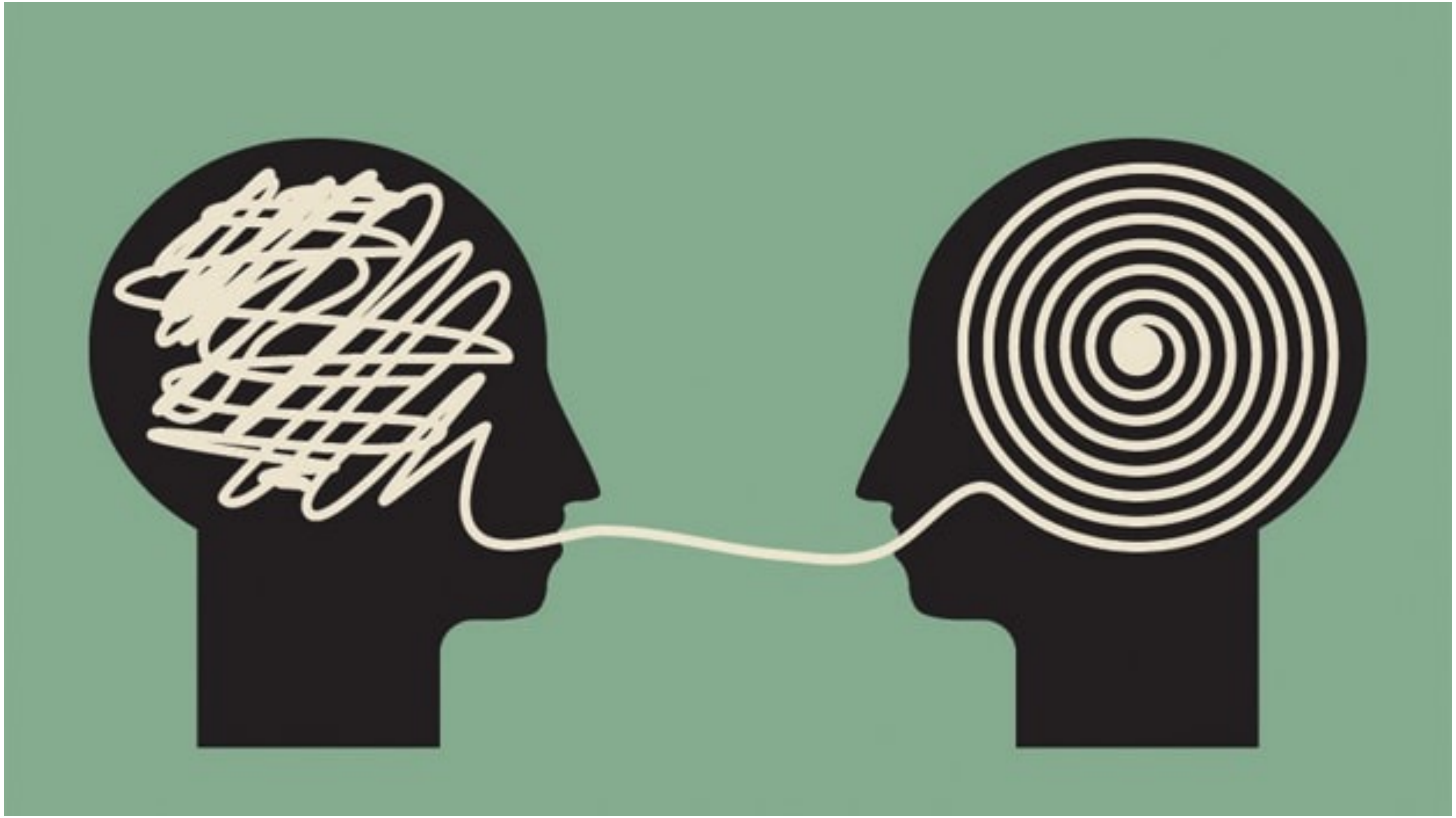
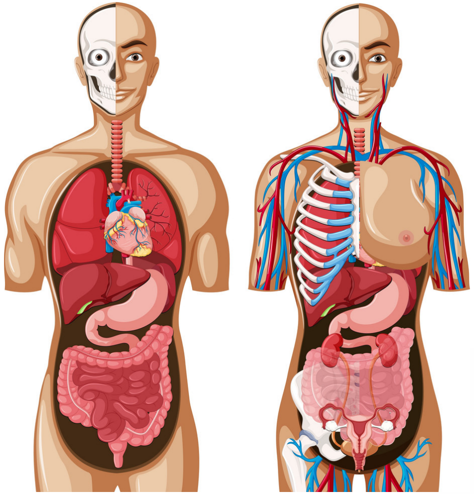
Model Execution: From a Retrospective on Code Generation to a Perspective on Model Compilation

