Automated Reasoning for Situational Awareness

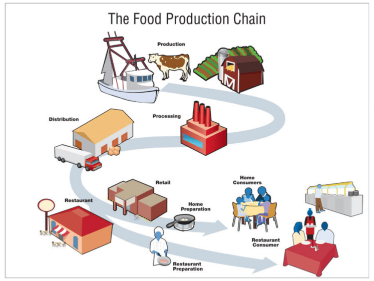
Peter Baumgartner, Alexander Krumpholz

Supply Chain Integrity Digital Mission

www.data61.csiro.au

Situational Awareness - Systems of Interest

- **Factory Floor**
  - Are the operations carried out according to the schedule?



- **Food Supply Chain**
  - Are goods delivered within 3 hours and stored below 25℃?
  - Why is the truck late?
  - Where did the strawberries/honey come from?
- **Data Cleansing**
  - Does the database have complete, correct, accurate and relevant data?

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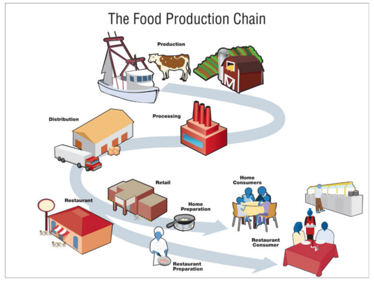

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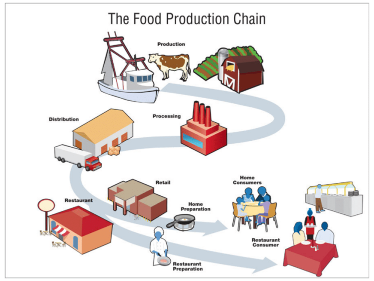

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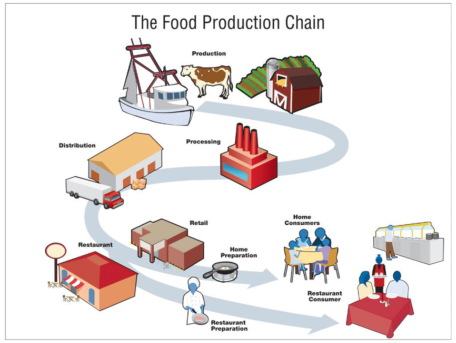

Events…

GPS coordinates

Temp sensor

Paperwork

Log DB

?

Why is the truck late?

Are the tomatoes still fresh?

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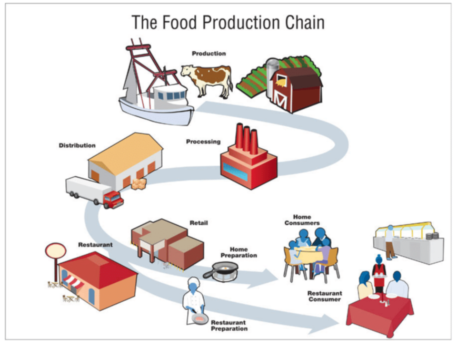

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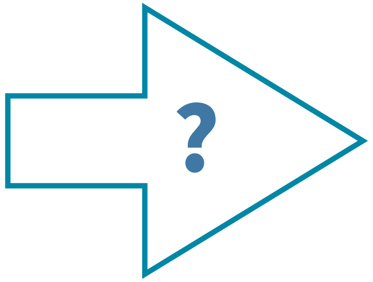

Why is the truck late?

Are the tomatoes still fresh?

Why this is hard

Incomplete/noisy/erroneous data

Need domain knowledge (“fresh”?)

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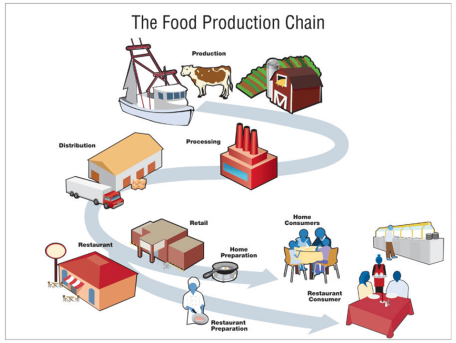

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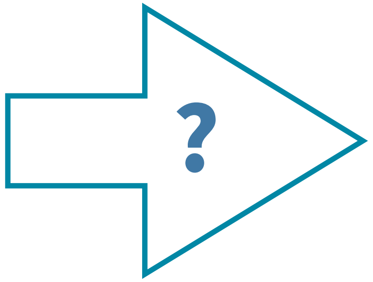

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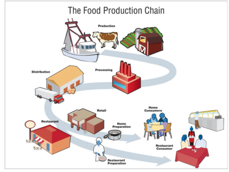

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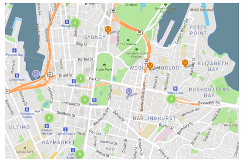

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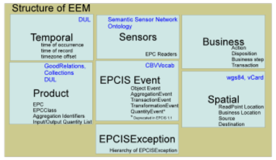


Structure of EEM

DUL
Temporal
time of occurrence
time of record
timezone offset

Semantic Sensor Network Ontology
Sensors
EPC Readers

Business
Action
Disposition
Business step
Transaction

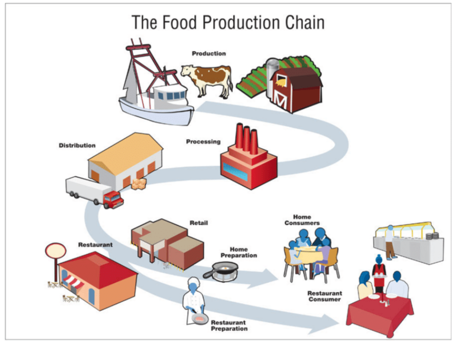
GoodRelations, Collections DUL
Product
EPC
EPCClass
Aggregation Identifiers
Input/Output Quantity List

CBVVocab
EPCIS Event
Object Event
AggregationEvent
TransactionEvent
TransformationEvent
QuantityEvent*
* Deprecated in EPCIS 1.1

wgs84, vCard
Spatial
ReadPoint Location
Business Location
Source
Destination

EPCISException
Hierarchy of EPCISException

Automated Reasoning for Situational Awareness



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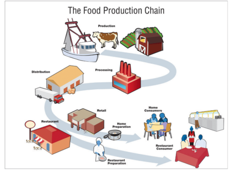
Domain *modelling* (first principles)
What-if *reasoning* and *explanations*



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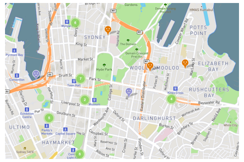

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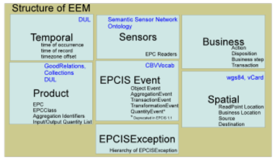

Stuck at warehouse / fresh

OR

Traffic jam / not fresh

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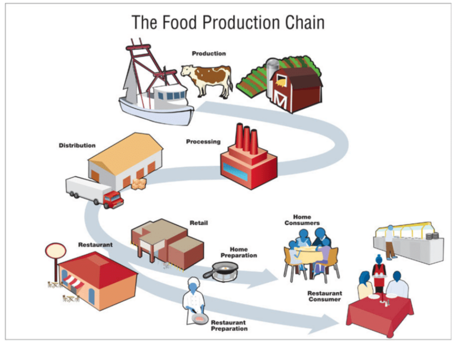

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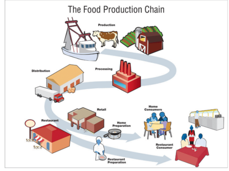

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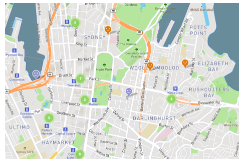

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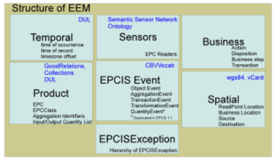

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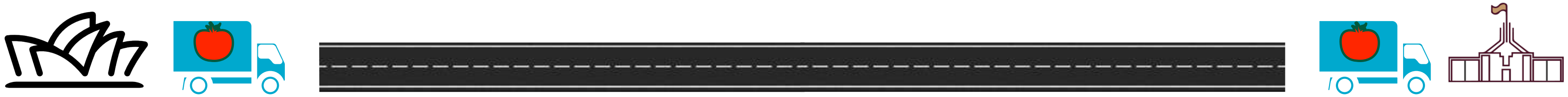
Implemented in the Fusemate system

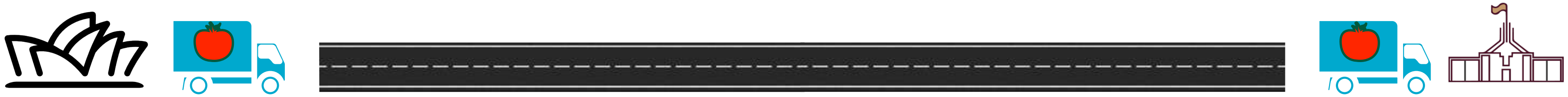
Demo



Observation: truck is in Sydney at the warehouse

T

Demo



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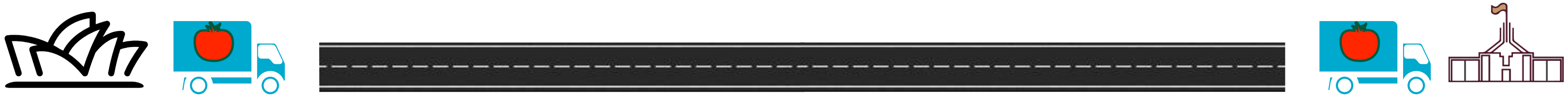

Observation: tomatoes are loaded

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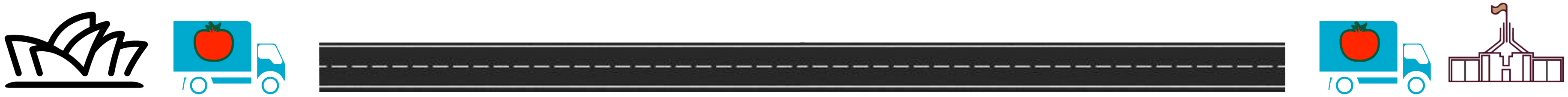

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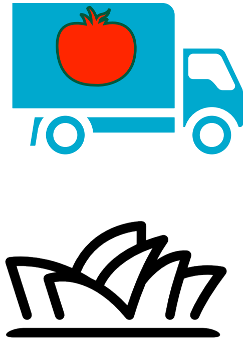

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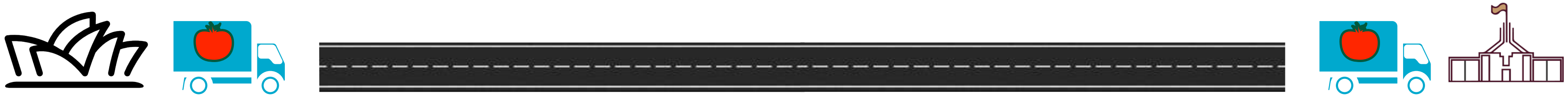

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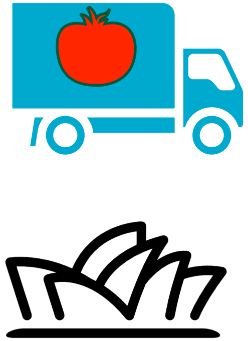

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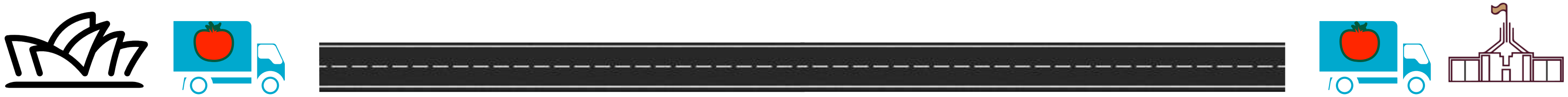

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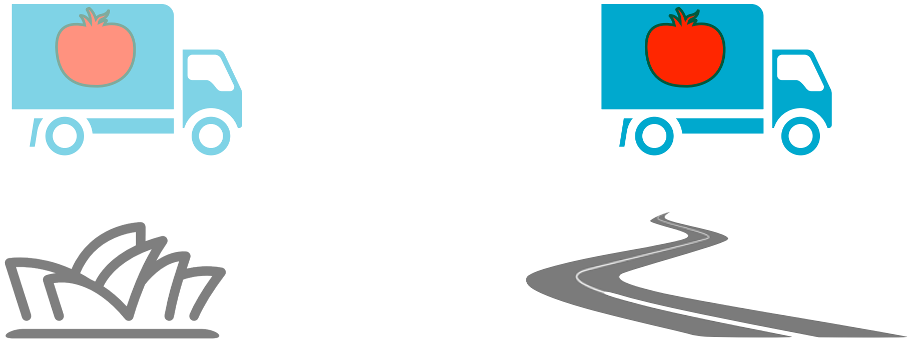
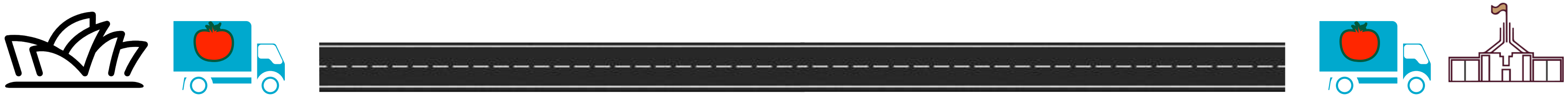


T **T+1**

Demo



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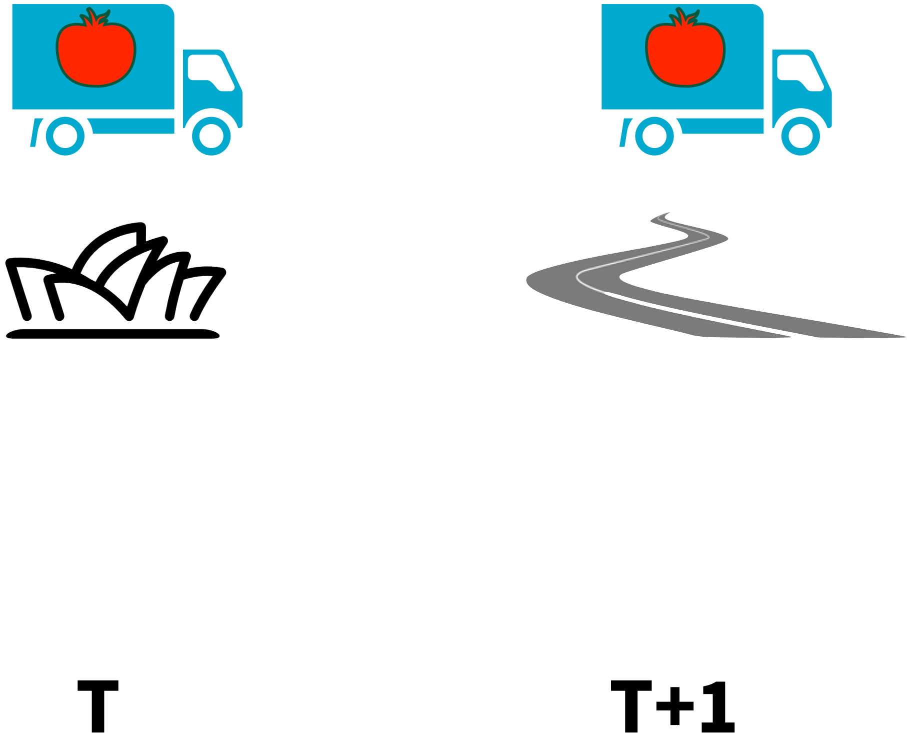

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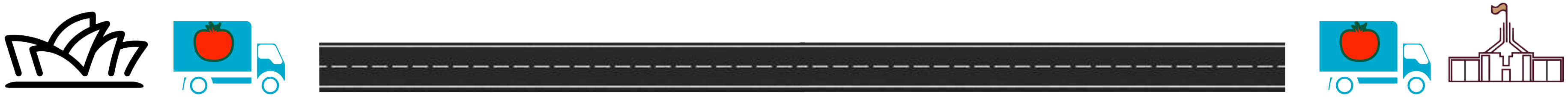

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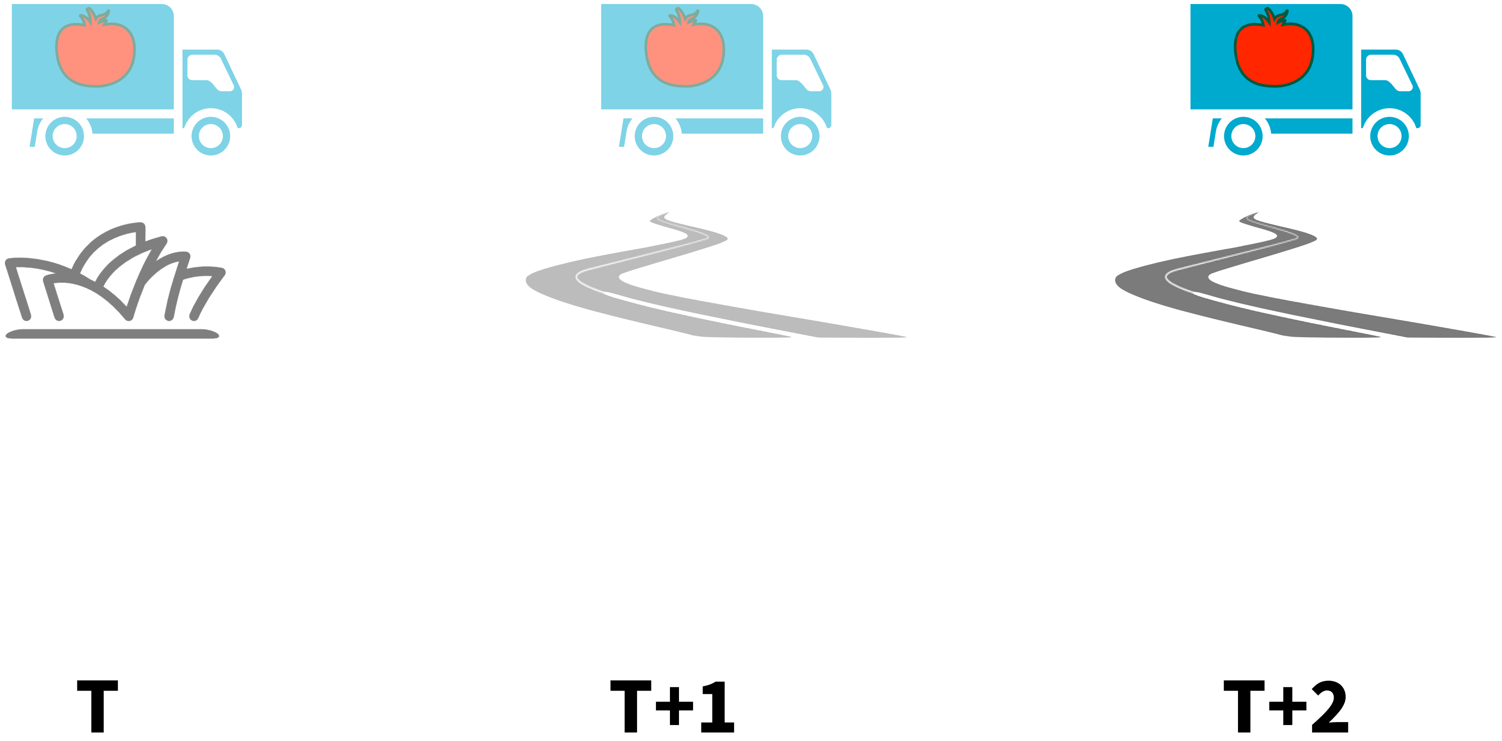

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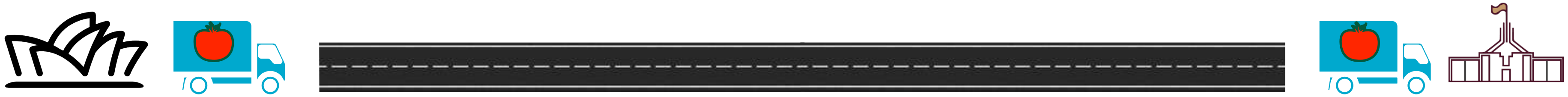
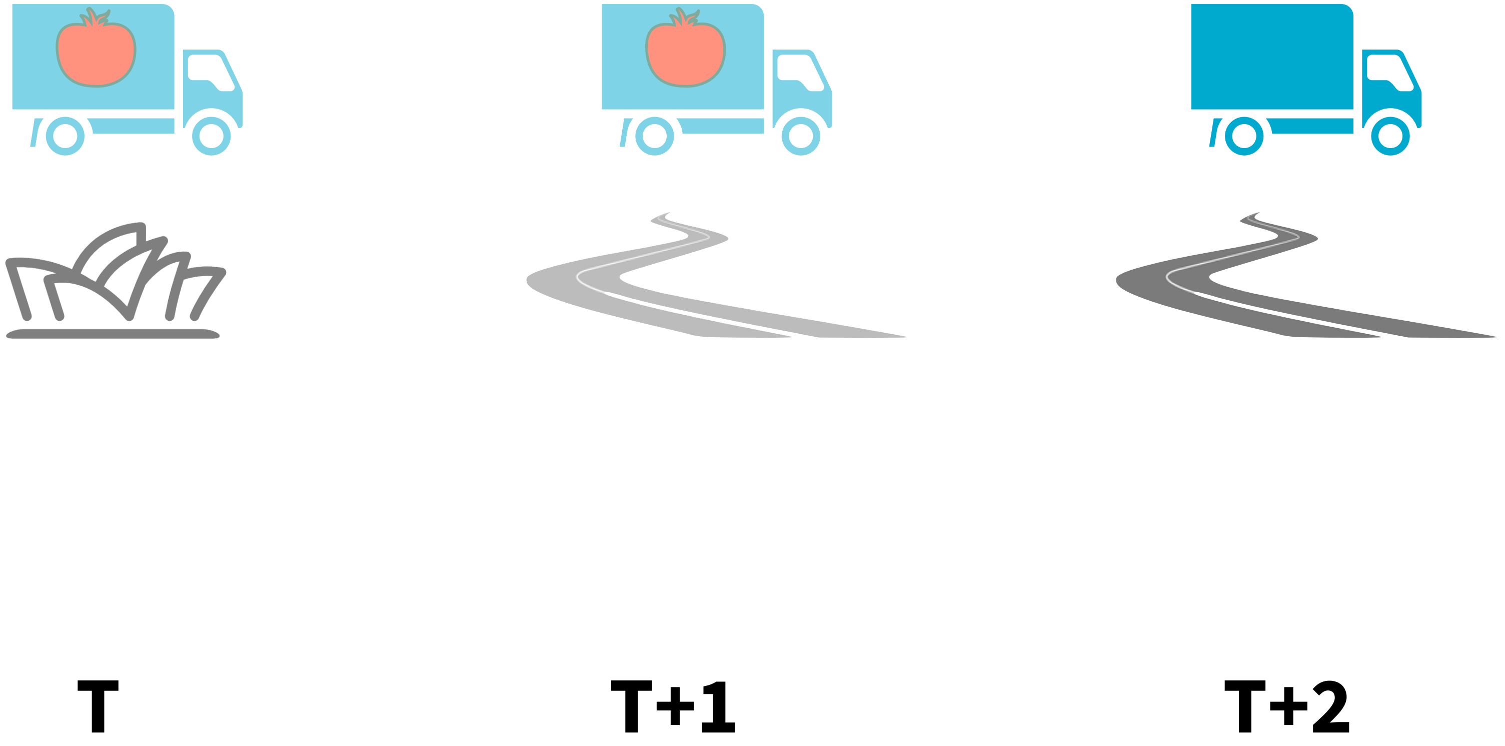


Conclusion: truck is on the road for too long - tomatoes are no longer fresh



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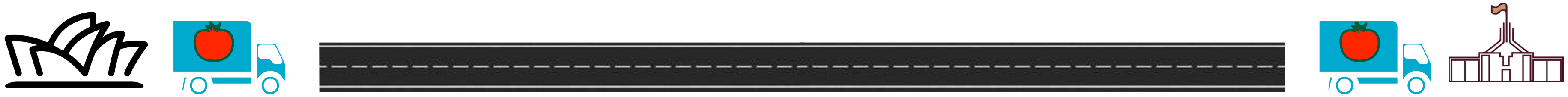

