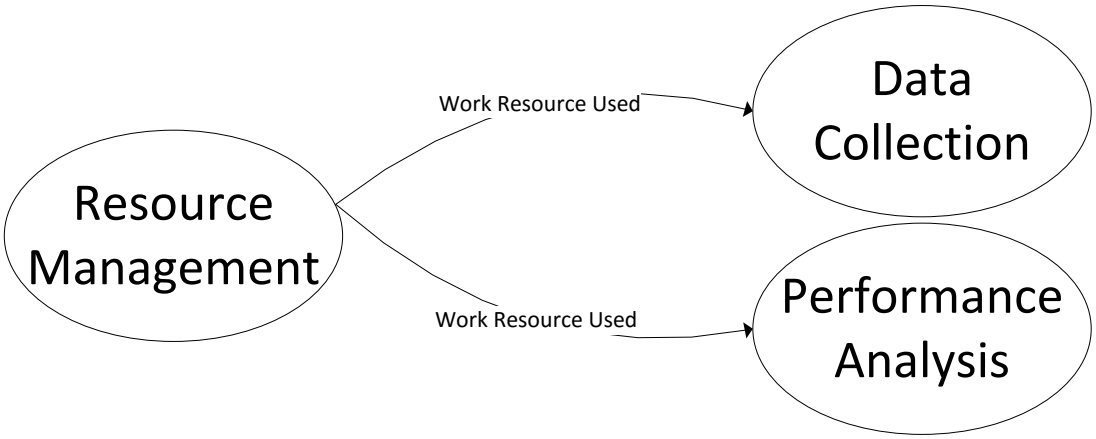
DESCRIPTION:

When a resource capability (Operations Capability) is used during work it will result in an added, changed and/or deleted of the associated Operations Capability Used and Unused).

Operations Resource Used	• Operations Capability (Used & Unused), (Add, Change, Delete)

3.13 Work Resource Used

INFORMATION FLOW:



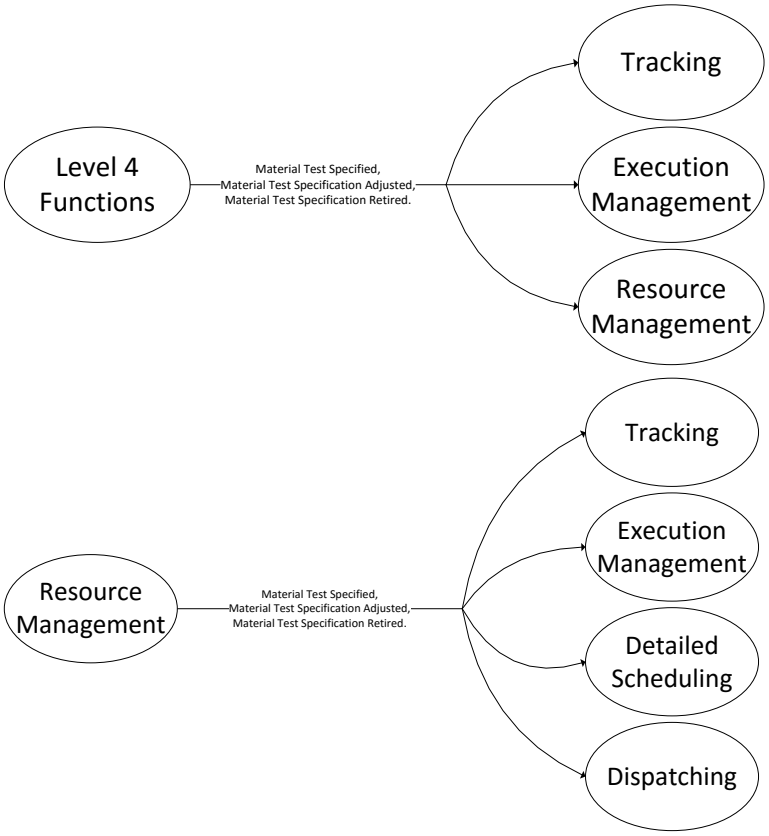
DESCRIPTION:

When a Work Capability is used in a schedule it will result in an added, changed and/or deleted of the associated Work Capability (Total, Available, Used and Unused).

Work Resource Used	• Work Capability (Used & Unused), (Add, Change, Delete)

3.14 Material Test Specified, Adjusted & Retired

INFORMATION FLOW:

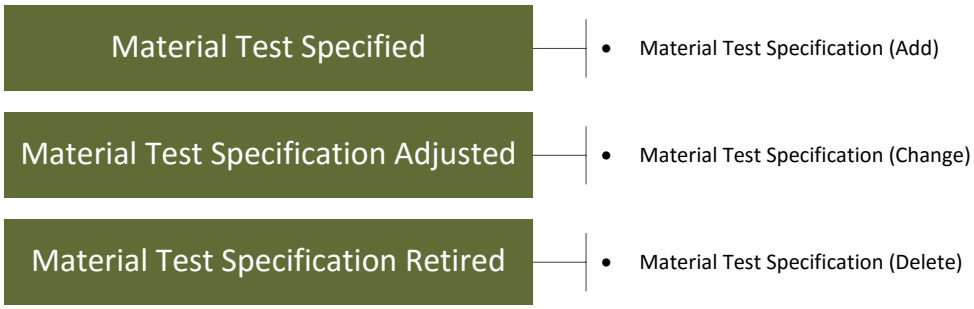


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

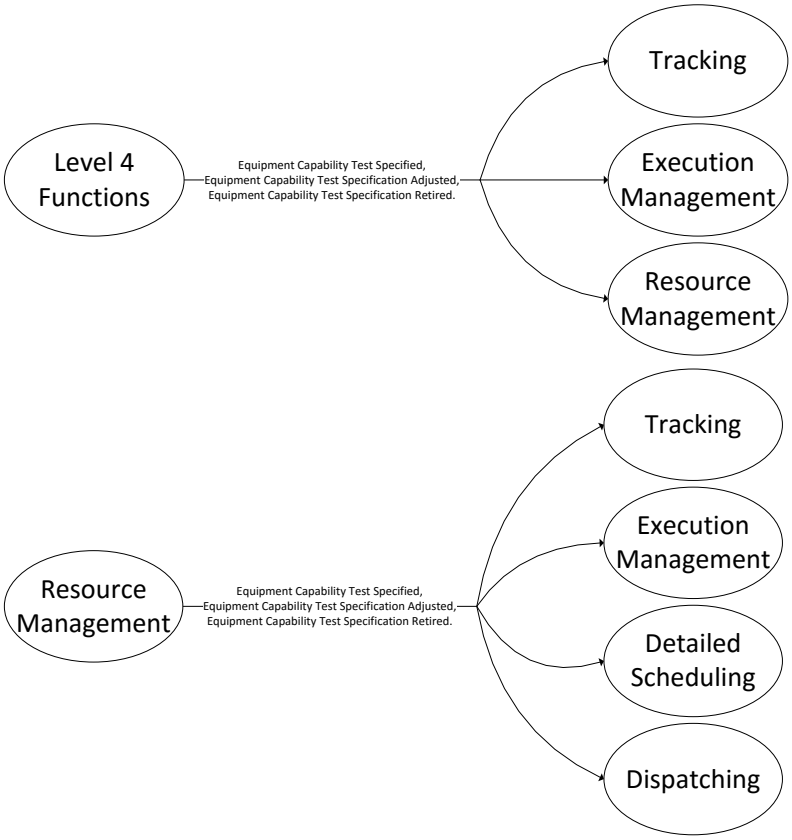
At any point after the design of Operations (Level 4) or Work (Level 3), Material Test Specification needs to be defined for Material through the use of the Added verb in the Material Test Specified event.

