

Temper

Temporal Programmer: An Introduction

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- **A Logic for Time**
 - **Point-Interval Logic**
 - **Point Graphs**
- **Temper** – **Software Implementation of Point-Interval Formalism**
- **Temporal Issues in Forensics**
- **Example: Applying Temper to London Bombing Data**

Point-Interval Logic (PIL)



- Allen introduced Interval Algebra as a framework for temporal reasoning. The algebra takes time intervals to be primitives.
- Zaidi expanded this logic by adding points to create Point Interval Logic (PIL)
 - Three Cases
- Case I: X and Y both intervals with non-zero lengths

$X = [sx, ex]$, $Y = [sy, ey]$ with $sx < ex$ and $sy < ey$

Before	X < Y	$ex < sy$	
Meets	X m Y	$ex = sy$	
Overlaps	X o Y	$sx < sy; sy < ex; ex < ey$	
Starts	X s Y	$sx = sy; ex < ey$	
During	X d Y	$sx > sy; ex < ey$	
Finishes	X f Y	$sy < sx; ey = ex$	
Equals	X = Y	$sx = sy; ex = ey$	

Case II: X and Y both points

$X = [px]$ and $Y = [py]$ with $sx = ex = px$ and $sy = ey = py$

Before	$X < Y$	$px < py$	$\overset{X}{\underset{\bullet}{px}}$ $\overset{Y}{\underset{\bullet}{py}}$
Equals	$X = Y$	$px = py$	$\overset{[X;Y]}{\underset{\bullet}{px}}$

A point-point relation “less than or equal to” (\leq) can be added to PIL without losing tractability.

Case III—X is a point and Y is an interval

$X = [px]$ and $Y = [sy, ey]$ with $px = sx = ex$ and $sy < ey$

Before	$X < Y$	$px < sy$	$\overset{X}{\bullet}$ $\overline{\hspace{1cm}}$ Y
Starts	$X \text{ s } Y$	$px = sy$	$\overset{X}{\bullet}$ $\overline{\hspace{1cm}}$ Y
During	$X \text{ d } Y$	$sy < px < ey$	$\overline{\hspace{1cm}}$ Y with $\overset{X}{\bullet}$ inside
Finishes	$X \text{ f } Y$	$px = ey$	$\overline{\hspace{1cm}}$ Y with $\overset{X}{\bullet}$ at the right end
Before	$Y < X$	$ey < px$	$\overline{\hspace{1cm}}$ Y $\overset{X}{\bullet}$



- **Quantitative Temporal Information**

- $d1 \leq \text{Length} [X, Y] \leq d2$

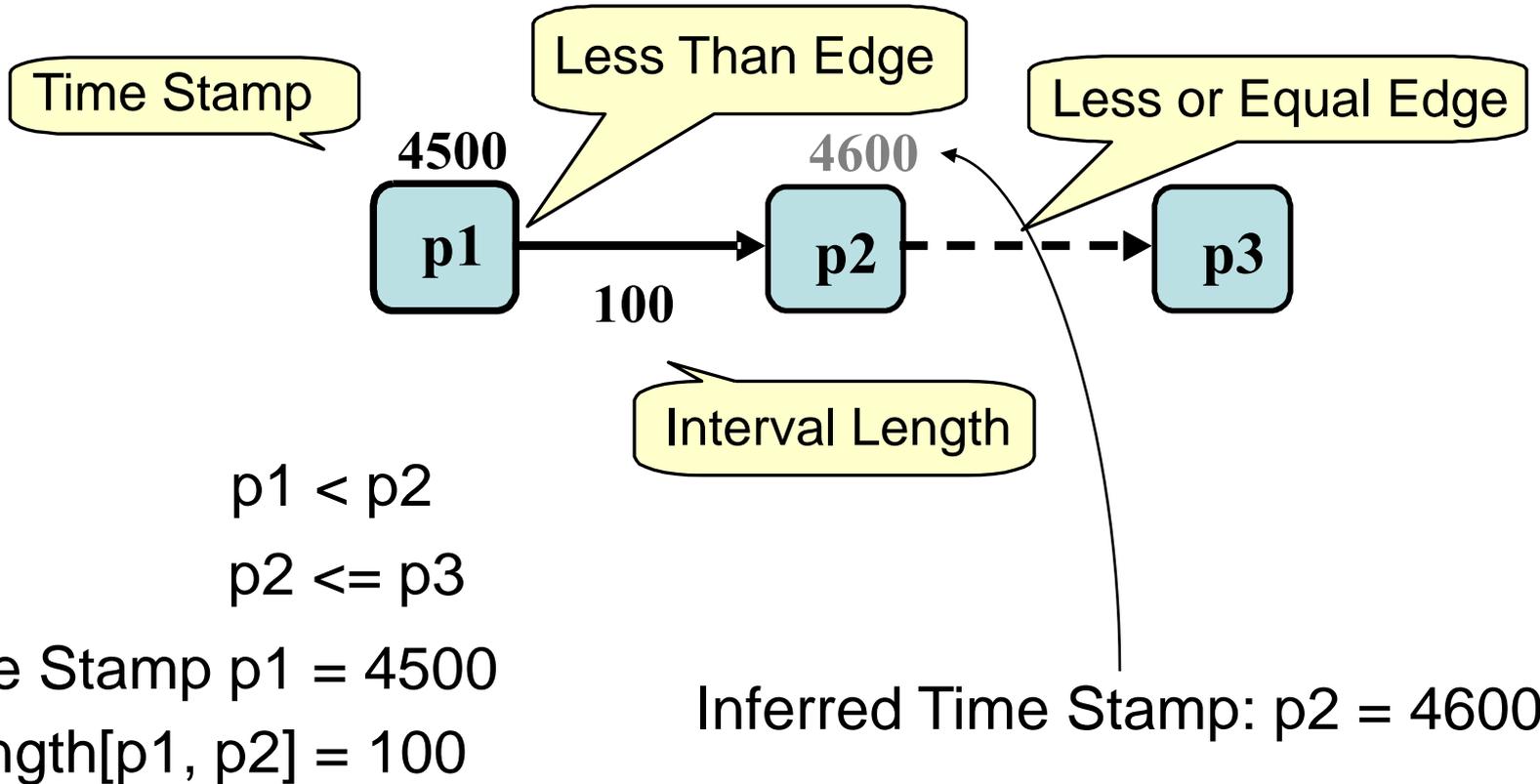
- $t1 \leq \text{Stamp} [X] \leq t2$

where $d1$, $d2$, $t1$, and $t2$ are rational numbers, and X , Y are points

- This allows for “at least” and “at most” temporal relationships for interval lengths, and “no earlier than” and “no later than” temporal relationships between time points