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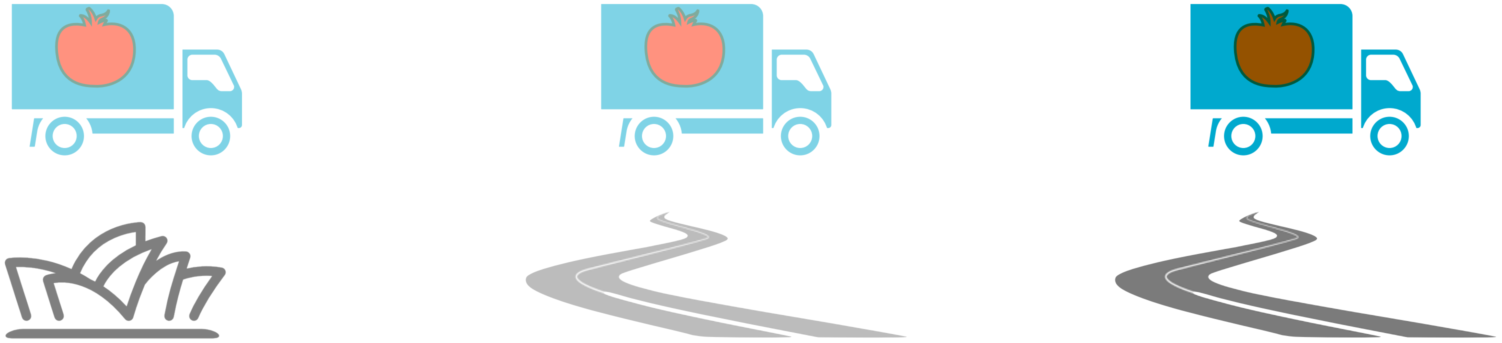


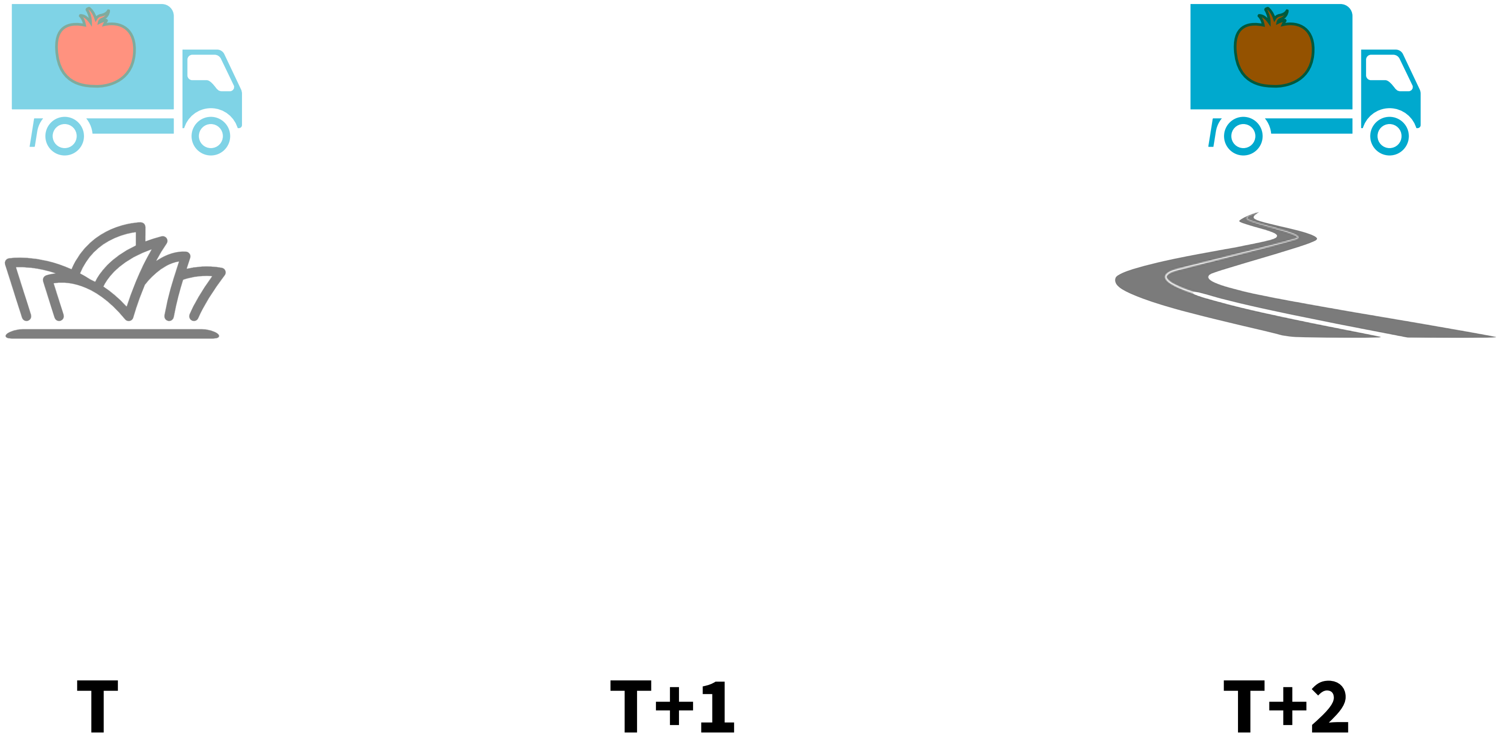
T

T+1

T+2

Demo

Report: actually, at T+1 truck was still in Sydney warehouse



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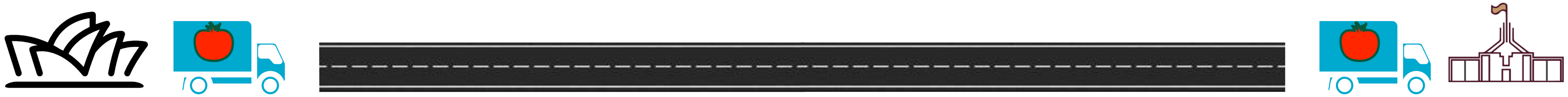

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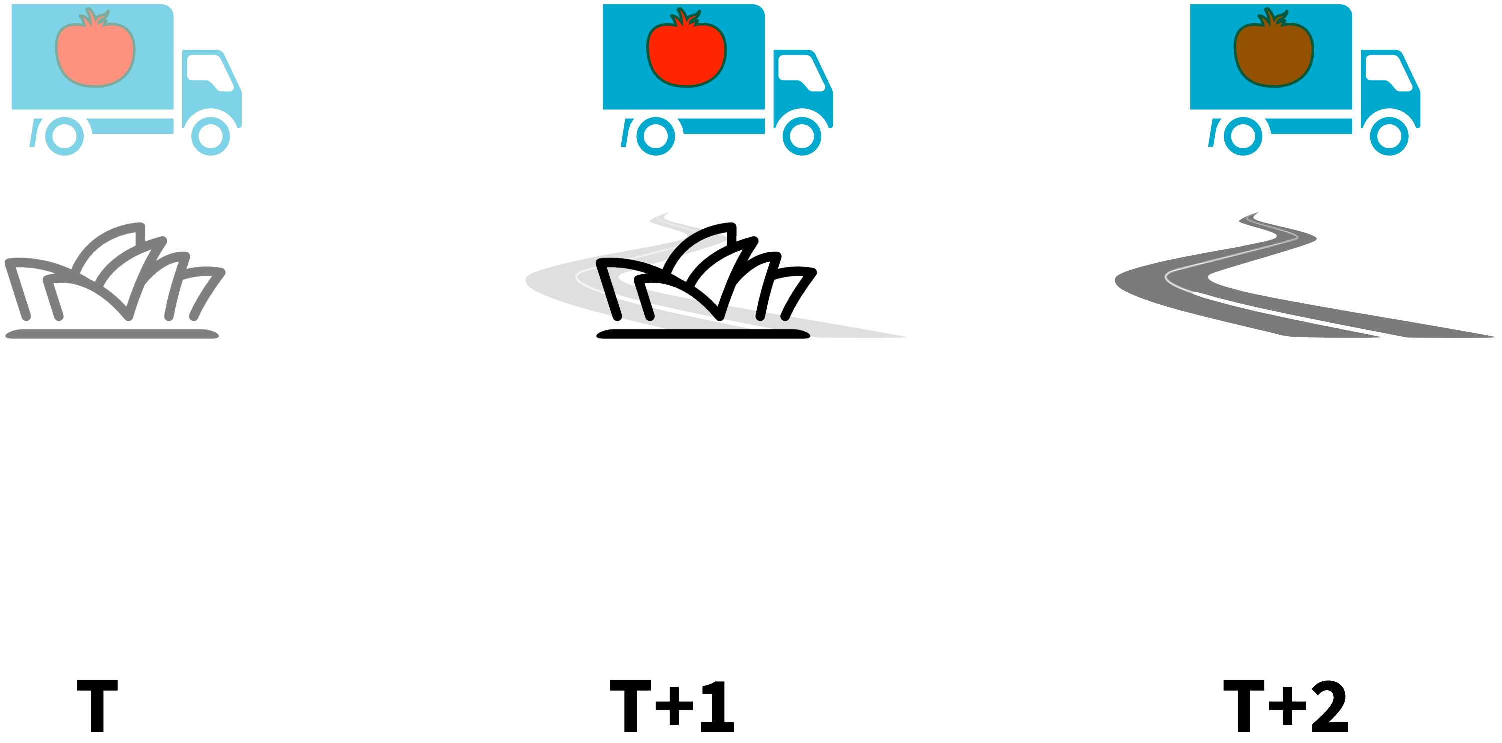

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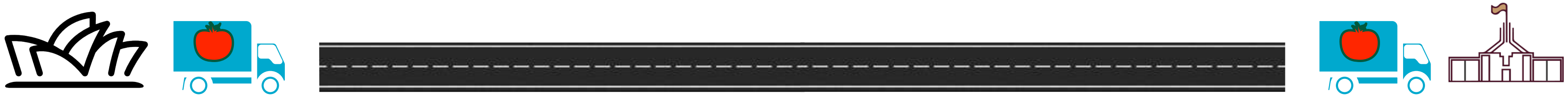
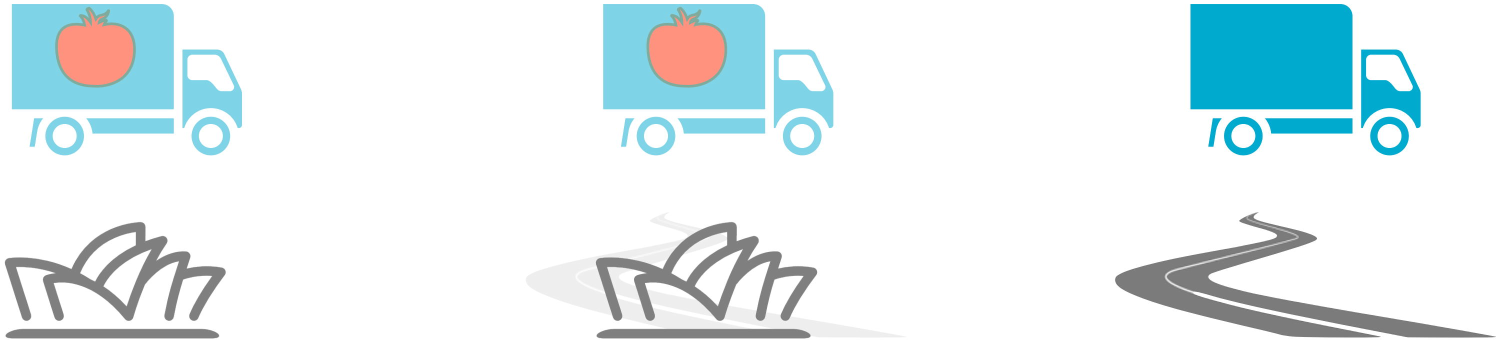


Conclusion: tomatoes are still fresh at T+2



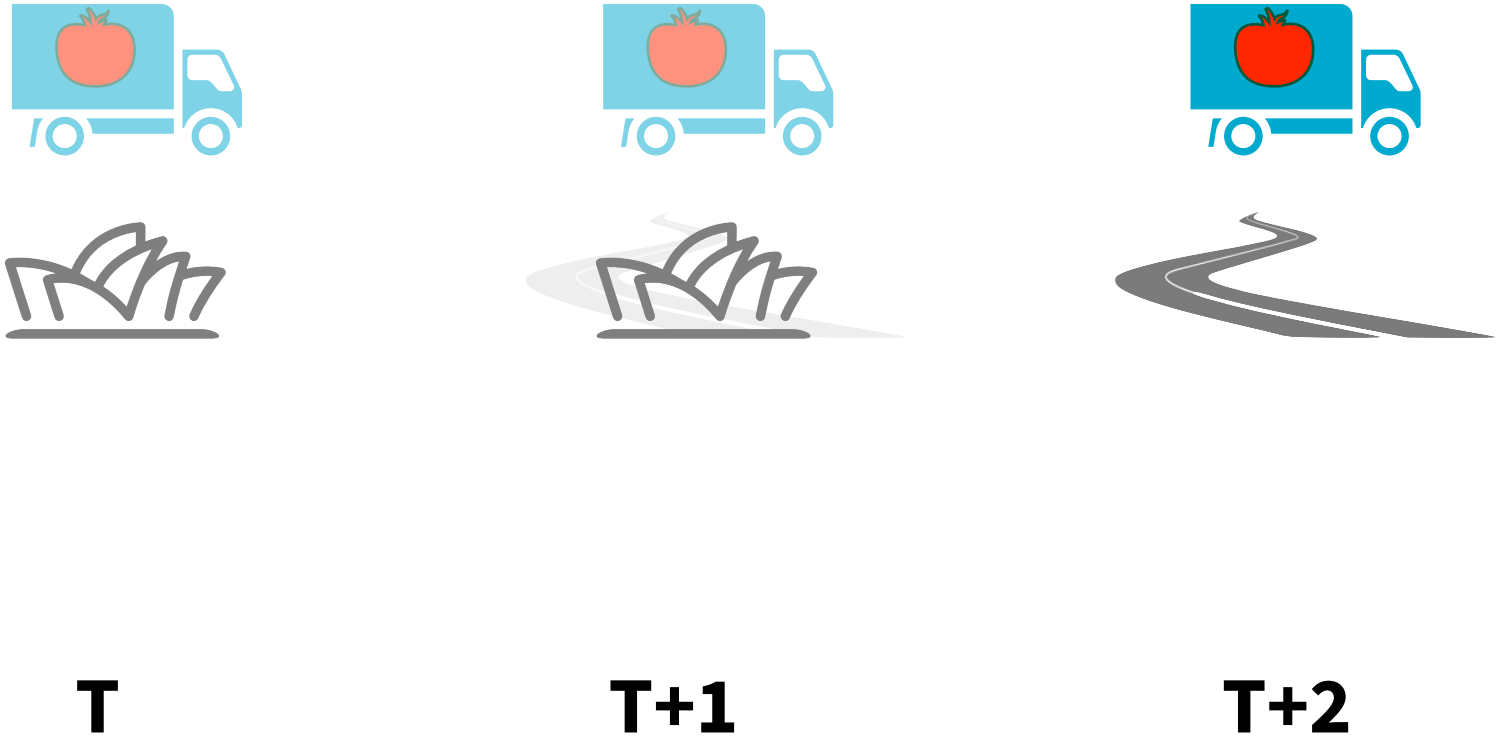
T

T+1

T+2

Demo

Conclusion: tomatoes are still fresh at T+2



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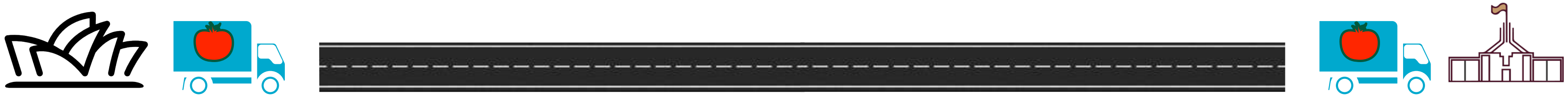
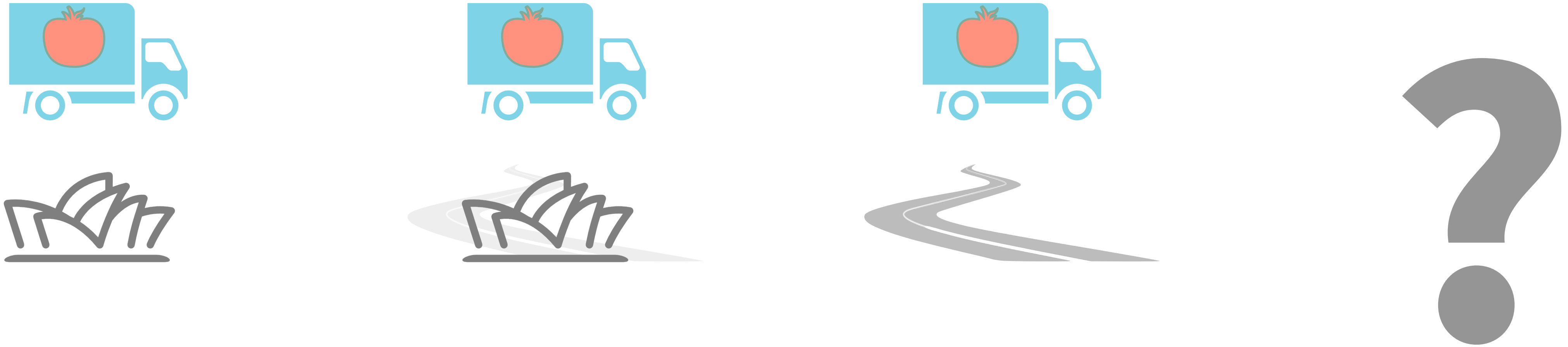


No information at T+3



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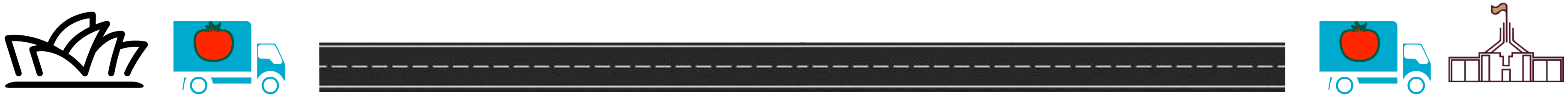
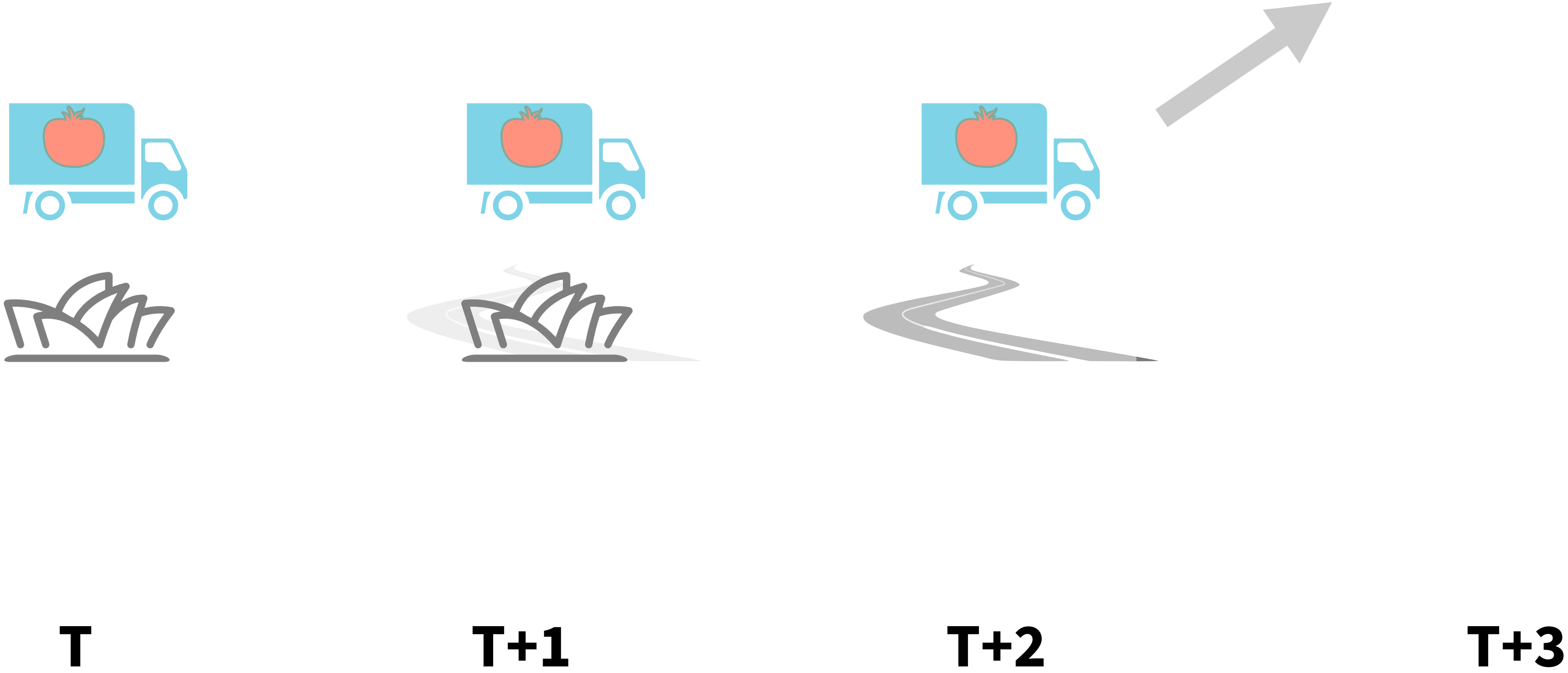


T+3: What if truck is on the road?



