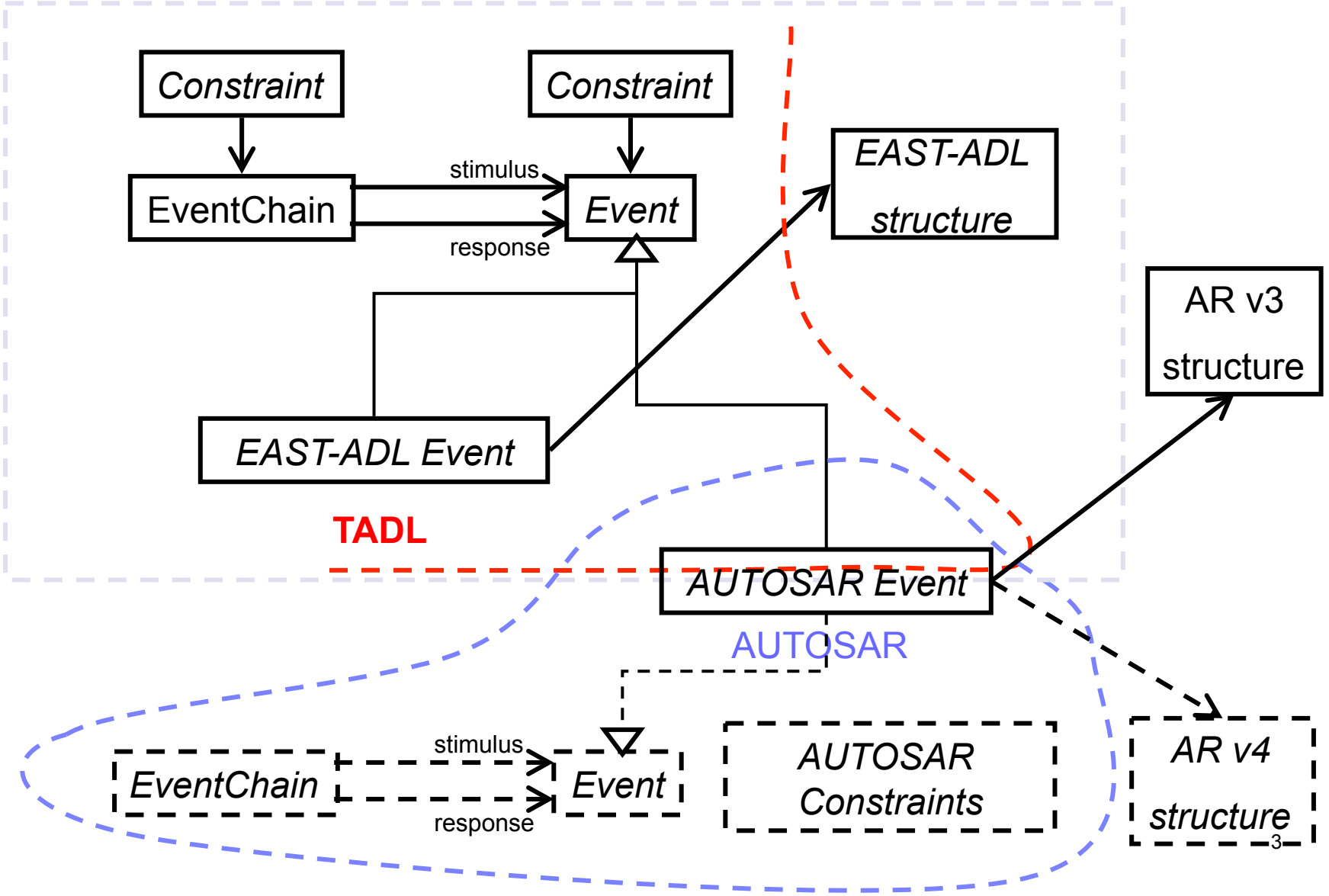
Outline, EAST-ADL support for Timing

Timing concepts are based on TIMMO project results (Timing Augmented Modelling Language, TADL)

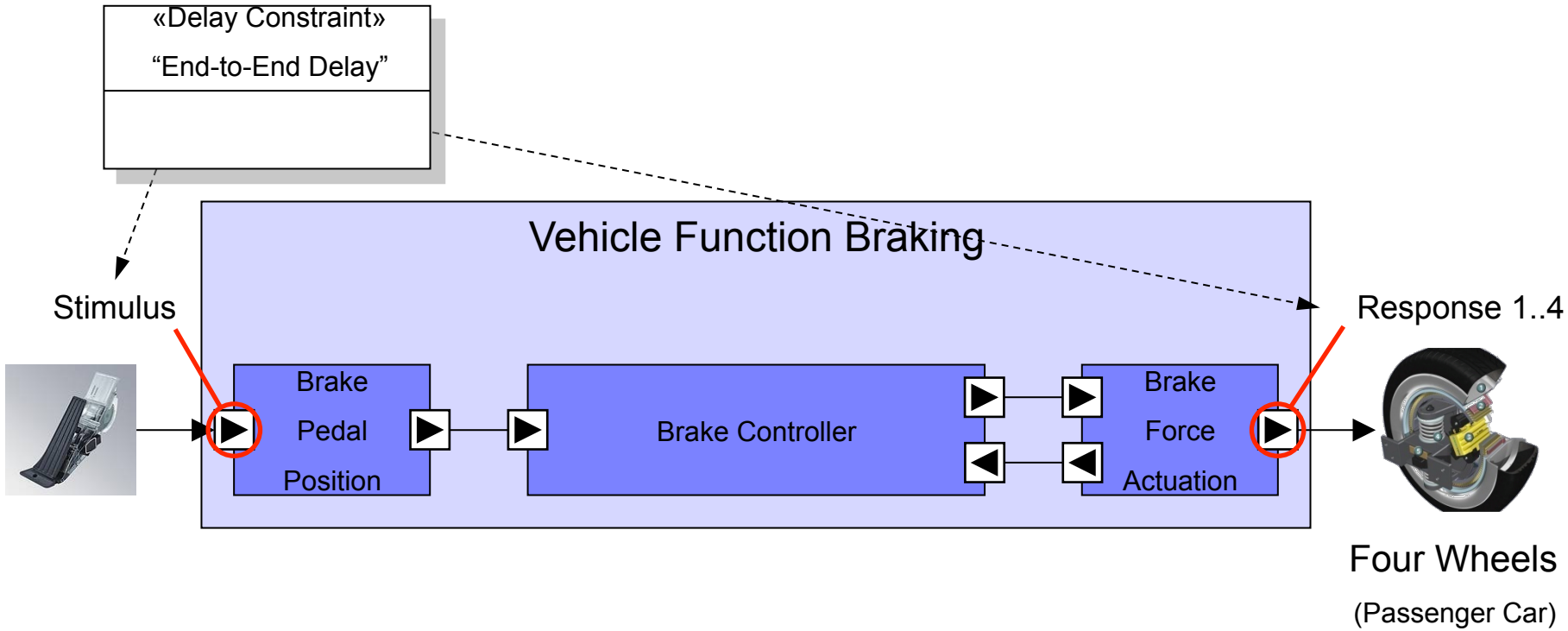
- Timing concepts are reviewed here, essentially
  - Events
    Related to EAST-ADL and AUTOSAR structural entities
  - Event Chains
    Binds together events to establish sequences/relations between events
  - Constraints
    Puts temporal constraints on sets of events or on event chains
- Ongoing Harmonization with MARTE with the purpose of allowing Timing analysis – see MAENAD analysis workbench

Metamodel Overview – Timing aspects



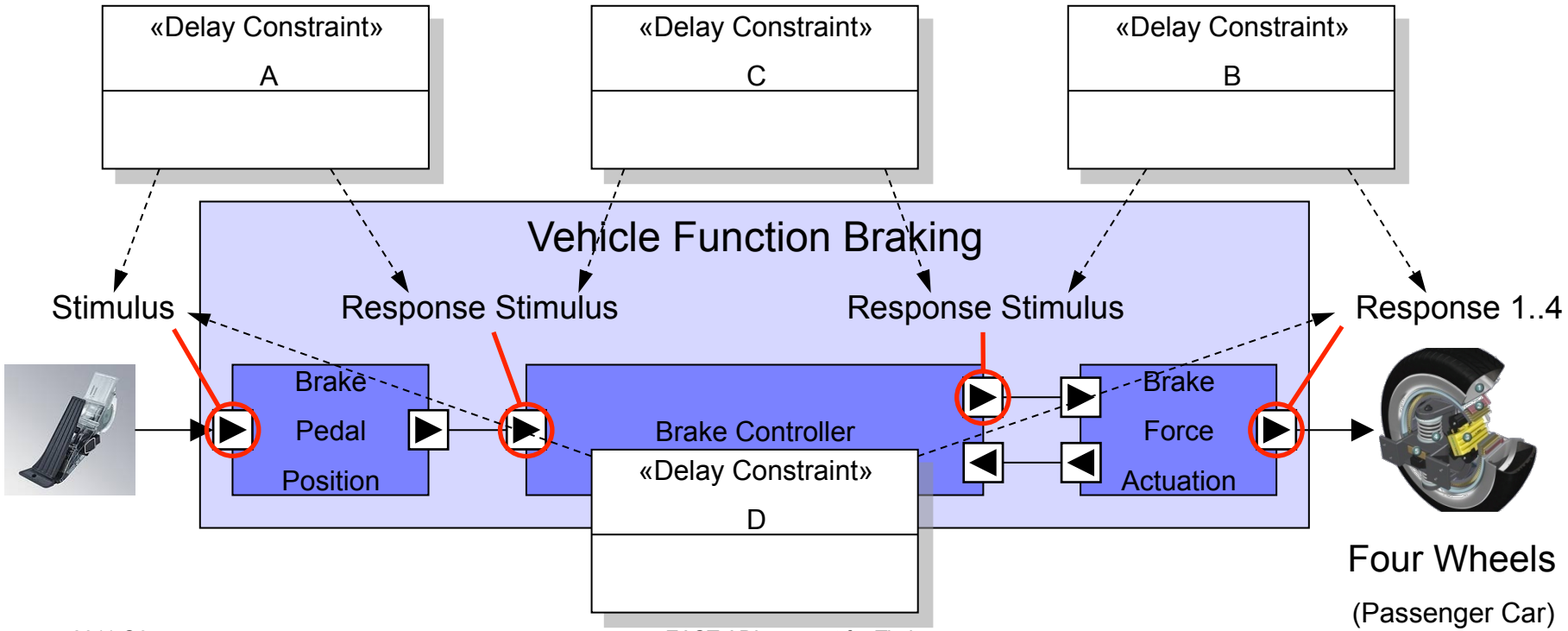
Introduction: Delay Constraint

- What is the maximum and/or minimum delay from brake pedal sensor to brake actuator?