- **Knowledge Representation**

- A graph with nodes representing time points and edges representing the ‘inequalities’ captures the information in PIL statements



Point Interval Logic Statements and the corresponding Point Graph

```

sB < eB
sC < eC
sD < eD
sF < eF
sG < eG
sH < eH
Length [sB,eB] = 8
Length [sC,eC] = 9
Length [sD,eD] = 4
Length [sF,eF] = 1

```

Point Graph

Input Window

System Architectures Laboratory
George Mason University

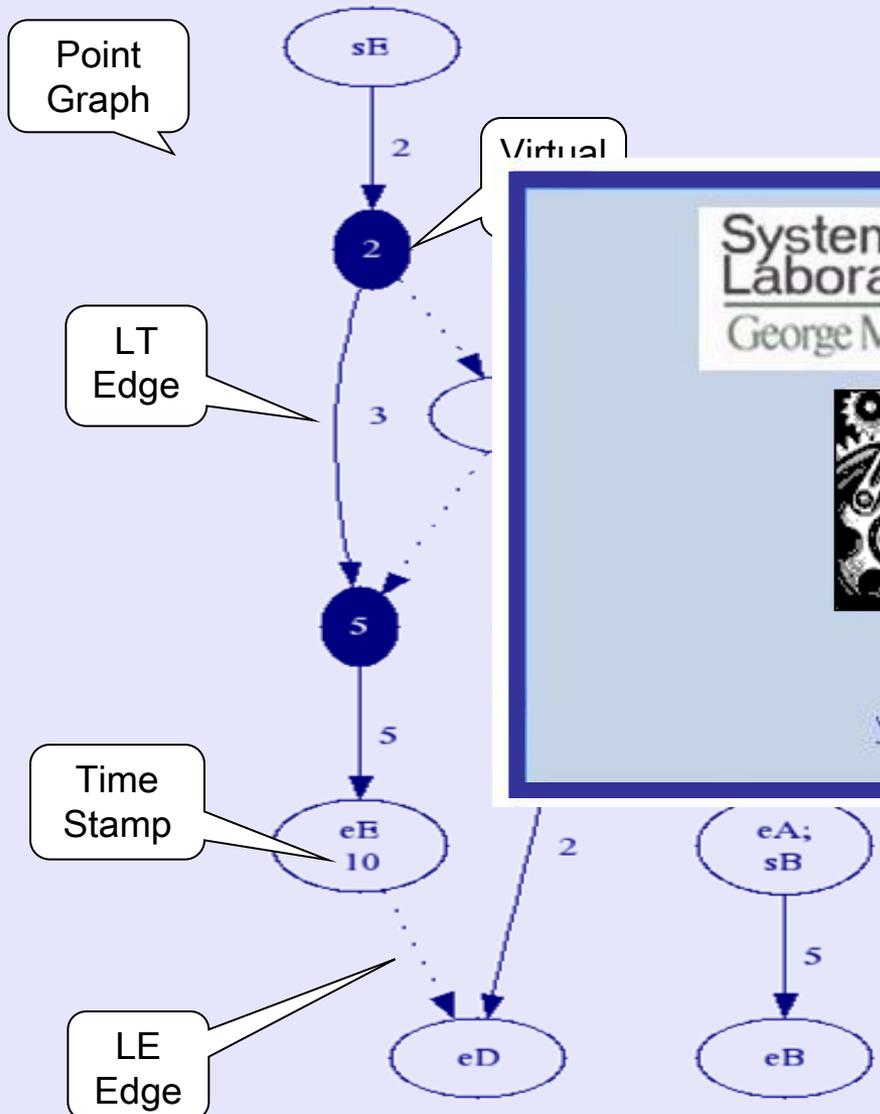
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LT Edge

Time Stamp

LE Edge

Output Window



Earliest Start Time	Latest End Time
0	8
0	12
8	12
9	13
12	15
10	15

Temper – The Software



- **Temper** is a tool for temporal knowledge representation, reasoning, and planning using **Point-Interval Logic (PIL)**.
- **PIL** is a formal algebraic framework for reasoning with time. It has the ability to handle both:
 - Events and Activities
 - Quantitative and Qualitative temporal relationships
 - Reasoning and Planning
- The relationships among various activities and events in a domain are specified in the form of **PIL** statements. These statements are converted into a graphical construct called **Point Graphs (PG)**.
 - Algorithms for verification, inference, and planning are implemented on the Point Graph representation.
- The implementation of **PIL** is in the form of a .NET class library called **PIL Engine**. It provides an application programming interface (API) that can be used in any .NET compliant programming language. It uses **QuickGraph**, which is an open-source C# implementation of the **Graphviz** library from AT&T.
- **Temper** provides a graphical user interface (GUI) to **PIL Engine**.