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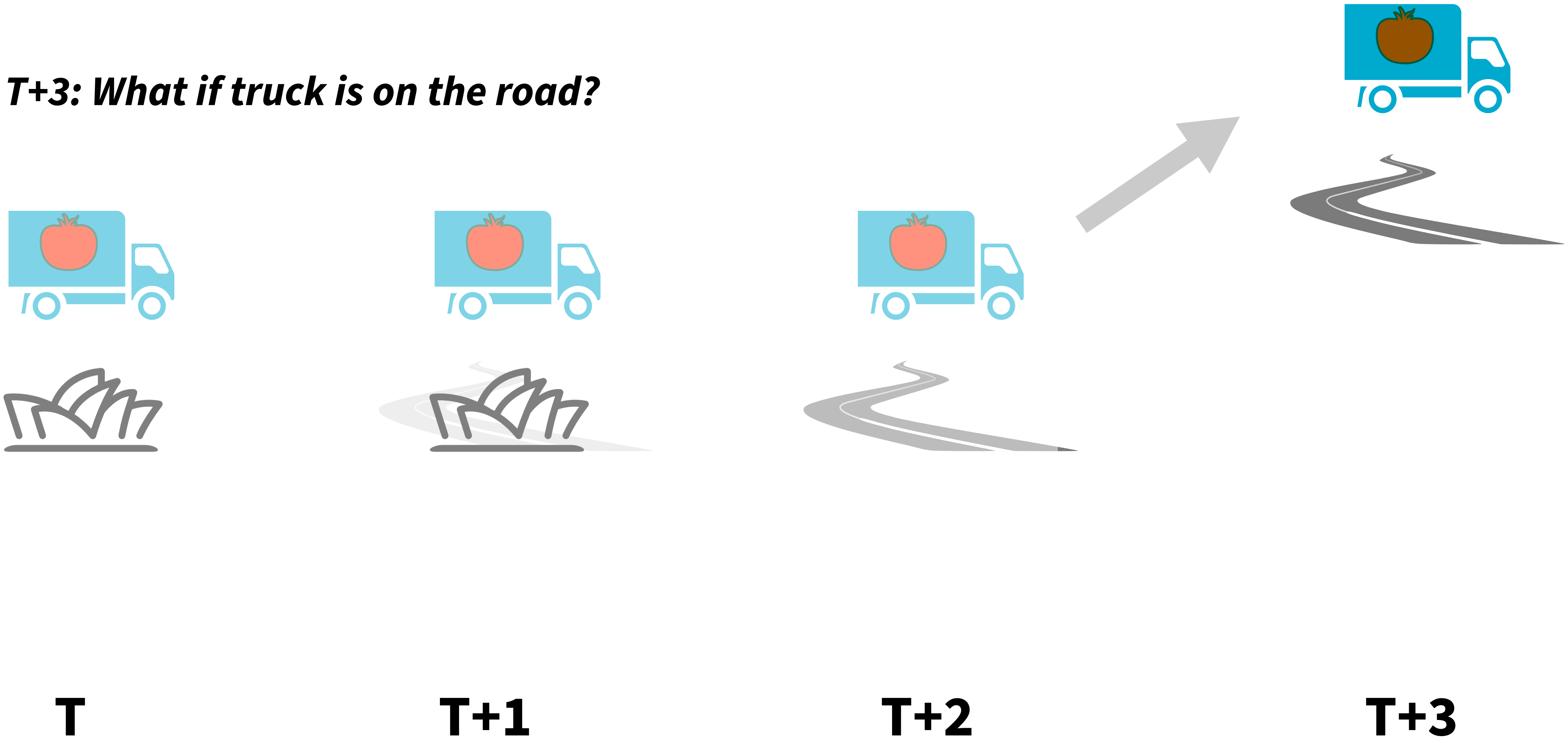
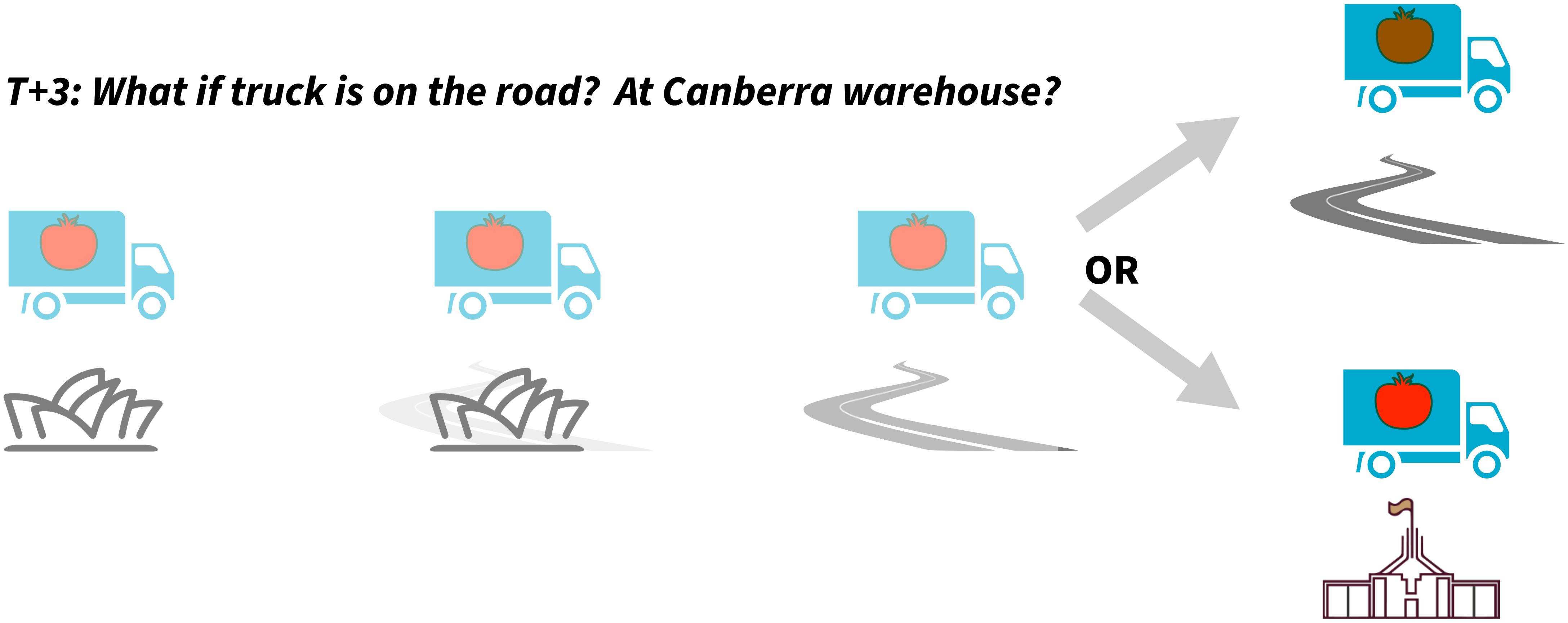


Demo

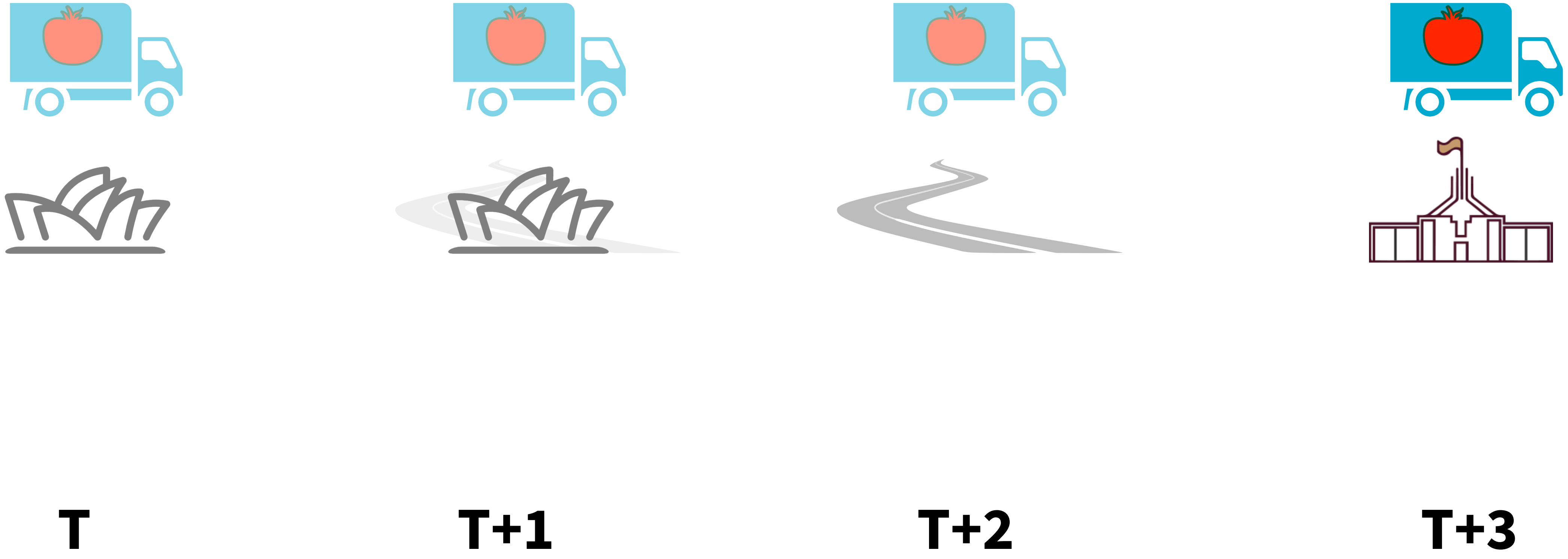
T+3: What if truck is on the road? At Canberra warehouse?



T T+1 T+2 T+3

Demo

Report: truck at Canberra warehouse



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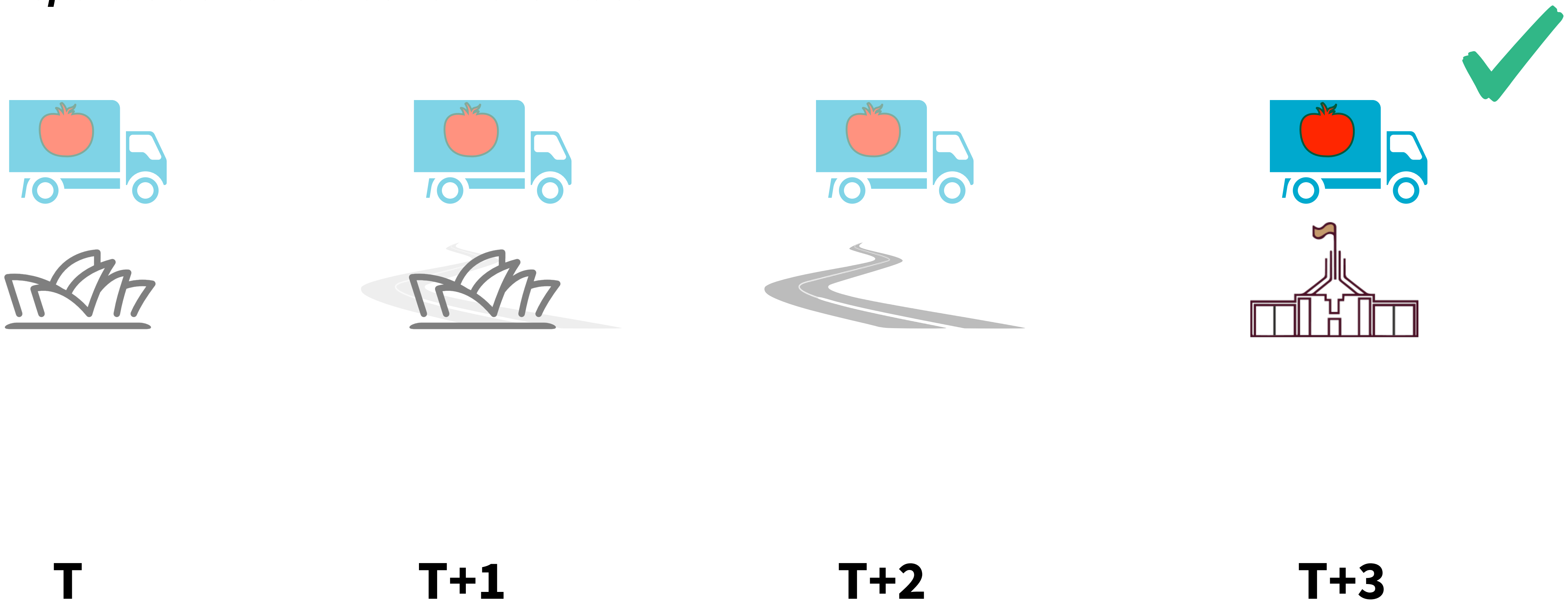

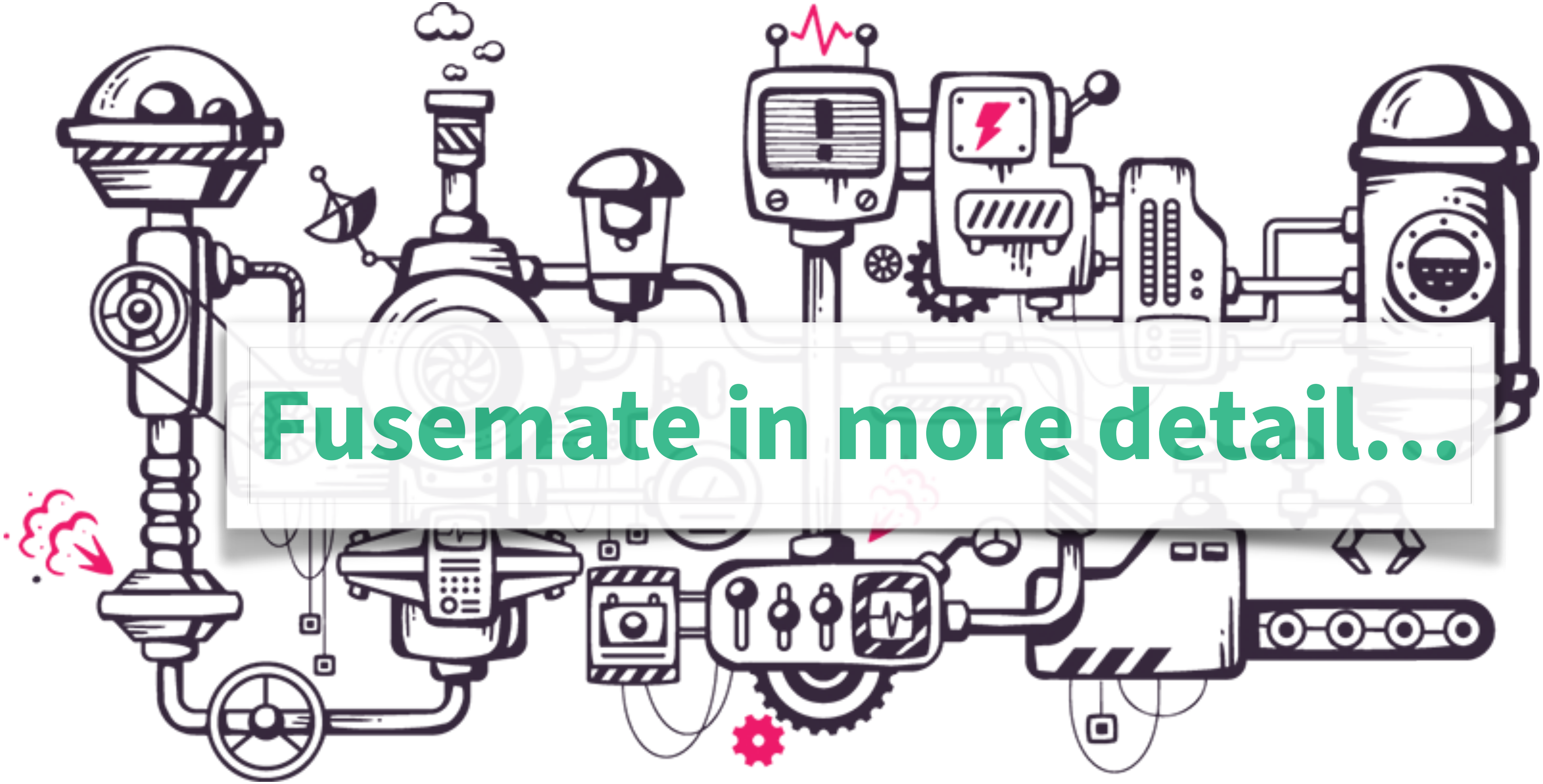

Fusemate in more detail...

Fusemate Model = If-Then Rules

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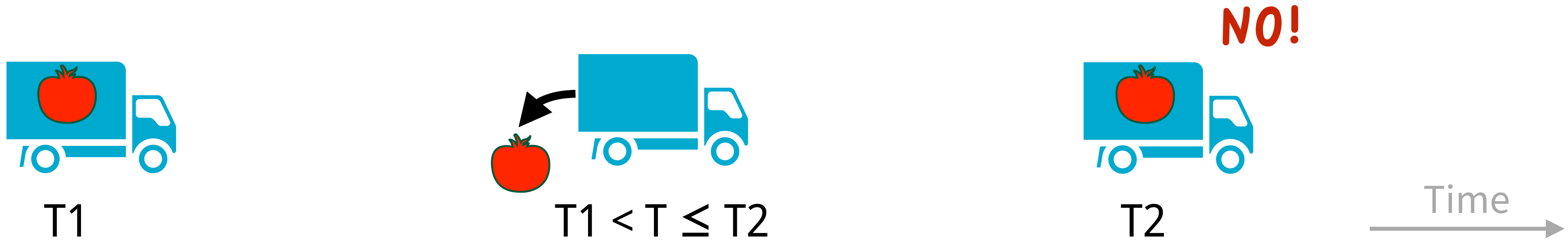

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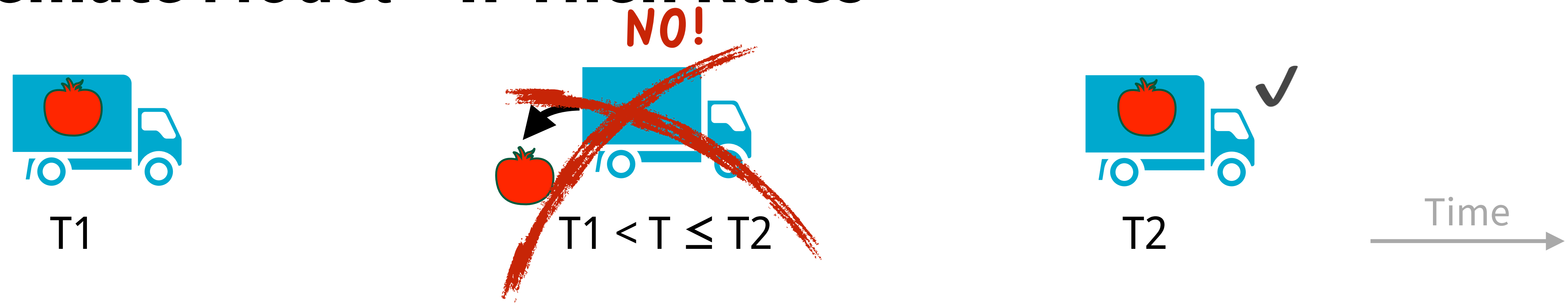


NO!

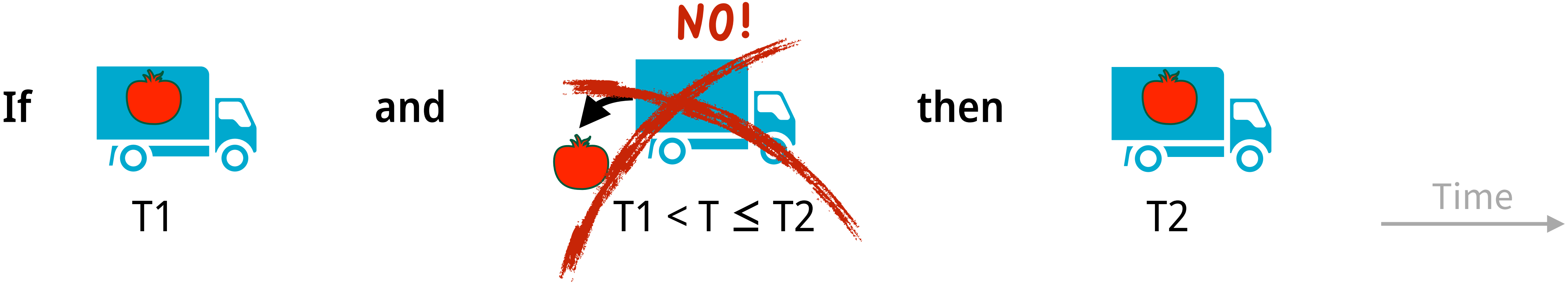
T1

T1 < T ≤ T2

T2

Time

Fusemate Model = If-Then Rules



NO!

If T1 and T1 < T ≤ T2 then T2

Time

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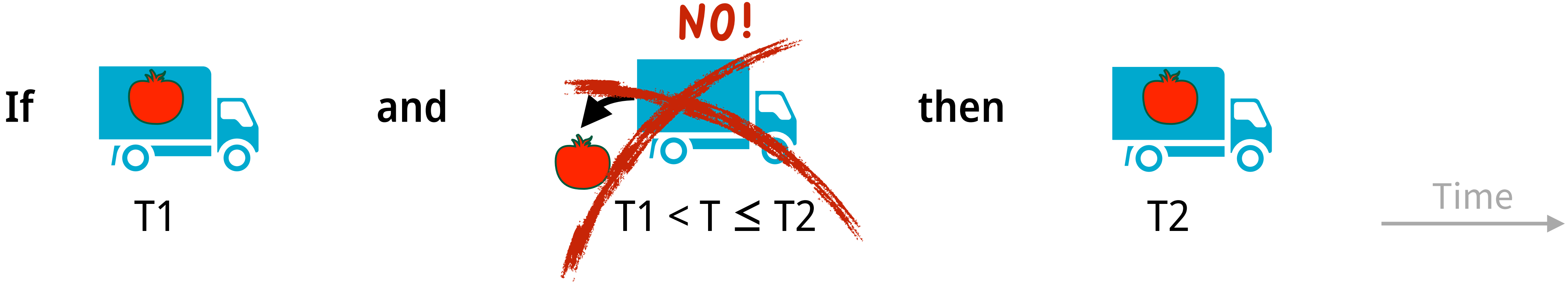

If T1 and NO! T1 < T ≤ T2 then T2

Time

If in(T1, B, C) **&** T1 < T2 **NOT exists** T **s.th.** T1 < T ≤ T2 **&** unload(T, B, C) **then** in(T2, B, C)

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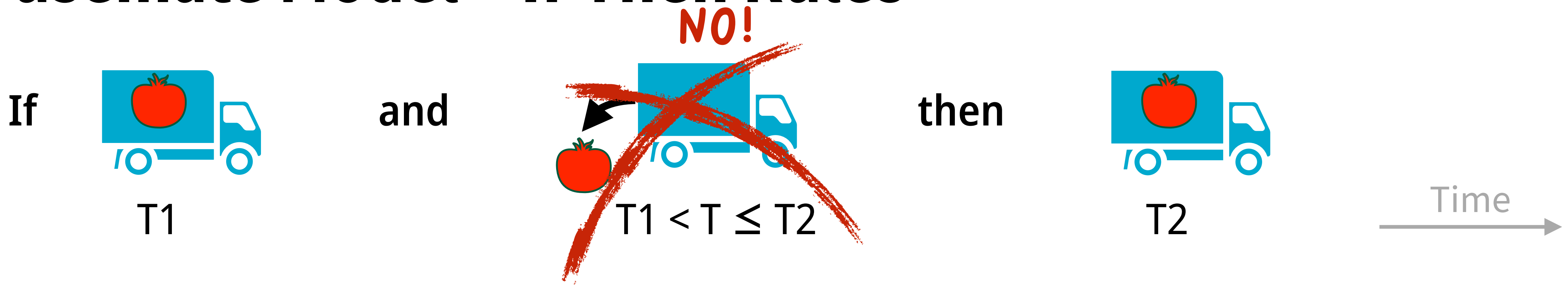

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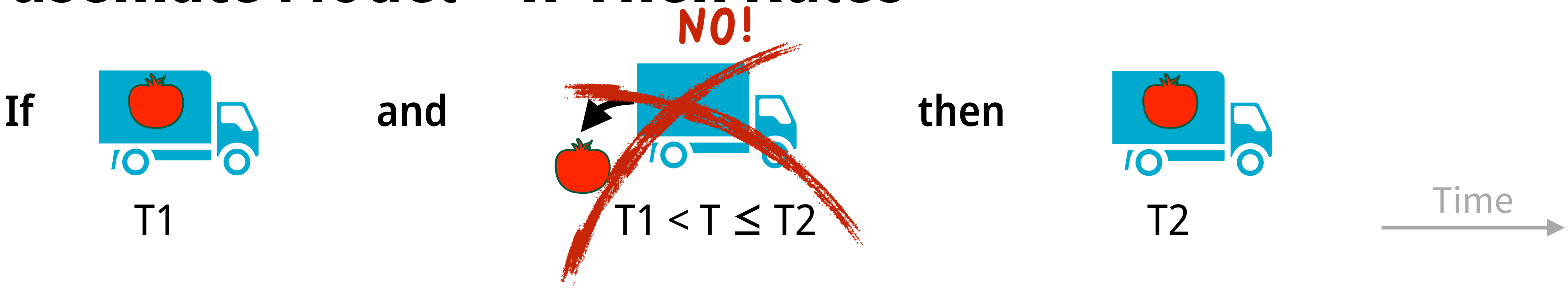