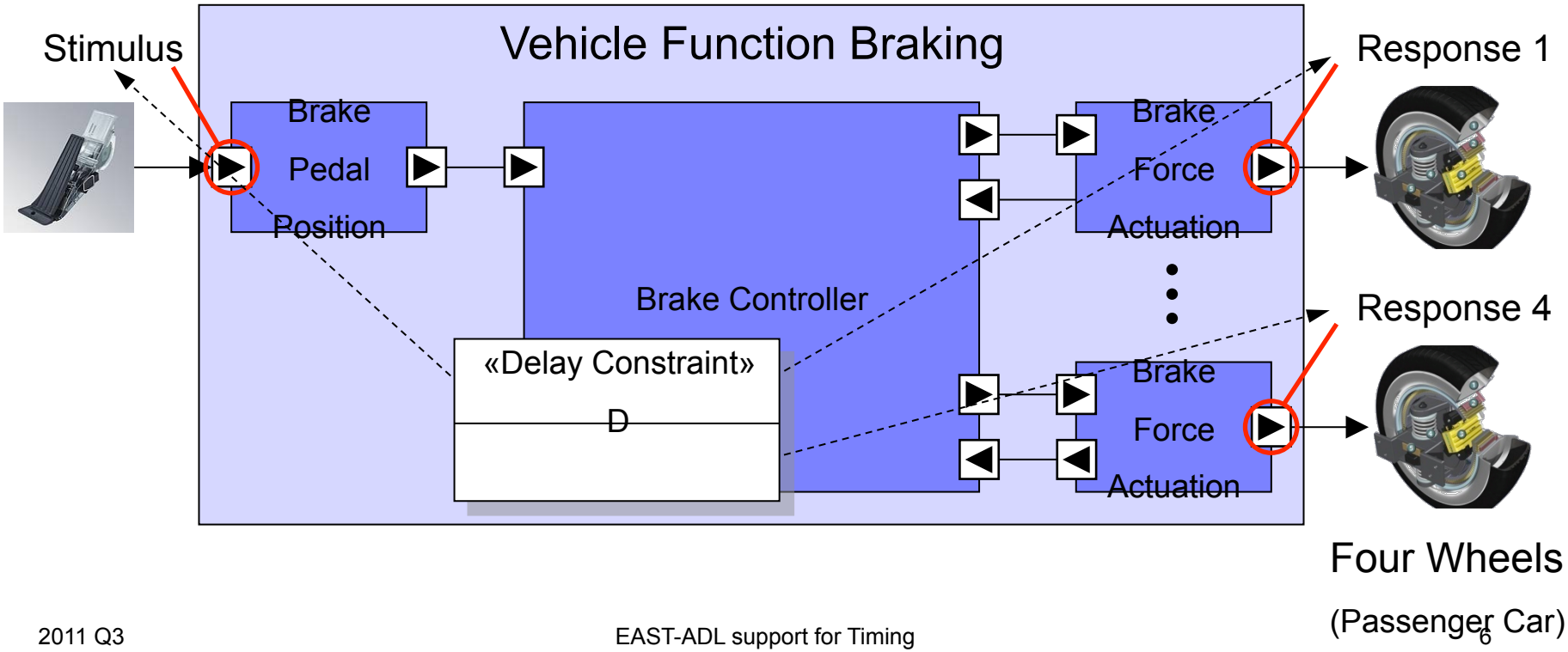
Delay Constraint Segments of a Chain

- One can identify a number of delay constraints that constitutes the *segments* of a “longer” chain:
- Example:
  - The total delay (Delay Constraint D) from Brake Pedal to Brake Actuator can be broken down into segments A, B and C.
  - D = A + B + C



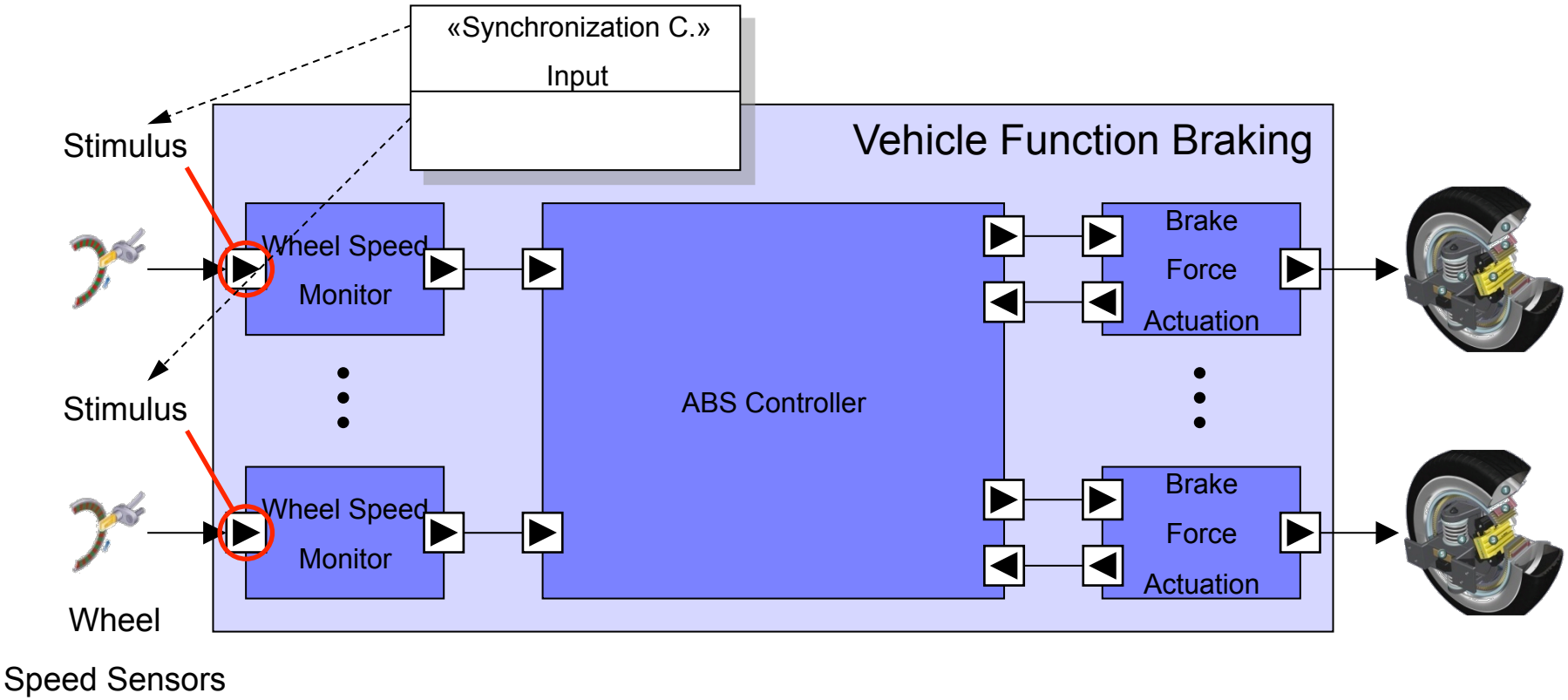
Delay Constraint Segments of a Chain

- One can have more than one stimulus and/or response for a delay constraint.
- Example:
  - What is the total delay from the Brake pedal to any of the four wheel brakes?



Input Synchronization

- What is the difference between a set of stimuli, regardless of when the response will happen?
- Example:
  - What is the tolerated maximum difference between the wheel speed sensors for the ABS?

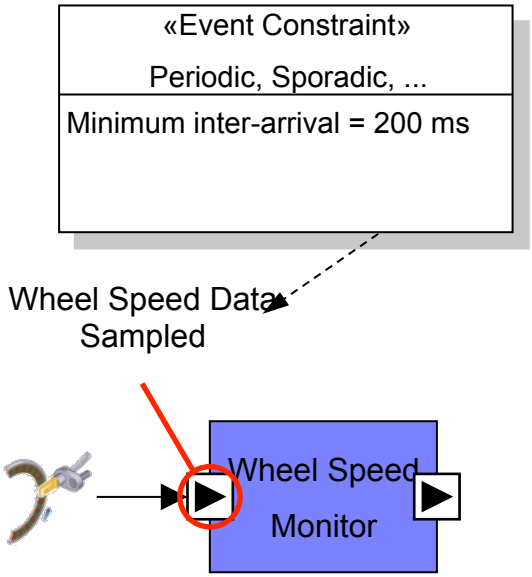


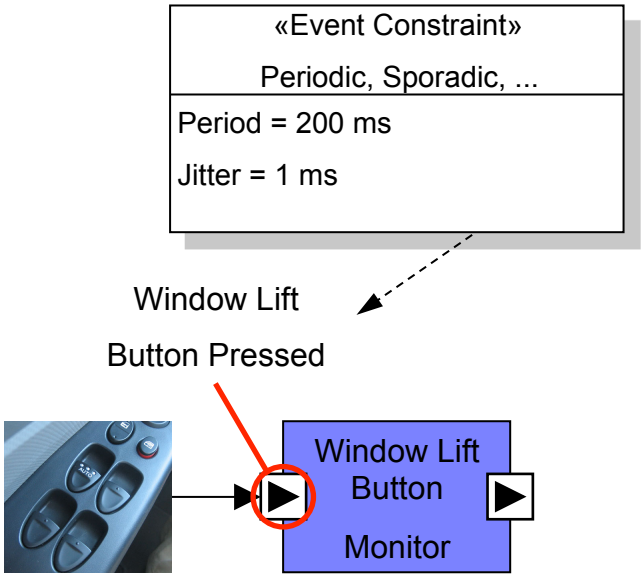
Introduction: Output Synchronization

- What is the difference between a set of responses, regardless of when the stimuli happened?
- Example:
  - What is the tolerated maximum difference between first and last door lock when locking the doors of a vehicle?

Event Constraint

- One can specify how often an event occurs.
- Example:
  - What is the interval between two samplings of a wheel speed sensor?
  - What is the minimum interval between two occurrences of a window lift button pressed?