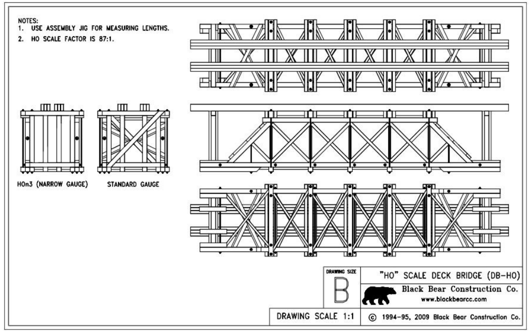
Federico Ciccozzi

federico.ciccozzi@mdu.se

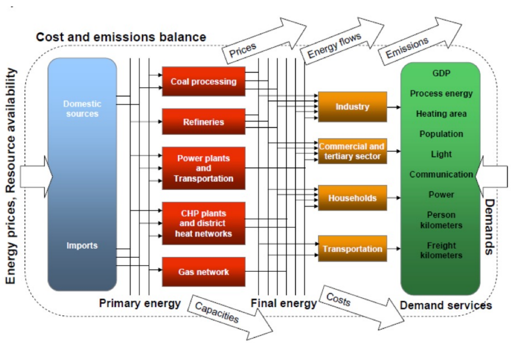


Models

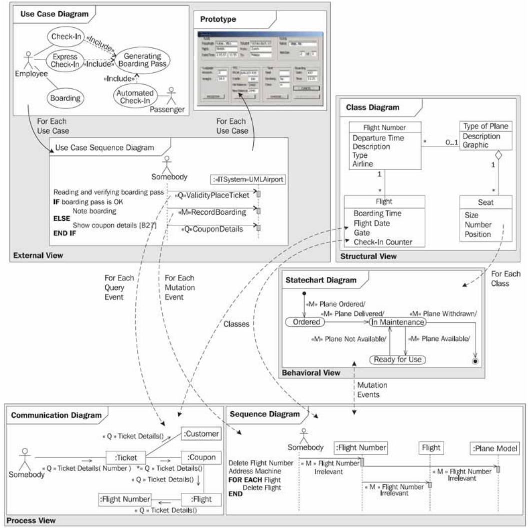




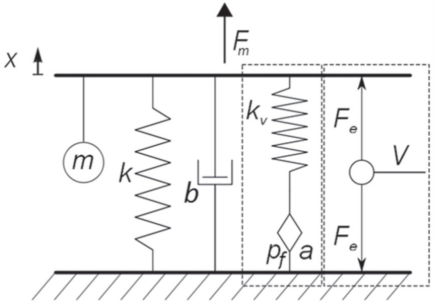
NOTES:
1. USE ASSEMBLY JIG FOR MEASURING LENGTHS.
2. HO SCALE FACTOR IS 87:1.
HOn3 (NARROW GAUGE)
STANDARD GAUGE
DRAWING SIZE
B
"HO" SCALE DECK BRIDGE (DB-HO)
Black Bear Construction Co.
www.blackbearcc.com
DRAWING SCALE 1:1
© 1994-95, 2009 Black Bear Construction Co.