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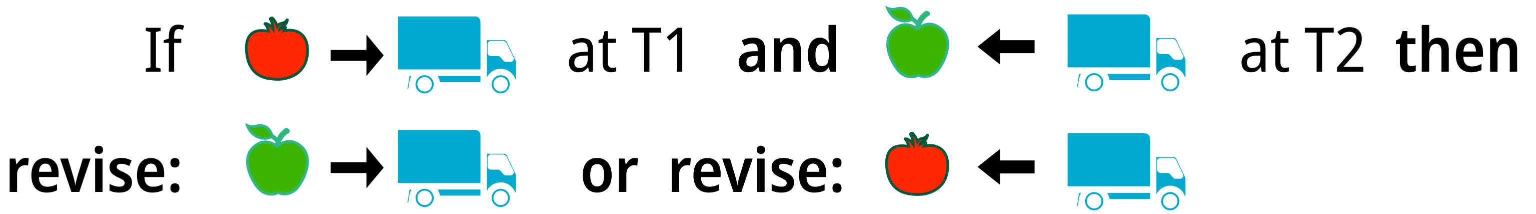
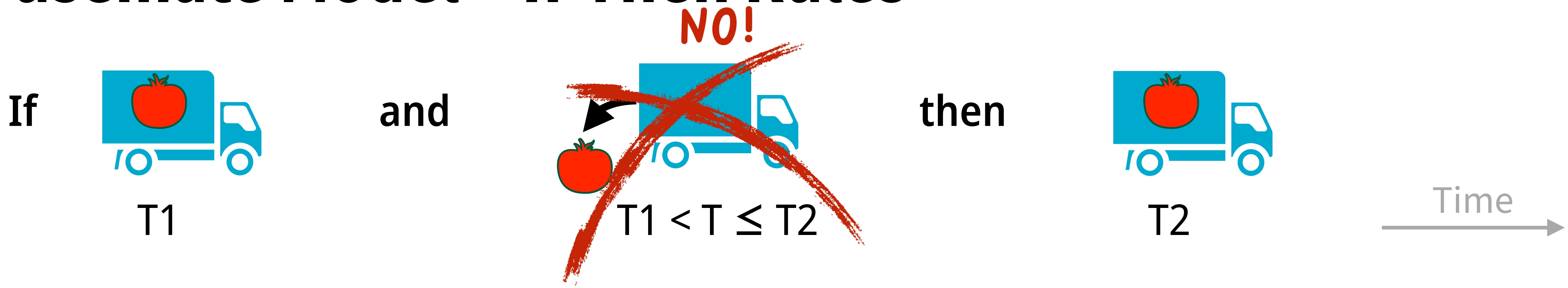


If → at T1 **and** ← at T2 **then**

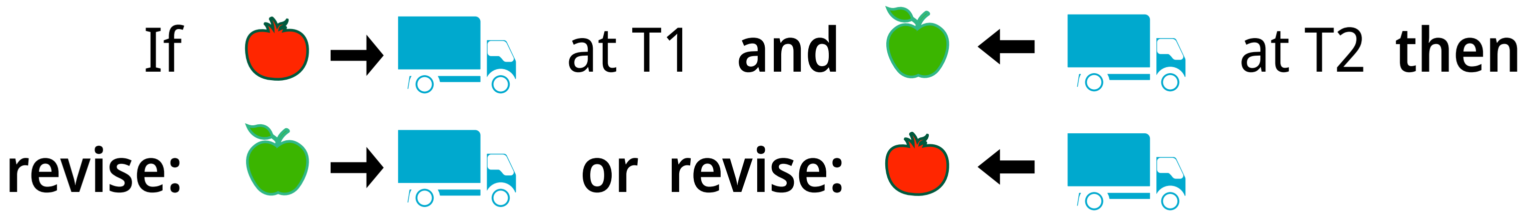
revise: → **or revise:** ←

Fusemate Model = If-Then Rules



If in(T1, B, C) **&** T1 < T2 **NOT exists** T **s.th.** T1 < T ≤ T2 **&** unload(T, B, C) **then** in(T2, B, C)

default reasoning: “not known” (≠ “known not”)



A model is a set of if-then rules plus …

Model = If-Then Rules + Scala Class Hierarchy

Scala code

```
abstract class Item { val perishable: Boolean }
abstract class Fruit extends Item { val perishable = true }

abstract class Vehicle { val speed: Int }

case class Truck(id: Int, time: DateTime, load: Set[Item]) extends  Vehicle with LogicFact {
   val speed = 80
   val rules = List(
            Truck(id, t, load - item) :- Unload(id, t, item), ... )
   def hasPerishableLoad = load contains { _.perishable = true }
}
```

Model = If-Then Rules + Scala Class Hierarchy

Scala code

```
abstract class Item { val perishable: Boolean }
abstract class Fruit extends Item { val perishable = true }

abstract class Vehicle { val speed: Int }

case class Truck(id: Int, time: DateTime, load: Set[Item]) extends  Vehicle with LogicFact {
  val speed = 80
  val rules = List(
        Truck(id, t, load - item) :- Unload(id, t, item), ... )
  def hasPerishableLoad = load contains { _.perishable = true }
}
```

If-then rule extension

Model = If-Then Rules + Scala Class Hierarchy

```
case class Truck(id: Int, time: DateTime, load: Set[Item]) … {
  …
  @rules(id, time, load)
  val rules = List(
    Fail :-
      Unload(id, time, item),
      IF (! load contains items)

    Truck(id, next, load - item) :-
      Step(next, time),
      Unload(id, time, item),
      NOT(t < time, Unload(id, t, item) )
  )
}
```

Model = If-Then Rules + Scala Class Hierarchy

Scala library “set”

```
case class Truck(id: Int, time: DateTime, load: Set[Item]) ... {
  ...
  @rules(id, time, load)
  val rules = List(
    Fail :-
      Unload(id, time, item),
      IF (! load contains items)

    Truck(id, next, load - item) :-
      Step(next, time),
      Unload(id, time, item),
      NOT(t < time, Unload(id, t, item) )
  )
}
```

Model = If-Then Rules + Scala Class Hierarchy

Scala library “set”

Macro annotation

```
case class Truck(id: Int, time: DateTime, load: Set[Item]) ... {
  ...
  @rules(id, time, load)
  val rules = List(
    Fail :-
      Unload(id, time, item),
      IF (! load contains items)

    Truck(id, next, load - item) :-
      Step(next, time),
      Unload(id, time, item),
      NOT(t < time, Unload(id, t, item) )
  )
}
```

Model = If-Then Rules + Scala Class Hierarchy

Scala library "set"

```
case class Truck(id: Int, time: DateTime, load: Set[Item]) ... {
  ...
  @rules(id, time, load)
```

Macro annotation

```
  val rules = List(
    Fail :-
      Unload(id, time, item),
      IF (! load contains items)

    Truck(id, next, load - item) :-
      Step(next, time),
      Unload(id, time, item),
      NOT(t < time, Unload(id, t, item) )
  )
}
```

Expansion

```
case (Step(next, time1), Unload(id1, time2, item)) if
  time1 == time && time2 == time && id1 == id
  ! (model exists {
      case Unload(id2, t, item1) if id2 == id &&
                         t < time && item1 == item => true
      case _ => false
    }
  }) => Truck(id, next, load - item)
```

Modelling Paradigm Summary

Rules

- ☑ **Inferences** on basis of incomplete information
- ☑ Derive **multiple** plausible explanations
- ☑ **Fix** erroneous event data and revise explanations

Declarative

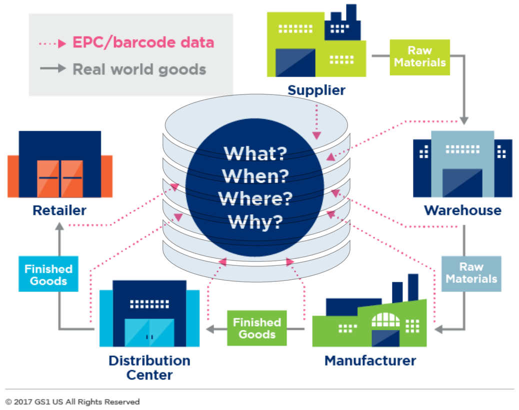
Scala

- ☑ **Rich data structures**
- ☑ **Java connectivity**
- ☑ **Inference engine**

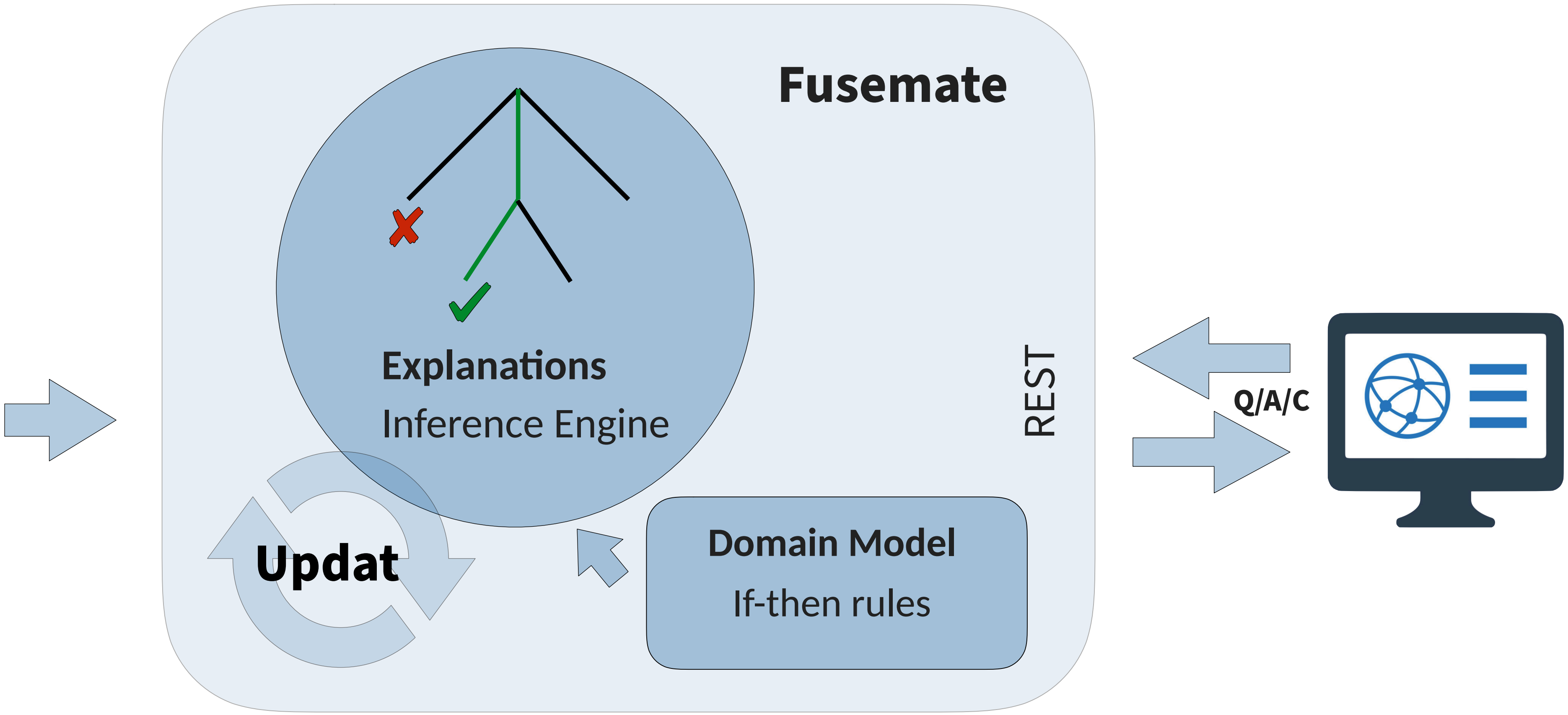
Infrastruture

CSIRO DATA 61

System Architecture



EPCIS Events



Fusemate

Explanations

Inference Engine

Updat

Domain Model

If-then rules

REST

Q/A/C

Domain Model - e.g., *If item I is unpacked from a container C at time T then I must have been packed into C at some time S < T*

EPCIS Events - EPCIS events are sent to fusemate as they become available

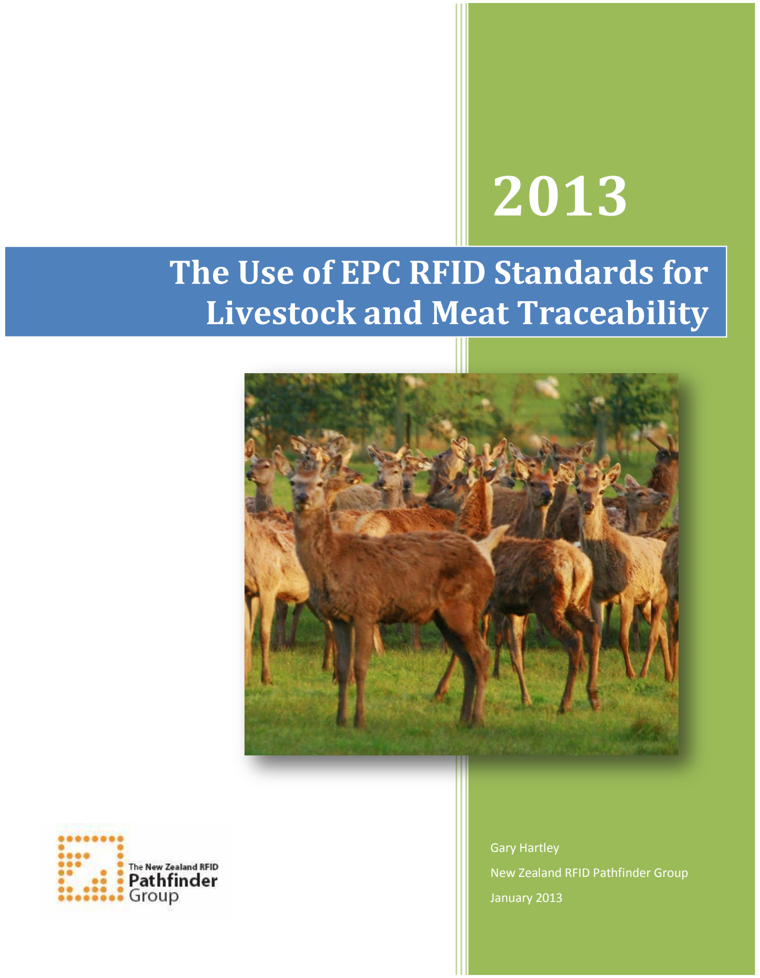
Explanations - The inference engine derives a set of plausible models consistent with the EPCIS events so far

Q/A/C - *Where was item I at time T? Item I was unpacked from container C at time T and loc L. Item I has never arrived at L!*

Update - Plausible models are updated on every new EPCIS event and command provided by user

Case Study

Case Study - Deer Supply Chain



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The Use of EPC RFID Standards for Livestock and Meat Traceability

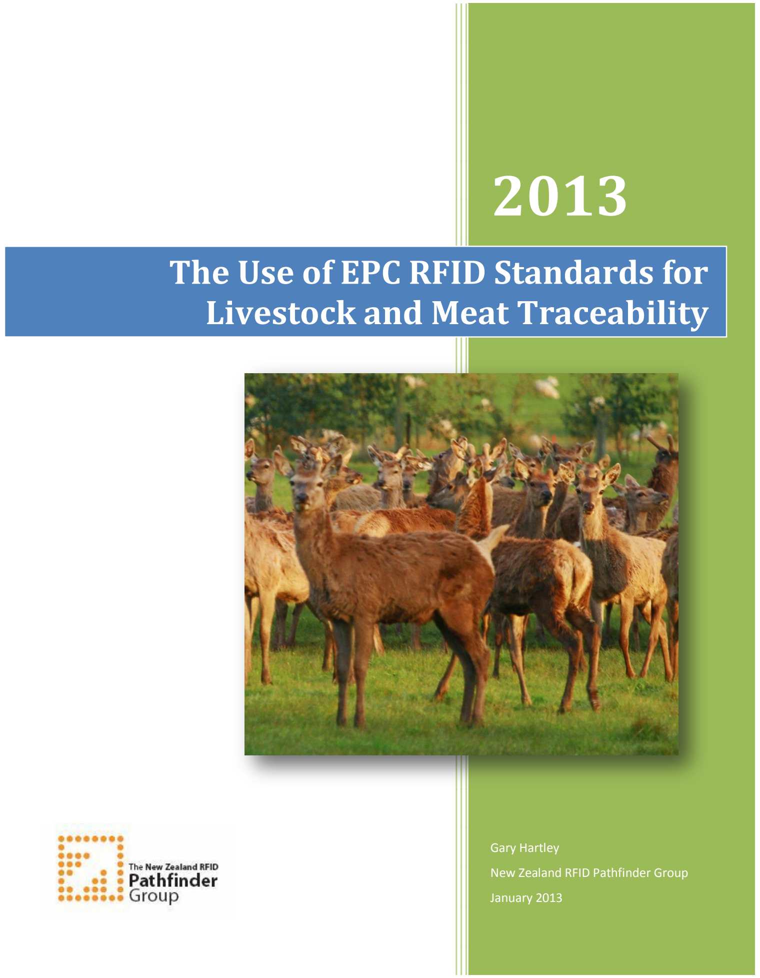
The New Zealand RFID Pathfinder Group

Gary Hartley

New Zealand RFID Pathfinder Group

January 2013

Case Study - Deer Supply Chain



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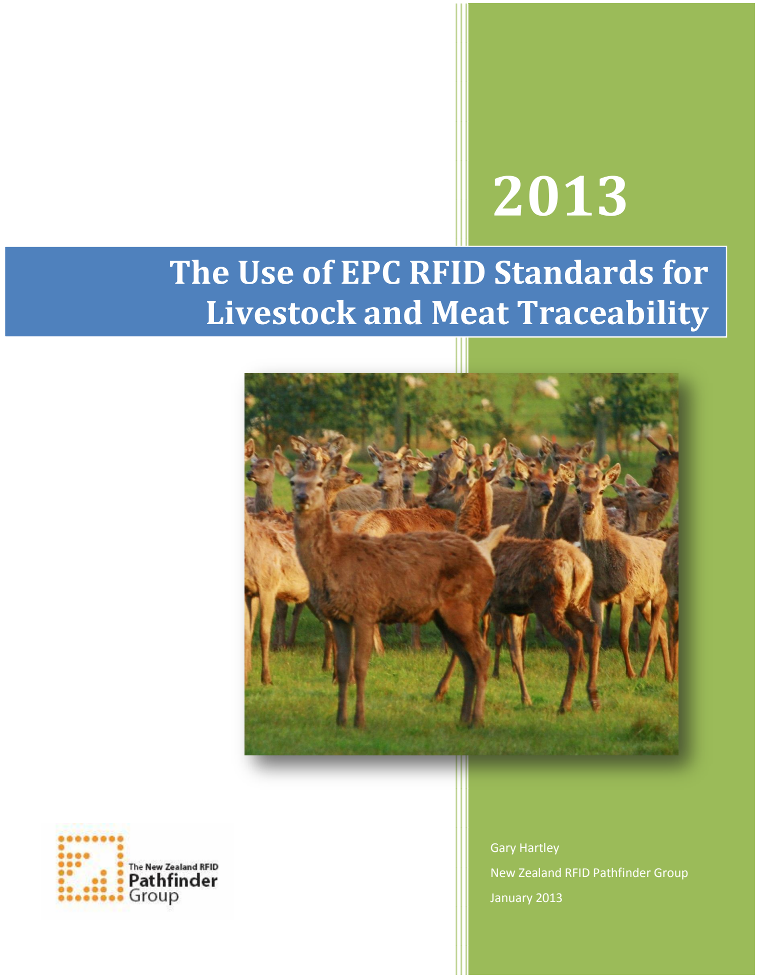
12 events - from farm (NZ) to retailer (DE) encoded in EPCIS

Case Study - Deer Supply Chain



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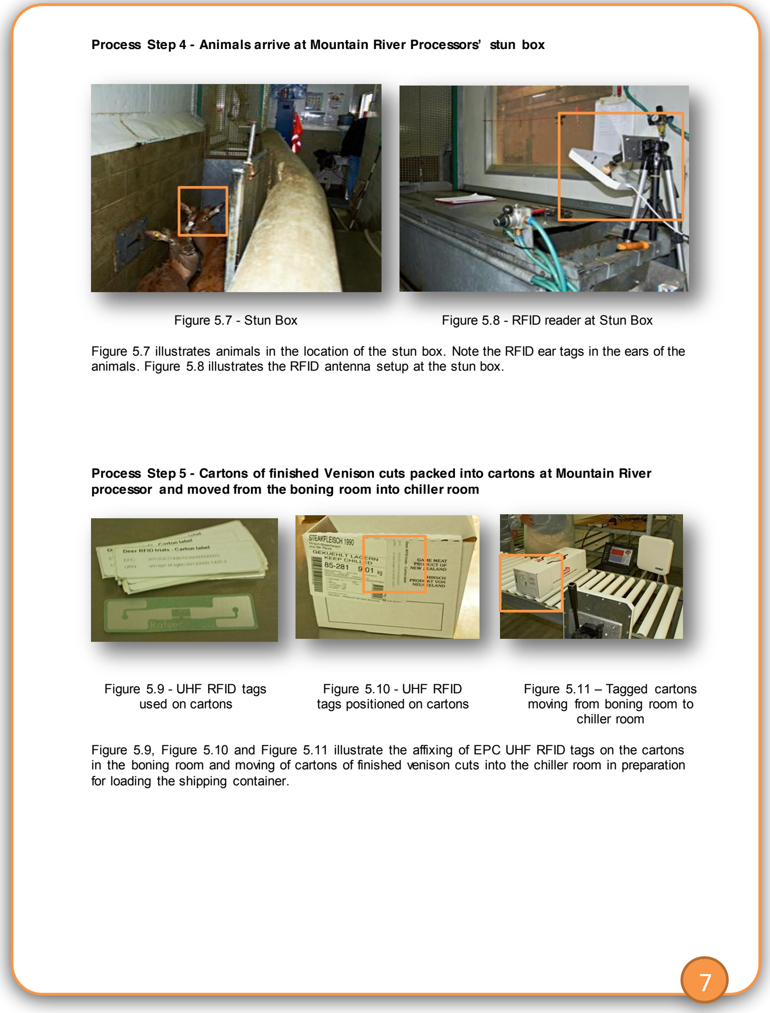


Process Step 4 - Animals arrive at Mountain River Processors' stun box

Figure 5.7 - Stun Box

Figure 5.8 - RFID reader at Stun Box

Figure 5.7 illustrates animals in the location of the stun box. Note the RFID ear tags in the ears of the animals. Figure 5.8 illustrates the RFID antenna setup at the stun box.

Process Step 5 - Cartons of finished Venison cuts packed into cartons at Mountain River processor and moved from the boning room into chiller room

Figure 5.9 - UHF RFID tags used on cartons

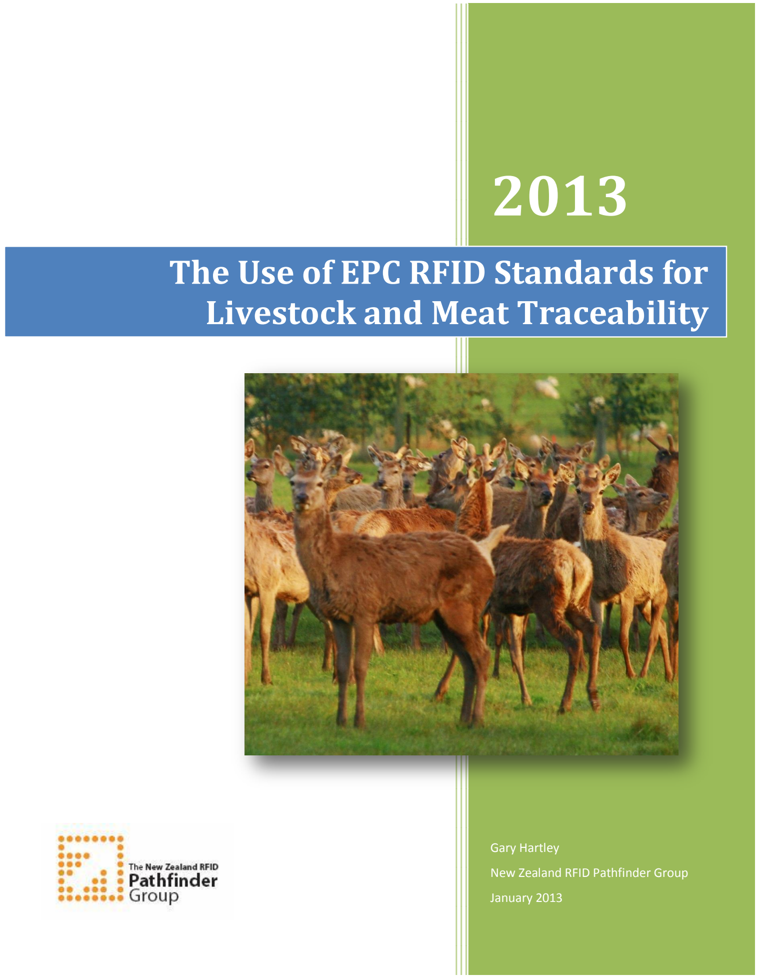
Figure 5.10 - UHF RFID tags positioned on cartons

Figure 5.11 – Tagged cartons moving from boning room to chiller room

Figure 5.9, Figure 5.10 and Figure 5.11 illustrate the affixing of EPC UHF RFID tags on the cartons in the boning room and moving of cartons of finished venison cuts into the chiller room in preparation for loading the shipping container.