Changes to the Material Test Specification through the use of Changed and Deleted verbs can occur without constituting a change to the design of the supply chain and are represented in the Material Test Specification Adjusted and Material Specification Retired events respectively.



3.15 Equipment Capability Test Specified, Adjusted & Retired

INFORMATION FLOW:

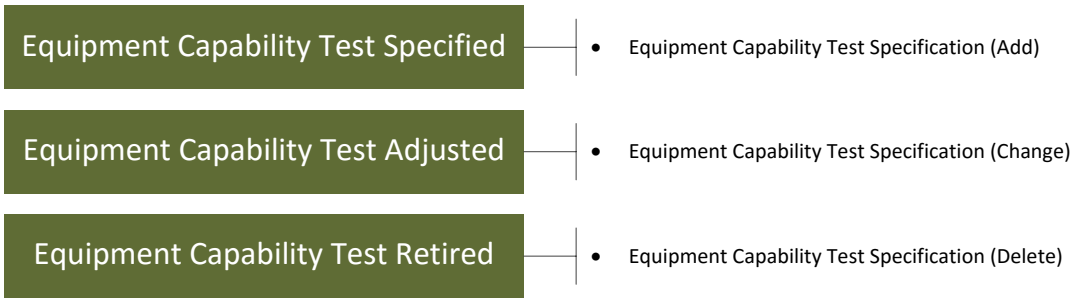


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

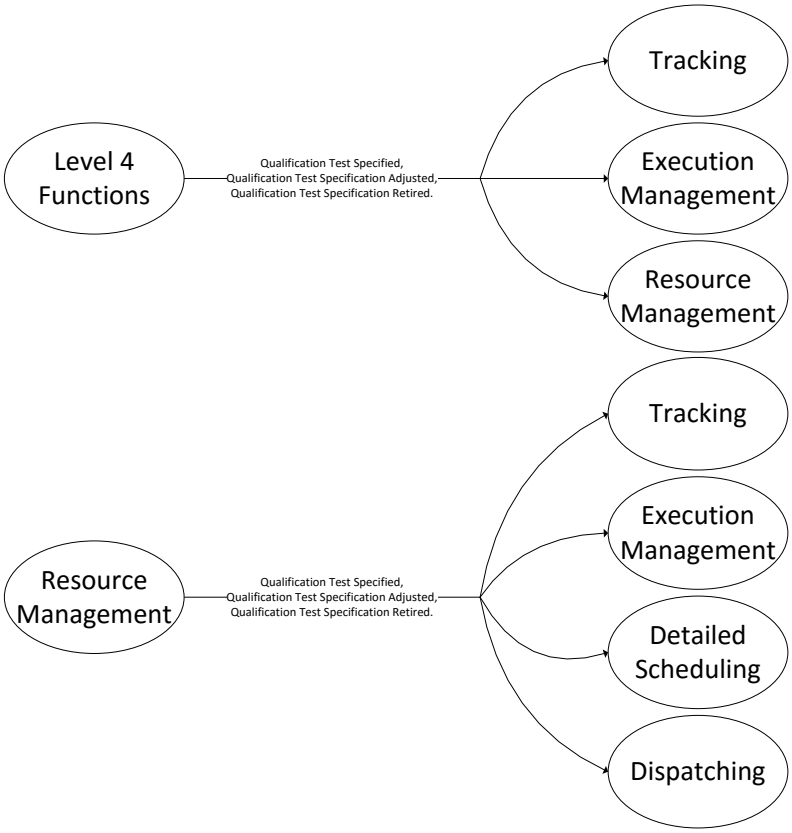
At any point after the design of Operations (Level 4) or Work (Level 3), Equipment Capability Test Specification needs to be defined for Equipment through the use of the Added verb in the Equipment Capability Test Specified event.

Changes to the Equipment Capability Test Specification through the use of Changed and Deleted verbs can occur without constituting a change to the design of the supply chain and are represented in the Equipment Capability Test Specification Adjusted and Equipment Capability Test Specification Retired events respectively.



3.16 Qualification Test Specified, Adjusted & Retired

INFORMATION FLOW:

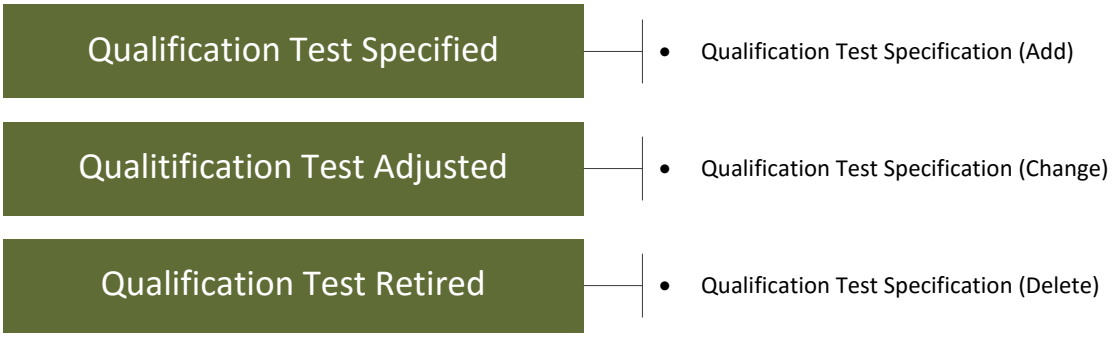


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

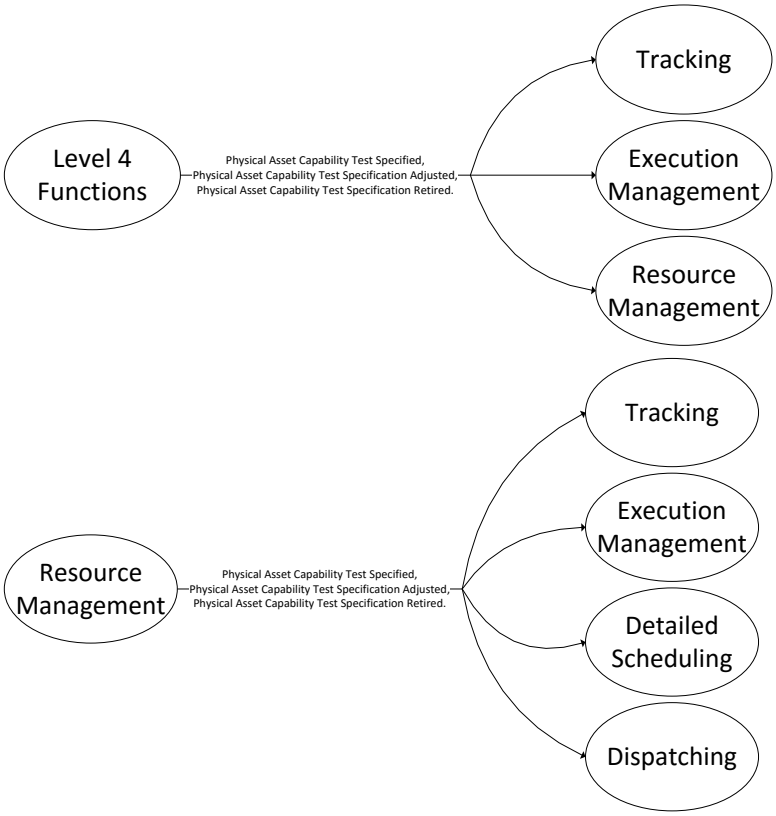
At any point after the design of Operations (Level 4) or Work (Level 3), Qualification Test Specification needs to be defined for Personnel through the use of the Added verb in the Qualification Test Specified event.