Add/Delete PIL Statements

Add Stamp	Delete Stamp	[Dropdown]	=	[Dropdown]	[Text]
Add Length	Delete Length	[Dropdown]	[Dropdown]	=	[Dropdown]
Add Relation	Delete Relation	[Dropdown]	<	[Dropdown]	[Dropdown]
Add Composite Relation		[Dropdown]	<	[Dropdown]	[Dropdown]
Reference Date and Time		Wednesday, October 11, 2006		24:00	

Numeric Stamp

Day Hour Minute Second

Language Editor

Query Editor

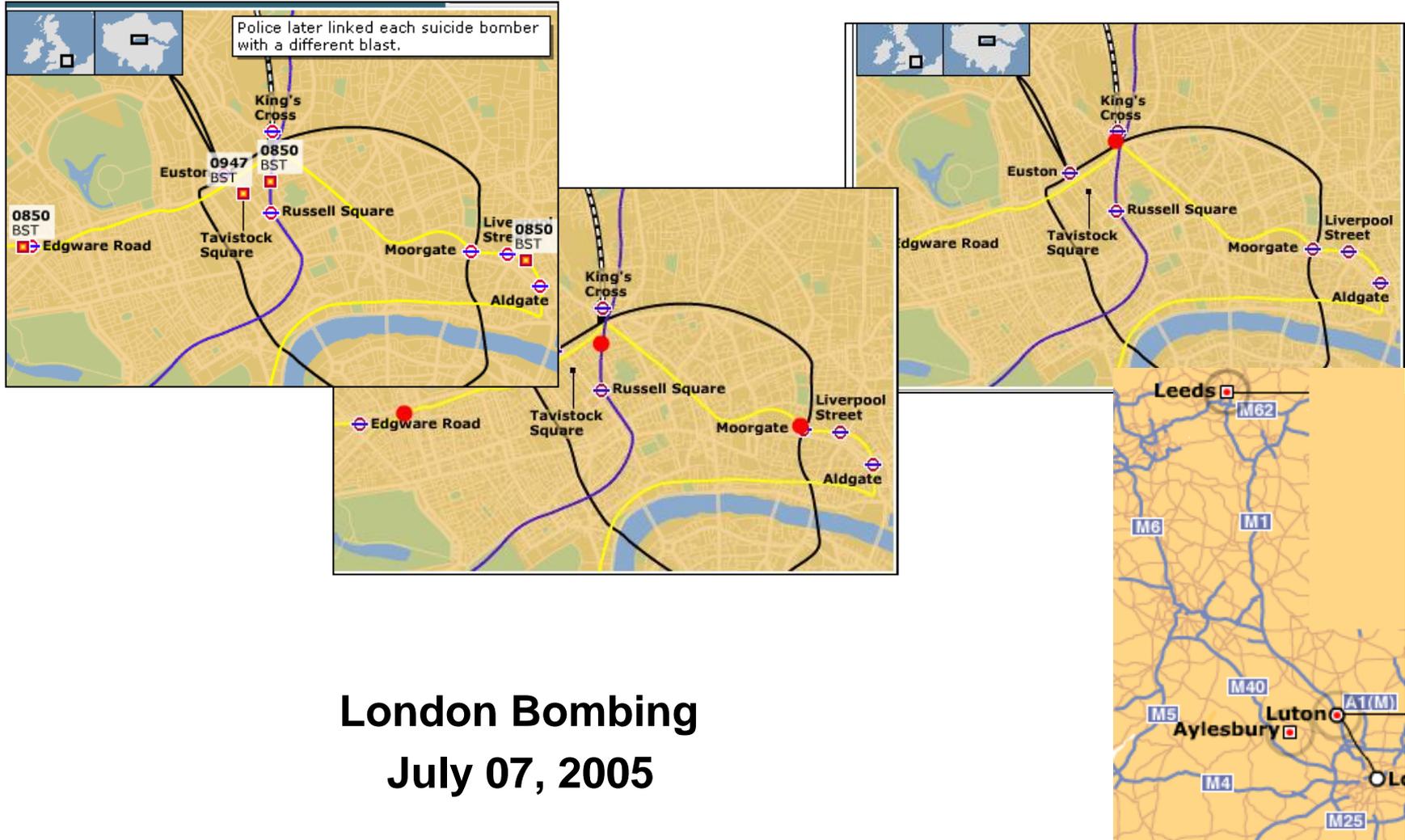
Query

Query Stamp	[Dropdown]	
Query Length	[Dropdown]	[Dropdown]
Query Relation	[Dropdown]	[Dropdown]

Close

- Convert the available temporal information into statements in Point-Interval Logic.
- Input these statements to **Temper** using the language editor of **Temper**.
- Construct a Point Graph representation of the set of Point Interval Logic (PIL) statements.
 - If the set of PIL statements is inconsistent then **Temper** will not be able to construct the Point Graph representation.
 - **Temper** will identify the subset of PIL statements causing the inconsistency.
 - User will remove the inconsistent statements.
- Once a consistent Point Graph has been constructed, it can be used to draw inferences.

- Knowledge Management and Reasoning
 - Forensics
 - Understanding of an incident of interest or a critical activity requires reconstruction of events that lead to an observable effect
 - Information regarding the incident/activity unfolds in no specific order and originates from different locations
 - Temporal information may be both qualitative and quantitative
 - Information may be inconsistent/incorrect
 - Information may contain hidden patterns or temporal relations that can help identify missing links
 - This calls for an automated tool for temporal knowledge representation, management, verification and reasoning
- **Temper** is also the temporal algorithm embedded in *Pythia*

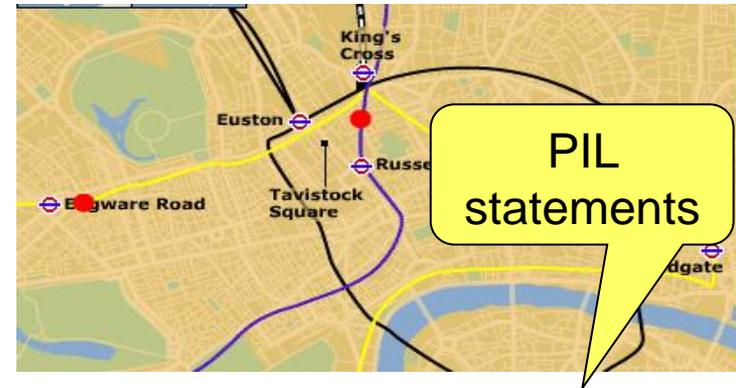


London Bombing July 07, 2005

Example: London Bombing



- There were four explosions in London.
- The sites of these explosions were: Travistock Square, Edgware Road, Aldgate and Russell Square.
- Three of these explosions (Edgware, Aldgate and Russell Square) were in trains.
- These trains left from King's Cross station. The journey of these trains ended in explosions.
- The time it takes a train from King's Cross to reach Edgware is at least 5 minutes.
- The time it takes a train from King's Cross to reach Aldgate is at least 4 minutes.
- The time it takes a train from King's Cross to reach Russell Square is at least 5 minutes.