12 events - from farm (NZ) to retailer (DE) encoded in EPCIS

Case Study - Deer Supply Chain



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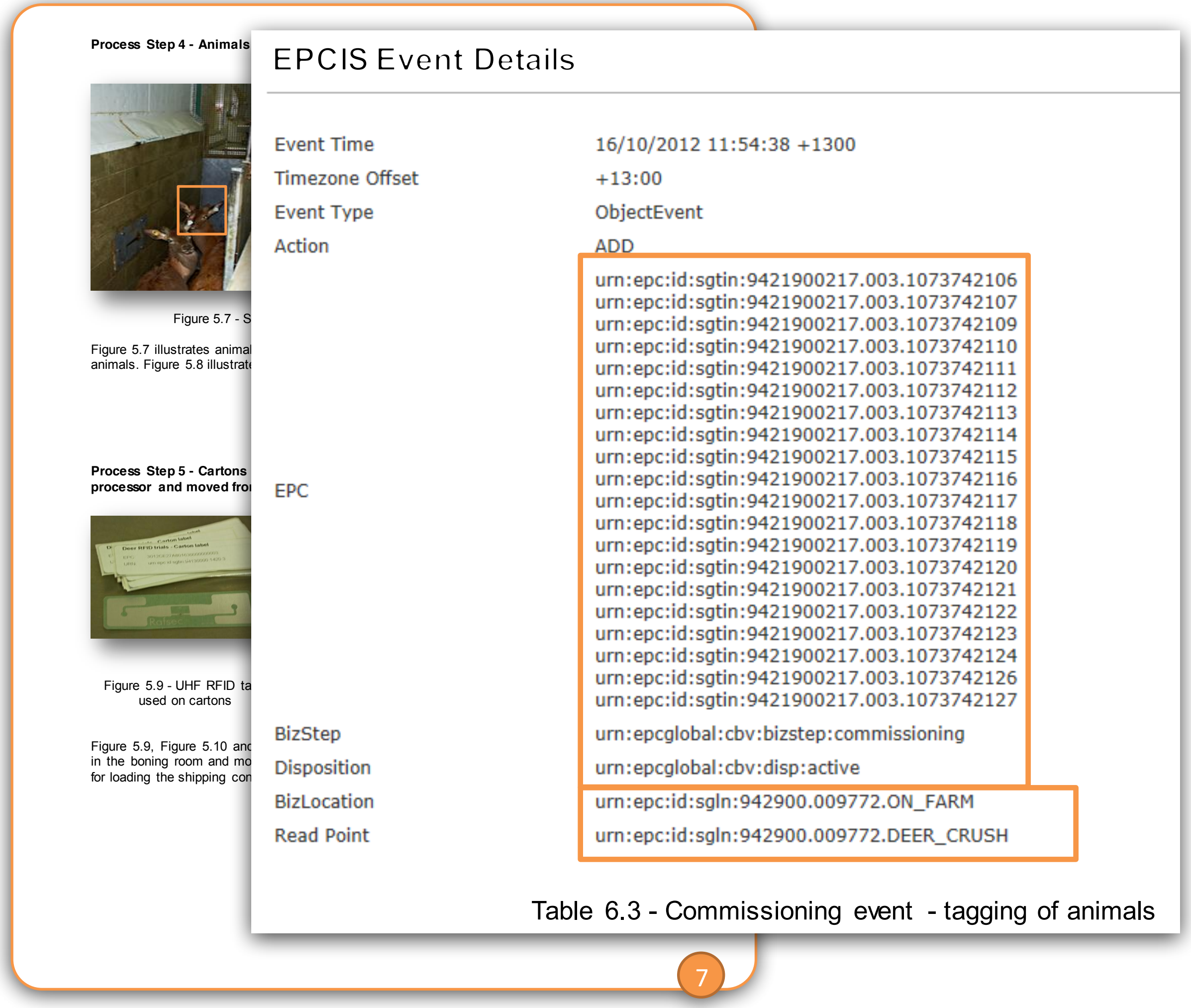


Process Step 4 - Animals

Figure 5.7 - S

Figure 5.7 illustrates animal animals. Figure 5.8 illustrat

Process Step 5 - Cartons processor and moved fro

Figure 5.9 - UHF RFID ta used on cartons

Figure 5.9, Figure 5.10 and in the boning room and mo for loading the shipping con

7

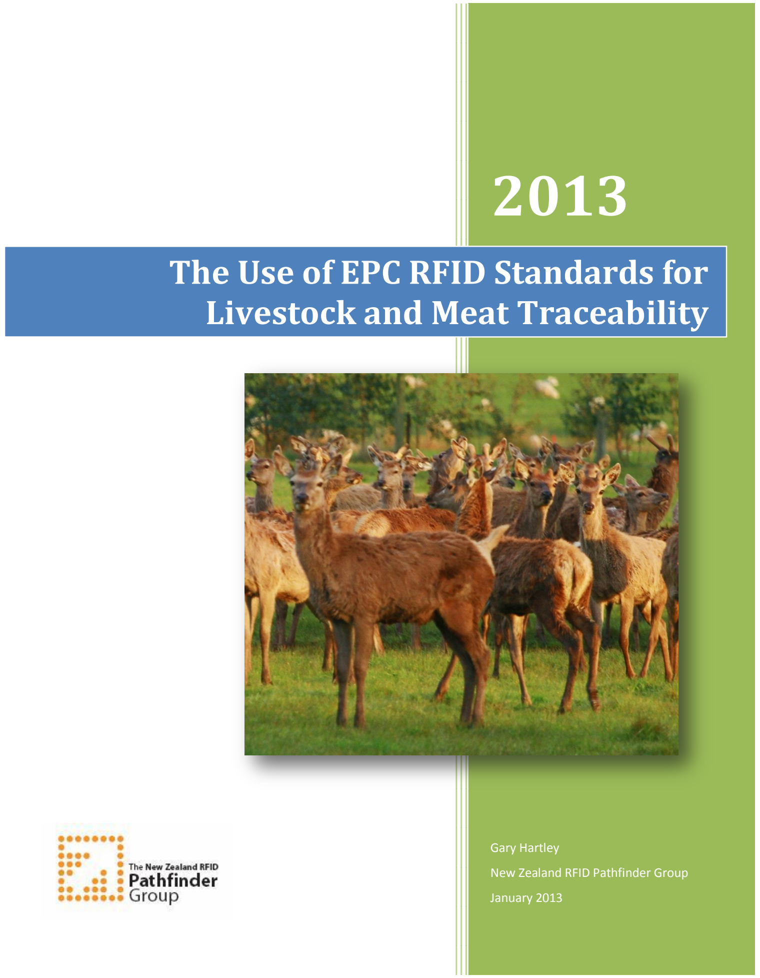
EPCIS Event Details

Event Time	16/10/2012 11:54:38 +1300
Timezone Offset	+13:00
Event Type	ObjectEvent
Action	ADD
EPC	urn:epc:id:sgtin:9421900217.003.1073742106 urn:epc:id:sgtin:9421900217.003.1073742107 urn:epc:id:sgtin:9421900217.003.1073742109 urn:epc:id:sgtin:9421900217.003.1073742110 urn:epc:id:sgtin:9421900217.003.1073742111 urn:epc:id:sgtin:9421900217.003.1073742112 urn:epc:id:sgtin:9421900217.003.1073742113 urn:epc:id:sgtin:9421900217.003.1073742114 urn:epc:id:sgtin:9421900217.003.1073742115 urn:epc:id:sgtin:9421900217.003.1073742116 urn:epc:id:sgtin:9421900217.003.1073742117 urn:epc:id:sgtin:9421900217.003.1073742118 urn:epc:id:sgtin:9421900217.003.1073742119 urn:epc:id:sgtin:9421900217.003.1073742120 urn:epc:id:sgtin:9421900217.003.1073742121 urn:epc:id:sgtin:9421900217.003.1073742122 urn:epc:id:sgtin:9421900217.003.1073742123 urn:epc:id:sgtin:9421900217.003.1073742124 urn:epc:id:sgtin:9421900217.003.1073742126 urn:epc:id:sgtin:9421900217.003.1073742127
BizStep	urn:epcglobal:cbv:bizstep:commissioning
Disposition	urn:epcglobal:cbv:disp:active
BizLocation	urn:epc:id:sgln:942900.009772.ON_FARM
Read Point	urn:epc:id:sgln:942900.009772.DEER_CRUSH

Table 6.3 - Commissioning event - tagging of animals

12 events - from farm (NZ) to retailer (DE) encoded in EPCIS

Case Study - Deer Supply Chain



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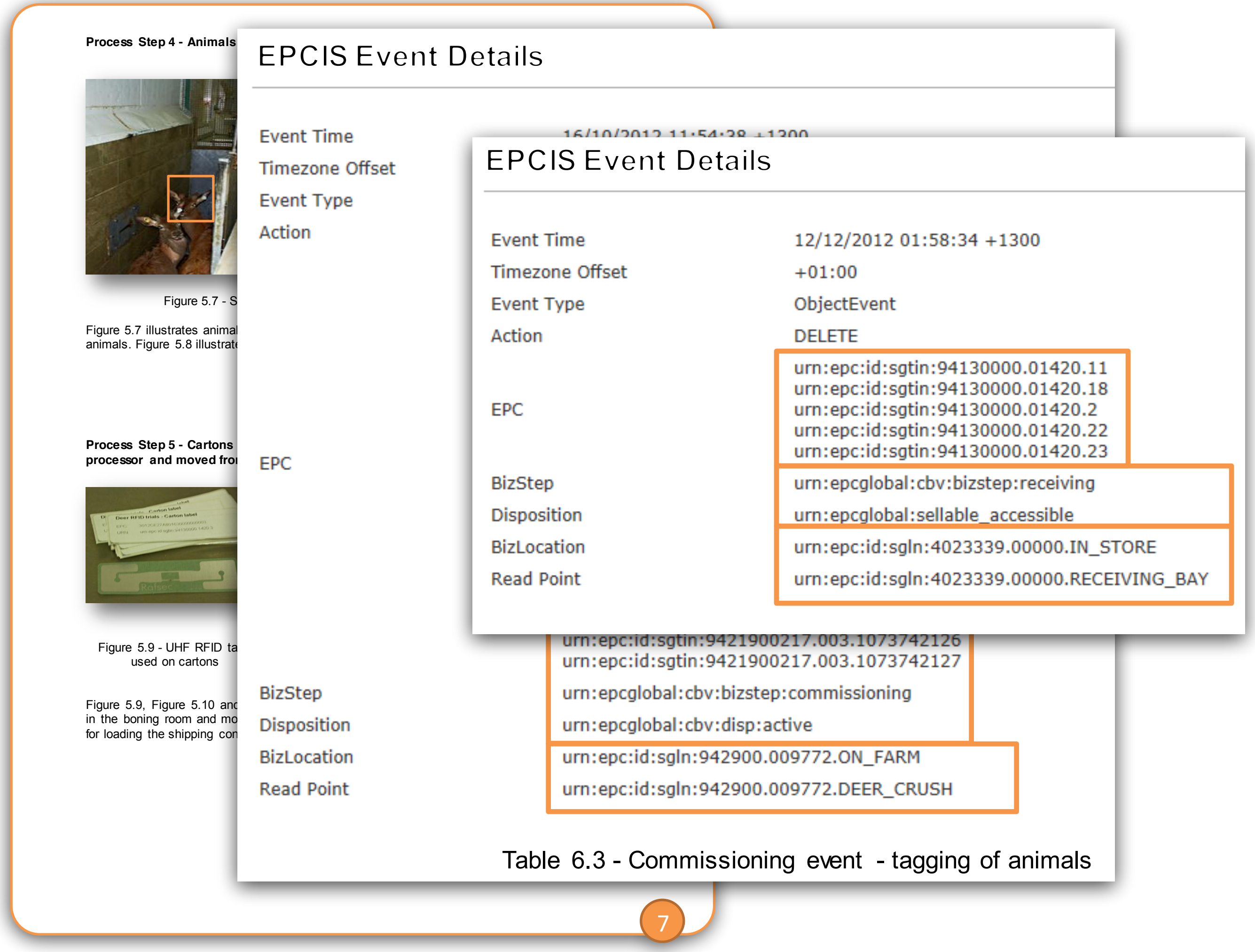


Process Step 4 - Animals

Figure 5.7 - S

Figure 5.7 illustrates animal animals. Figure 5.8 illustrate

Process Step 5 - Cartons processor and moved fro

Figure 5.9 - UHF RFID ta used on cartons

Figure 5.9, Figure 5.10 and in the boning room and mo for loading the shipping con

7

EPCIS Event Details

Event Time	16/10/2012 11:54:38 +1300
Timezone Offset	
Event Type	
Action	
EPC	urn:epc:id:sgtin:9421900217.003.1073742126 urn:epc:id:sgtin:9421900217.003.1073742127
BizStep	urn:epcglobal:cbv:bizstep:commissioning
Disposition	urn:epcglobal:cbv:disp:active
BizLocation	urn:epc:id:sgln:942900.009772.ON_FARM
Read Point	urn:epc:id:sgln:942900.009772.DEER_CRUSH

Table 6.3 - Commissioning event - tagging of animals

EPCIS Event Details

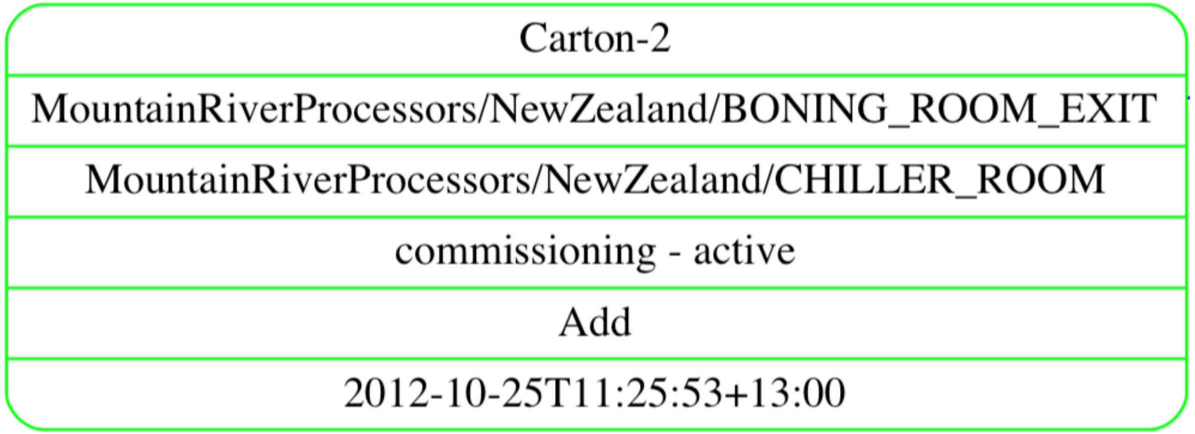
Event Time	12/12/2012 01:58:34 +1300
Timezone Offset	+01:00
Event Type	ObjectEvent
Action	DELETE
EPC	urn:epc:id:sgtin:94130000.01420.11 urn:epc:id:sgtin:94130000.01420.18 urn:epc:id:sgtin:94130000.01420.2 urn:epc:id:sgtin:94130000.01420.22 urn:epc:id:sgtin:94130000.01420.23
BizStep	urn:epcglobal:cbv:bizstep:receiving
Disposition	urn:epcglobal:sellable_accessible
BizLocation	urn:epc:id:sgln:4023339.00000.IN_STORE
Read Point	urn:epc:id:sgln:4023339.00000.RECEIVING_BAY