Changes to the Qualification Test Specification through the use of Changed and Deleted verbs can occur without constituting a change to the design of the supply chain and are represented in the Qualification Test Specification Adjusted and Material Specification Retired events respectively.



3.17 Physical Asset Capability Test Specified, Adjusted & Retired

INFORMATION FLOW:

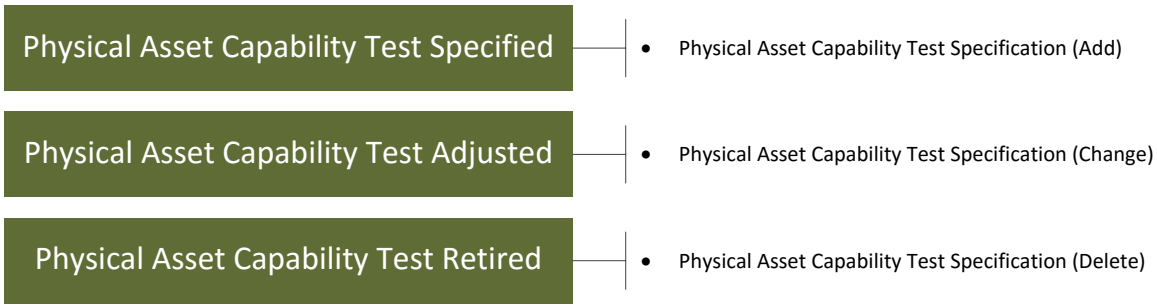


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

At any point after the design of Operations (Level 4) or Work (Level 3), Physical Asset Capability Test Specification needs to be defined for Physical Assets through the use of the Added verb in the Physical Asset Capability Test Specified event.

Changes to the Physical Asset Capability Test Specification through the use of Changed and Deleted verbs can occur without constituting a change to the design of the supply chain and are represented in the Physical Asset Capability Test Specification Adjusted and Physical Asset Capability Test Specification Retired events respectively.

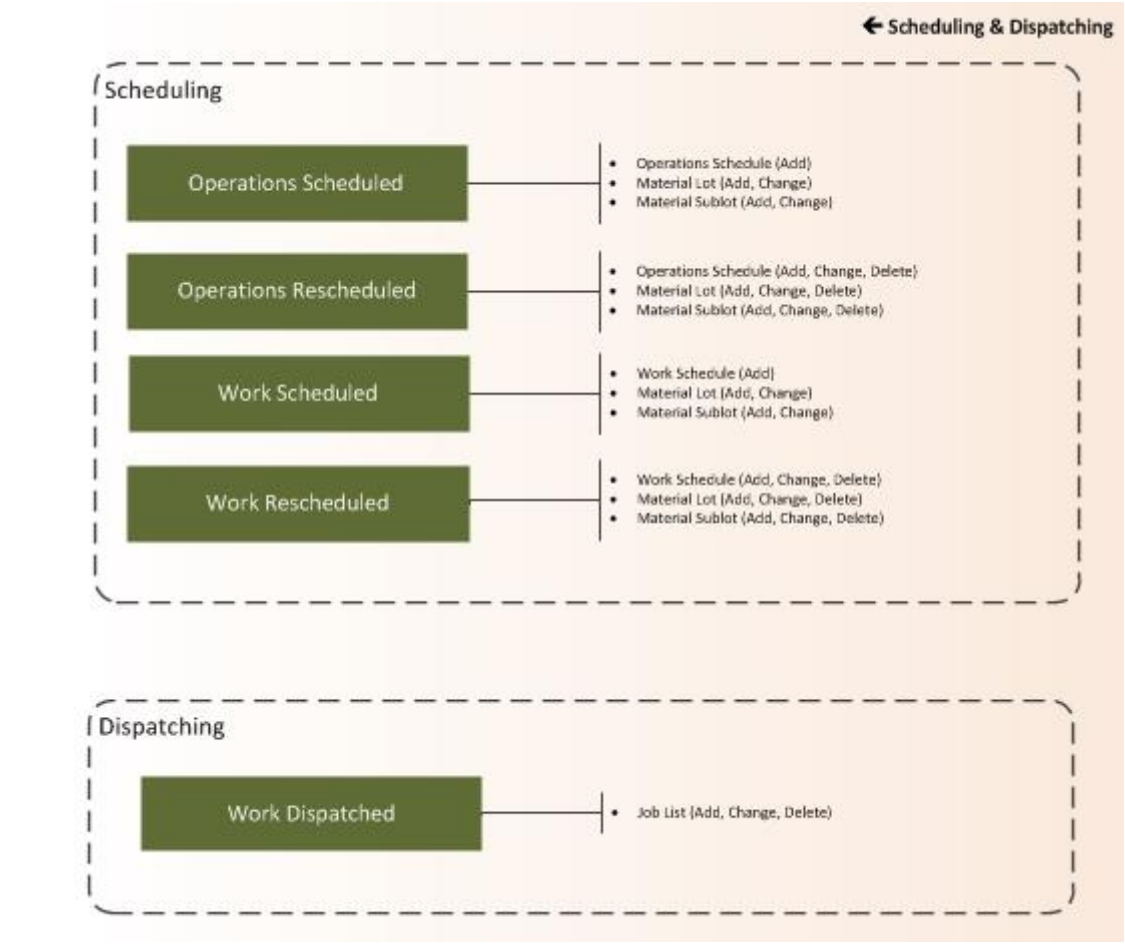


4 Scheduling & Dispatching

OVERVIEW:

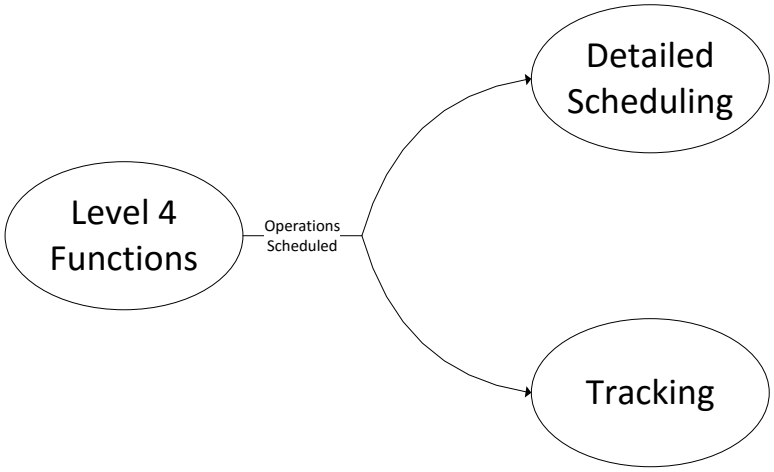
The creation of schedules (Operations Schedules or Work Schedules) could possibly introduce new Material resources (Material Lots and Sub-lots) not yet made available by Resource Management. Equally these Material resources could be updated during the creation of the schedule.