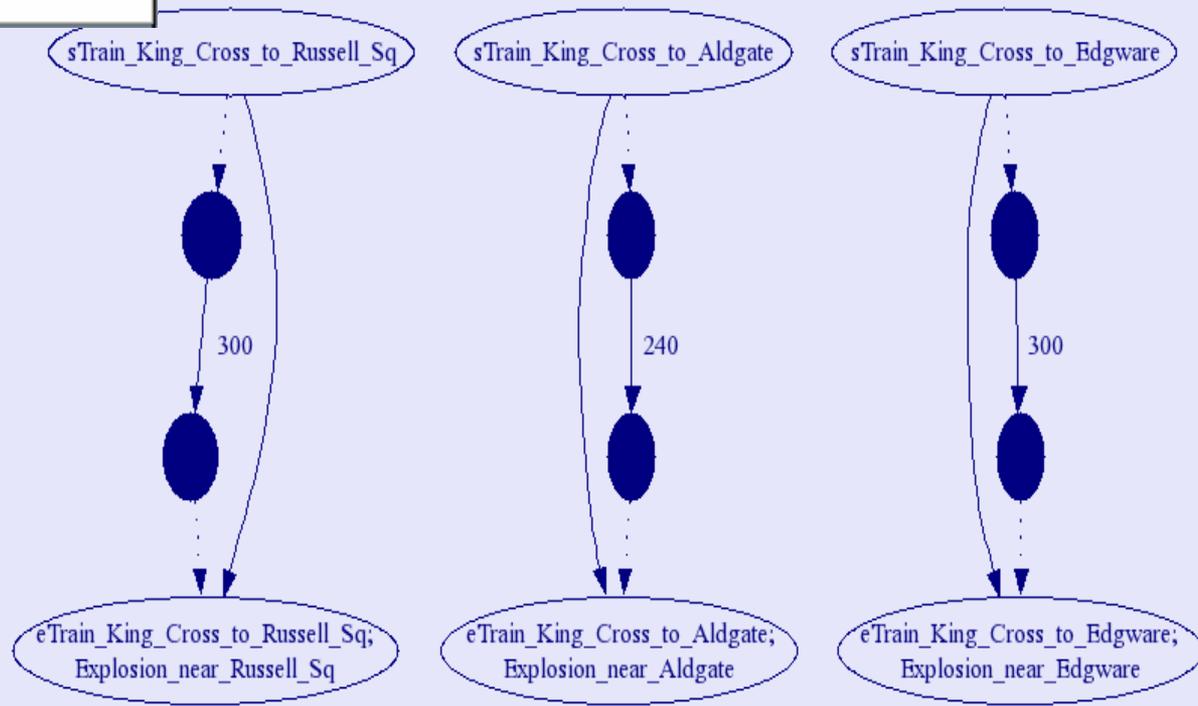
Interval Train_King_Cross_to_Edgware,
 Train_King_Cross_to_Aldgate,
 Train_King_Cross_to_Russell_Sq
Point Explosion_at_Travistock_Square,
 Explosion_near_Edgware,
 Explosion_near_Aldgate,
 Explosion_near_Russell_Sq
 Explosion_near_Edgware *finishes*
 Train_King_Cross_to_Edgware
 Explosion_near_Aldgate *finishes*
 Train_King_Cross_to_Aldgate
 Explosion_near_Russell_Sq *finishes*
 Train_King_Cross_to_Russell_Sq
Length [Train_King_Cross_to_Edgware] >= 0:5:0
Length [Train_King_Cross_to_Aldgate] >= 0:4:0
Length [Train_King_Cross_to_Russell_Sq] >= 0:5:0

File Settings Help

- New
- Open ...
- Append ...
- Close
- Save ...
- Save As ...
- Recent Files
- Exit

Queries

Point Graph



PIL Statements

Compiled To Be Deleted Inferred To Be Added Comments

```

sTrain_King_Cross_to_Edgbare < eTrain_King_Cross_to_Edgbare
sTrain_King_Cross_to_Aldgate < eTrain_King_Cross_to_Aldgate
sTrain_King_Cross_to_Russell_Sq < eTrain_King_Cross_to_Russell_Sq
Length [sTrain_King_Cross_to_Edgbare,eTrain_King_Cross_to_Edgbare]
Length [sTrain_King_Cross_to_Aldgate,eTrain_King_Cross_to_Aldgate]
Length [sTrain_King_Cross_to_Russell_Sq,eTrain_King_Cross_to_Russell_Sq]
Explosion_near_Edgbare f [sTrain_King_Cross_to_Edgbare,eTrain_King_Cross_to_Edgbare]
Explosion_near_Aldgate f [sTrain_King_Cross_to_Aldgate,eTrain_King_Cross_to_Aldgate]
Explosion_near_Russell_Sq f [sTrain_King_Cross_to_Russell_Sq,eTrain_King_Cross_to_Russell_Sq]
  