12 events - from farm (NZ) to retailer (DE) encoded in EPCIS

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

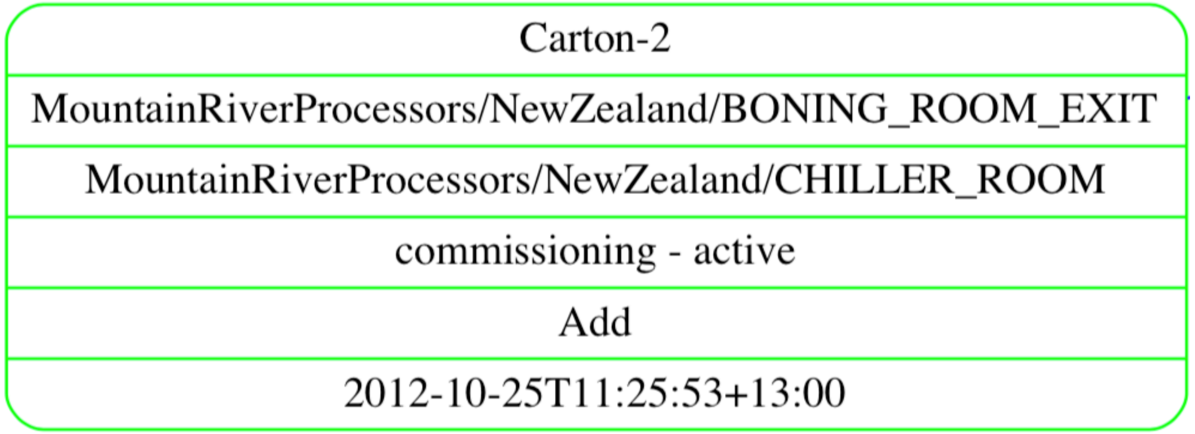
Add

2012-10-25T11:25:53+13:00

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

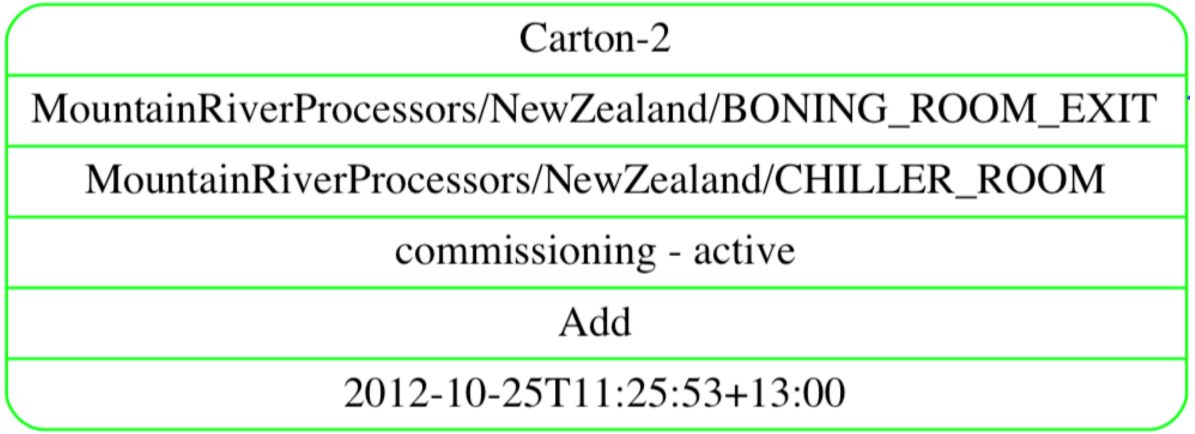
2012-10-25T11:25:53+13:00

What

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

2012-10-25T11:25:53+13:00

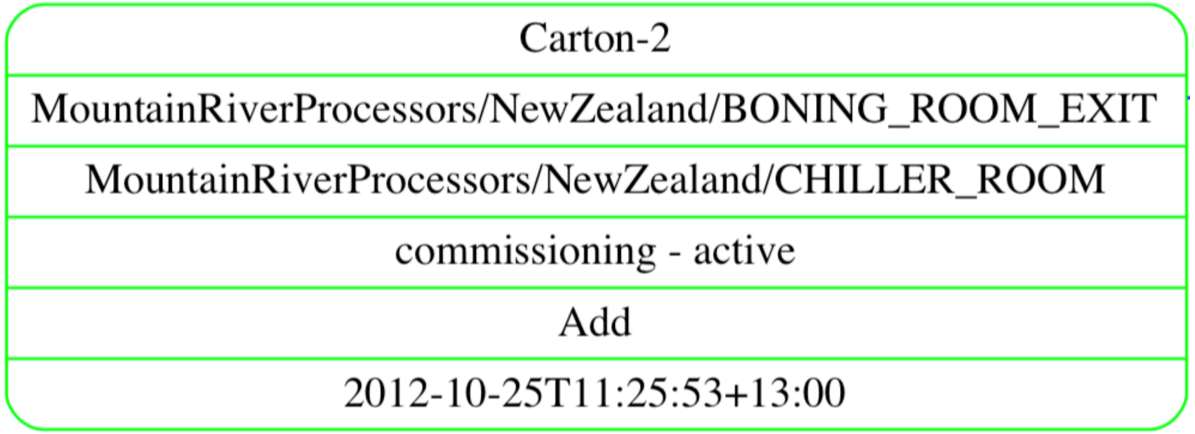
What

Where - Read point

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

What

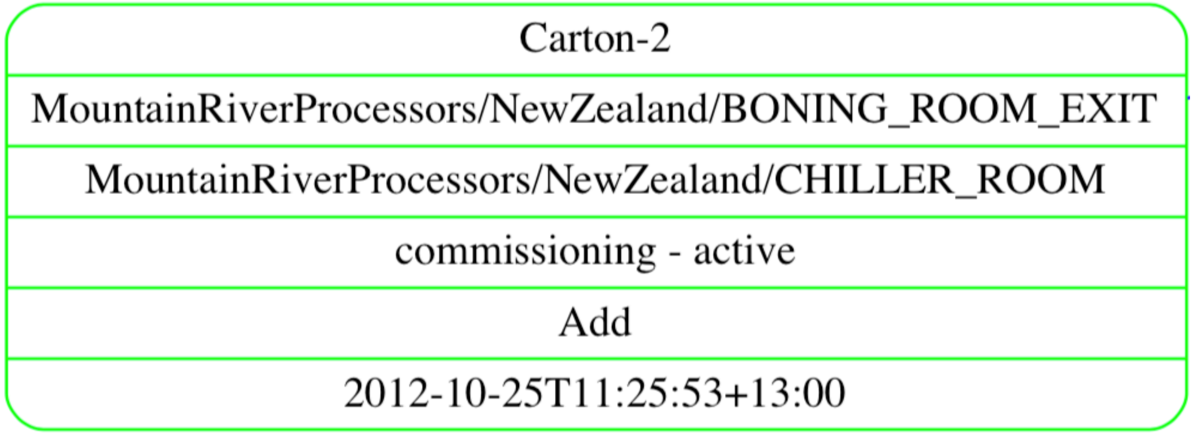
Where - Read point

Where - Biz location

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

2012-10-25T11:25:53+13:00

What

Where - Read point

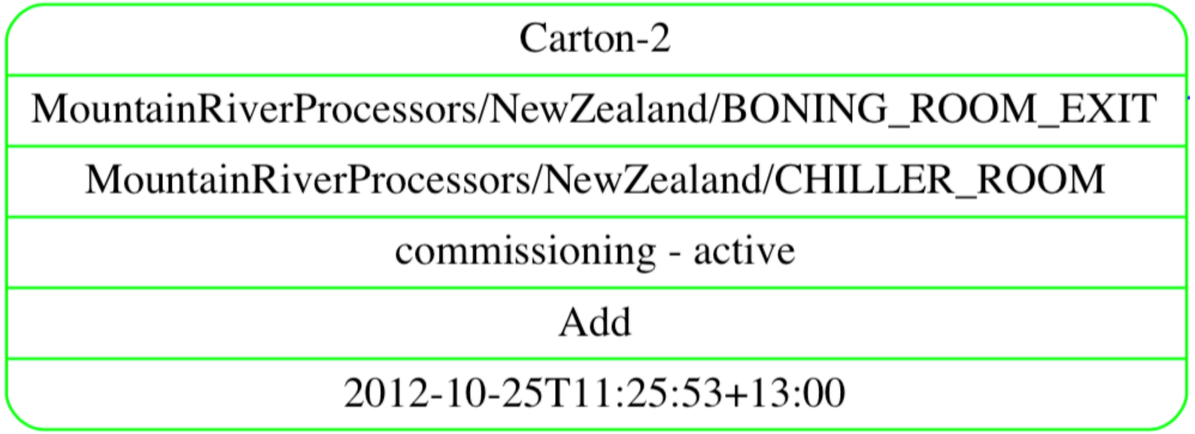
Where - Biz location

Why - Biz step - Disposition

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

2012-10-25T11:25:53+13:00

What

Where - Read point

Where - Biz location

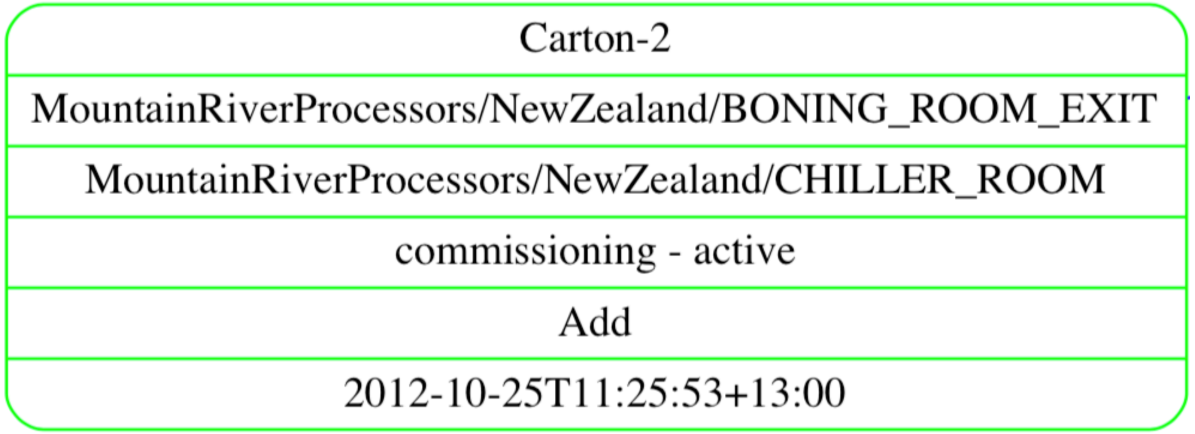
Why - Biz step - Disposition

How

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

2012-10-25T11:25:53+13:00

What

Where - Read point

Where - Biz location

Why - Biz step - Disposition

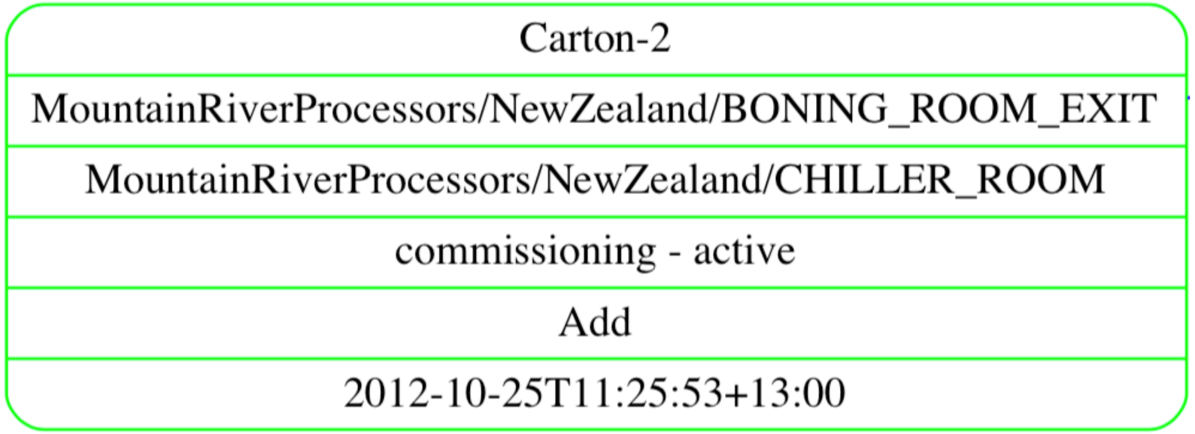
How

When

Case Study - WWWW

EPCIS defines lower-level events and higher-level “WWWW” concepts

WWWW - What? Where? When? Why?



Carton-2

MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT

MountainRiverProcessors/NewZealand/CHILLER_ROOM

commissioning - active

Add

2012-10-25T11:25:53+13:00

What

Where - Read point

Where - Biz location

Why - Biz step - Disposition

How

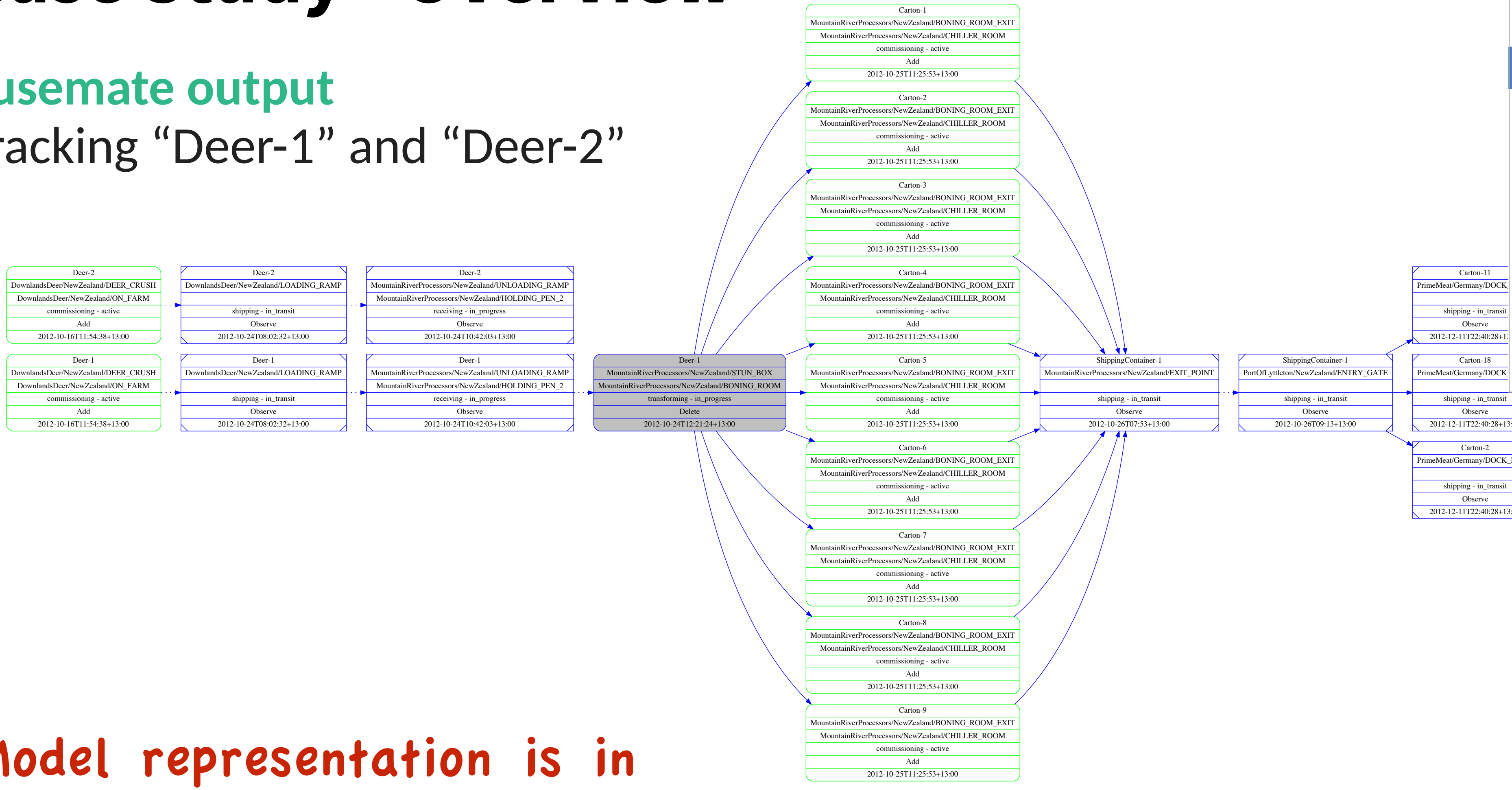
When

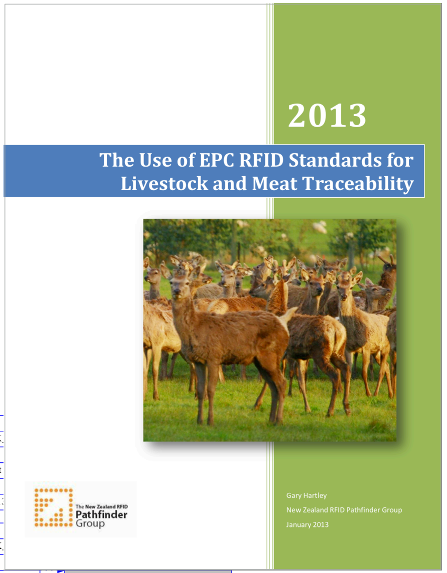
There are if-then rules for deriving **WWWW**s from EPCIS low-level events

Case Study - Overview

Fusemate output

Tracking “Deer-1” and “Deer-2”


Deer-2
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00
Deer-2
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00
Deer-2
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00
Deer-1
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00
Deer-1
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00
Deer-1
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00
Deer-1
MountainRiverProcessors/NewZealand/STUN_BOX
MountainRiverProcessors/NewZealand/BONING_ROOM
transforming - in_progress
Delete
2012-10-24T12:21:24+13:00
Carton-1
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-3
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-4
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-5
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-6
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-7
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-8
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-9
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00
ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00
Carton-11
PrimeMeat/Germany/DOCK_
shipping - in_transit
Observe
2012-12-11T22:40:28+1
Carton-18
PrimeMeat/Germany/DOCK_
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00
Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00
Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00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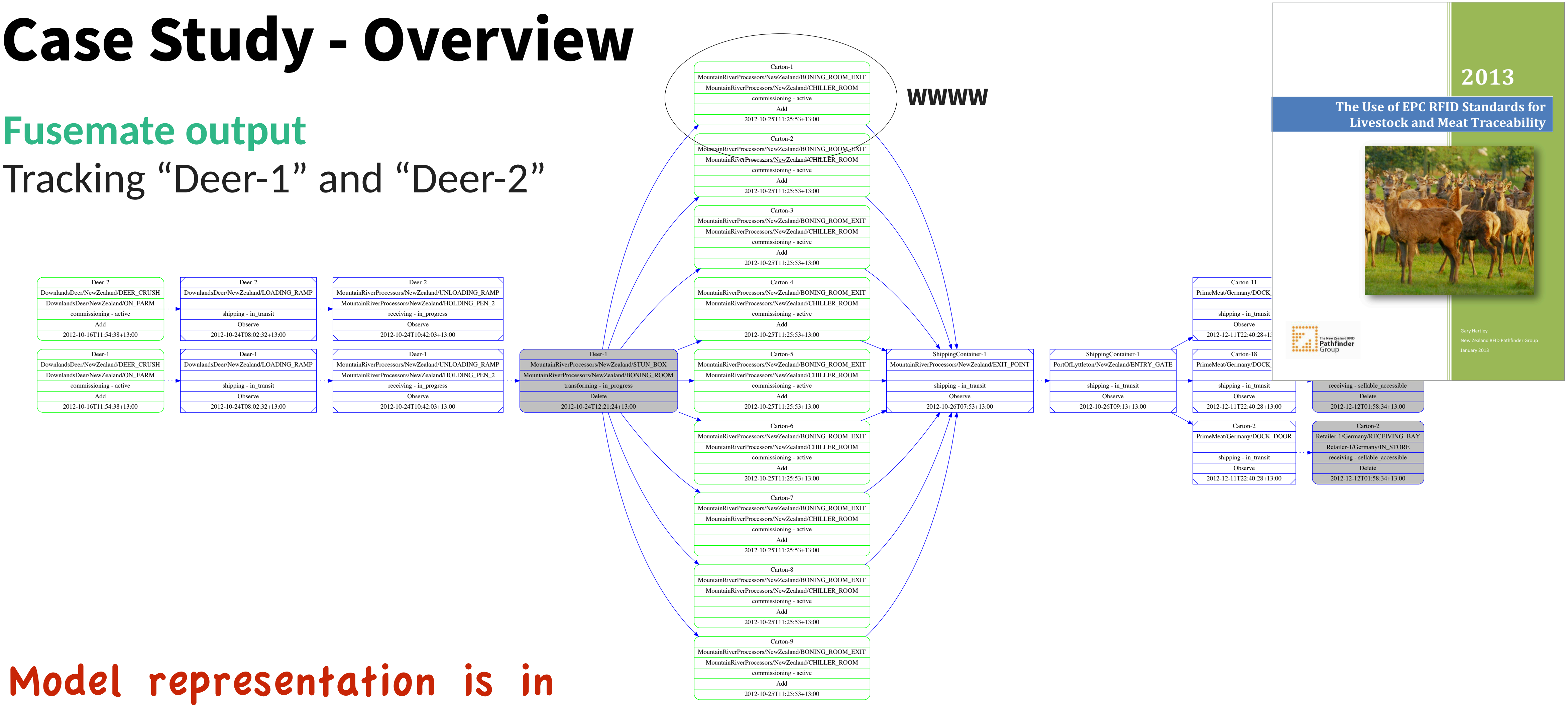
Model representation is in terms of WWWW, Aggregation and Association concepts

Case Study - Overview

Fusemate output

Tracking “Deer-1” and “Deer-2”



WWWW

Deer-2
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-2
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-2
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-1
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-1
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
MountainRiverProcessors/NewZealand/STUN_BOX
MountainRiverProcessors/NewZealand/BONING_ROOM
transforming - in_progress
Delete
2012-10-24T12:21:24+13:00

Carton-1
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-3
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-4
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-5
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-6
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-7
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-8
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-9
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

Carton-11
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+1

Carton-18
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

2013

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Gary Hartley
New Zealand RFID Pathfinder Group
January 2013

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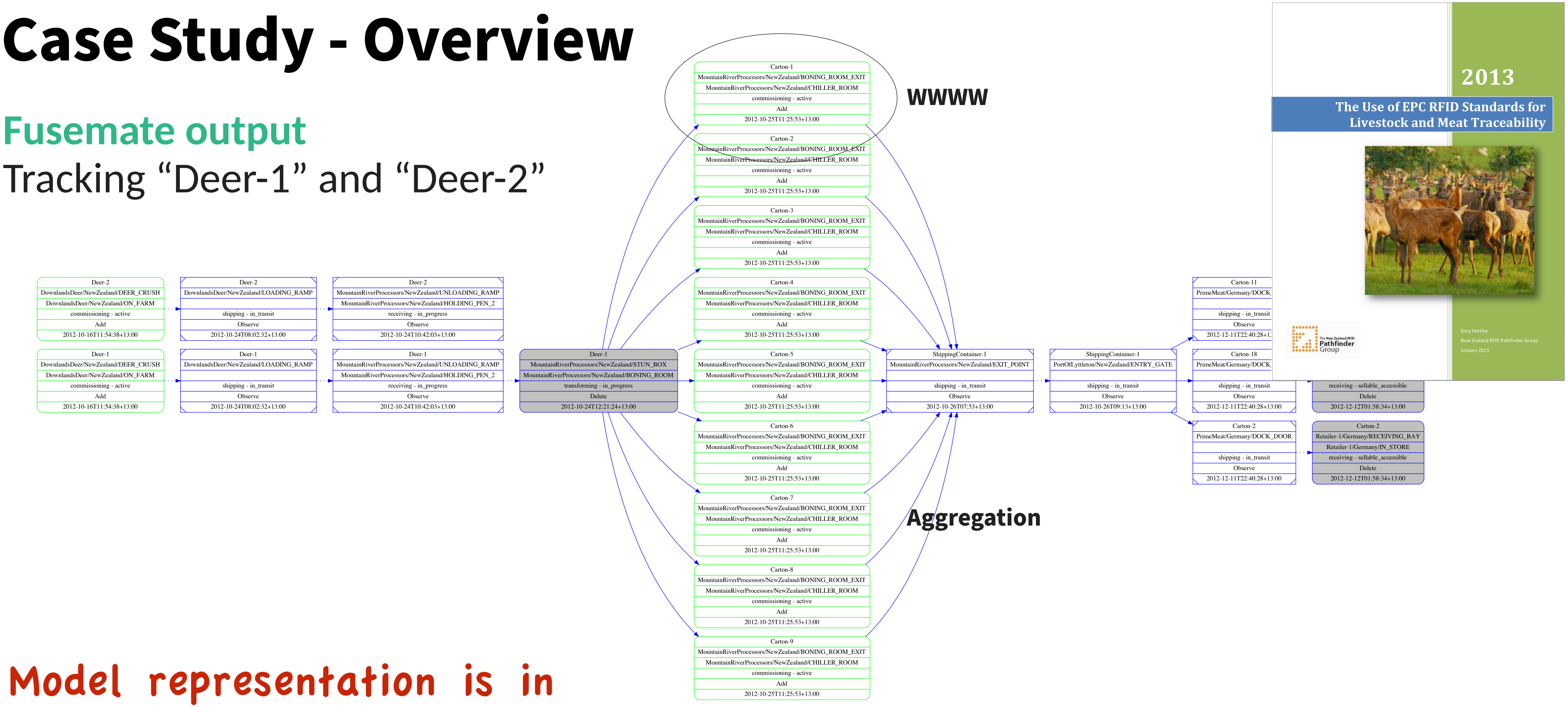
Fusemate output

Tracking “Deer-1” and “Deer-2”



WWWW

Aggregation

Deer-2
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-2
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-2
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-1
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-1
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
MountainRiverProcessors/NewZealand/STUN_BOX
MountainRiverProcessors/NewZealand/BONING_ROOM
transforming - in_progress
Delete
2012-10-24T12:21:24+13:00

Carton-1
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-3
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-4
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-5
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-6
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-7
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-8
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-9
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

Carton-11
PrimeMeat/Germany/DOCK_
shipping - in_transit
Observe
2012-12-11T22:40:28+1

Carton-18
PrimeMeat/Germany/DOCK_
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

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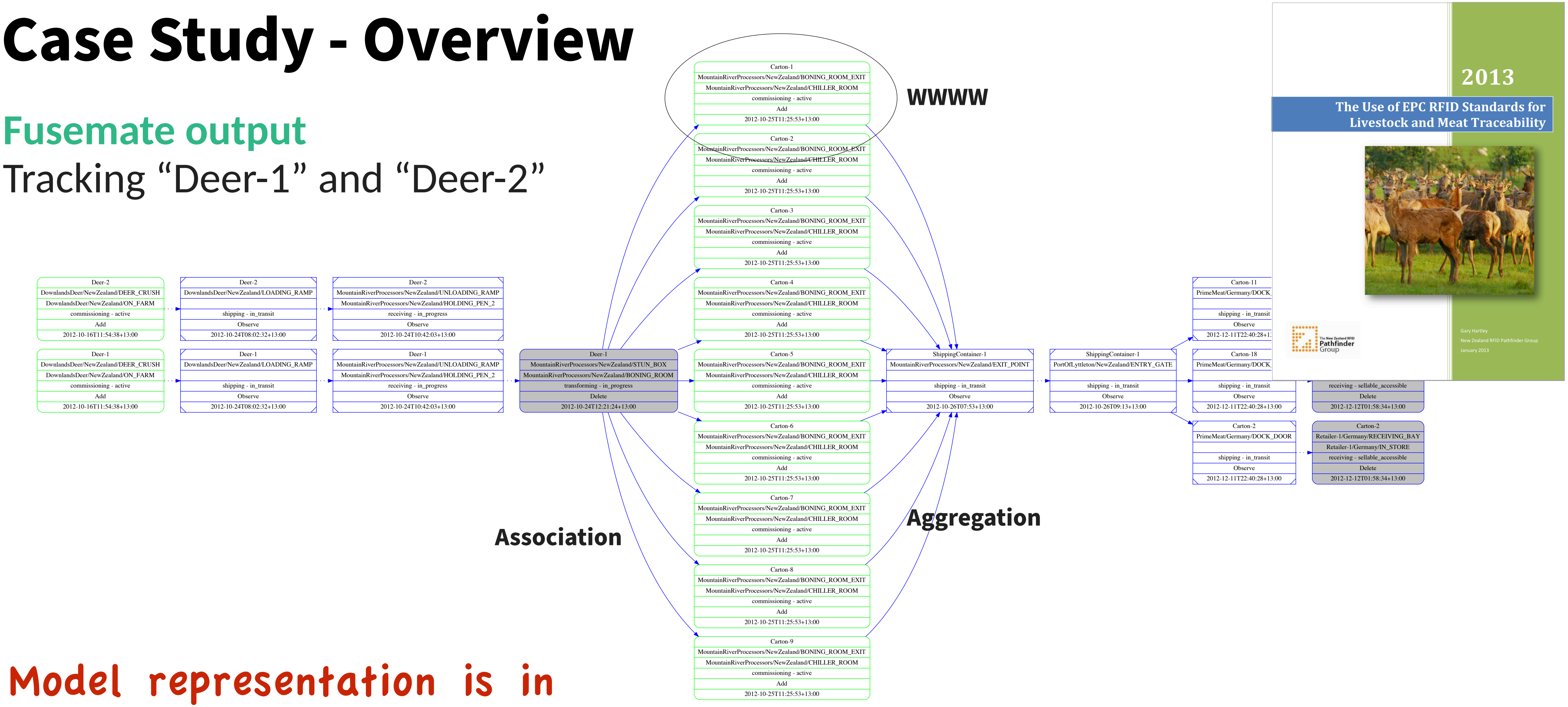

WWWW

Association

Aggregation

Deer-2
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-2
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-2
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-1
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-1
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
MountainRiverProcessors/NewZealand/STUN_BOX
MountainRiverProcessors/NewZealand/BONING_ROOM
transforming - in_progress
Delete
2012-10-24T12:21:24+13:00

Carton-1
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-3
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-4
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-5
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-6
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-7
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-8
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-9
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

Carton-11
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+1

Carton-18
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

2013

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Gary Hartley

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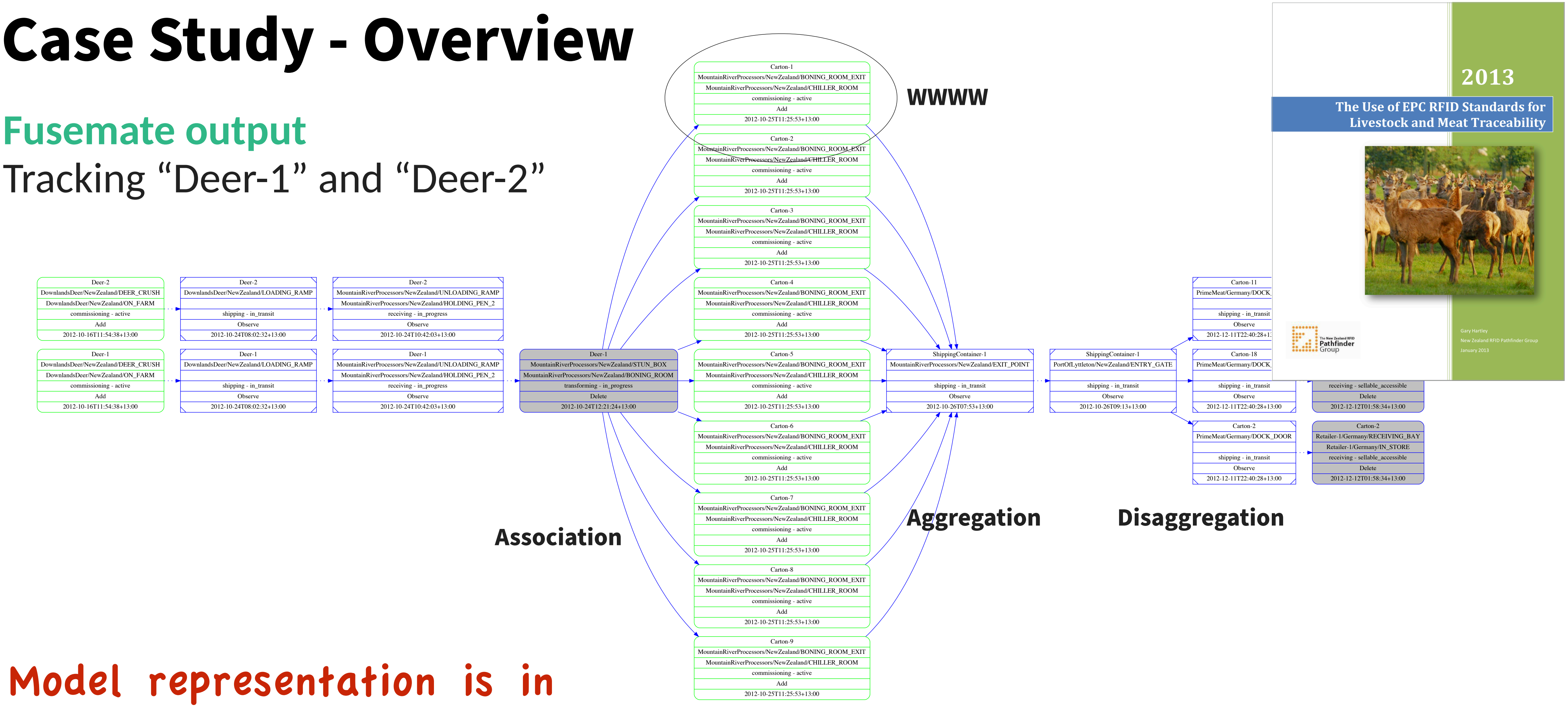
Tracking “Deer-1” and “Deer-2”