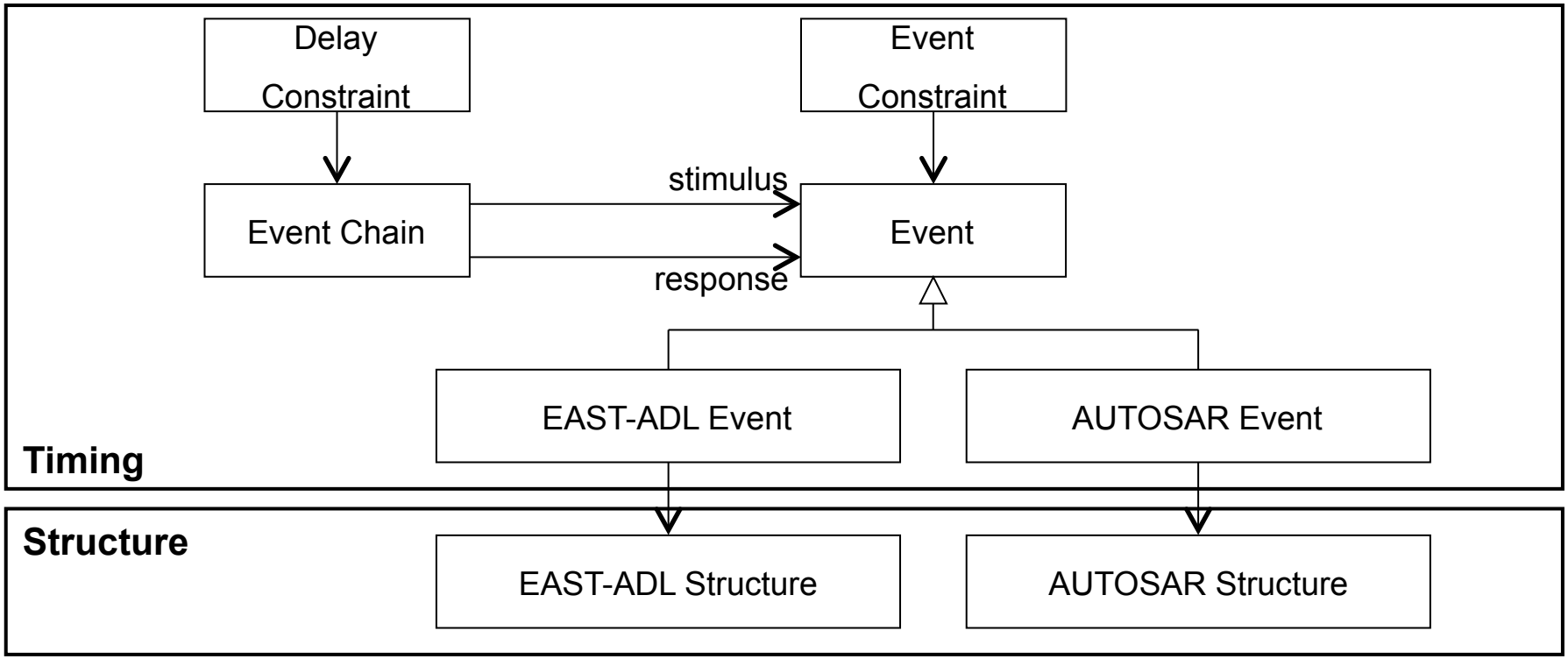




Timing Information

- **Timing Descriptions**
  - Event
  - Event Chain
- **Timing Constraints**
  - Delay Constraint – Requirements/constraints imposed on event chains
    - Age Timing Constraint
    - Reaction Constraint
    - Input and Output Synchronization Constraint
  - Event Constraint (a.k.a. Event Models, Event Repetition Constraints) – Requirements/constraints imposed on events
    - Periodic Event Constraint
    - Sporadic Event Constraint
    - Pattern Event Constraint
    - Arbitrary Event Constraint
  - Offset Constraint – Requirement/constraint imposed on two events

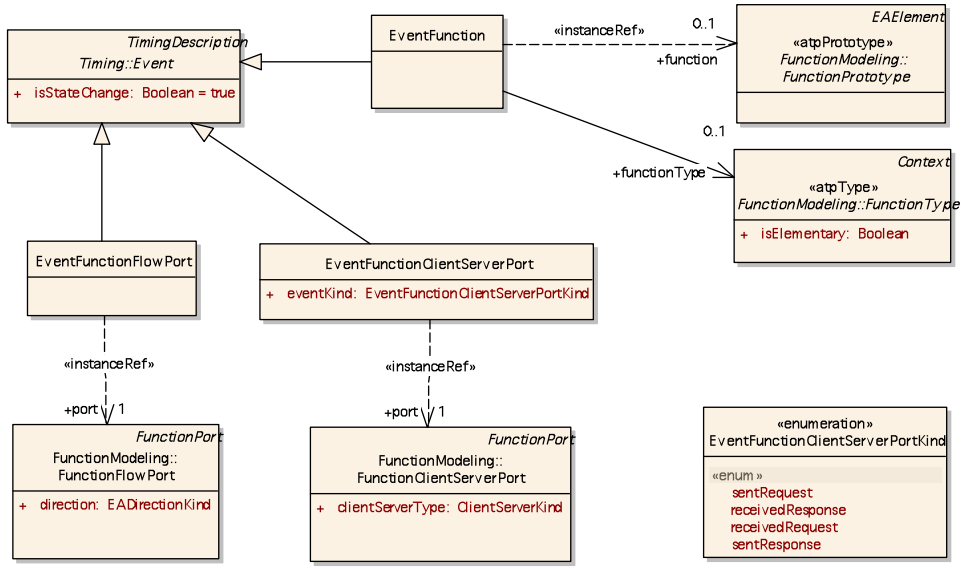
Basic Syntax



- A delay constraint is imposed on an event chain
- An event chain points to events playing the roles of stimuli and responses
- An event constraint is imposed on an event
- An event points to a system model in EAST-ADL

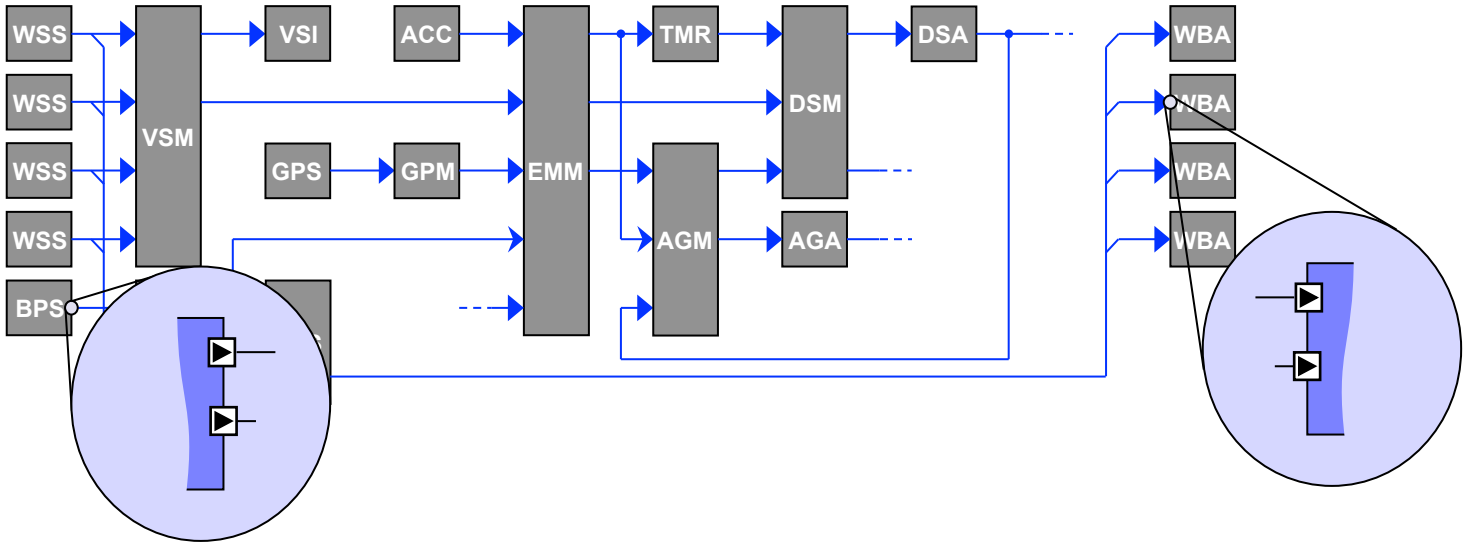
EAST-ADL Predefined Events

- EventFunctionFlowPort
  - Data received or sent on port
- EventClientServerPort
  - Client request or server response sent on port
  - Client response or server request received on port
- EventFunction
  - Function instance triggered
  - Function type triggered

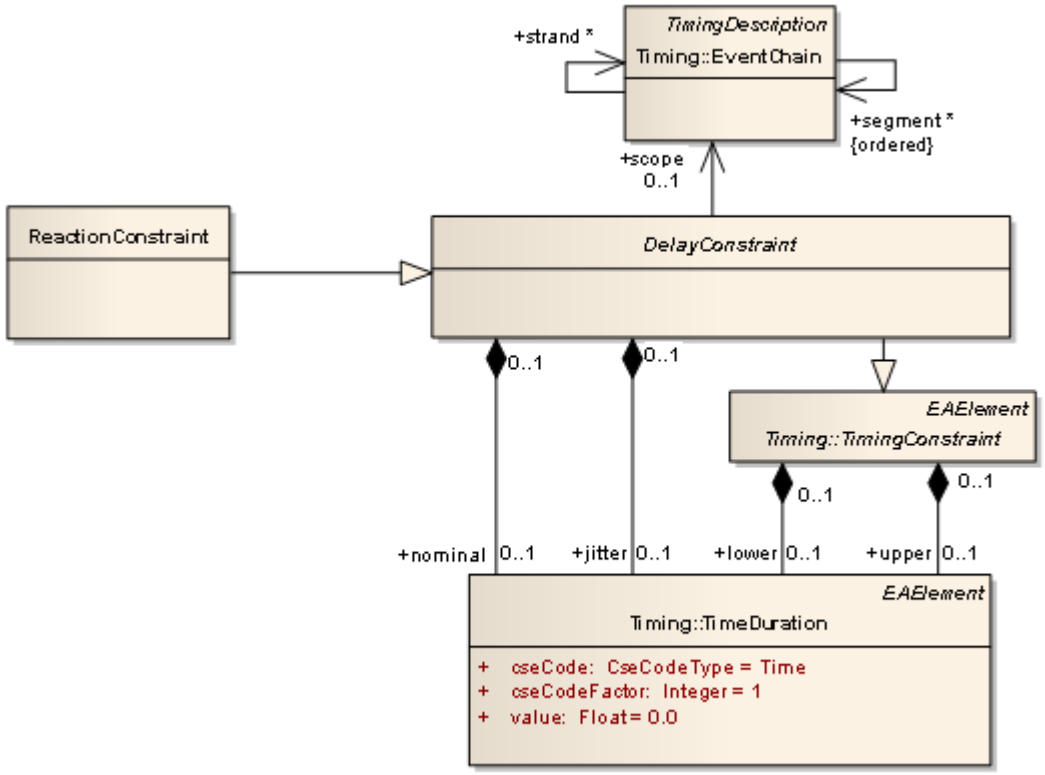


Event Chain

- Relates events with each other
- Establishes a causality between events: stimulus and response
- Can be broken into further Event Chain Segments (decomposition)
- Can be composed by existing Event Chain Segments (composition)
- Subsumes a number of event chains, called event chain strands