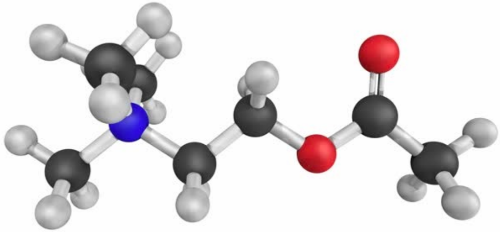
Cost and emissions balance
Prices
Energy flows
Emissions
Energy prices, Resource availability
Domestic sources
Imports
Coal processing
Refineries
Power plants and Transportation
CHP plants and district heat networks
Gas network
Industry
Commercial and tertiary sector
Households
Transportation
GDP
Process energy
Heating area
Population
Light
Communication
Power
Person kilometers
Freight kilometers
Demands
Primary energy
Capacities
Final energy
Costs
Demand services



Use Case Diagram
Prototype
Check-In
Express Check-In
Generating Boarding Pass
Employee
Boarding
Automated Check-In
Passenger
For Each Use Case
For Each Use Case
Use Case Sequence Diagram
Somebody
External View
Class Diagram
Flight Number
Departure Time
Description
Type
Airline
Type of Plane
Description
Graphic
Flight
Boarding Time
Flight Date
Gate
Check-In Counter
Seat
Size
Number
Position
Structural View
For Each Query Event
For Each Mutation Event
Classes
For Each Class
Statechart Diagram
Ordered
In Maintenance
Ready for Use
Behavioral View
Mutation Events
Communication Diagram
:Customer
:Ticket
:Coupon
Somebody
:Flight Number
:Flight
Sequence Diagram
Somebody
:Flight Number
Flight
:Plane Model
Process View



F_m
x
m
k
b
k_v
F_e
V
F_e
p_f
a