Deer-2
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-2
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-2
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
DownlandsDeer/NewZealand/DEER_CRUSH
DownlandsDeer/NewZealand/ON_FARM
commissioning - active
Add
2012-10-16T11:54:38+13:00

Deer-1
DownlandsDeer/NewZealand/LOADING_RAMP
shipping - in_transit
Observe
2012-10-24T08:02:32+13:00

Deer-1
MountainRiverProcessors/NewZealand/UNLOADING_RAMP
MountainRiverProcessors/NewZealand/HOLDING_PEN_2
receiving - in_progress
Observe
2012-10-24T10:42:03+13:00

Deer-1
MountainRiverProcessors/NewZealand/STUN_BOX
MountainRiverProcessors/NewZealand/BONING_ROOM
transforming - in_progress
Delete
2012-10-24T12:21:24+13:00

Carton-1
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

WWWW

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-3
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-4
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-5
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-6
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-7
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-8
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-9
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

Carton-11
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+1

Carton-18
PrimeMeat/Germany/DOCK
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Association

Aggregation

Disaggregation

2013

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Gary Hartley
New Zealand RFID Pathfinder Group
January 2013

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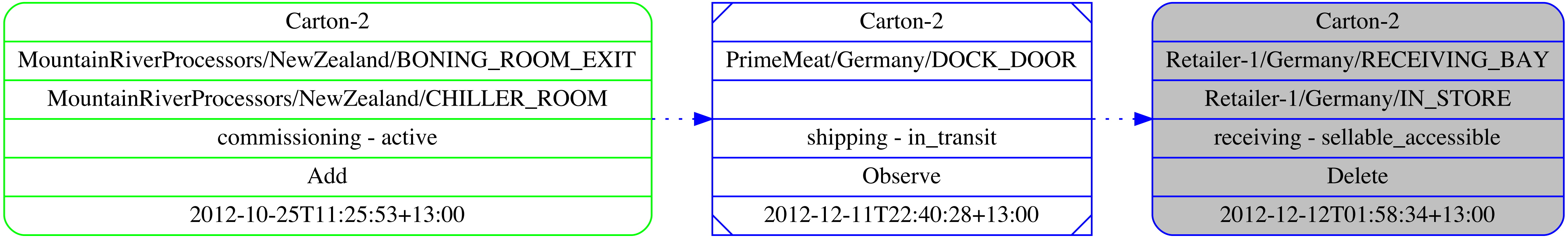
Modelling Experiment - Multiple Explanations



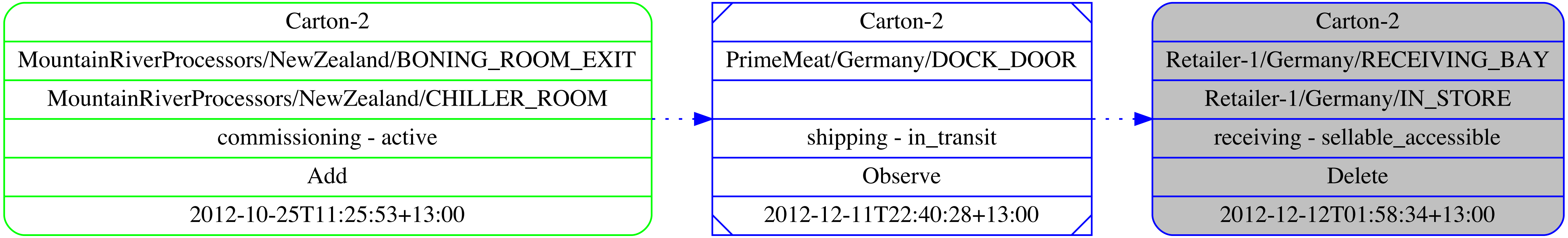
Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Modelling Experiment - Multiple Explanations



Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

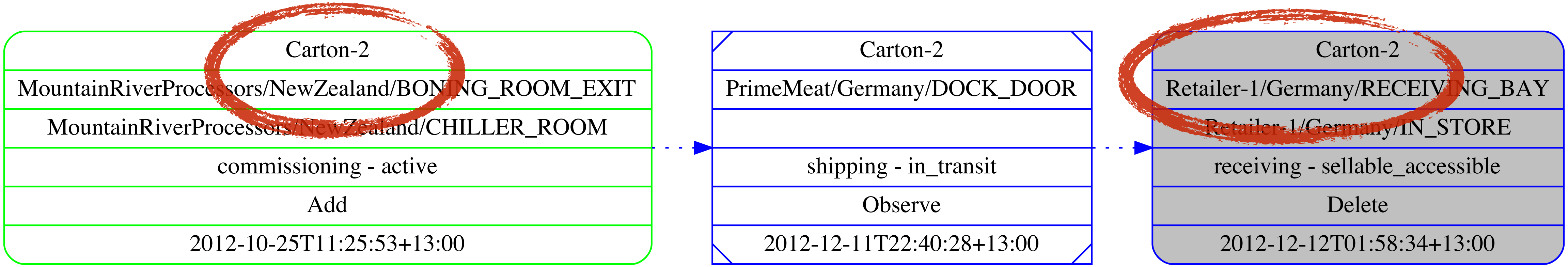
Carton-2
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

What is known

Modelling Experiment - Multiple Explanations

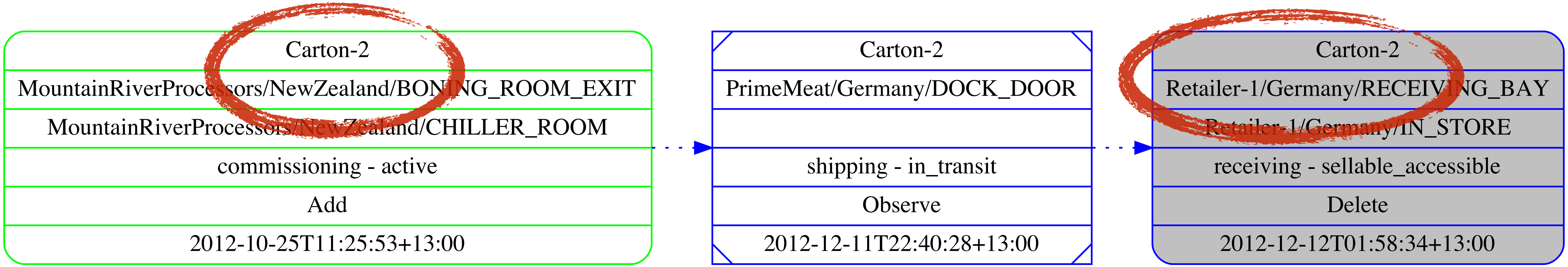


Carton-2	Carton-2	Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT	PrimeMeat/Germany/DOCK_DOOR	Retailer-1/Germany/RECEIVING_BAY
MountainRiverProcessors/NewZealand/CHILLER_ROOM		Retailer-1/Germany/IN_STORE
commissioning - active	shipping - in_transit	receiving - sellable_accessible
Add	Observe	Delete
2012-10-25T11:25:53+13:00	2012-12-11T22:40:28+13:00	2012-12-12T01:58:34+13:00

What is known

- Carton-2 has arrived at Retailer-1 in Germany

Modelling Experiment - Multiple Explanations



Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR

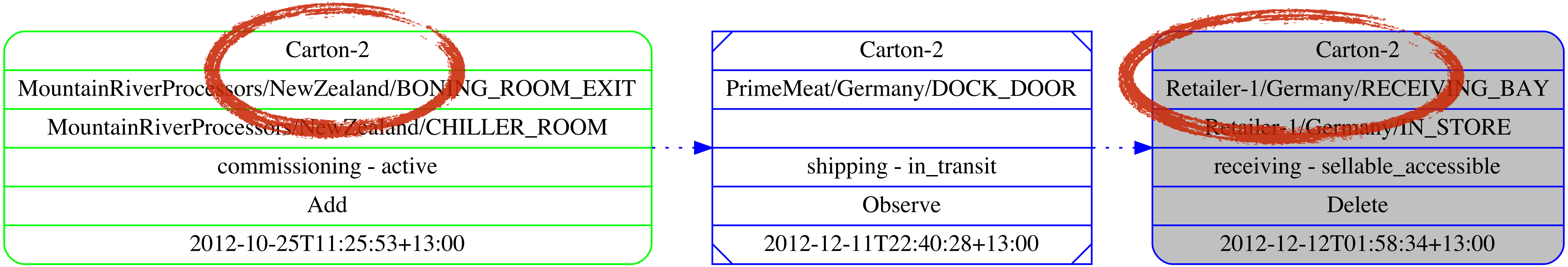
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

What is known

- Carton-2 has arrived at Retailer-1 in Germany
- Carton-13 was added to the supply chain like Carton-2 above

Modelling Experiment - Multiple Explanations



Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

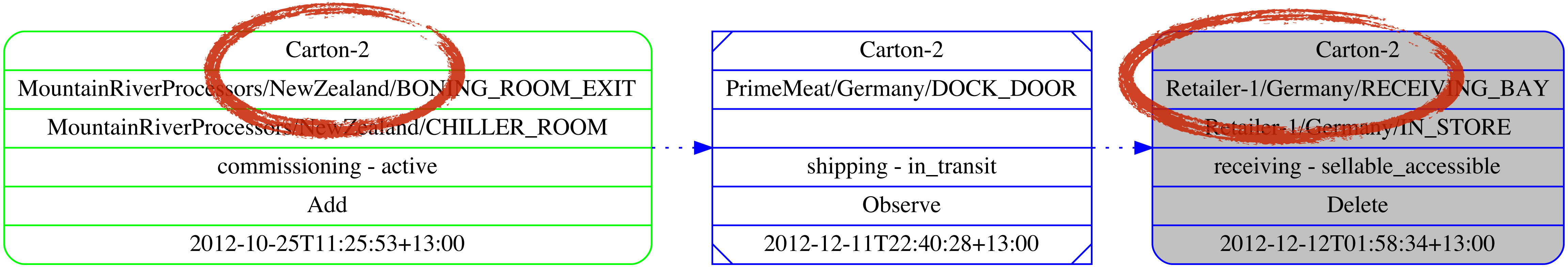
Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

What is known

- Carton-2 has arrived at Retailer-1 in Germany
- Carton-13 was added to the supply chain like Carton-2 above
- Carton-13 leaves no trace but it should also have arrived at Retailer-1 in Germany

Modelling Experiment - Multiple Explanations



Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

What is known

- Carton-2 has arrived at Retailer-1 in Germany
- Carton-13 was added to the supply chain like Carton-2 above
- Carton-13 leaves no trace but it should also have arrived at Retailer-1 in Germany

What went wrong?

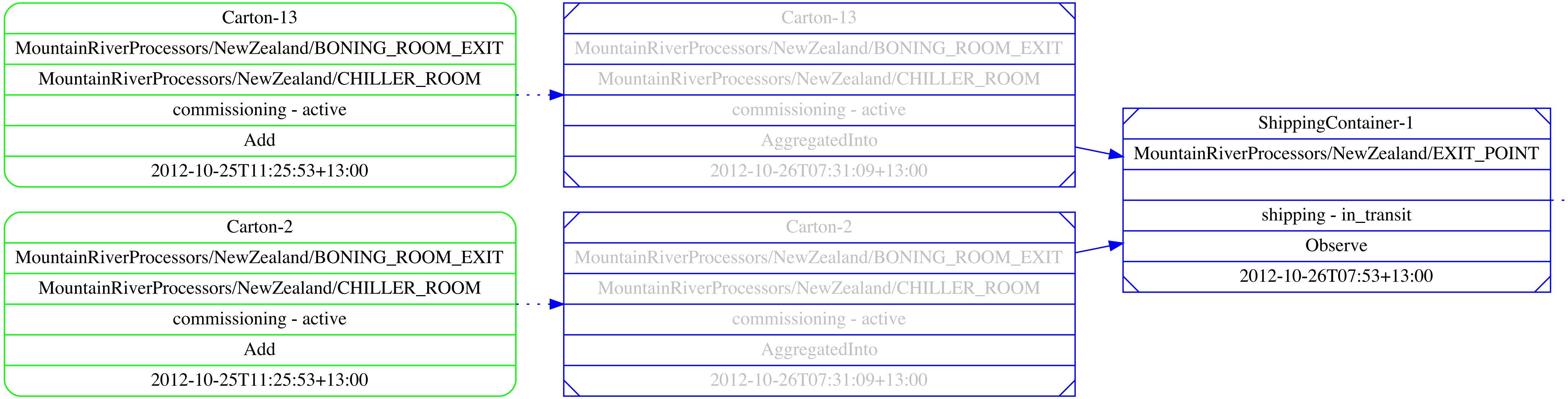
Fusemate diagnosis scenario - Compute some plausible explanations

Modelling Experiment - Multiple Explanations

We start the diagnosis by telling Fusemate that Carton-13 behaves like Carton-2

```
trackByCopy("urn:epc:id:sgtin:94130000.01420.2", "urn:epc:id:sgtin:94130000.01420.13")
```

Result



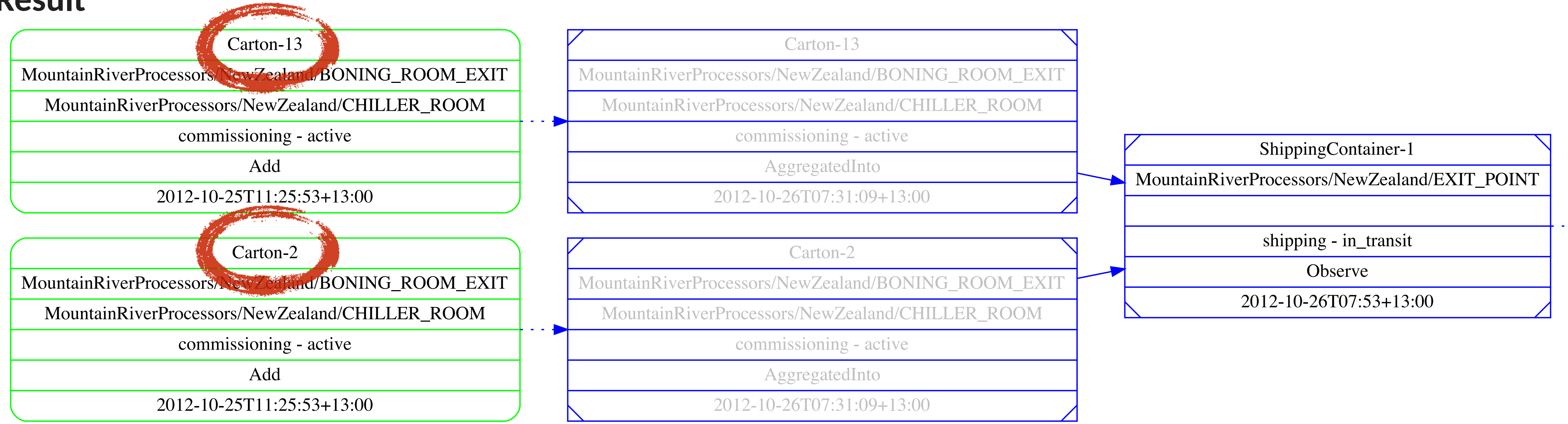
Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
AggregatedInto
2012-10-26T07:31:09+13:00
Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
AggregatedInto
2012-10-26T07:31:09+13:00
ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

Modelling Experiment - Multiple Explanations

We start the diagnosis by telling Fusemate that Carton-13 behaves like Carton-2

```
trackByCopy("urn:epc:id:sgtin:94130000.01420.2", "urn:epc:id:sgtin:94130000.01420.13")
```

Result



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
AggregatedInto
2012-10-26T07:31:09+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
AggregatedInto
2012-10-26T07:31:09+13:00

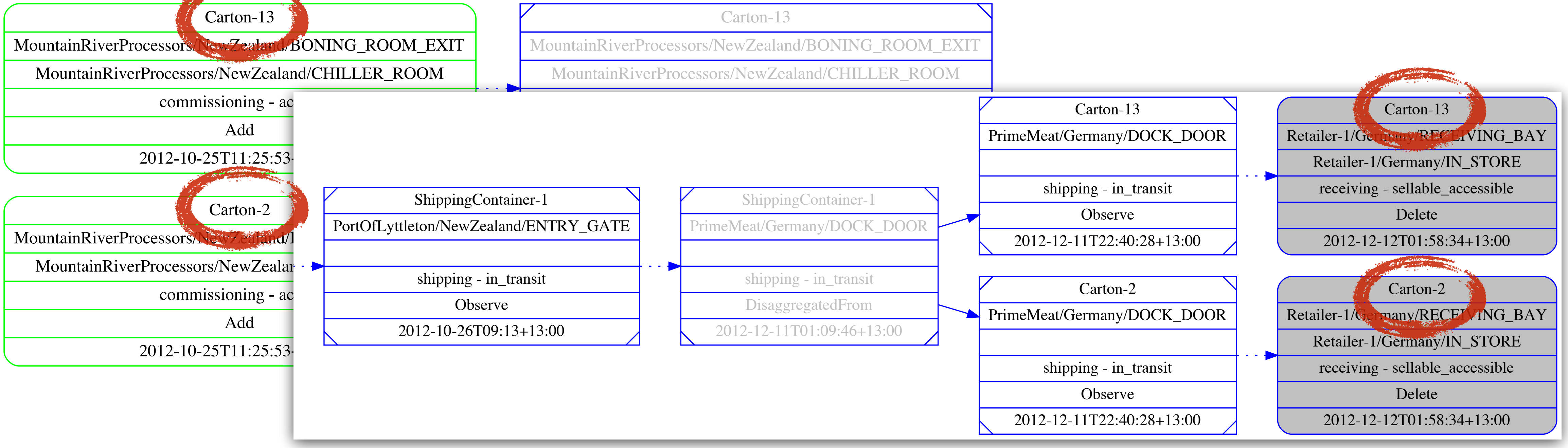
ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

Modelling Experiment - Multiple Explanations

We start the diagnosis by telling Fusemate that Carton-13 behaves like Carton-2

```
trackByCopy("urn:epc:id:sgtin:94130000.01420.2", "urn:epc:id:sgtin:94130000.01420.13")
```

Result



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - ac
Add
2012-10-25T11:25:53-

Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM

Carton-2
MountainRiverProcessors/NewZealand/I
MountainRiverProcessors/NewZealar
commissioning - ac
Add
2012-10-25T11:25:53-

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

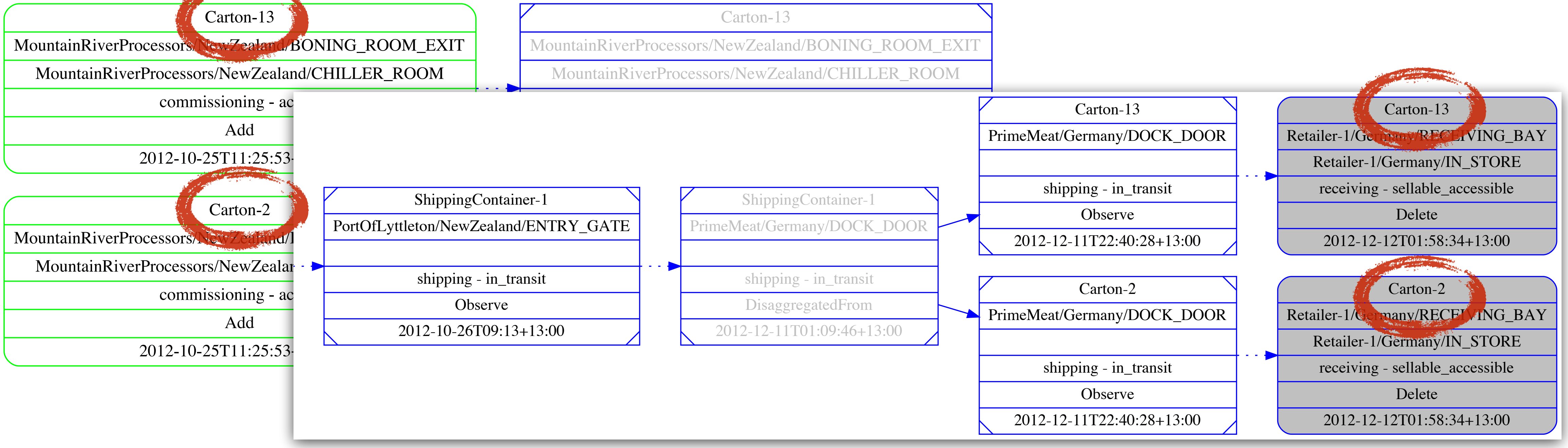
Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Modelling Experiment - Multiple Explanations

We start the diagnosis by telling Fusemate that Carton-13 behaves like Carton-2

```
trackByCopy("urn:epc:id:sgtin:94130000.01420.2", "urn:epc:id:sgtin:94130000.01420.13")
```

Result



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - ac
Add
2012-10-25T11:25:53-

Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM

Carton-2
MountainRiverProcessors/NewZealand/I
MountainRiverProcessors/NewZealar
commissioning - ac
Add
2012-10-25T11:25:53-

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Now add knowledge of what (not) happened

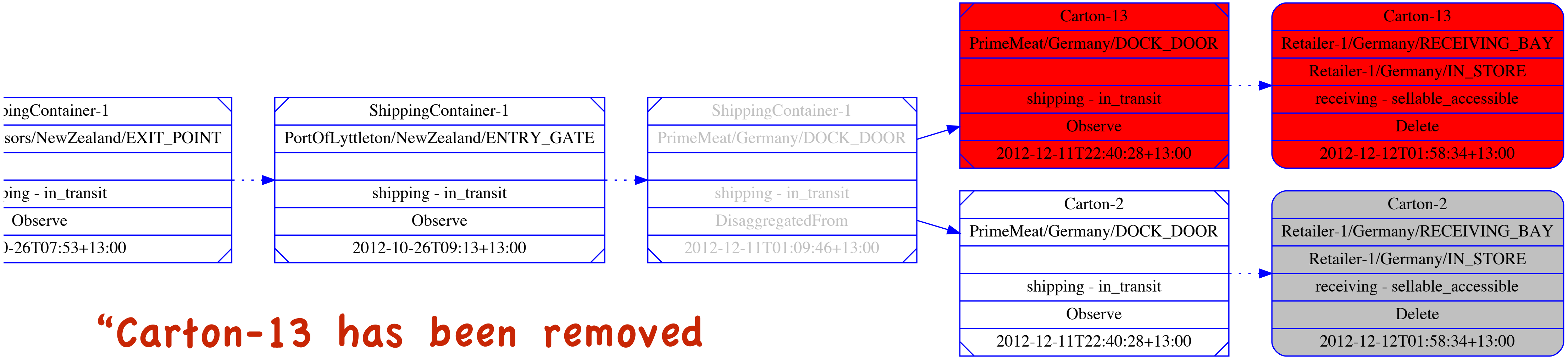
Modelling Experiment - Multiple Explanations

