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# Reconciling SCXML Statechart Representations and Event-B Lower Level Semantics

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# Motivation

- Event-B provides verification by formal proof…
- … but notation is restricted to simplify verification.
- Engineers are used to a richer notation..
- .. they may find the restrictions difficult to accept.
- iUML-B State-machines help but still close to Event-B.
- Can Harel style state-chart semantics be reconciled with iUML-B?
- We investigate a translation from SCXML state-charts to iUML-B state-machines (and hence to Event-B).

# SCXML

- State Chart XML :
  - State Machine Notation for Control Abstraction
- XML notation
- Harel Statecharts
- Executable (via simulator tools)
- Related to CCXML Call Control XML, event-based telephony

# SCXML

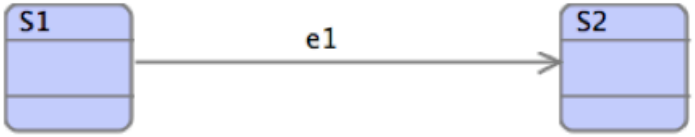
```
<?xml version="1.0"?>
<scxml
xmlns="http://www.w3.org/2005/07/scxml"
      version="1.0"
      datamodel="ecmascript"
      initial="off">

  <!-- trivial 5 second microwave oven example -->
  <datamodel>
    <data id="cook_time" expr="5"/>
    <data id="door_closed" expr="true"/>
    <data id="timer" expr="0"/>
  </datamodel>

  <state id="off">
    <!-- off state -->
    <transition event="turn.on" target="on"/>
  </state>

  <state id="on">
    <initial>
      <transition target="idle"/>
    </initial>
    <!-- on/pause state -->
    <transition event="turn.off" target="off"/>
    <transition cond="timer &gt;= cook_time" target="off"/>
    <state id="idle">
      <!-- default immediate transition if door is shut -->
      <transition cond="door_closed" target="cooking"/>
      <transition event="door.close" target="cooking">
        <assign location="door_closed" expr="true"/>
        <!-- start cooking -->
      </transition>
    </state>
    <state id="cooking">
      <transition event="door.open" target="idle">
        <assign location="door_closed" expr="false"/>
      </transition>
      <!-- a 'time' event is seen once a second -->
      <transition event="time">
        <assign location="timer" expr="timer + 1"/>
      </transition>
    </state>
  </state>
</scxml>
```