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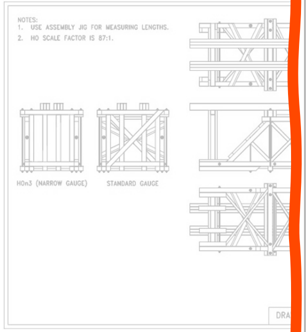
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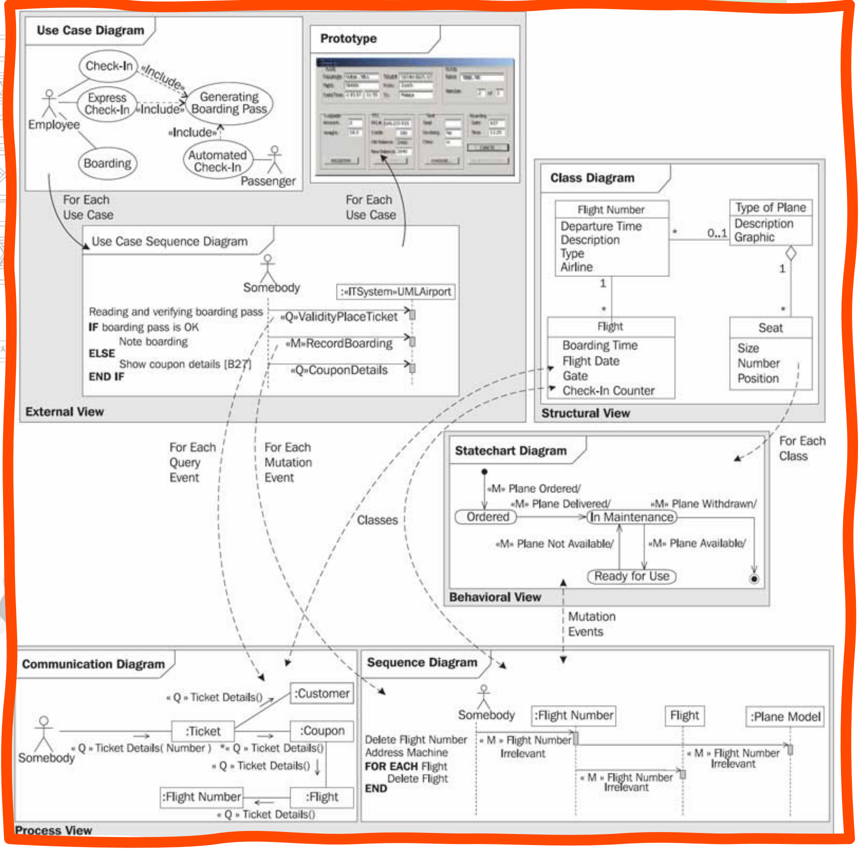
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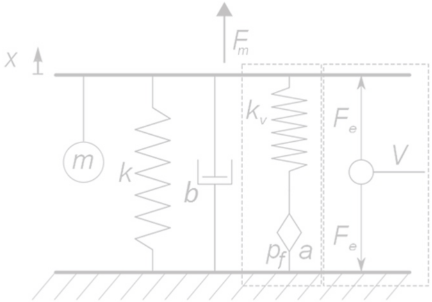
Use Case Sequence Diagram
Somebody
:«ITSystem»UMLAirport
Reading and verifying boarding pass
IF boarding pass is OK
Note boarding
ELSE
Show coupon details [B27]
END IF
«Q»ValidityPlaceTicket
«M»RecordBoarding
«Q»CouponDetails
External View
Class Diagram
Flight Number
Departure Time
Description
Type
Airline
Type of Plane
Description
Graphic
Flight
Boarding Time
Flight Date
Gate
Check-In Counter
Seat
Size
Number
Position
Structural View
For Each Query Event
For Each Mutation Event
Classes
For Each Class
Statechart Diagram
«M» Plane Ordered/
«M» Plane Delivered/
«M» Plane Withdrawn/
Ordered
In Maintenance
«M» Plane Not Available/
«M» Plane Available/
Ready for Use
Behavioral View
Mutation Events
Communication Diagram
Somebody
:Customer
:Ticket
:Coupon
:Flight Number
:Flight
« Q » Ticket Details()
« Q » Ticket Details(Number)
Sequence Diagram
Somebody
:Flight Number
Flight
:Plane Model
Delete Flight Number
Address Machine
FOR EACH Flight
Delete Flight
END
« M » Flight Number Irrelevant
Process View