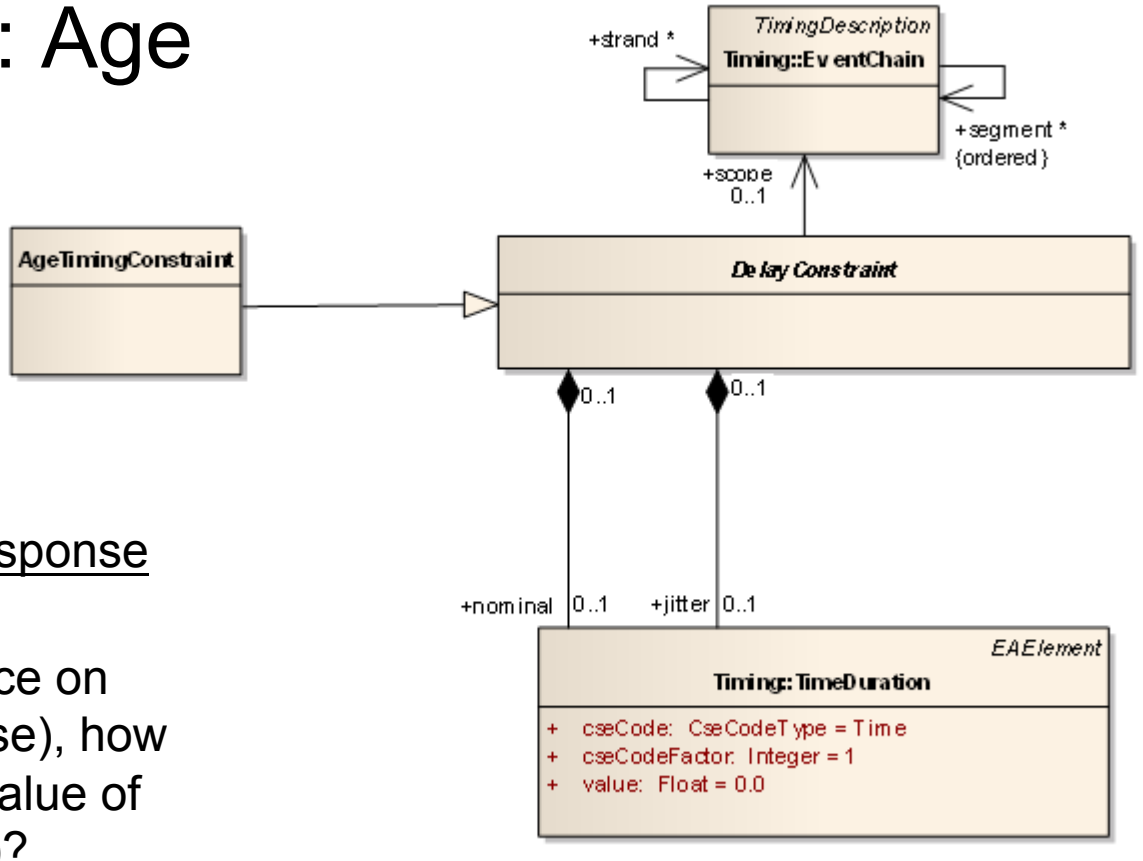


Delay Constraint: Reaction



- Perspective is from the stimulus event forward
- Example: When brake pedal is pressed (stimulus), how long will it take before brake is active on wheel (response)?

Delay Constraint: Age



- Perspective is from the response event backward
- Example: When brake force on wheel is updated (response), how old is the corresponding value of the brake pedal (stimulus)?

Delay Constraint: Reaction versus Age

- Both:
  - Delay between stimulus and response
- Reaction:
  - Perspective is from the stimulus event
  - Example: When brake pedal is pressed (stimulus), how long will it take before brake is active on wheel (response)?
- Age:
  - Perspective is from the response event
  - Example: When brake force on wheel is updated (response), how old is the corresponding value of the brake pedal (stimulus)?

Delay Constraint: Reaction versus Age ... *continued*

- Both:
  - Delay between stimulus and response
- But:
  - In sampled systems the difference is important to be able to
    - Compose segments to a longer chain
      - Constraint of longer chain is the sum of Segment Constraints (even in multi rate systems)
    - Uniquely identify the corresponding events and the path between them

Delay Constraint: Reaction versus Age ... Conclusion

- Age is defined for each response
  - Several Age event chains can originate from a certain stimulus, but only one can end in a certain response-
- Reaction is defined for each stimulus
- One can compose and decompose constraints of the same type
  - Age = Age + Age + ...
  - Reaction = Reaction + Reaction + ...
  - Reaction event chains can end in a certain response, but only one can originate from a certain ~~response.~~

This constraint provides an alternative to the ordinary DelayConstraint (section 3.6.1) for situations where the causal relation between event occurrences must be taken into account. It differs from the DelayConstraint in that it applies to an event chain, and only looks at the *response* occurrences that have the same color as each particular *stimulus* occurrence. It is the earliest of these *response* occurrences that is required to lie within the prescribed time bounds. If the roles of *stimulus* and *response* are swapped, and the time bounds negated, an AgeConstraint is obtained (see section 3.6.16).

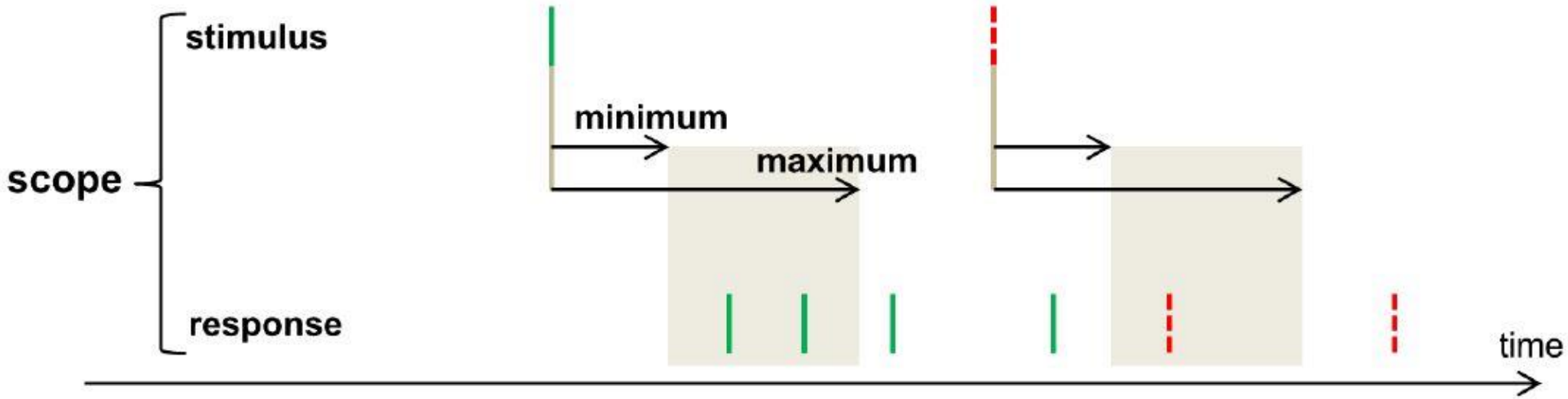


Figure 17. A set of event occurrences satisfying a ReactionConstraint. Causally connected event occurrences are shown by the same line style. Two sets are shown, one by a solid line and one by a dashed line.