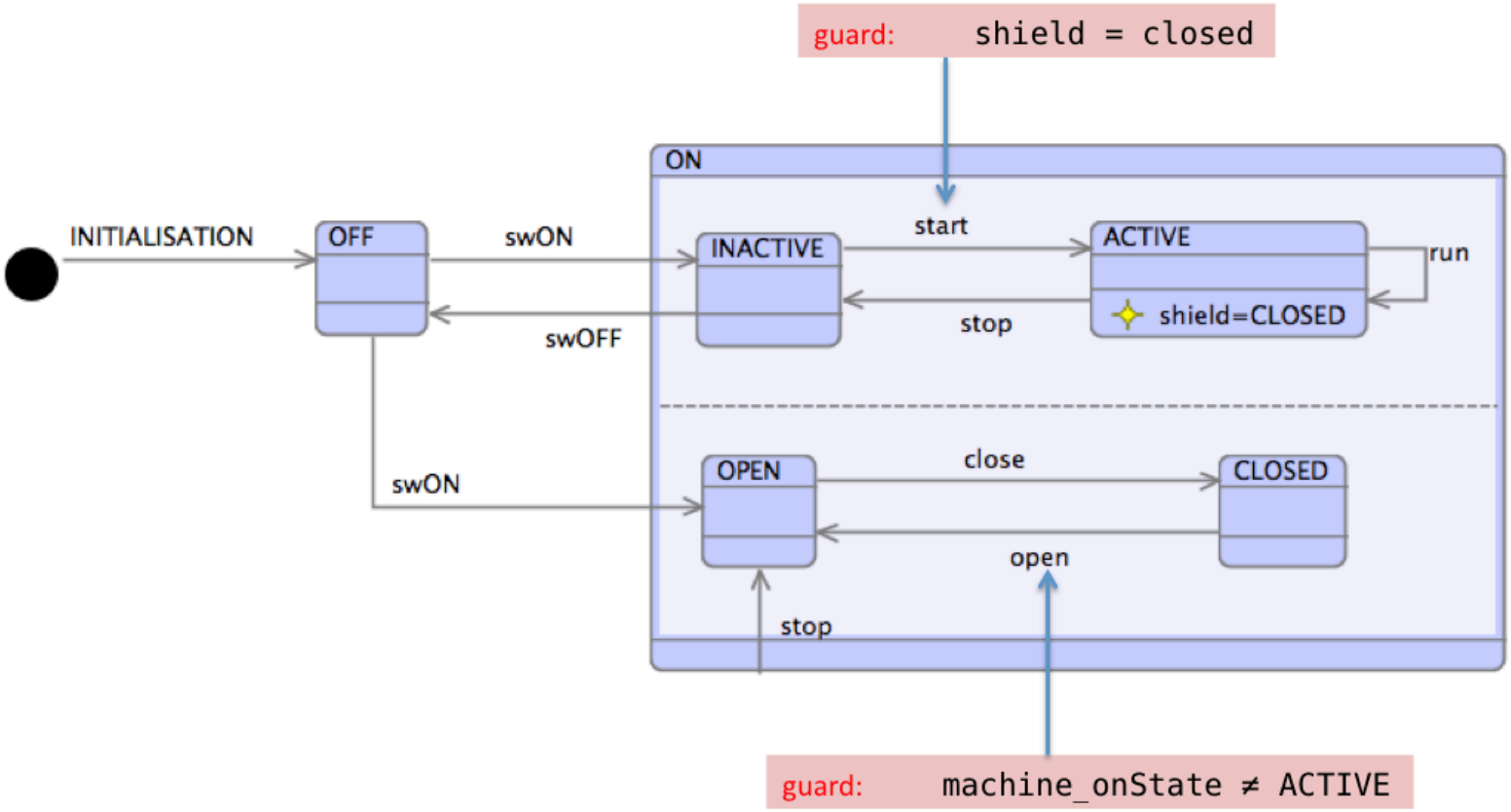
# iUML-B Statemachines




```
EVENTS
    e1 ≙ WHEN <in S1> THEN <becomes S2> END
```

*where, <in S1> and <becomes S2> depend on the data that represents state*

# iUML-B Statemachines



# Similarities

- Hierarchical nested state-charts
- Transitions with
  - Conditions / Guards
  - Actions
- States can have Entry and Exit Actions
  - (use with care in iUML-B)

# Differences

- Event-B has..
  - Refinement
  - Invariants
- SCXML has..
  - External Trigger events
    - Hence transitions do not have a name/label
  - Sequential actions
  - Run to Completion – Big step/little step

# SCXML Extensions

- XML tools allow new meta-model 'namespaces' to be introduced.
  - Existing SCXML tools will ignore them

- Needed in order to support:
  - Refinement levels (new attribute <iumlb:refinement …>)
  - Invariants (new element <iumlb:invariant …>)
  - Guards (new element <iumlb:guard …>)

# SCXML Extension Attributes

Table 1: SCXML Extension Attributes

| Attribute name: | Meaning | Allowed Parents |
|---|---|---|
| label | string used as the name of an Event-B event elaborated by the generated i-UML-B | scxml:transition |
| refinement | non-negative integer representing the refinement level at which the parent element should be introduced | scxml:scxml, scxml:datamodel, scxml:data, scxml:state, scxml:parallel, scxml:transition, scxml:onEntry, scxml:onExit, scxml:assign, iumlb:invariant, iumlb:guard |
| type | string used as the membership set for the Event-B variable generated from the parent data element | scxml:data |
| name | string used for the name or label of a generated iUML-B element | iumlb:invariant, iumlb:guard |
| predicate | string used for the predicate of a guard or invariant | iumlb:invariant, iumlb:guard |
| derived | boolean indicating that the guard is a theorem (default to false) | iumlb:invariant, iumlb:guard |