Figure 6 – Common Scheduling & Dispatching Process Centric Events



4.1 Operations Scheduled & Operations Rescheduled

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

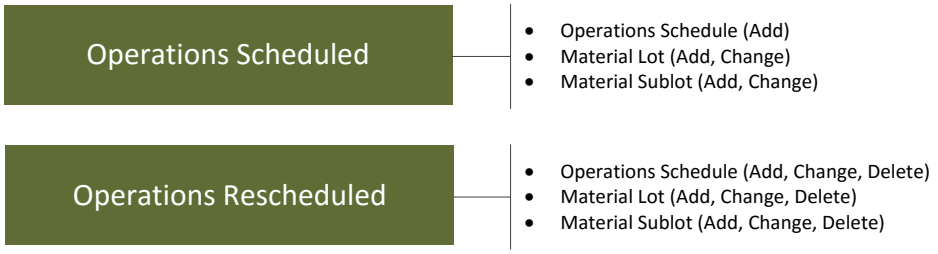
DESCRIPTION:

A Level 4 scheduling run may result in the creation of new schedules, but it may also result in updating or deleting of existing schedules. For example, regularly published Operations Schedules (e.g. weekly or monthly) will often replace a previously published Operations Schedule. In this case, the previously published Operations Schedule may require an update to its status, or in some implementations may be deleted.

Any new Level 4 schedule may introduce new Material Lots/Sublots (in a planned status) or may change already defined Material Lots. Consequently the Operations Scheduled event must include an Operations Schedule and any added or changed Material Lots resulting from the scheduling activity and possibly a changed or deleted Operations Schedule.

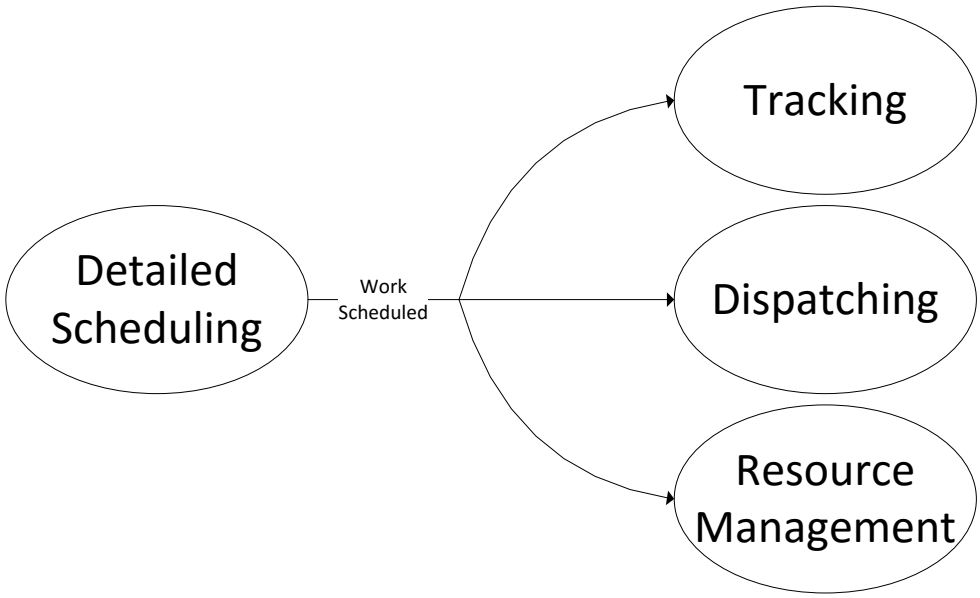
A Level 4 Operations Rescheduled event is similar to an Operations Scheduled event and may introduce new Material Lots/Sublots (in a planned status) or may change already-defined Material Lots. Consequently any change to a schedule could potentially result in the change of an existing schedule (Operations Schedule) or the delete of an existing schedule and an addition of a new schedule replacing the previous schedule (or part thereof). The Operations Rescheduled event will also include any added or changed Material Lots resulting from the rescheduling activity.

A Level 4 scheduling may include but is not limited to Sales and Operations Planning, Master Scheduling, Rough Cut Capacity Planning, Material Requirements Planning and Capacity Requirements Planning.



4.2 Work Scheduled & Work Rescheduled

INFORMATION FLOW:



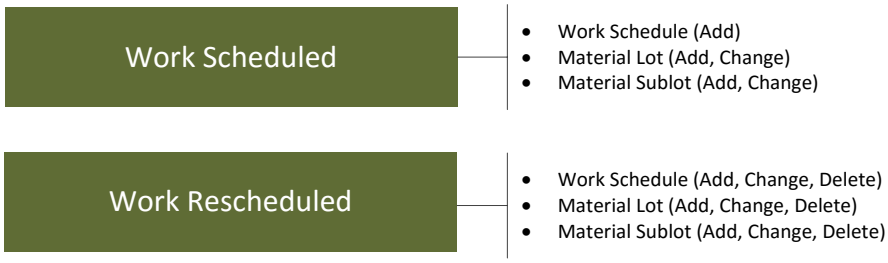
*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

A scheduling run may result in the creation of new schedules, but it may also result in updating or deleting of existing schedules. For example, regularly published Work Schedules (e.g. daily or weekly) will often replace a previously published Work Schedule. In this case, the previously published Work Schedule may require an update to its status, or in some implementations may be deleted.

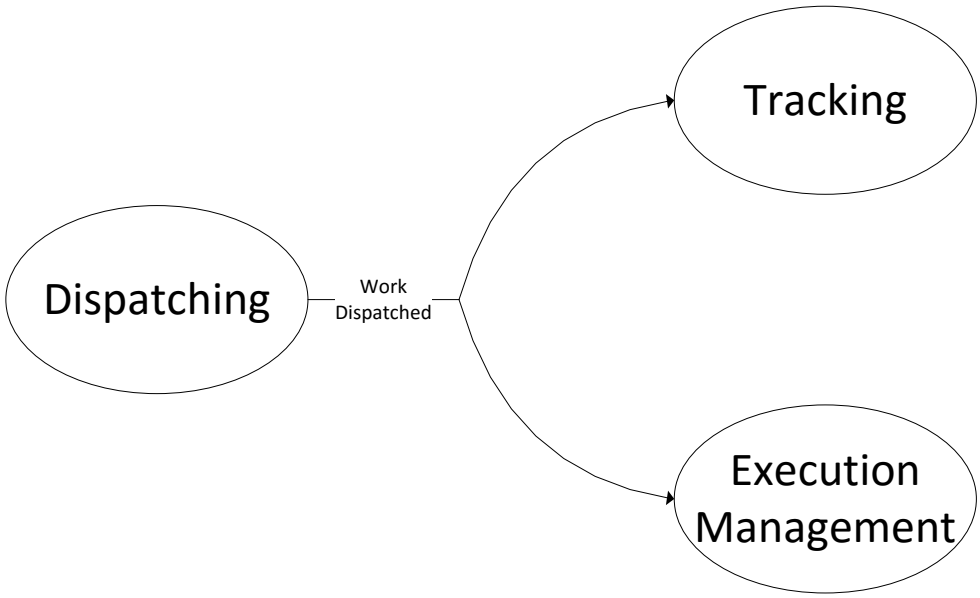
Any new Level 3 schedule may introduce new Material Lots/Sublots (in a planned status) or may change already defined Material Lots. Consequently the Work Scheduled event must include a Work Schedule and any added or changed Material Lots/Sublots resulting from the scheduling activity.

A Level 3 Work Rescheduled event is similar to a Work Scheduled event and may introduce new Material Lots/Sublots (in a planned status) or may change already-defined Material Lots. Consequently any change to a schedule could potentially result in the change of an existing schedule (Work Schedule) or the delete of an existing schedule and an addition of a new schedule replacing the previous schedule (or part thereof). The Work Rescheduled event will also include any added or changed Material Lots resulting from the rescheduling activity.