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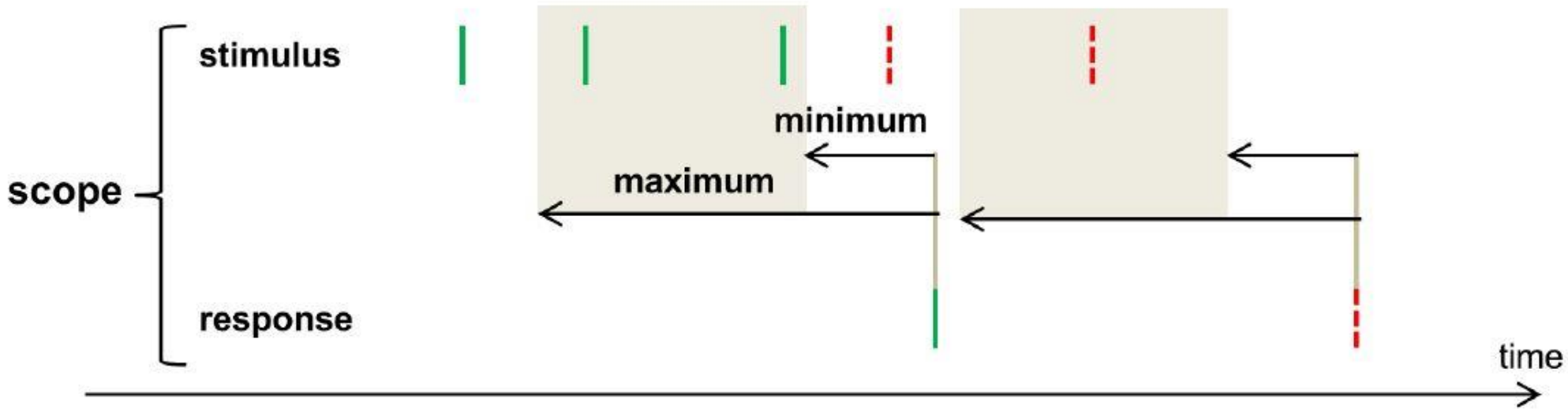
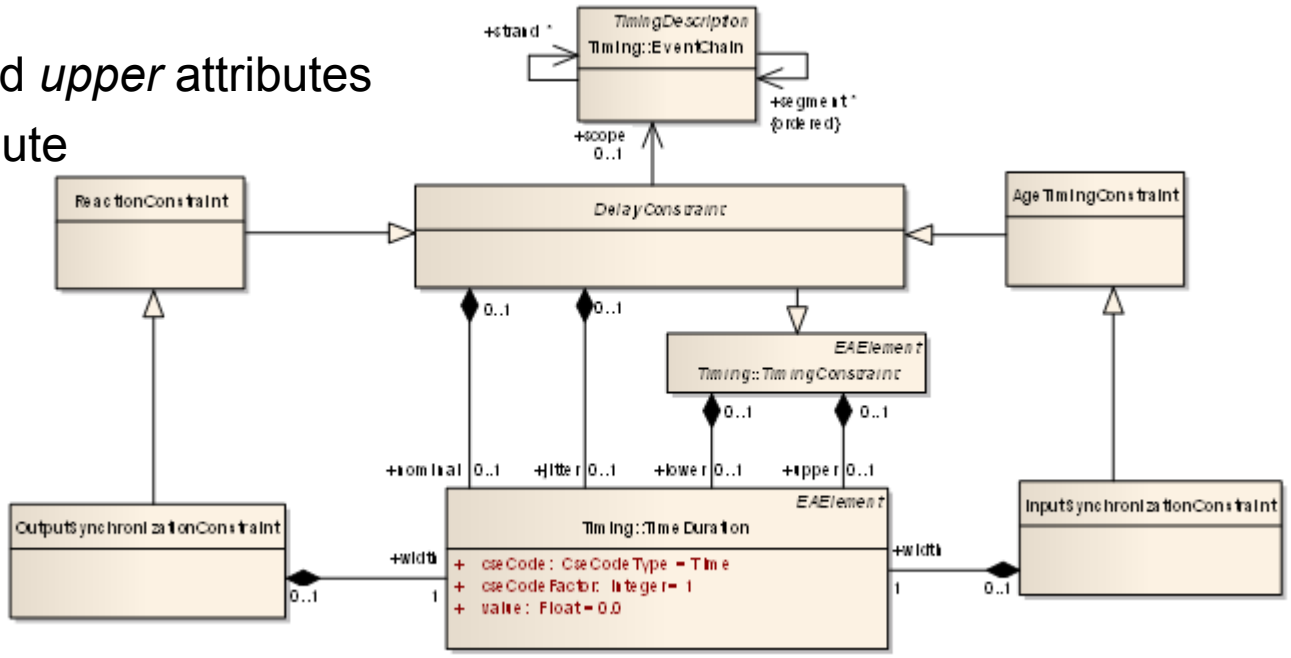


Figure 18. A set of event occurrences satisfying an AgeConstraint. Causally connected event occurrences are shown by the same line style. Two sets are shown, one by a solid line and one by a dashed line.

Delay Constraint: Synchronization

- Input Synchronization specializes Age
  - Inherits: *lower* and *upper* attributes
  - Adds: *width* attribute
- Output Synchronization specializes Reaction
  - Inherits: *lower* and *upper* attributes
  - Adds: *width* attribute



This form of synchronization only takes the width and completeness of each occurrence cluster into account; it does not care whether some events occur multiple times within a cluster or whether some clusters overlap and share occurrences. In particular, event occurrences are not partitioned into clusters according to their role or what has caused them. Stray occurrences of single events are not allowed, though, since these would just count as incomplete clusters according to this constraint.

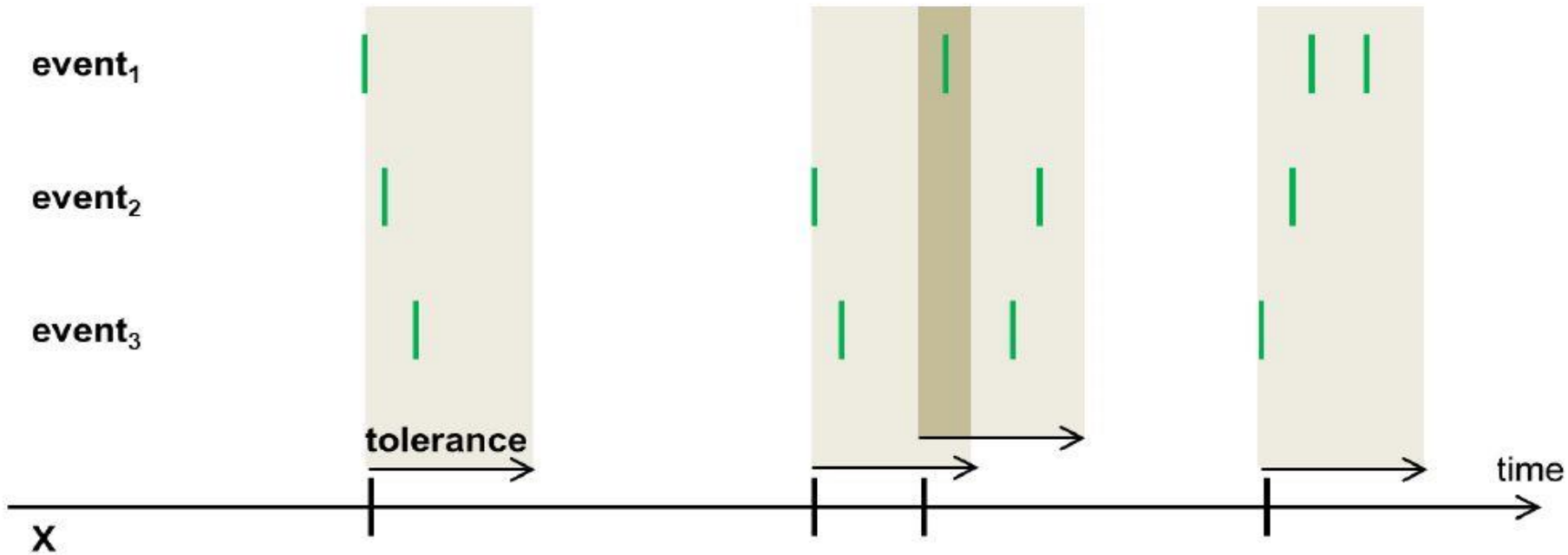


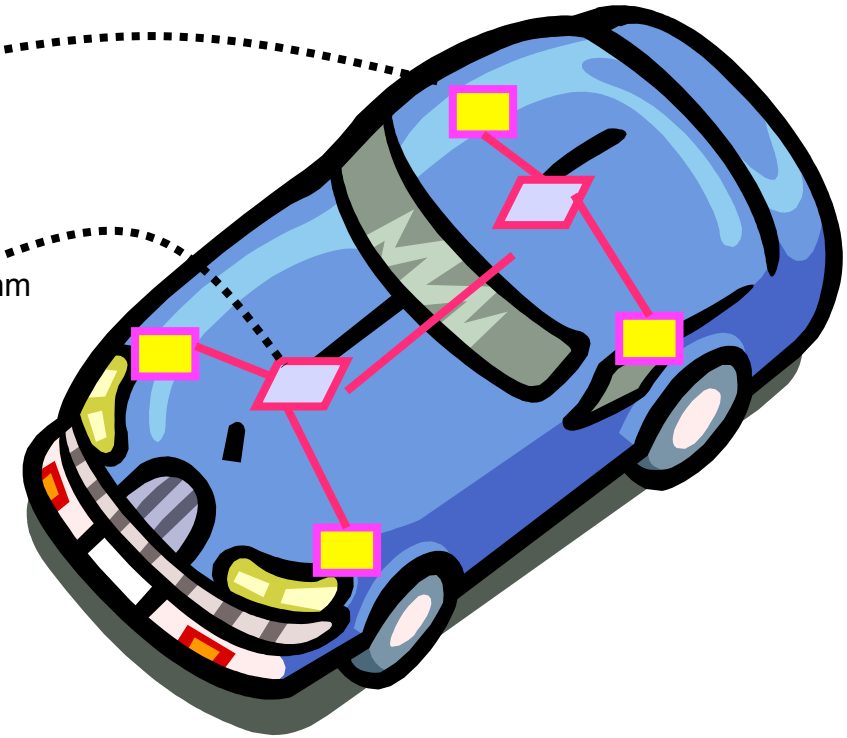
Figure 8. A set of event occurrences of three events satisfying a SynchronizationConstraint.

Strands and Segments: Example

- Distributed ABS
- Different possibilities for break-down / sum-up
  - Segments first
  - Strands first
- General for sum-up and break-down
  - Max Age/Reaction
    - Σ Segments $\leq$ Whole
    - Max(Strands) $\leq$ Whole
  - Min Age/Reaction
    - Σ Segments $\geq$ Whole
    - Min(Strands) $\geq$ Whole

Example: Distributed ABS

- 4 wheel control units
  - Brake actuator
  - Wheel speed sensor
  - Local control of wheel
- 2 algorithm control units
  - Distributed control algorithm
    - Front
    - Rear



Timing Modelling Challenge

- Express maximum age constraints
  - **Age of wheel speed data when updating brake force data to each wheel**
- Break down overall end-to-end age constraint into several age constraints
- Build up end-to-end age constraint from age constraints of smaller EventChains