# Example extended SCXML

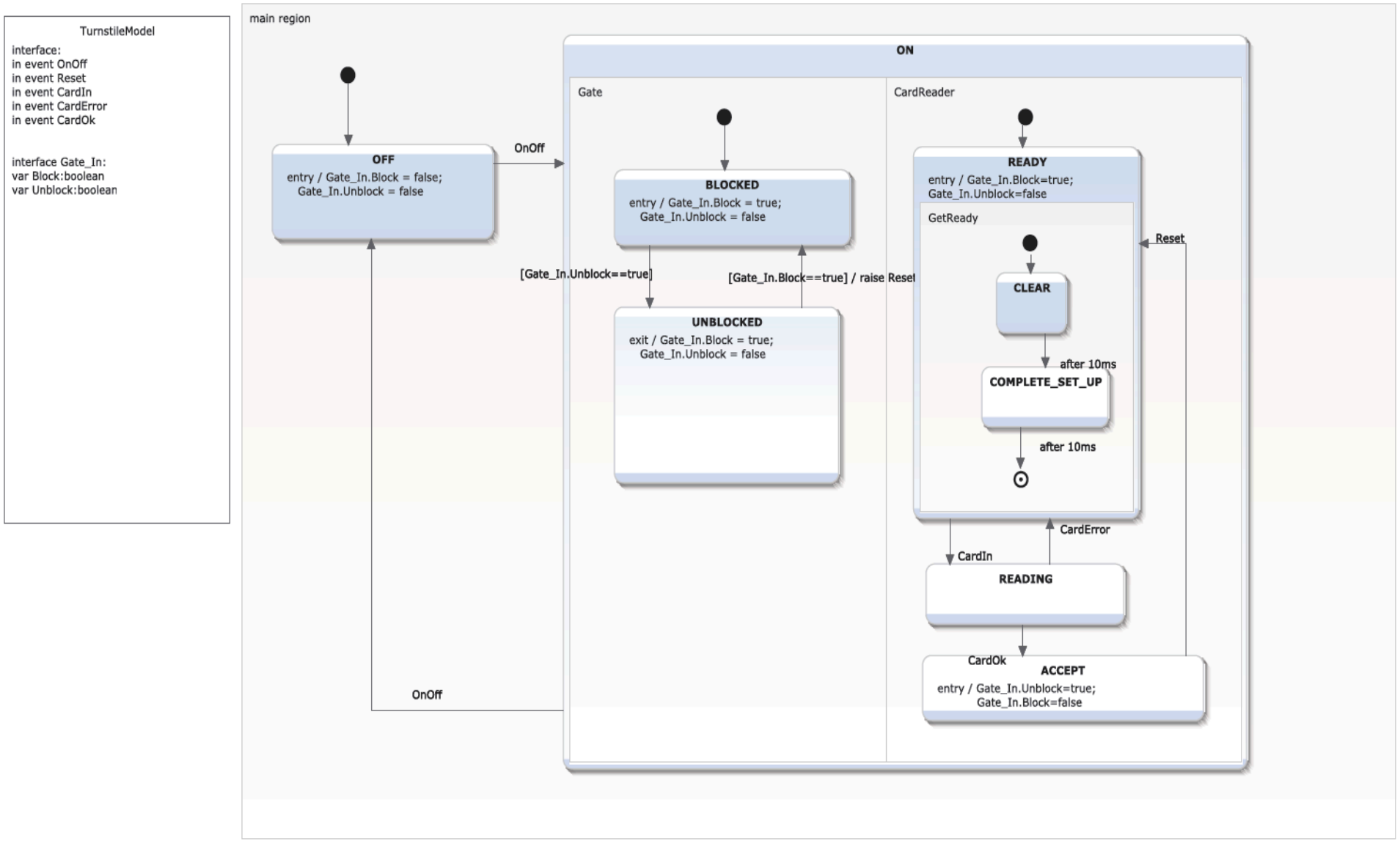
(extensions are captured in red)

```
<datamodel iumlb:refinement="2">
  <data expr="false" id="Gate_In.Block" iumlb:type="BOOL"/>
</datamodel>
<!-- Other model details -->
<state id="BLOCKED">
  <transition cond="[On_In.CardAccept==true]" target="UNBLOCKED">
    <iumlb:guard name="gd1" predicate="On_In.CardAccept==true" refinement="2"/>
    <assign expr="true" location="Gate_In.Block" iumlb:refinement="3"/>
  </transition>
  <onentry>
    <assign expr="true" location="Gate_In.Block"/>
    <assign expr="false" location="On_In.Reset"/>
  </onentry>
  <onexit>
    <assign expr="false" location="Gate_In.Block"/>
  </onexit>
  <iumlb:invariant predicate="Gate_In.Block == TRUE" name="GateCondition"/>
</state>
```