4.3 Work Dispatched

INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

Triggered when work has been dispatched. The work may be planned (i.e. in accordance with a Job Order). The work may also be in accordance with a Work Master and can contain Add, Change or Delete verbs to indicate this status of the Job Lists.

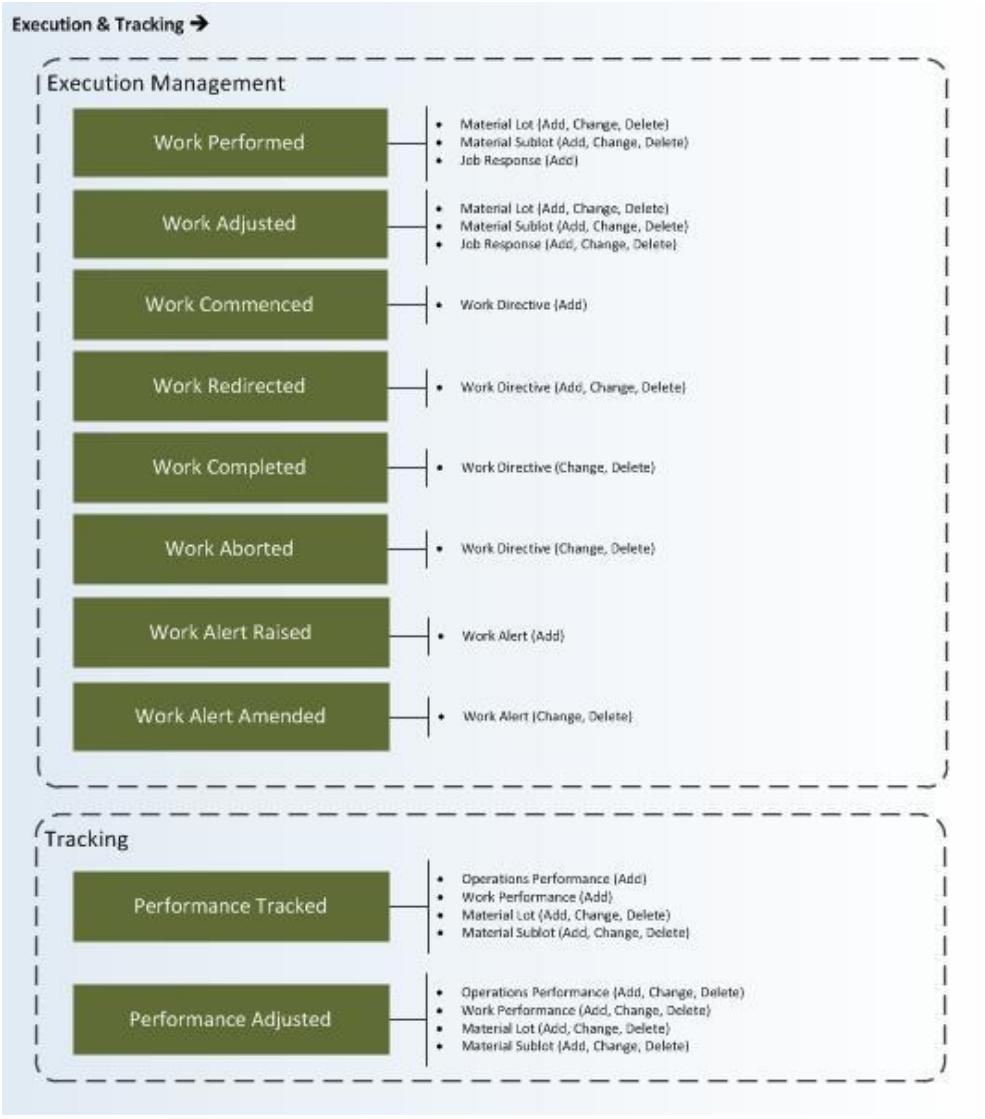
5 Execution Management & Tracking

OVERVIEW:

All Level 2 functions must inform the Execution Management Function of work that has been performed. As work is performed Material Resources (Material Lots and Sub-lots) could potentially be created (where they were not described by any schedule but were still executed) or adjusted (as the Material Resource depletes or increases or is blended with other material). Specifically, an example in bulk commodity mining is where Material Resources (i.e. stockpiles) are accumulated prior to the processing of the materials through the fixed plant. The balance of the material (tonnes) and the properties of the material are adjusted continuously as material is added or removed from the Material Resource. For this reason any update to Physical Material Resources (Material Lots and Sub-lots) as part of Work Performed needs to be captured at the same time. Equally any adjustments made to Work Performed will also potentially result in changes to Material Resources (Material Lot and Sub-lot).

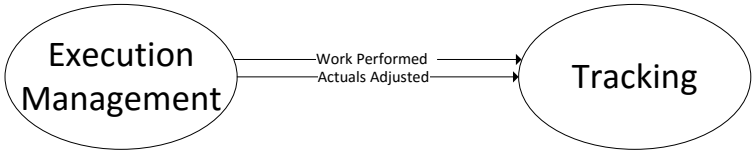
In turn the Tracking Function (Level 3) will inform Level 4 and Level 3 functions of that work that has been tracked. The Tracking Function will aggregate and consolidate the information to a level required by the Level 4 functions. All other Resources (Persons, Equipment, Physical Assets and associated Classes) will be managed entirely as part of Resource and Definition Management because it is not influenced directly by Work Performance.

Figure 7 – Common Execution Management & Tracking Process Centric Events



5.1 Work Performed & Actuals Adjusted

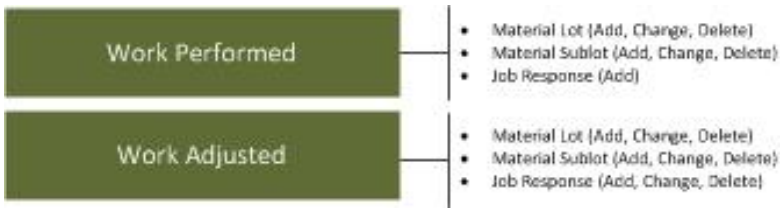
INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

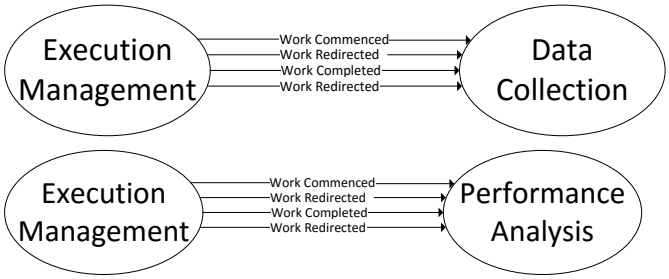
DESCRIPTION:

When work has been performed the Execution Management Function would need to capture any potential change to the underlying Material Lots/Sublots. Similarly, when work that has been previously performed has been adjusted (Actuals Adjusted process centric event) it could potentially result in further adjustments to the underlying Material Lots/Sub Lots. It may also result in an update to the dispatched orders (Job Orders) through an add, change or delete to the previously published Job Response.