```

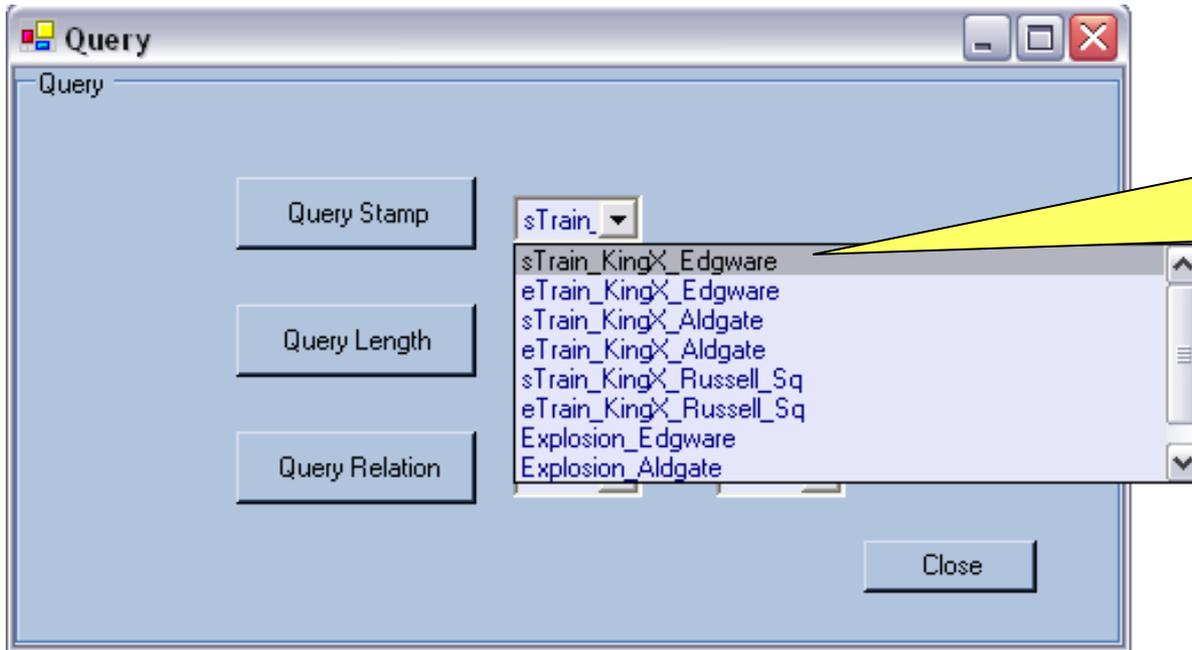
PIL statements

Activity Table Real Time Gantt Chart Output

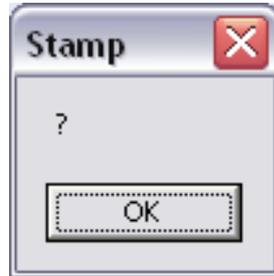
```

sTrain_King_Cross_to_Edgbare : 0 days 0 hour 0 minute 0 second
eTrain_King_Cross_to_Edgbare : 0 days 0 hour 0 minute 0 second
sTrain_King_Cross_to_Aldgate : 0 days 0 hour 0 minute 0 second
eTrain_King_Cross_to_Aldgate : 0 days 0 hour 0 minute 0 second
sTrain_King_Cross_to_Russell_Sq : 0 days 0 hour 0 minute 0 second
eTrain_King_Cross_to_Russell_Sq : 0 days 0 hour 0 minute 0 second
Explosion_near_Edgbare : 0 days 0 hour 0 minute 0 second
Explosion_near_Aldgate : 0 days 0 hour 0 minute 0 second
Explosion_near_Russell_Sq : 0 days 0 hour 0 minute 0 second
Explosion_at_Travistock_Square : 0 days 0 hour 0 minute 0 second
  
```

Example: London Bombing (cont'd)



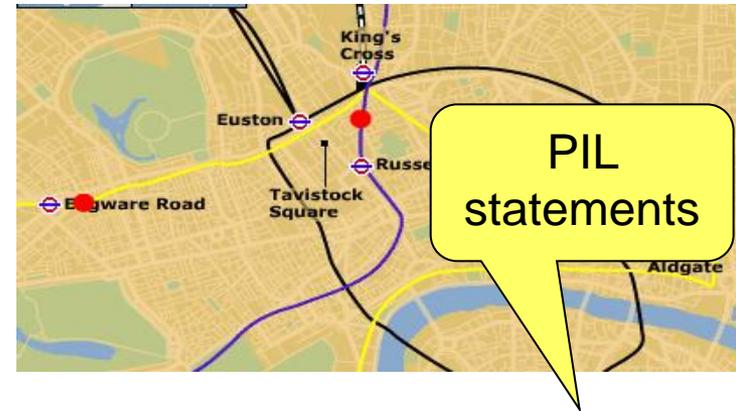
Query Stamp
(when did the train
to Edgbare leave
from King's Cross?)



Example: London Bombing (cont'd)



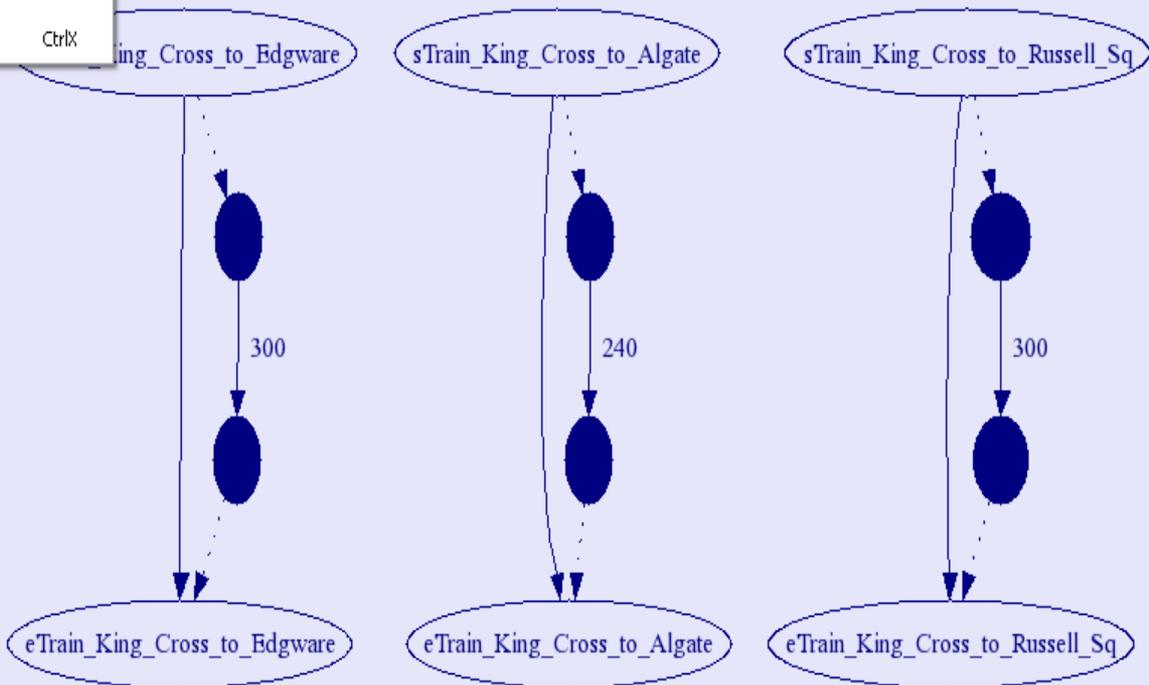
- The explosion near Edgware Road took place between time units 8:40 and 8:52.
- The explosion near Aldgate took place between time units 8:45 and 8:50.
- The explosion near Russell Square took place between time units 8:40 and 8:50.
- The explosion at Tavistock Square took place between time units 9:45 and 9:55.