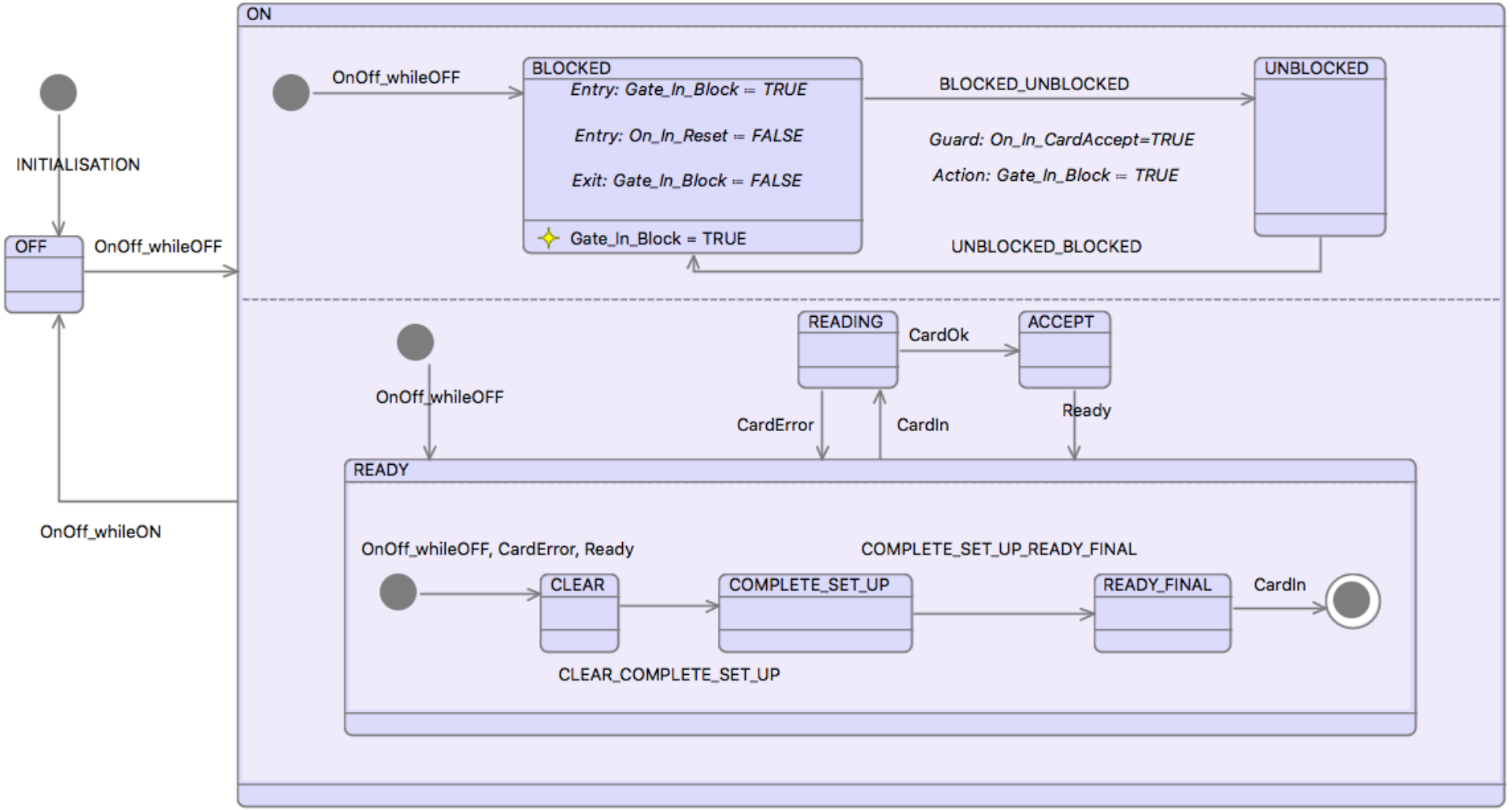
# Initial translation supports..