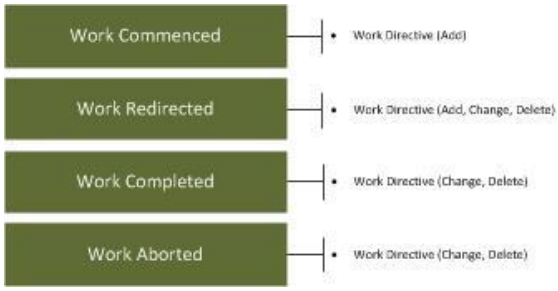
5.2 Work Commenced, Redirected, Completed & Aborted

INFORMATION FLOW:



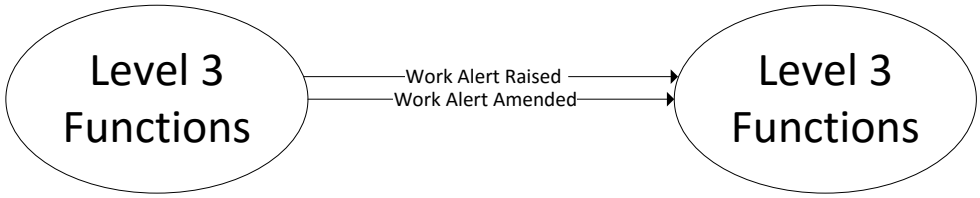
DESCRIPTION:

The Work Commenced event is raised when new work commences. The Work Redirected event is raised when existing in flight work is changed. This may take the form of changing one or more existing Work Directives, or may also result in replacing existing Work Directives with new ones. Therefore Added, Changed and Deleted verbs are all permitted in this event. The Work Completed and Work Aborted events are raised when work is completed or aborted respectively.


Work Commenced
Work Directive (Add)
Work Redirected
Work Directive (Add, Change, Delete)
Work Completed
Work Directive (Change, Delete)
Work Aborted
Work Directive (Change, Delete)

5.3 Work Alert Raised & Work Alert Amended

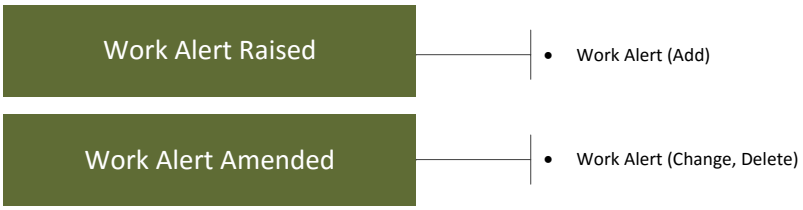
INFORMATION FLOW:



*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

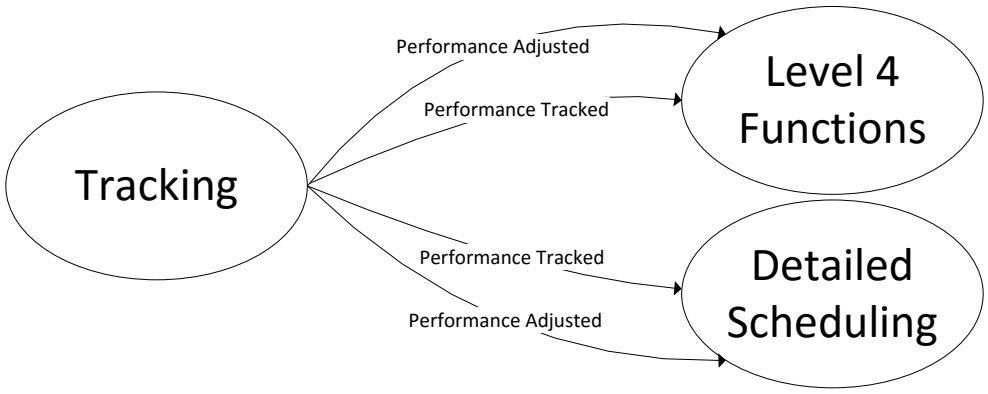
DESCRIPTION:

Published by any Level 3 Function and send to any Level 3 Function and triggered when an alert is flagged against work. The Work Alert Raised includes add verbs of type Work Alert and Work Alert Amended includes change and/or delete verbs of type Work Alert to signify an update to a previously published Work Alert Raised event.



5.5 Performance Tracked & Performance Adjusted

INFORMATION FLOW:

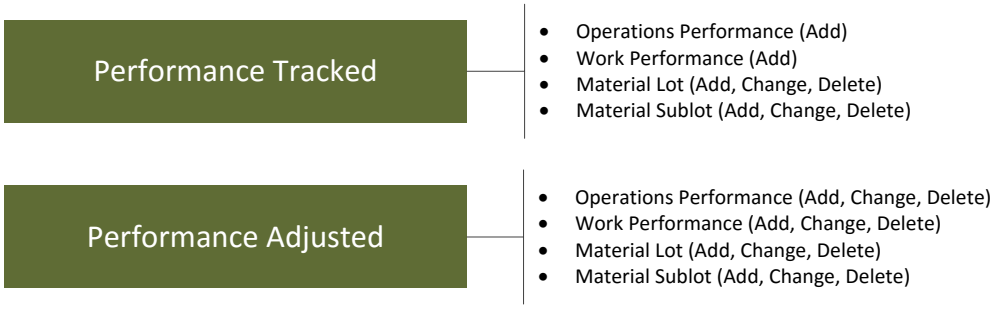


*Data Collection and Performance Analysis Functions have been omitted from these figures because it is assumed that they will receive all event messages.

DESCRIPTION:

A Performance Tracked event tracks the production, logistics, quality and maintenance actuals (and not just changes to the Material Lots/Sublots).

Similarly, when work that has been previously tracked has been adjusted it could potentially result in further adjustments to the Material Lots/Sub Lots, as well as the production, logistics, quality and maintenance actuals.



6 Sample Cross Industry Business Process (Informative)

This section illustrates how a manufacturing organisation could employ the process-centric event messages detailed in this paper to support their business processes. This section is informative only, containing only examples of how organisations *might* structure their processes based on the event model presented in this paper.