8:40 \Leftarrow *Stamp* [Explosion_near_Edgware] \Leftarrow 8:52
 8:45 \Leftarrow *Stamp* [Explosion_near_Aldgate] \Leftarrow 8:50
 8:40 \Leftarrow *Stamp* [Explosion_near_Russell_Sq] \Leftarrow 8:50
 9:45 \Leftarrow *Stamp* [Explosion_at_Tavistock_Square] \Leftarrow 9:55

- New CtrlN
- Open ... CtrlO
- Open PIL Binary ...
- Append ...
- Close
- Save ...
- Save As ...
- Save PIL Binary ...
- Recent Files
- Exit CtrlX

Queries



PIL Statements

Compiled	To Be Deleted	Inferred	To Be Added	Comments
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```

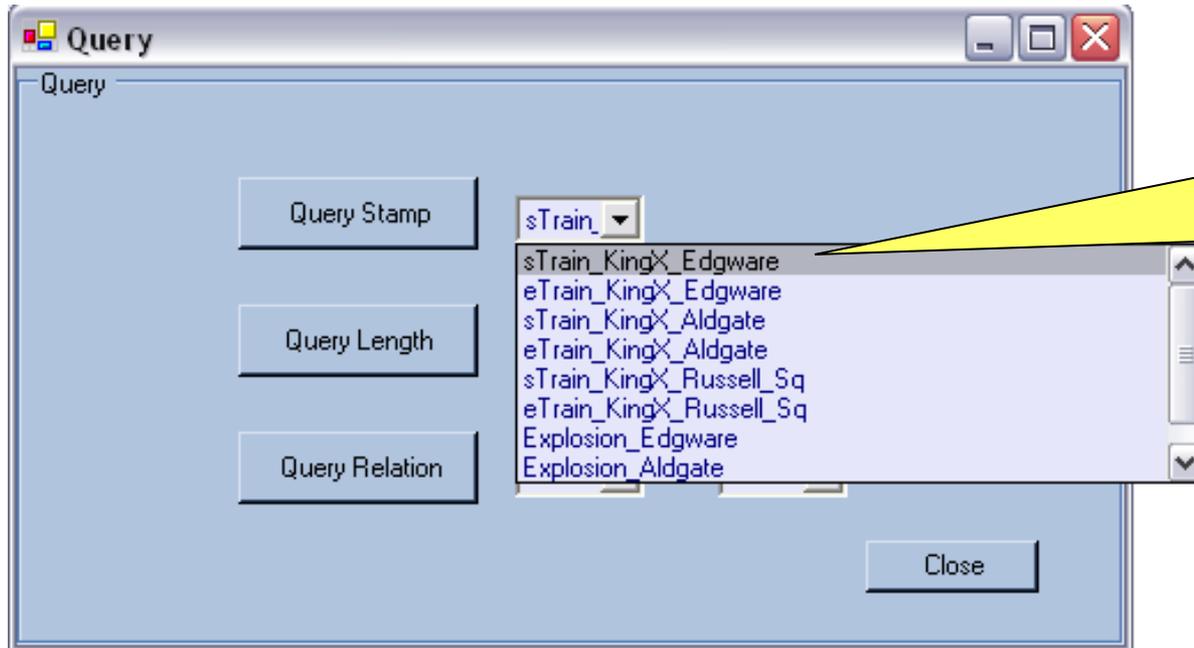
sTrain_King_Cross_to_Edgware < eTrain_King_Cross_to_Edgware
sTrain_King_Cross_to_Algate < eTrain_King_Cross_to_Algate
sTrain_King_Cross_to_Russell_Sq < eTrain_King_Cross_to_Russell_Sq
Length [sTrain_King_Cross_to_Edgware,eTrain_King_Cross_to_Ed
Length [sTrain_King_Cross_to_Algate,eTrain_King_Cross_to_Alga
Length [sTrain_King_Cross_to_Russell_Sq,eTrain_King_Cross_to_
  
```

Activity Table	Real Time	Gantt Chart	Output
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```

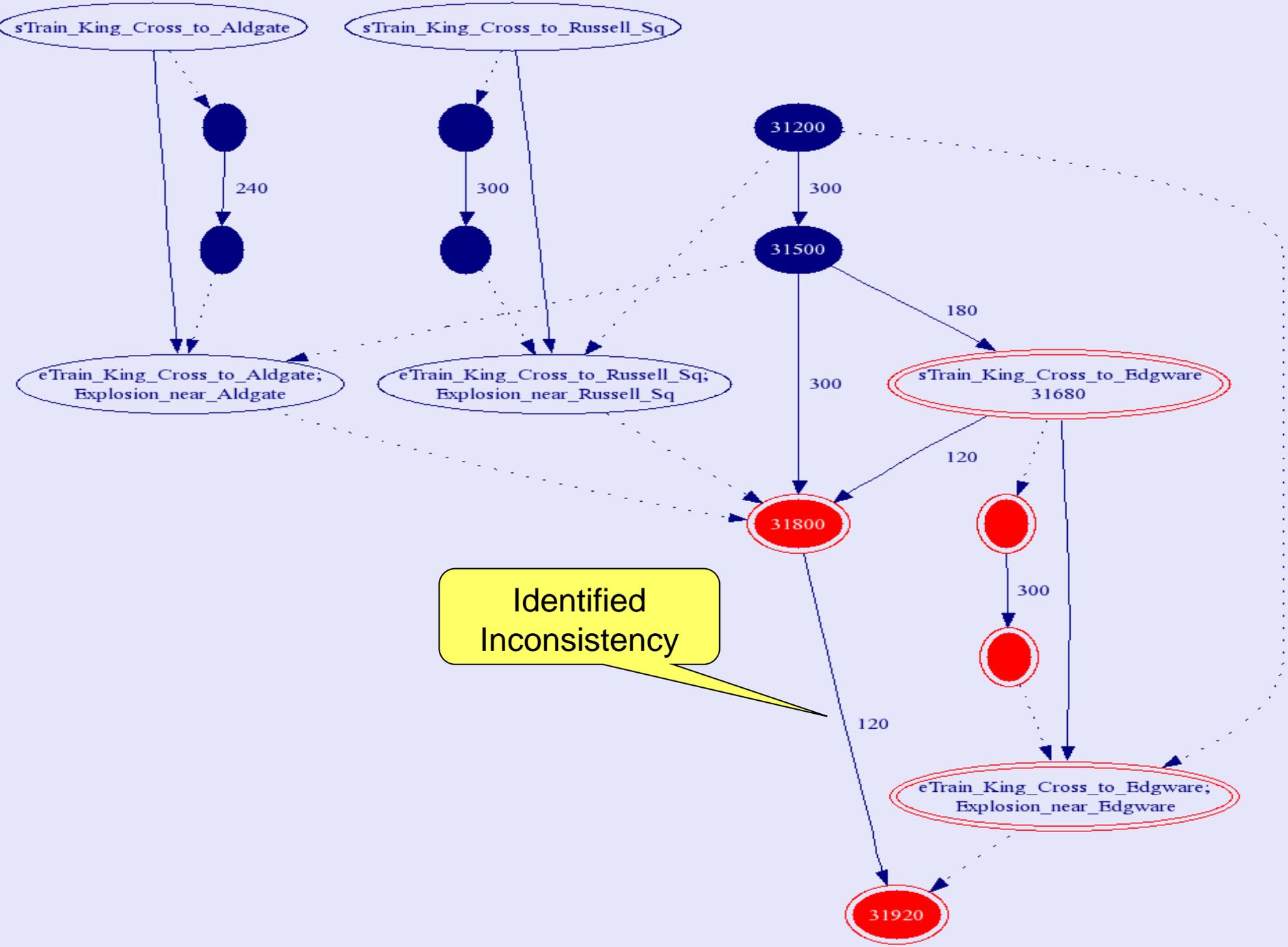
sTrain_King_Cross_to_Edgware : 0 days 0 hour 0 minute 0 seco
eTrain_King_Cross_to_Edgware : 0 days 0 hour 0 minute 0 seco
sTrain_King_Cross_to_Algate : 0 days 0 hour 0 minute 0 second
eTrain_King_Cross_to_Algate : 0 days 0 hour 0 minute 0 second
sTrain_King_Cross_to_Russell_Sq : 0 days 0 hour 0 minute 0 se
eTrain_King_Cross_to_Russell_Sq : 0 days 0 hour 0 minute 0 se
Explosion_near_Edgware : 0 days 0 hour 0 minute 0 second
Explosion_near_Algate : 0 days 0 hour 0 minute 0 second
Explosion_near_Russell_Sq : 0 days 0 hour 0 minute 0 second
Explosion_at_Travistock_Square : 0 days 0 hour 0 minute 0 sec
  