- Data models
- Hierarchical nested statemachines
- Parrallel Statemachines
- 'When' Transitions (label)
- Transition parameters, guards and actions
- Invariants
- Initial and Final states
- Refinement (superposition only)

# Diagram of SCXML



# Example – generated iUML-B



# Next steps

- Try modelling the run to completion semantics
- E.g. trigger events create a token,
  - A new token can only be consumed when no transitions are enabled
- Try enforcing transition run-to-completion sequences
- *Still omit sequencing of actions*

# Enhance iUML-B to support triggers

- iUML-B Statemachines will own a collection of triggers.
  - Each trigger will generate an Event-B BOOL variable.
    - (Note simplification of SCXML, which permits several triggers of a kind to be queued).
  - Transitions may reference a trigger.
    - The reference will generate a guard, *<trigger variable> = TRUE*
    - And an action *<trigger variable> := FALSE.*
  - Transitions may own a collection of 'Raise' actions that reference an internal trigger.
    - This will generate an action *<trigger variable> := TRUE.*
  - Transitions may be designated as external.
    - An interface event will be generated to create a new trigger *( <trigger variable> := TRUE )*
    - when it has been consumed *( <trigger variable> = FALSE ) and*
    - *No transitions are enabled. (run to completion)*
- A partial 'run-to-completion' semantics will be introduced by disabling all interface events while any external or internal transition is enabled.

# External Trigger Event

```
o  In_Event_OnOff:  not extended ordinary ›
   WHERE
     o  grd0:  OnOff=FALSE not theorem ›
     o  grd1:  ¬(OnOff=TRUE ∧ main=OFF) not theorem ›OFF2ON not enabled
     o  grd2:  ¬(OnOff=TRUE ∧ main=ON) not theorem ›ON2OFF not enabled
     o  grd3:  ¬(CardReader = ACCEPT ∧ Gate = BLOCKED)  not theorem ›
     o  grd4:  ¬(Reset=TRUE ∧ Gate = UNBLOCKED)  not theorem ›
     o  grd5:  ¬(CardReader = READY ∧ CardIn = TRUE)  not theorem ›
     o  grd6:  ¬(CardReader = READING ∧ CardError = TRUE)  not theorem ›
     o  grd7:  ¬(CardReader = READING ∧ CardOk = TRUE)  not theorem ›
     o  grd8:  ¬(CardReader = ACCEPT ∧ Ready = TRUE)  not theorem ›
   THEN
     o  act1:  OnOff = TRUE ›
   END
```

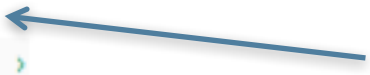
Old trigger has been consumed

No transitions enabled

Raise new trigger

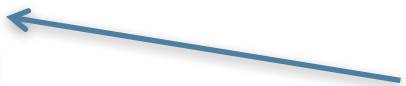
# Triggered transition

```
o  UNBLOCKED2BLOCKED:   not extended ordinary ›
   WHERE
      o  Gate_guards2:   Reset = TRUE not theorem ›
      o  isin_UNBLOCKED: Gate = UNBLOCKED not theorem ›
   THEN
      o  Gate_entryActions1: GateIn_Block = TRUE ›
      o  Gate_exitActions1:  GateIn_Unblock = FALSE ›
      o  Gate_actions1:  Ready = TRUE ›
      o  Gate_actions2:  Reset = FALSE ›
      o  enter_BLOCKED:  Gate = BLOCKED ›
   END
```



The trigger guard

Raise an internal trigger



Consume the external trigger

# Conclusions

- Strong motivation from engineers
- Difficult to reconcile semantic differences
  - Run-to-completion, Sequential execution
- We adopt a compromise
  - Support what we can
    - Add extensions where necessary
  - Otherwise, restrict SCXML

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# Thank you

Questions?