Events for End-to-End Age Constraint

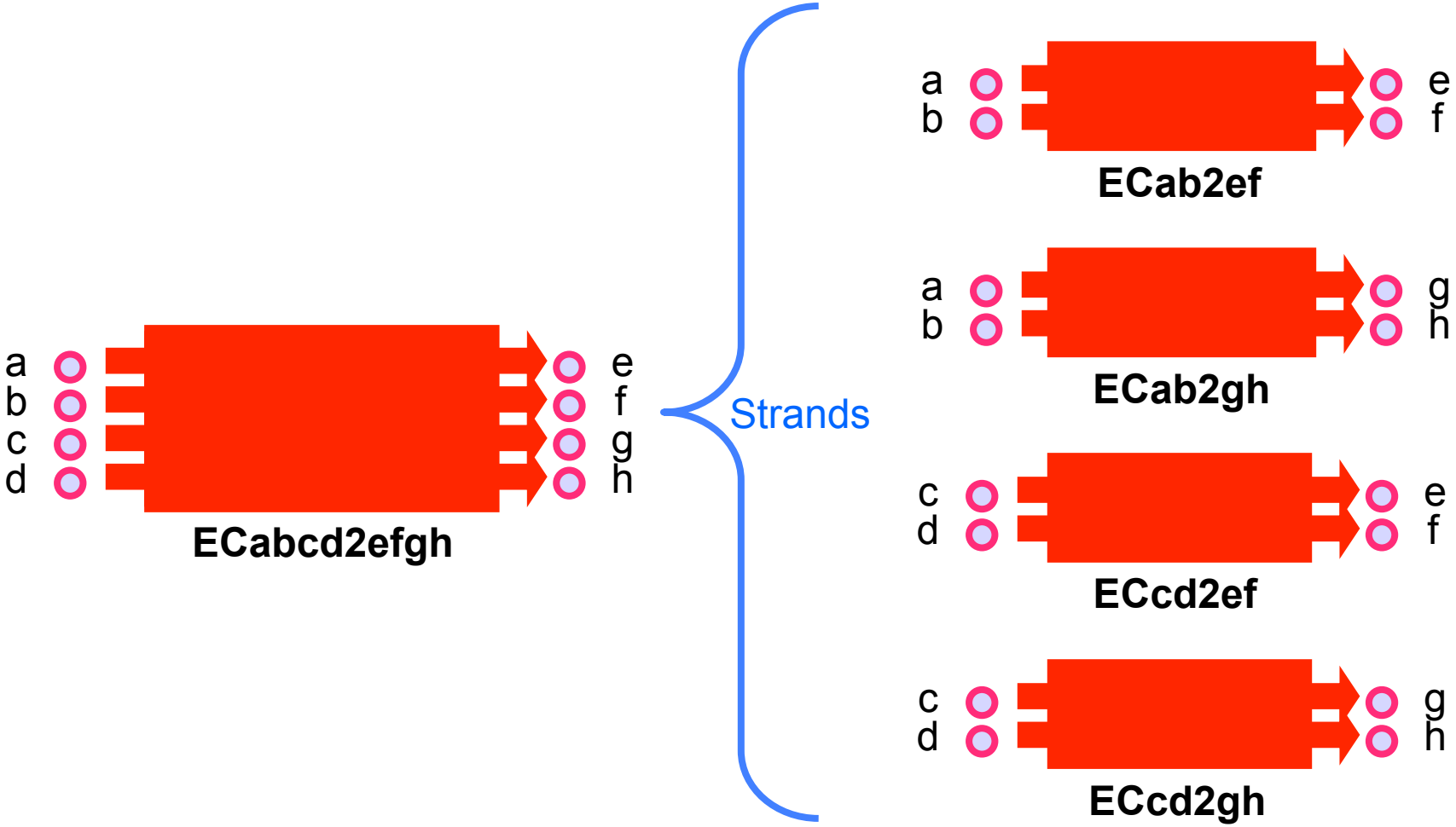
- 4 Response Events
  - Update of brake force value for one wheel
  - Denote these Ea, Eb, Ec and Ed
    (front: Ea and Eb, rear: Ec and Ed)
- 4 Stimuli Events
  - Sampling of wheel speed for one wheel
  - Denote these events Ee, Ef, Eg and Eh
    (front: Ee and Ef, rear: Eg and Eh)

- 1 EventChain
  - Having these above events as stimuli and responses respectively
  - Denote this EventChain ECabcd2efgh

One Age Constraint

- Constraint: Max Age = 35
- For all 4 responses the maximum age from any of the 4 stimuli should be 35 (independent of the path between stimulus and response)

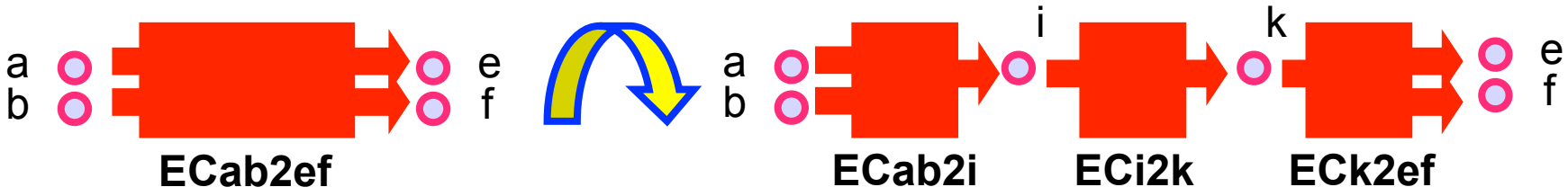
Alternative 1: Strand Break-down First



- Max Age Constraint for these 4 Event Chains: 35 each

Alternative 1: … then Segments

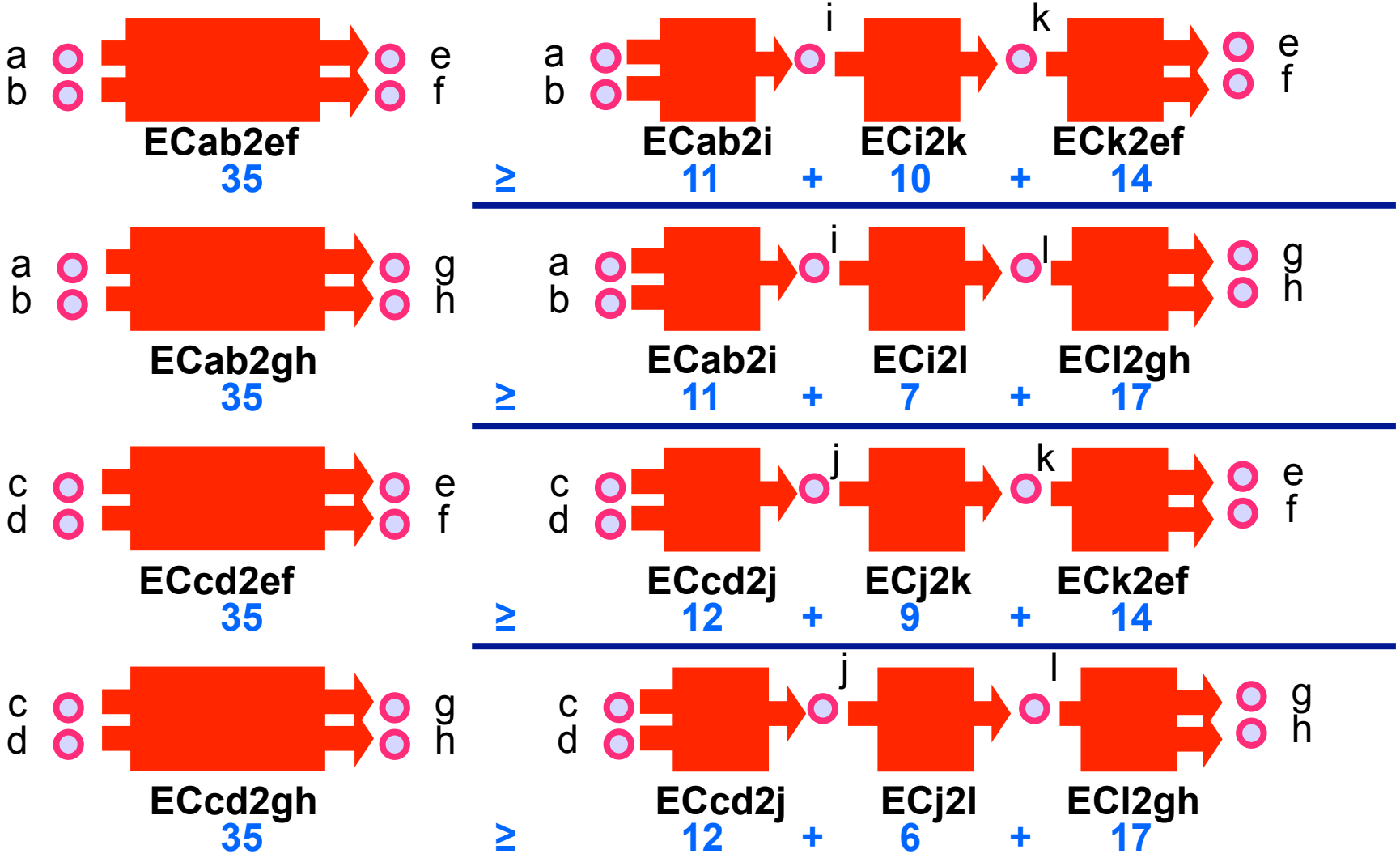
- 4 Events related to Brake Control Units
  - Ei: Front control unit ready to send sensor data from front wheels to rear control unit
  - Ej: Rear control unit ready to send sensor data from rear wheels to front control unit
  - Ek: Front control unit ready to send actuator values to front wheel units
  - El: Rear control unit ready to send actuator values to rear wheel units