Figure 8 – Supply Chain Design Process

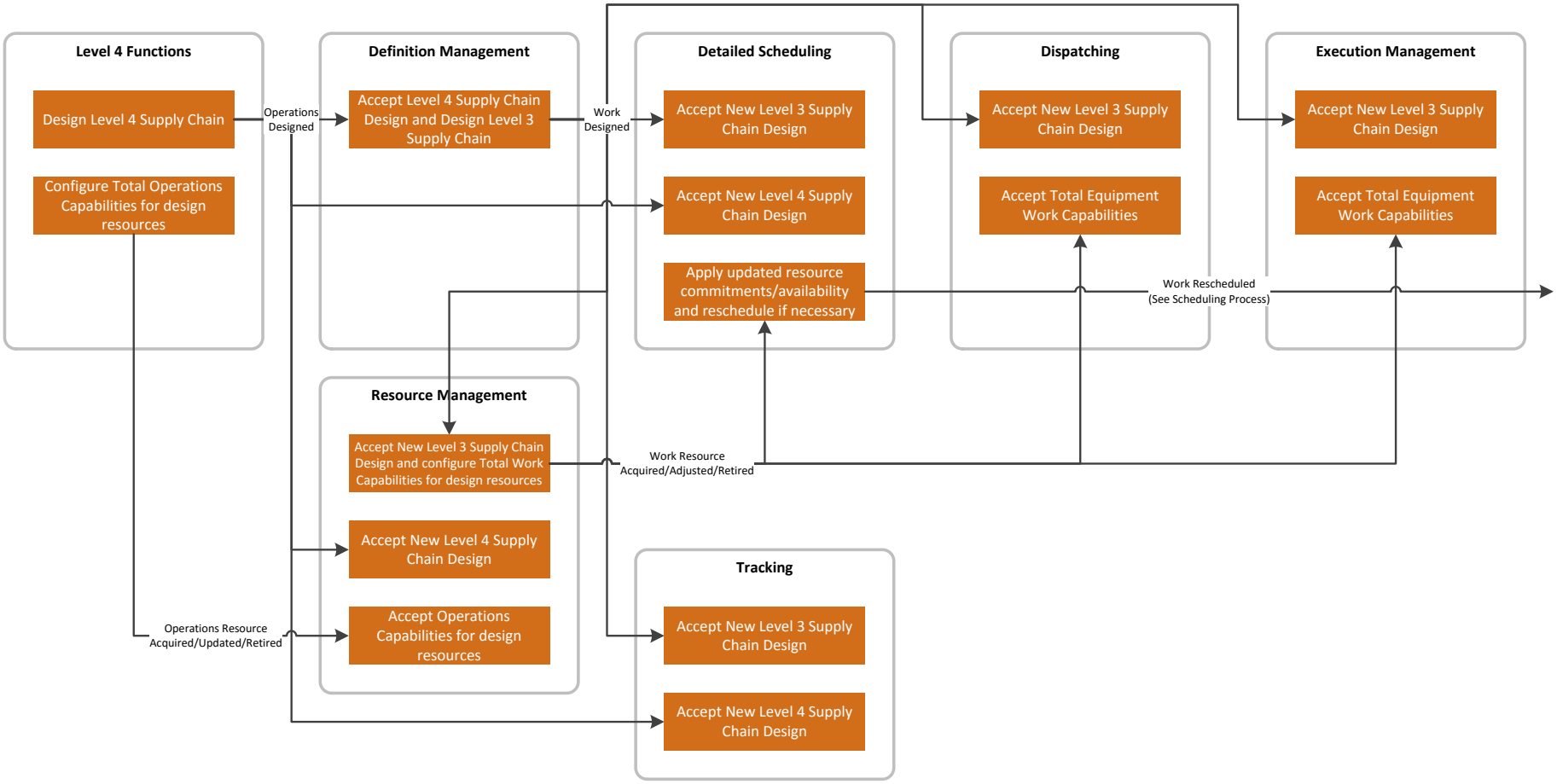


Figure 9 – Procurement Process

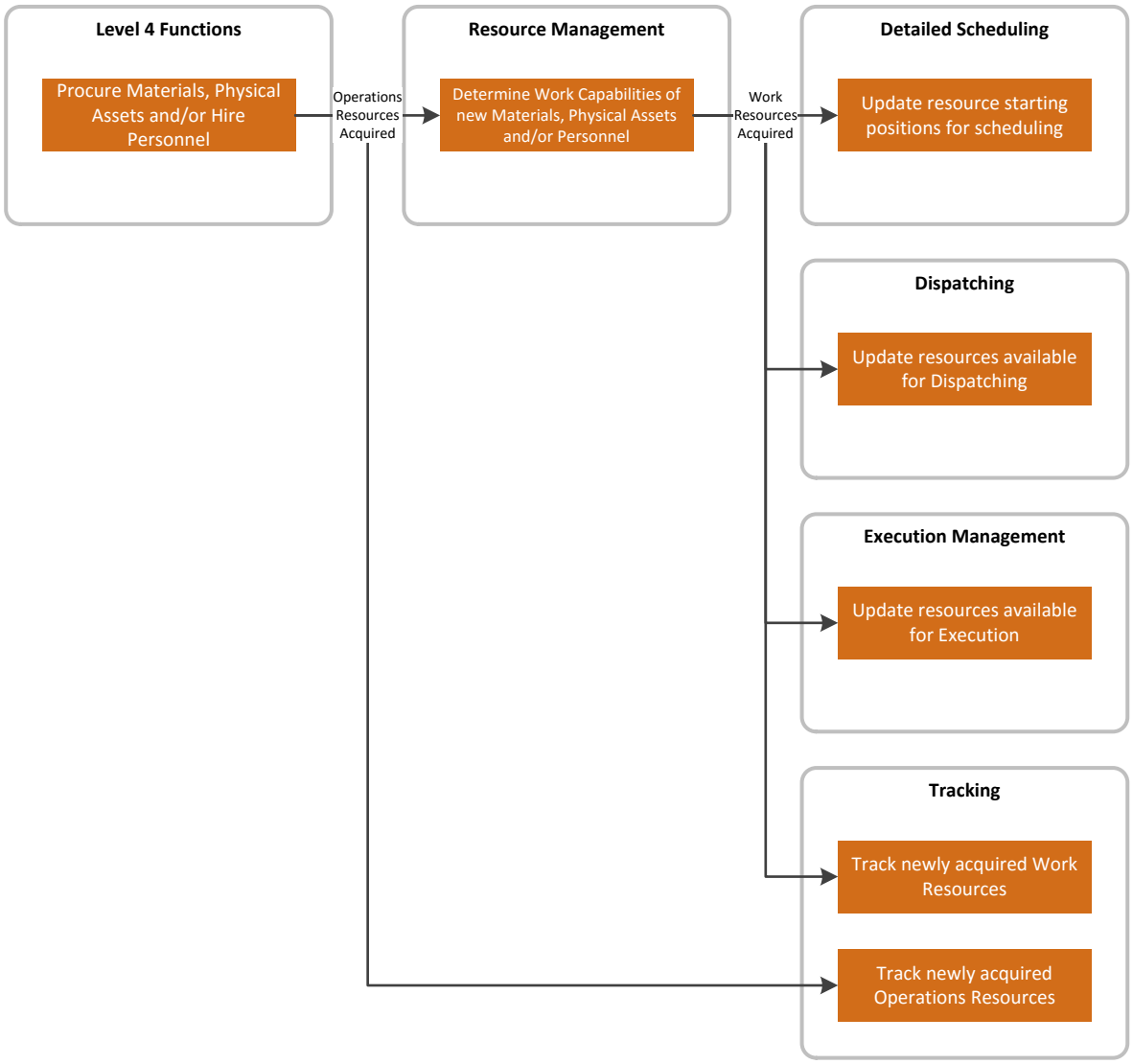


Figure 10 – Scheduling Process

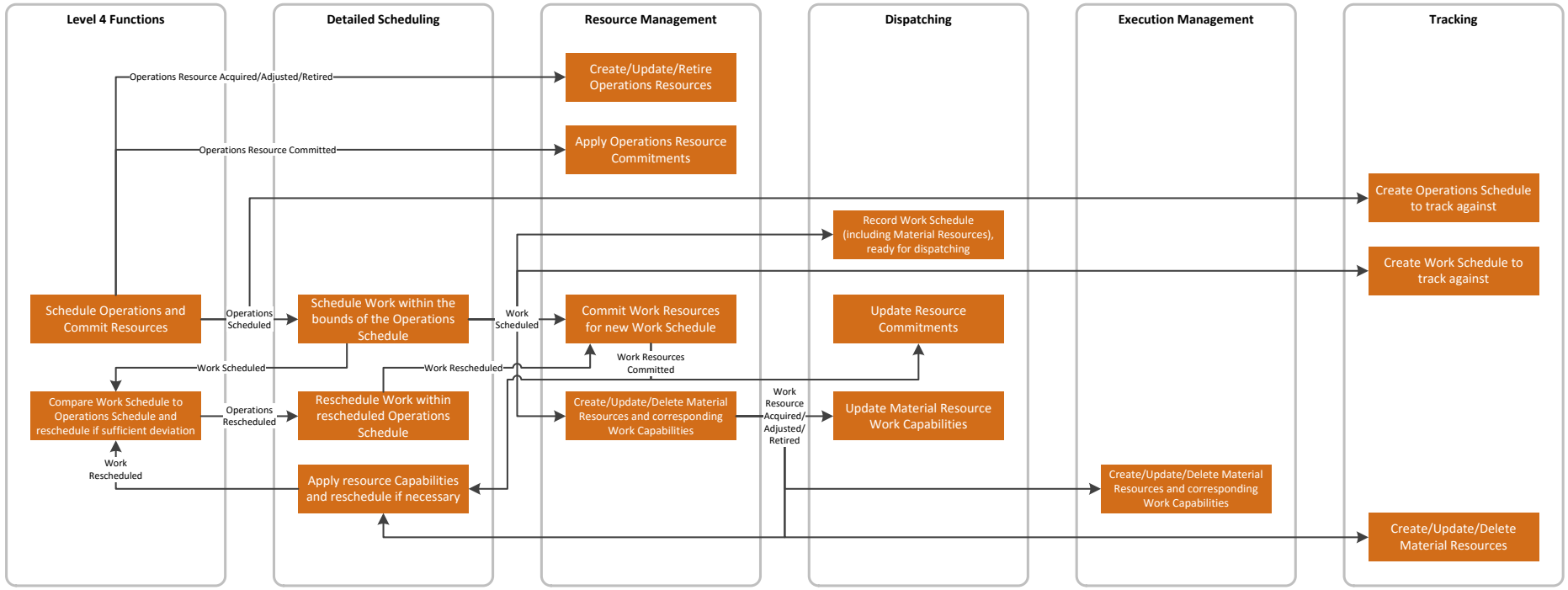


Figure 11 – Dispatching Process

Figure 12 – Execution Process

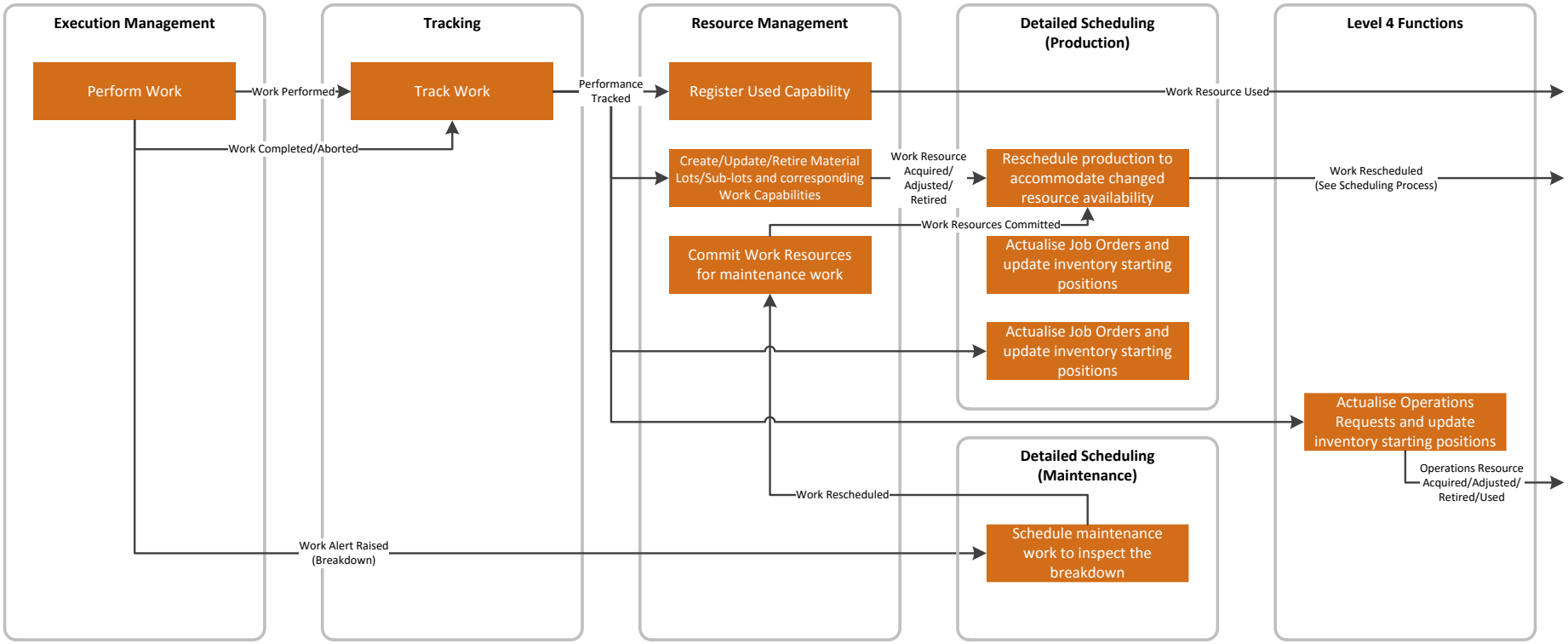


Figure 13 – Breakdown Inspection & Repair Process

7 Considered Alternatives

7.1 ebXML Related Message Bundling

7.1.1 Overview

ebXML is a standard that is an extension on top of the SOAP standard. It has a number of features, one of which is the ability to package a number of message parts up into a single message. ebXML is also very feature rich in that it is a set of specifications that enable a modular framework and its use is governed by mutually agreed trading partner protocol agreements. If ebXML were used to meet the process centric messaging requirements:

- Each application would publish an arbitrary bundle of B2MML messages, wrapped in a single ebXML message;
- Application vendors would define outbound messaging interfaces that have specific meanings and the applications would publish these message bundles to those interfaces.

7.1.2 Consideration

In principle, ebXML could be used to meet the requirements. However, the implications would be:

- Product vendors would have to implement ebXML and SOAP – whereas at the moment in order to use B2MML, they are only required to implement B2MML;
- Application vendors would define application-specific (non-standard) outbound queues that would have specific meaning (e.g. 'Performance Tracked' or 'Performance Adjusted'), and the applications would publish these message bundles on those queues