A phone call confirms that Carton-13 was not seen at the DOCK_DOOR any time after 11/12/2012:

This information is provided to Fusemate (details not shown here)

Plausible Explanation (1)

🟥 Negative conclusions = “known not”



)ingContainer-1
sors/NewZealand/EXIT_POINT

)ing - in_transit
Observe
)-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE

shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

“Carton-13 has been removed from Container-1 but there is no trace from then on”

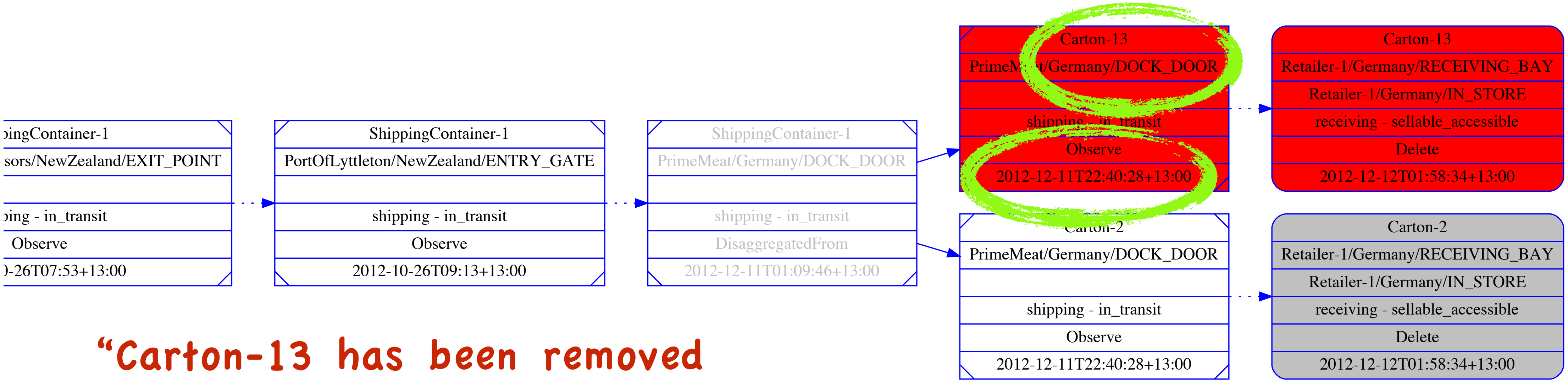
Modelling Experiment - Multiple Explanations

A phone call confirms that Carton-13 was not seen at the DOCK_DOOR any time after 11/12/2012:

This information is provided to Fusemate (details not shown here)

Plausible Explanation (1)

🟥 **Negative conclusions** = "known not"



ɔingContainer-1
sors/NewZealand/EXIT_POINT
ɔing - in_transit
Observe
)-26T07:53+13:00
ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00
ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00
Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00
Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00
Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00
Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

"Carton-13 has been removed from Container-1 but there is no trace from then on"

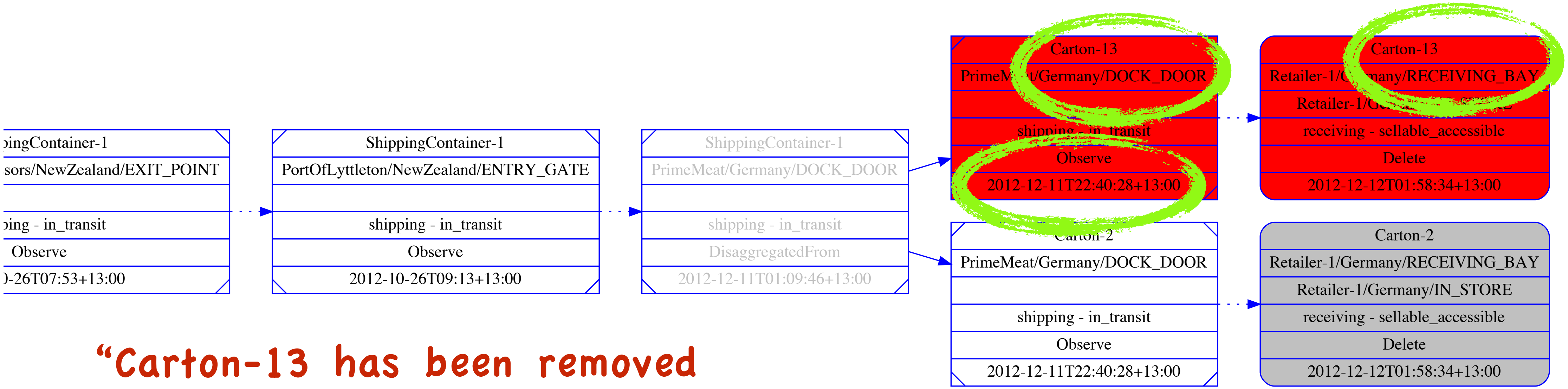
Modelling Experiment - Multiple Explanations

A phone call confirms that Carton-13 was not seen at the DOCK_DOOR any time after 11/12/2012:

This information is provided to Fusemate (details not shown here)

Plausible Explanation (1)

🟥 **Negative conclusions** = “known not”



pingContainer-1
sors/NewZealand/EXIT_POINT

ping - in_transit
Observe
)-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE

shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR

shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

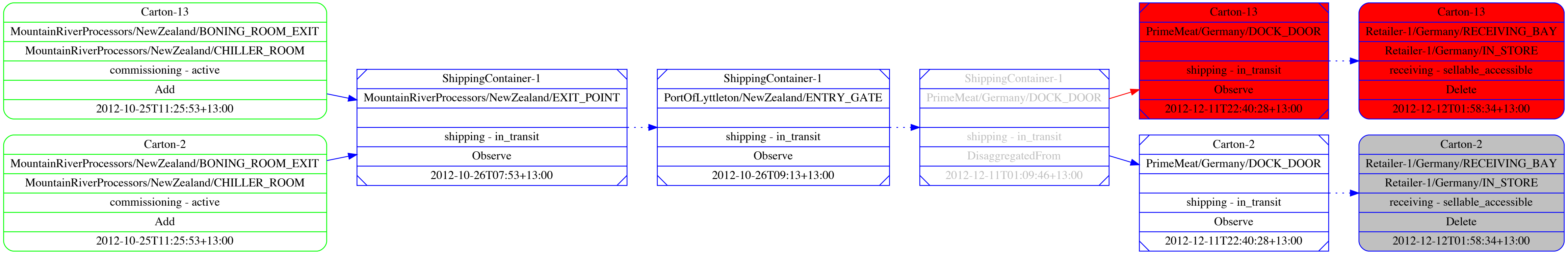
Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

“Carton-13 has been removed from Container-1 but there is no trace from then on”

Modelling Experiment - Multiple Explanations

The user asks the system to compute the next plausible model

Plausible Explanation (2)



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

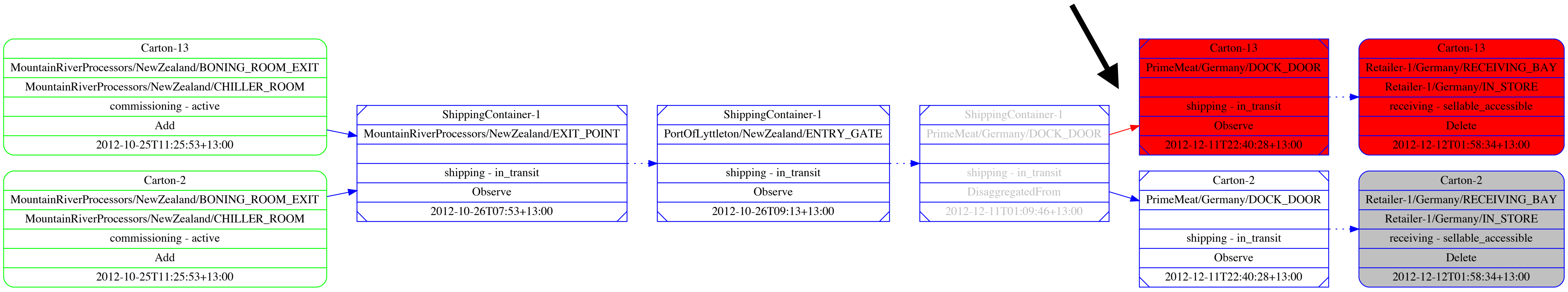
“Carton-13 has not been removed from Container-1 (still in the container?)”

Modelling Experiment - Multiple Explanations

The user asks the system to compute the next plausible model

Plausible Explanation (2)

Arrow in red now



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

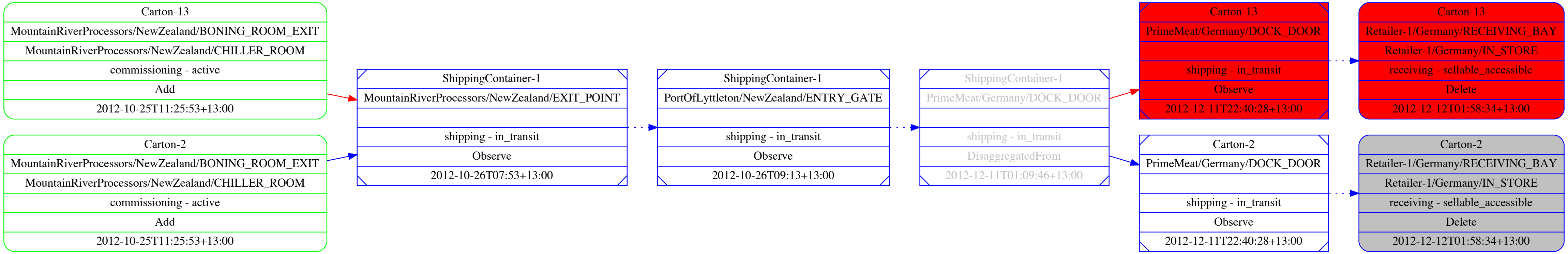
Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

“Carton-13 has not been removed from Container-1 (still in the container?)”

Modelling Experiment - Multiple Explanations

The user asks the system to compute the next plausible model

Plausible Explanation (3)



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

"Carton-13 was not loaded into Container-1 in the first place"

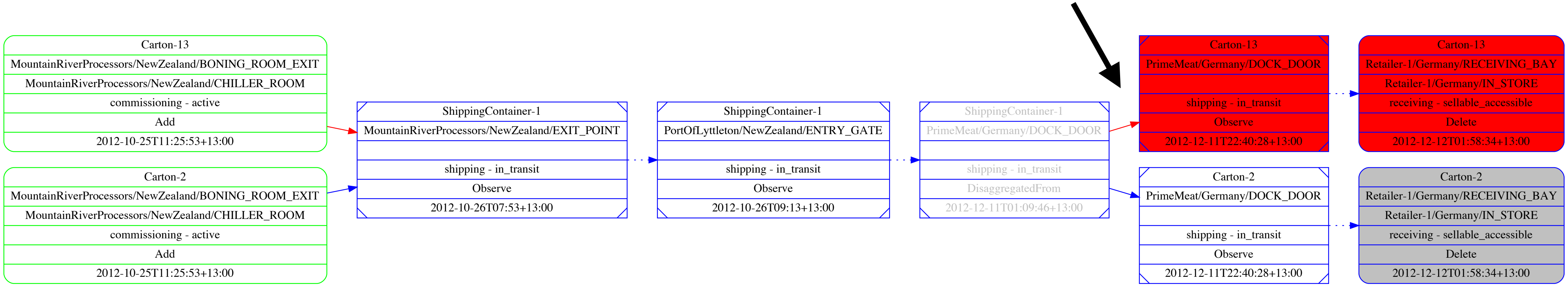
(And hence cannot be unloaded either as per rules)

Modelling Experiment - Multiple Explanations

The user asks the system to compute the next plausible model

Plausible Explanation (3)

Arrow remans in red



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

"Carton-13 was not loaded into Container-1 in the first place"

(And hence cannot be unloaded either as per rules)

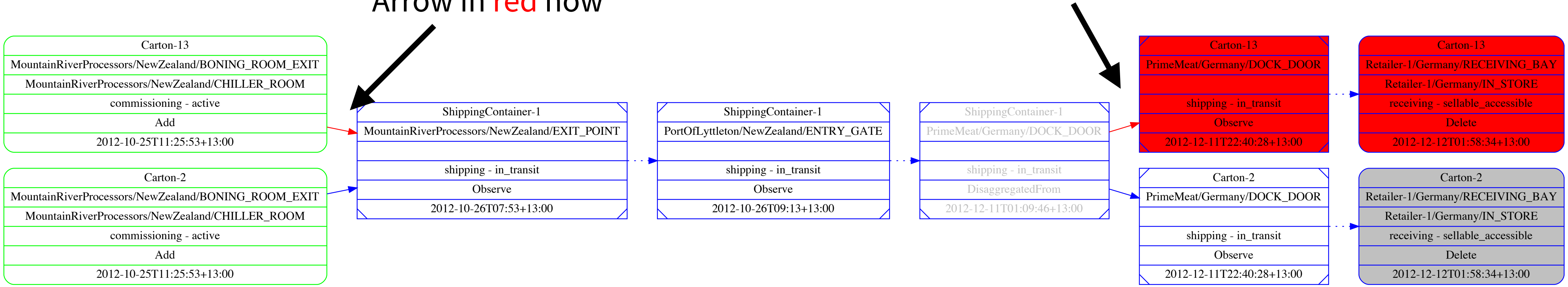
Modelling Experiment - Multiple Explanations

The user asks the system to compute the next plausible model

Plausible Explanation (3)

Arrow in red now

Arrow remans in red



Carton-13
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT
MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00

ShippingContainer-1
MountainRiverProcessors/NewZealand/EXIT_POINT
shipping - in_transit
Observe
2012-10-26T07:53+13:00

ShippingContainer-1
PortOfLyttleton/NewZealand/ENTRY_GATE
shipping - in_transit
Observe
2012-10-26T09:13+13:00

ShippingContainer-1
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
DisaggregatedFrom
2012-12-11T01:09:46+13:00

Carton-13
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-2
PrimeMeat/Germany/DOCK_DOOR
shipping - in_transit
Observe
2012-12-11T22:40:28+13:00

Carton-13
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

Carton-2
Retailer-1/Germany/RECEIVING_BAY
Retailer-1/Germany/IN_STORE
receiving - sellable_accessible
Delete
2012-12-12T01:58:34+13:00

"Carton-13 was not loaded into Container-1 in the first place"

(And hence cannot be unloaded either as per rules)

Modelling Experiment - Multiple Explanations

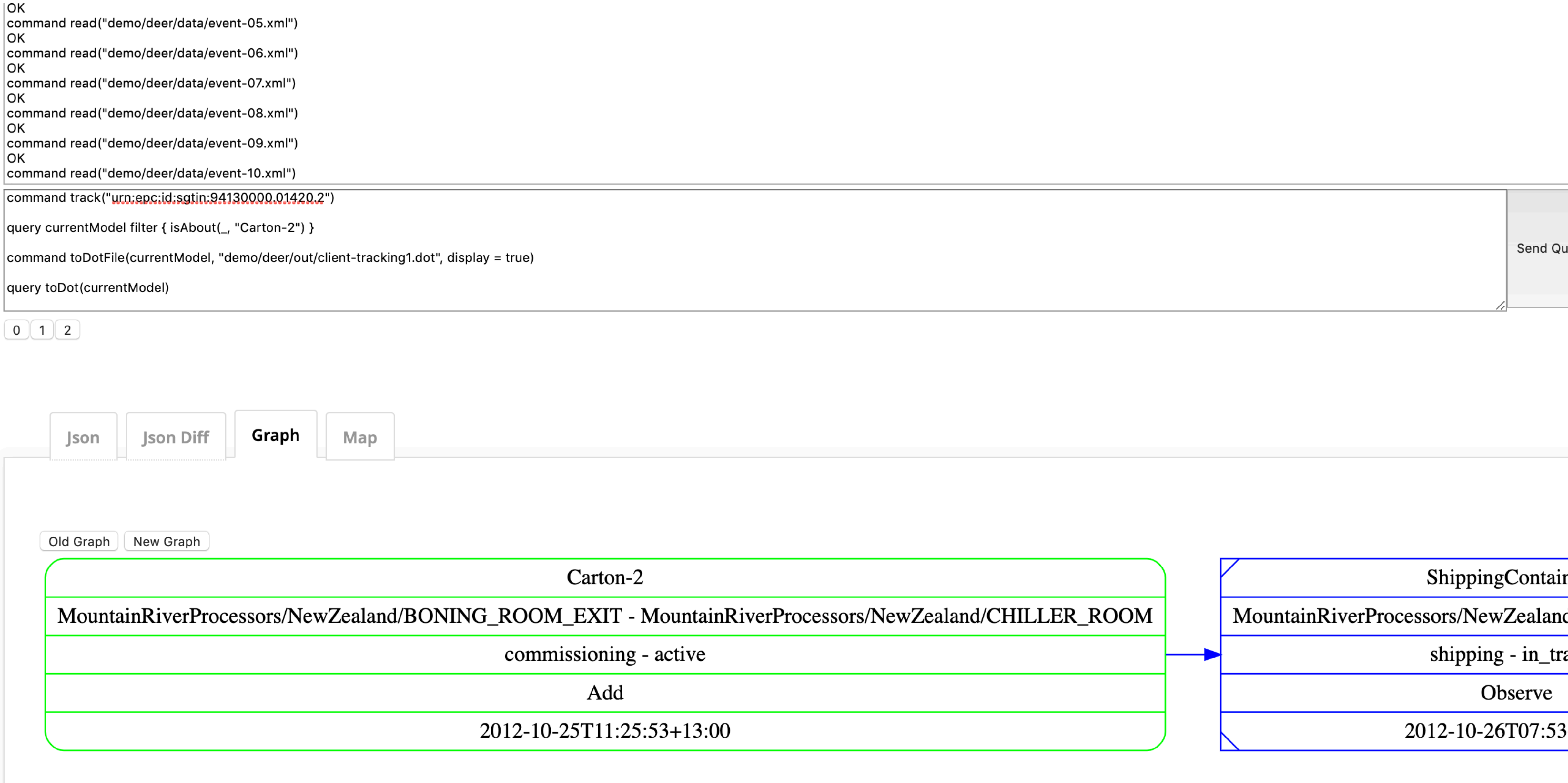
The user asks the system to compute the next plausible model

Plausible Explanation (4)

N/A

In particular Fusemate does not generate:
“Carton-13 has been removed from the Container 1
but was not loaded earlier into Container 1”

User Interface - Under Development

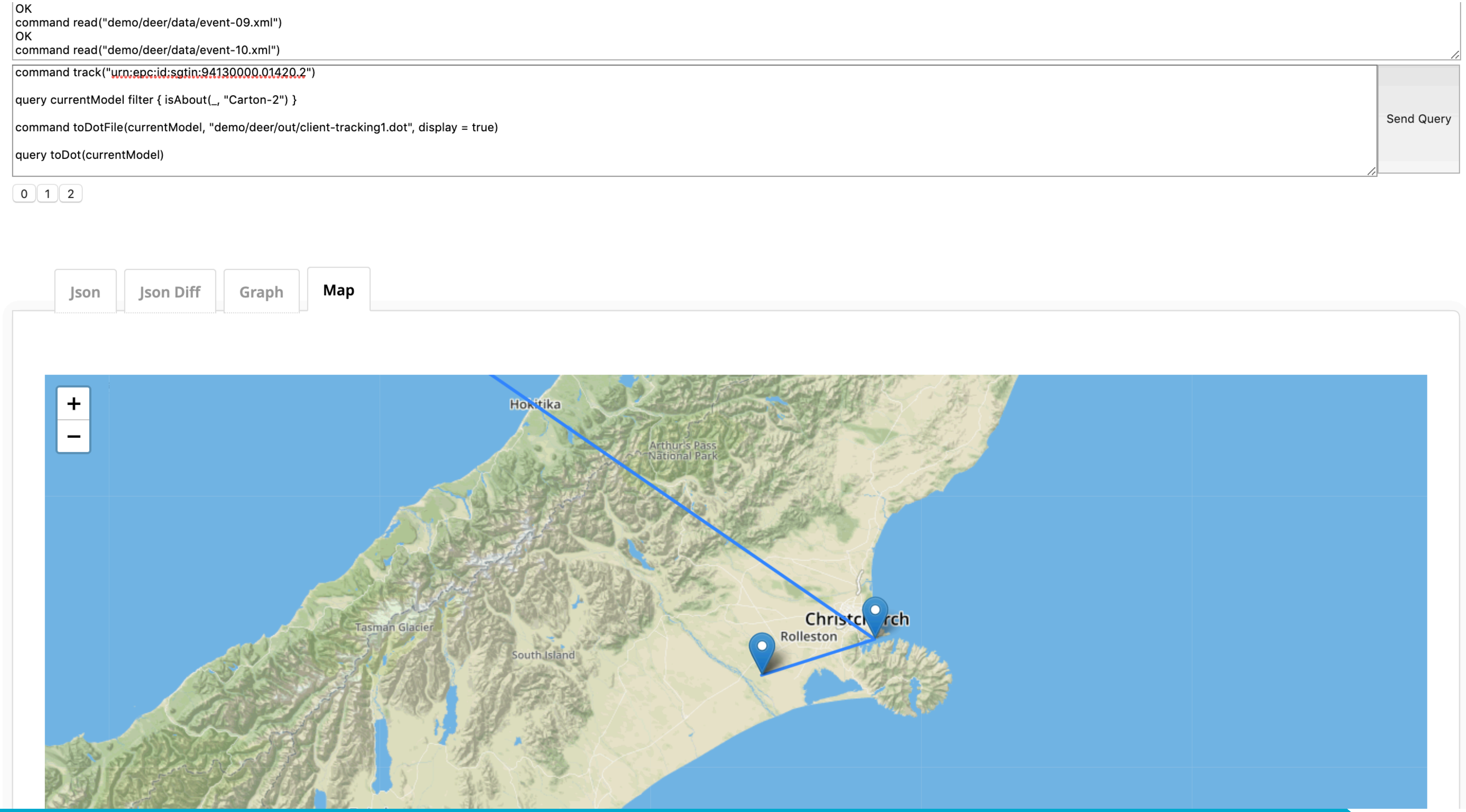


```
OK
command read("demo/deer/data/event-05.xml")
OK
command read("demo/deer/data/event-06.xml")
OK
command read("demo/deer/data/event-07.xml")
OK
command read("demo/deer/data/event-08.xml")
OK
command read("demo/deer/data/event-09.xml")
OK
command read("demo/deer/data/event-10.xml")
```

```
command track("urn:epc:id:sgtin:94130000.01420.2")

query currentModel filter { isAbout(_, "Carton-2") }

command toDotFile(currentModel, "demo/deer/out/client-tracking1.dot", display = true)

query toDot(currentModel)
```

Send Qu
0
1
2
Json
Json Diff
Graph
Map
Old Graph
New Graph
Carton-2
MountainRiverProcessors/NewZealand/BONING_ROOM_EXIT - MountainRiverProcessors/NewZealand/CHILLER_ROOM
commissioning - active
Add
2012-10-25T11:25:53+13:00
ShippingContair
MountainRiverProcessors/NewZealanc
shipping - in_tra
Observe
2012-10-26T07:53

User Interface - Under Development



```
OK
command read("demo/deer/data/event-09.xml")
OK
command read("demo/deer/data/event-10.xml")
```

```
command track("urn:epc:id:sgtin:94130000.01420.2")

query currentModel filter { isAbout(_, "Carton-2") }

command toDotFile(currentModel, "demo/deer/out/client-tracking1.dot", display = true)

query toDot(currentModel)
```

Conclusions and Future Work

- Developed Fusemate situational awareness system
- Fusemate = Logic Programming + Belief Revision + Scala programming language
- Experimented with Deer supply chain case study
- Future work
  - User interface
  - More case studies
  - Integration with video tracking
  - Probabilities
  - Temporal logic $\Box t \,.\, \mathsf{shipped}(B) \to \Diamond s \,.\, s \leq t + 5 \land \mathsf{received}(B)$
  - Ontologies