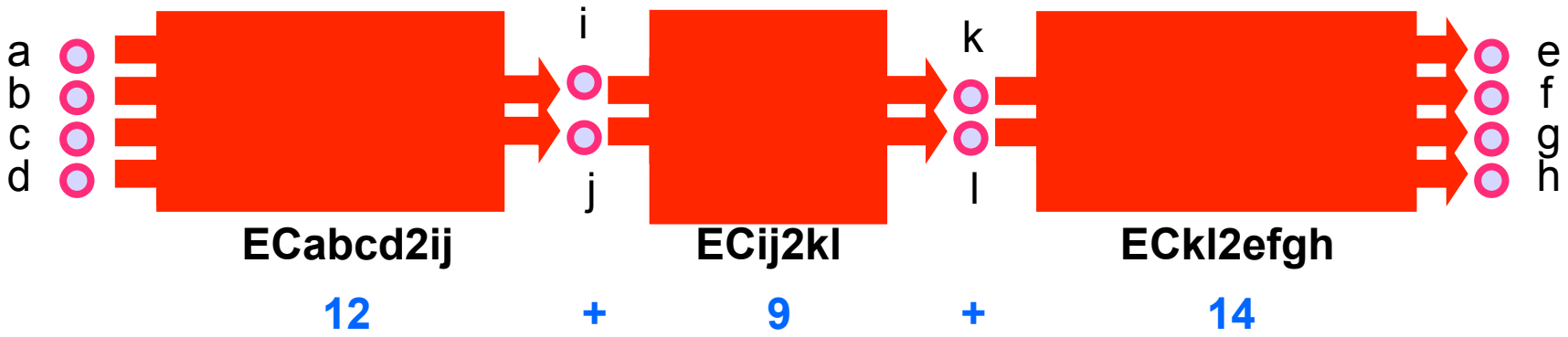
35 ≥ 11 + 10 + 14

Max age constraint broken down among the segments

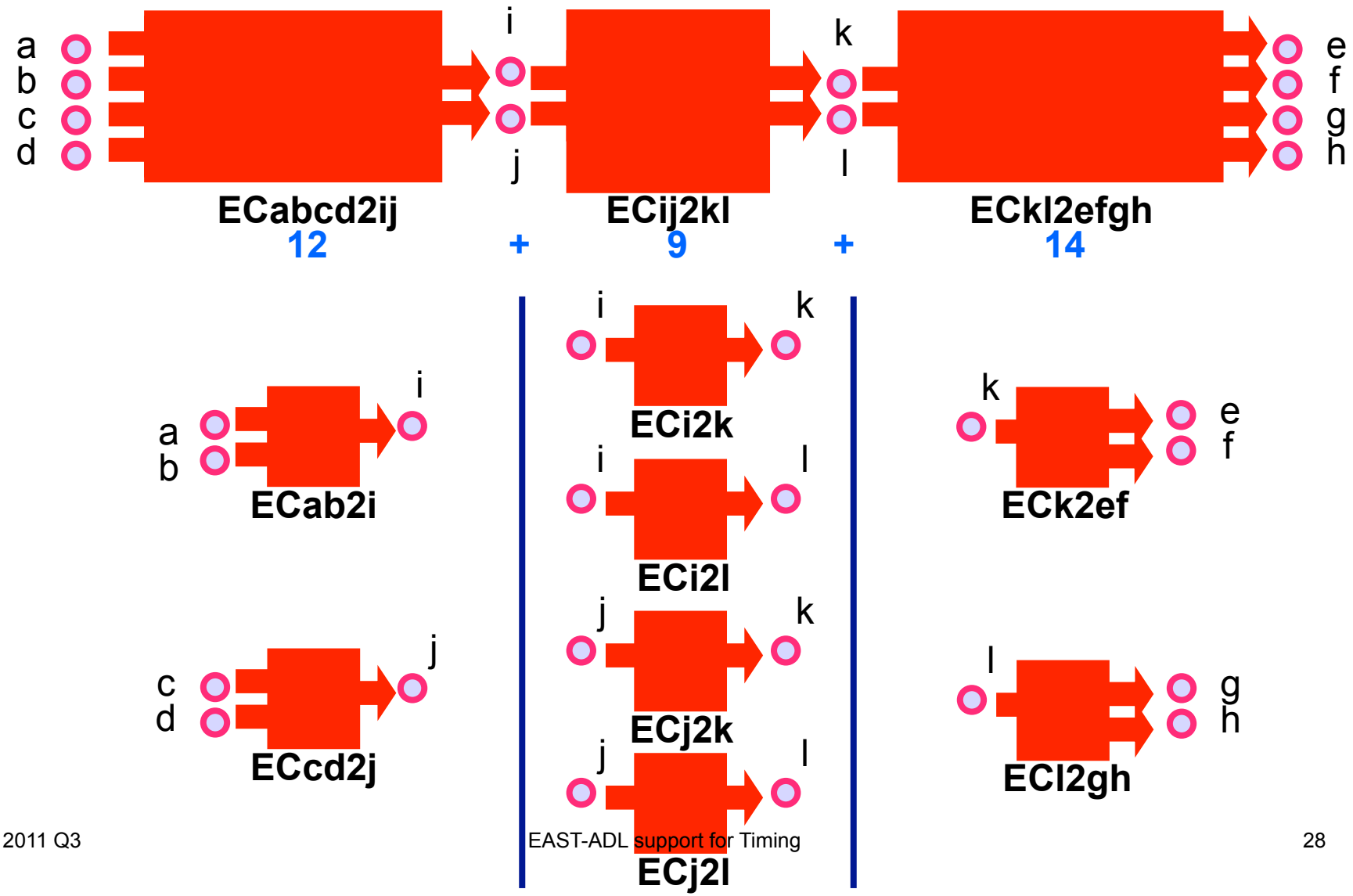
Alternative 1: … Segments for all Strands



Alternative 2: Segment Break-down First



Alternative 2: … then Strands



Break-down of Requirements

- Strands first or Segments first?
- The order makes a difference!
- In any step:
  - Max Age/Reaction
    - Σ Segments $\leq$ Whole
    - Max(Strands) $\leq$ Whole
  - Min Age/Reaction
    - Σ Segments $\geq$ Whole
    - Min(Strands) $\geq$ Whole

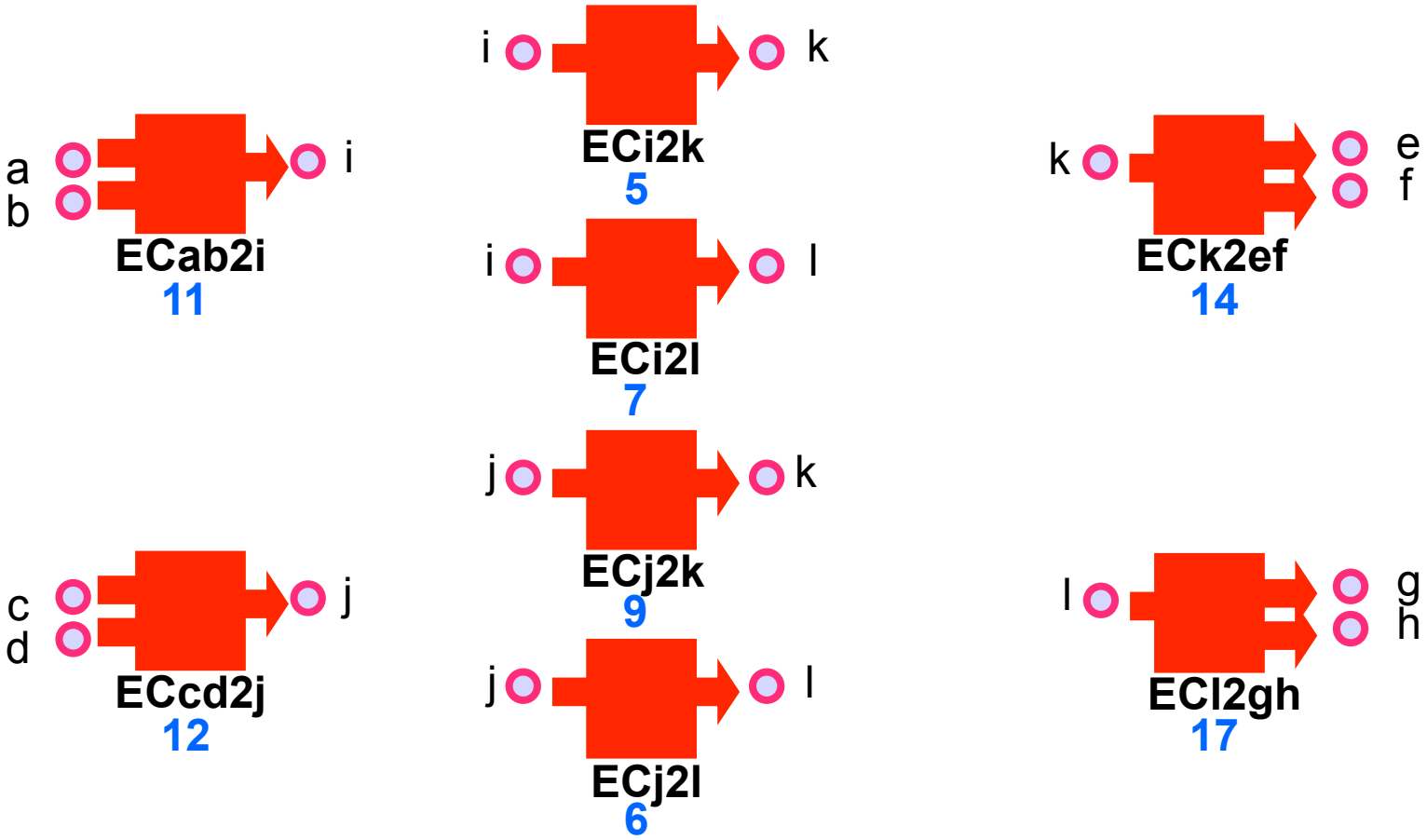
Composition of Constraints

Summing up for a “data sheet”