```


Example: London Bombing (cont'd)



Query Stamp
(when did the train
to Edgware leave
from King's Cross?)

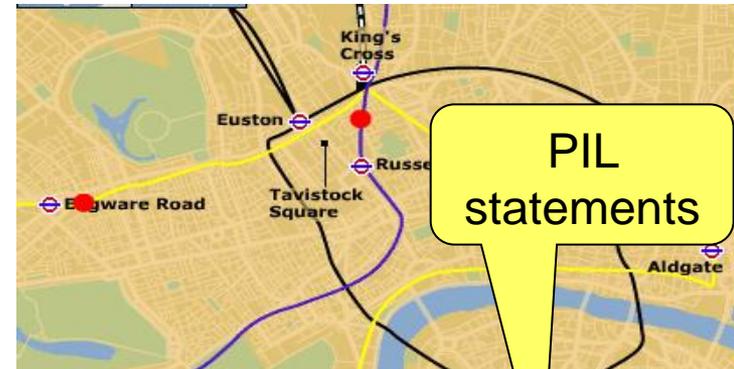




Example: London Bombing (cont'd)

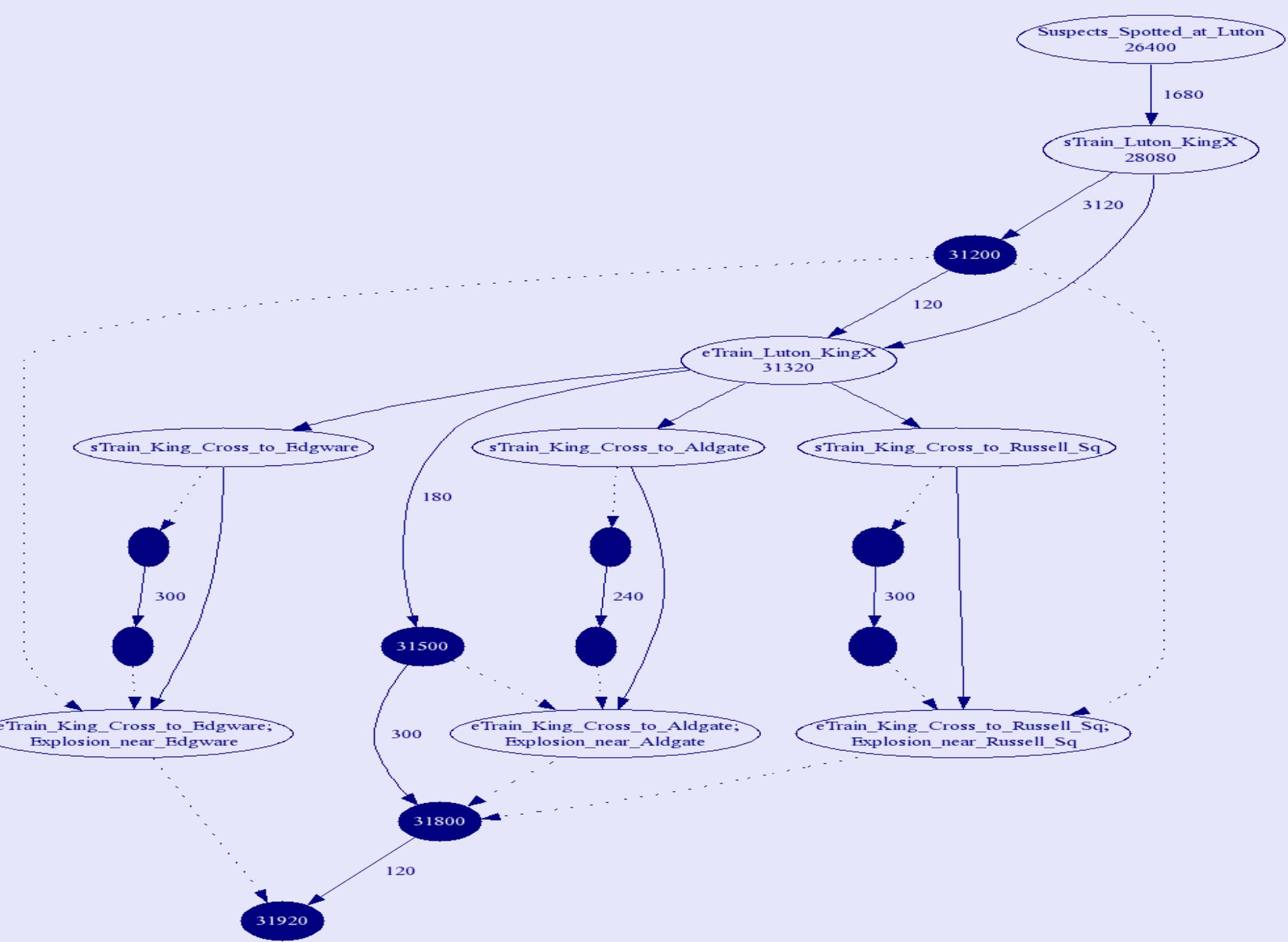


- The alleged four bombers spotted entering the Luton station at time unit 7:20.
- The next train from Luton to King's Cross left at 7:48 reaching King's Cross at 8:42.
- Train to Edgware left after the train from Luton.
- Train to Aldgate left after the train from Luton.
- Train to Russell Sq. left after the train from Luton.

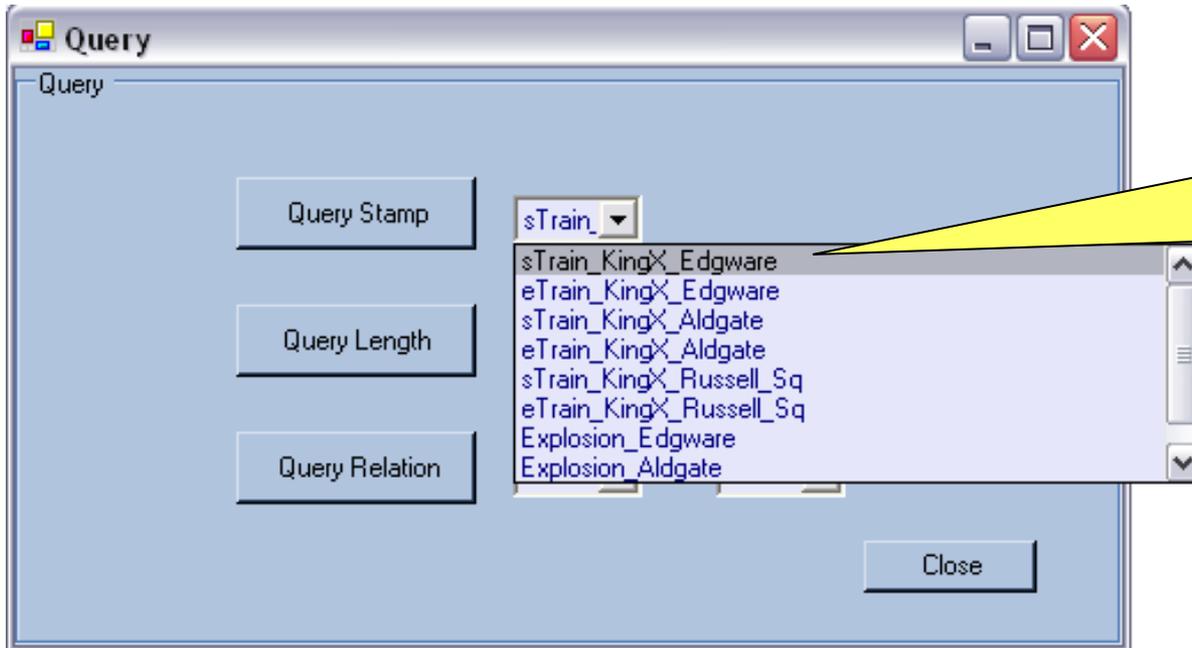


Interval Train_Luton_to_King_Cross
Point Bombers_spotted_at_Luton
Stamp [Bombers_spotted_at_Luton] = 7:20
Stamp [sTrain_Luton_to_King_Cross] = 7:48
Stamp [eTrain_Luton_to_King_Cross] = 8:42
 eTrain_Luton_to_King_Cross *before*
 Train_King_Cross_to_Edgware
 eTrain_Luton_to_King_Cross *before*
 Train_King_Cross_to_Aldgate
 eTrain_Luton_to_King_Cross *before*
 Train_King_Cross_to_Russell_Sq





Example: London Bombing (cont'd)



Query Stamp
(when did the train
to Edgware leave
from King's Cross?)





- **A formal approach to modeling and analyzing temporal information related to an event of interest, e.g., terrorist acts**
- **A software implementation of the approach with**
 - **An easy-to-use input language**
 - **Analysis toolkit that includes a consistency checker and a reasoning tool with a query language/interface**
 - **An efficient revision mechanism that helps add/modify temporal information without restarting the whole process**
 - **A graphical interface**
- **What might be added in future**
 - **Connectivity to temporal information in databases**
 - **Automated extraction of temporal information from textual source(s)**
 - **Better user/analyst input/output interfaces for display of information (both input and inferred)**

- Integration of the three dimensions of spatial knowledge with the temporal dimension to create a unified approach for handling change