- Organisations would need to define specific messaging interfaces with organisation-specific semantics (e.g. 'Performance Tracked' or 'Performance Adjusted'), upon which to publish those messages. They would then set up subscriptions to those messaging interfaces so those messages are delivered to the appropriate applications, which would just read through all the B2MML sub-messages and process each one individually.

7.1.3 Conclusion

In summary, the key disadvantages with an ebXML approach are:

- The overall ebXML message wouldn't have any standards-defined semantics (e.g. 'Performance Tracked or 'Work Scheduled'). It would just be a bundle of B2MML messages, where each B2MML message has its existing semantics;
- Event messages have no specific ISA-95 (function/process) semantics. Subscribing systems therefore just have to process each B2MML part with no understanding of the process context that triggered the publication of the event. This is fine unless the subscribing application would want to behave differently depending on the triggering event;
- Event messages would be non-standard (i.e. differing between each organisations implementation of ebXML);
- Product vendors would have to implement ebXML (which is an exhaustive standard) and SOAP – whereas at the moment in order to use B2MML, they only need to implement B2MML. It may be more appropriate to define a generic 'Event Occurred' transaction that can have zero-to-many of any kind of B2MML element in it. That would eliminate the need for any ebXML or SOAP support.

Furthermore, the proposal set out in this paper is to standardise a set of ISA-95 L3 and L4 Function specific event messages with specific semantics to be defined by the standard. Such event messages (with their expected contents) do not (obviously) feature in ebXML or SOAP.