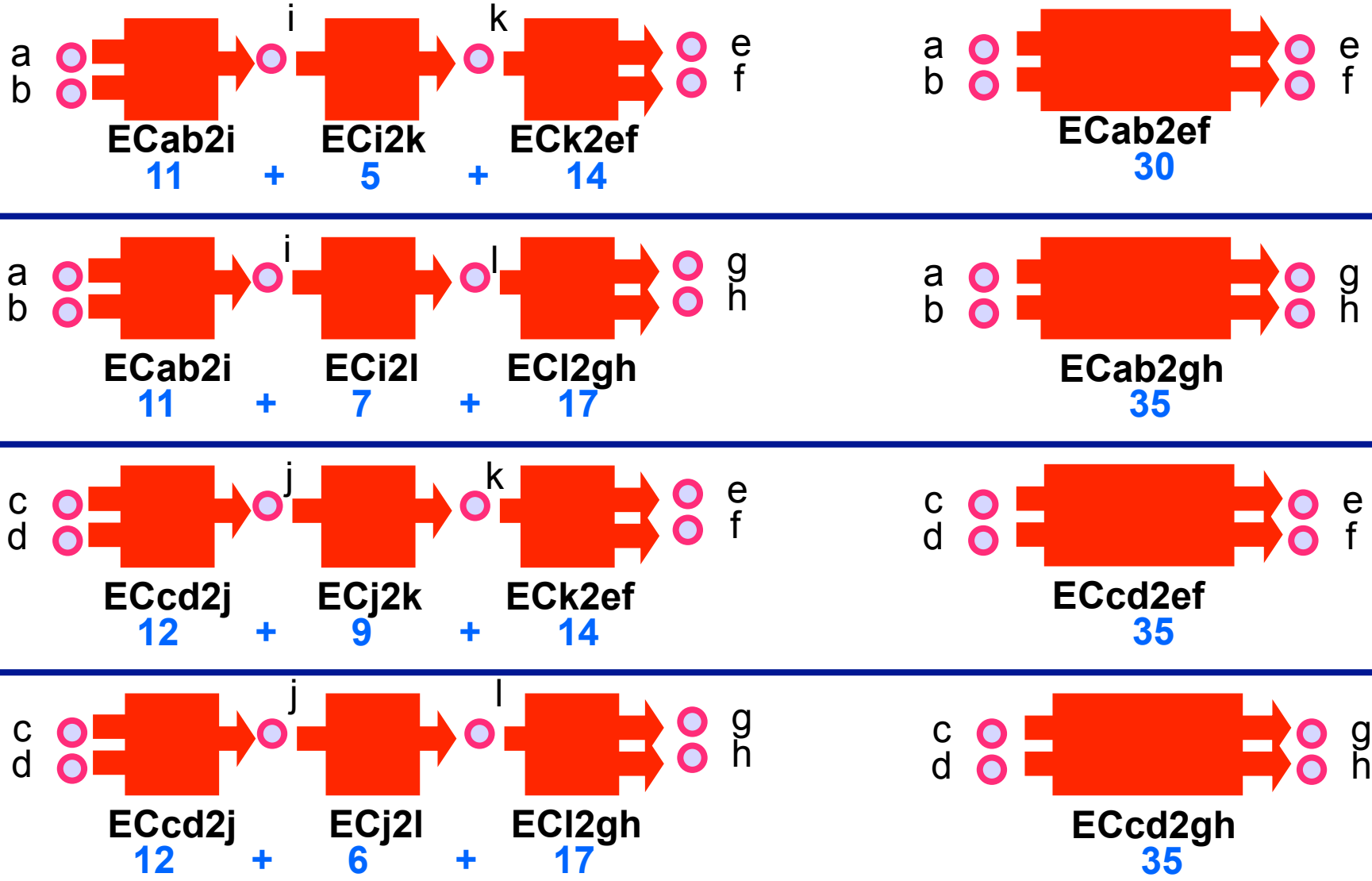
- Given constraints of smaller EventChains
  - **What are the derived constraints for larger (composed) EventChains**
- Composition by either
  - **Segments after each other**
  - **Strands besides each other**

Example Revisited

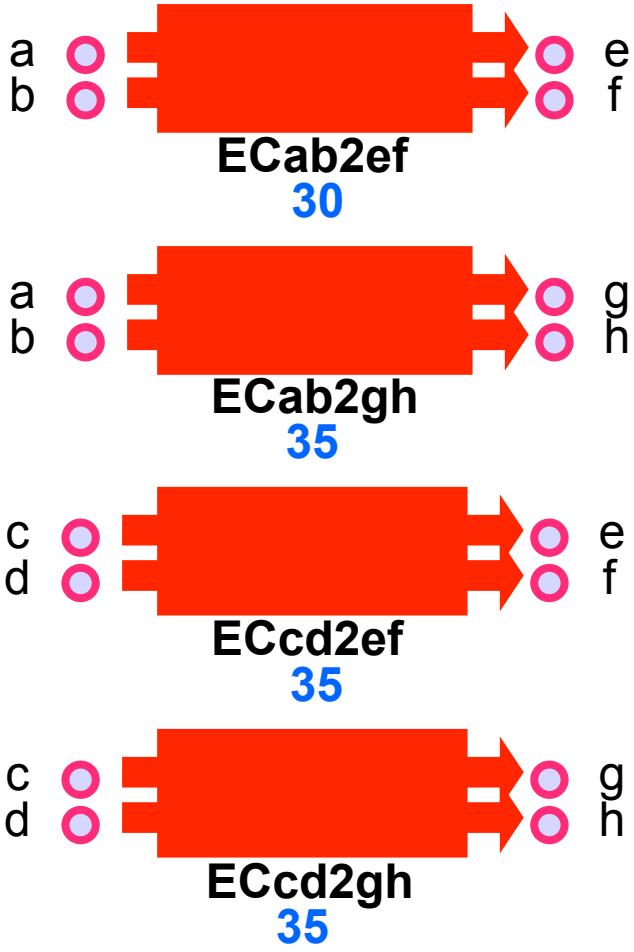
Start with 8 smaller EventChains and associated max age constraints:



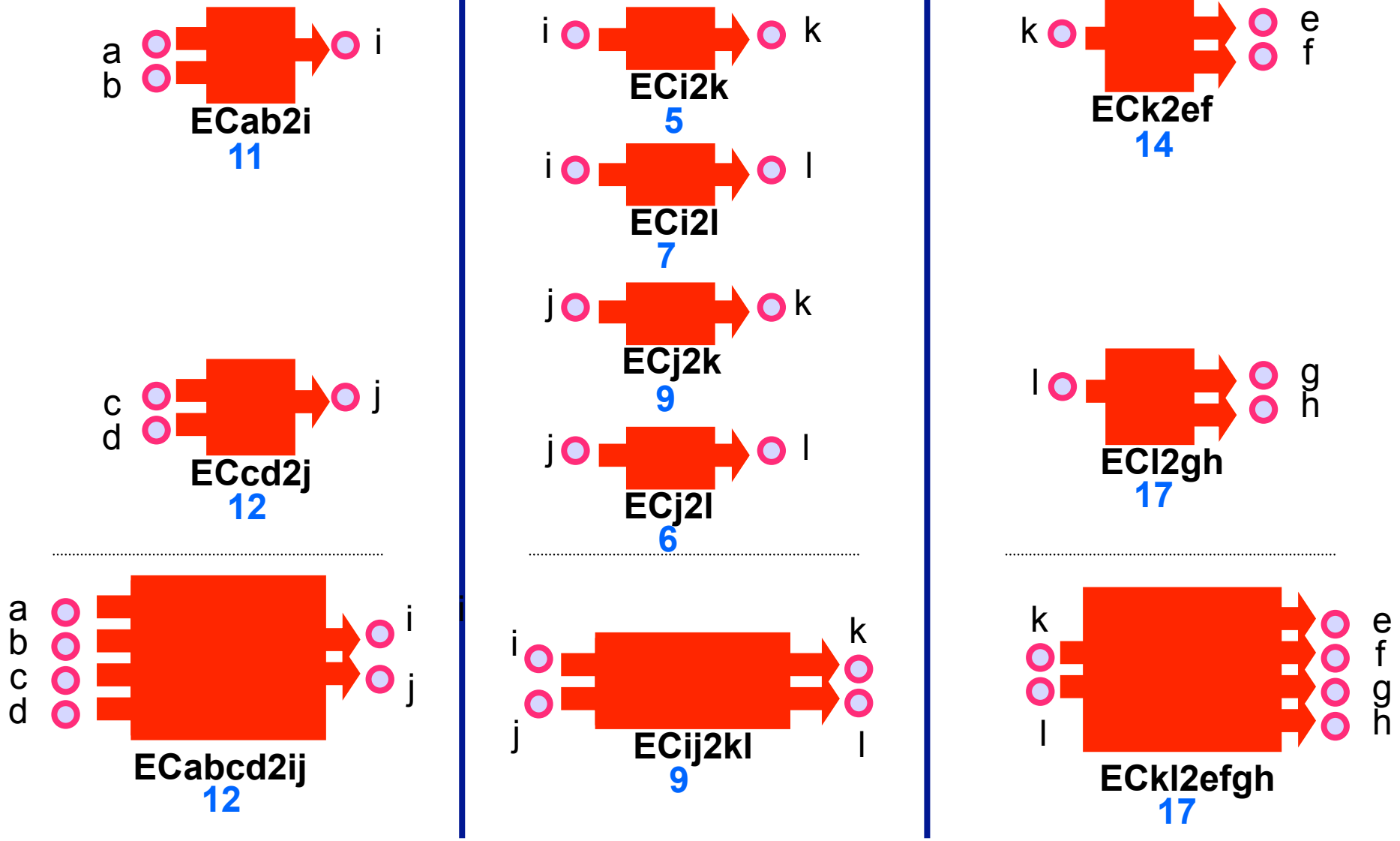
Compose: Segments First



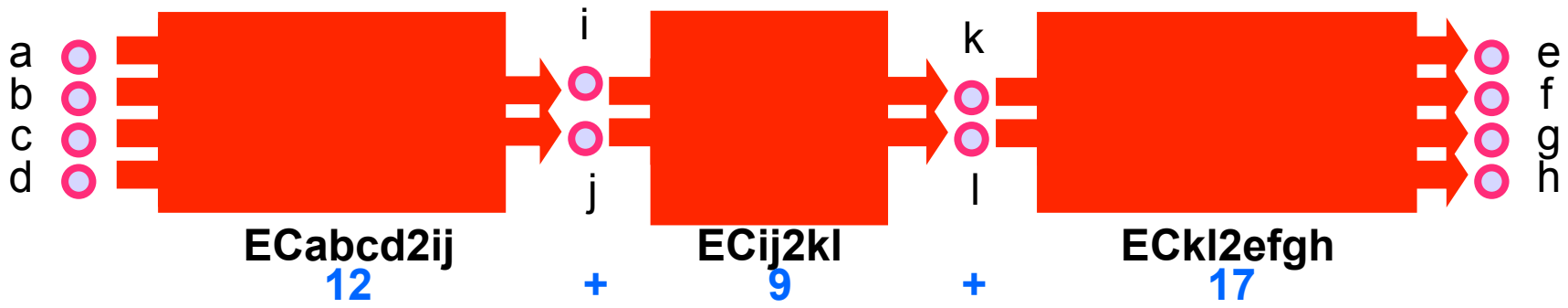
Compose: … then Strands



Compose: Strands First



Compose: … then Segments



Conclusion

The order of Composition/Decomposition makes a difference

- Strands First then Segments

  may differ from

- Segments First then Strands

What order of Composition/Decomposition to choose depends on what Constraints that are relevant to express in a certain context

Rules for Composition/Decomposition are the same

- Max Age/Reaction
  - **Σ Segments ≤ Whole**
  - **Max(Strands) ≤ Whole**
- Min Age/Reaction
  - **Σ Segments ≥ Whole**
  - **Min(Strands) ≥ Whole**

This holds as long as Age/Reaction not are mixed with one another