x
F_m
m
k
b
k_v
F_e
V
p_f
a
F_e

Models

- Models can be found in any scientific discipline
- We need to be precise and specific on ***WHAT a model is***

Models

- Models can be found in any scientific discipline
- We need to be precise and specific on ***WHAT a model is***

"A model is an abstract representation of a specific part, problem, solution, or feature of a specific domain"

Software models (some definitions)

“Software models are ways of expressing a software design”

“Software models are representations of software systems made to understand, analyze, and design such systems”

“A software model is a collection of representations whose contents depend on the languages and tools used”

“Software models are formal methods for handling the process of creating software”

Software models in our context

A (software) model

- is a ***blue-print*** of a software application,

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- is a ***blue-print*** of a software application,
- can be itself ***executable***, and
- is directly usable for ***automating the development*** process

Model execution

- Process of partly or fully running a computational model in a software environment

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Model execution

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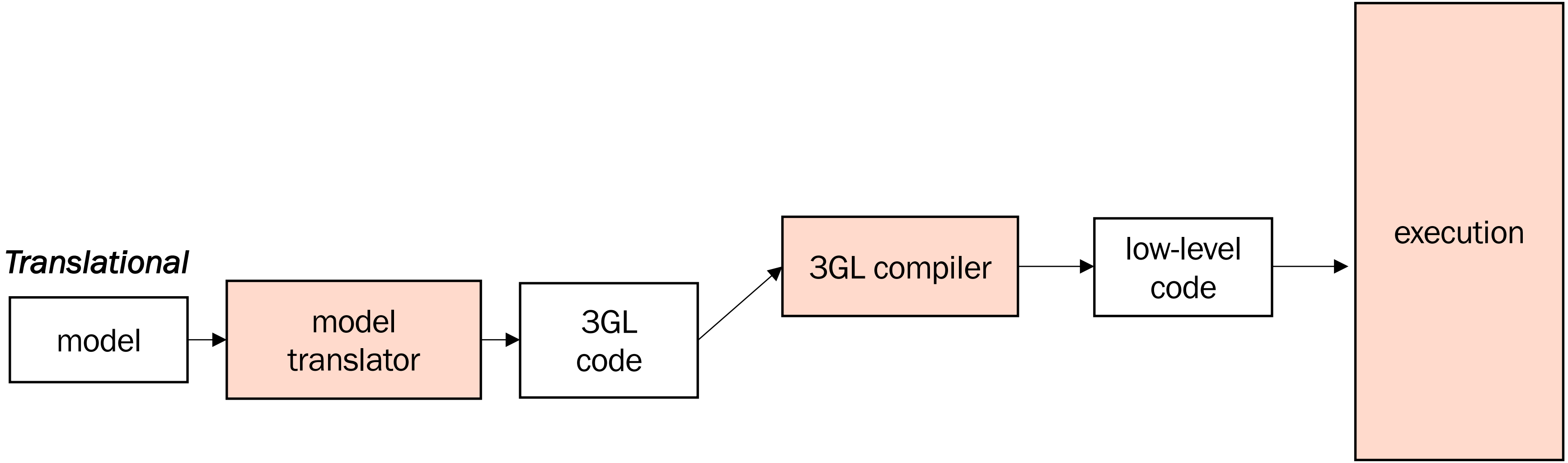
- Simulation for prediction/monitoring based on specific inputs and configurations
- Pivotal to understand complex systems
- Pivotal to forecast outcomes related to criticality aspects (e.g., time, safety, security)
- Essential in domains like data science, AI, machine learning

Model execution strategies



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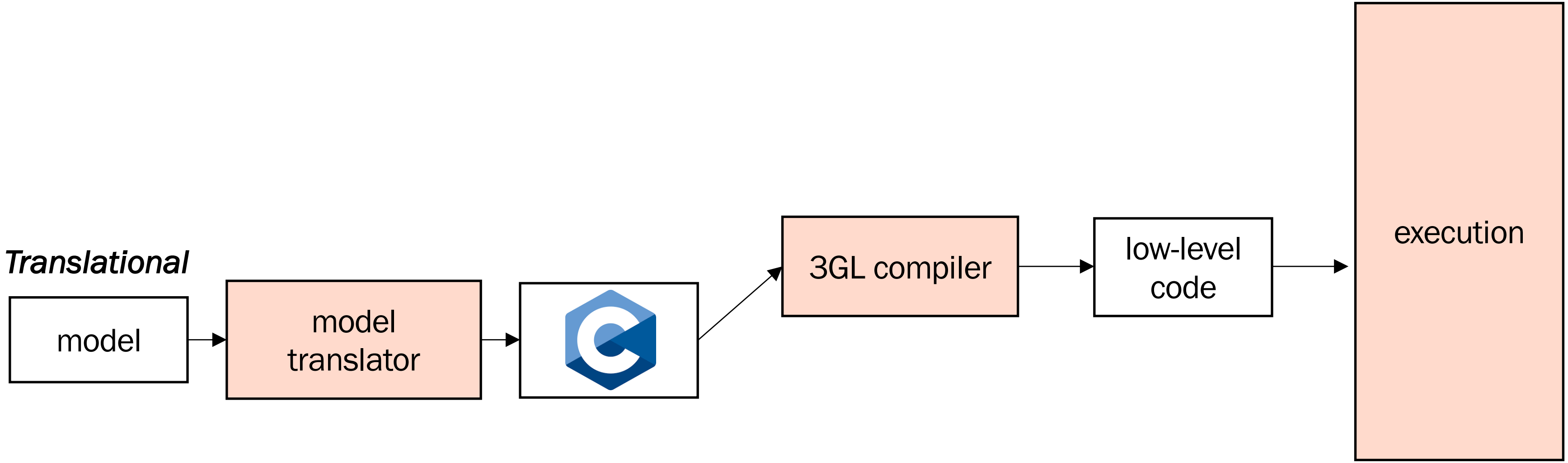
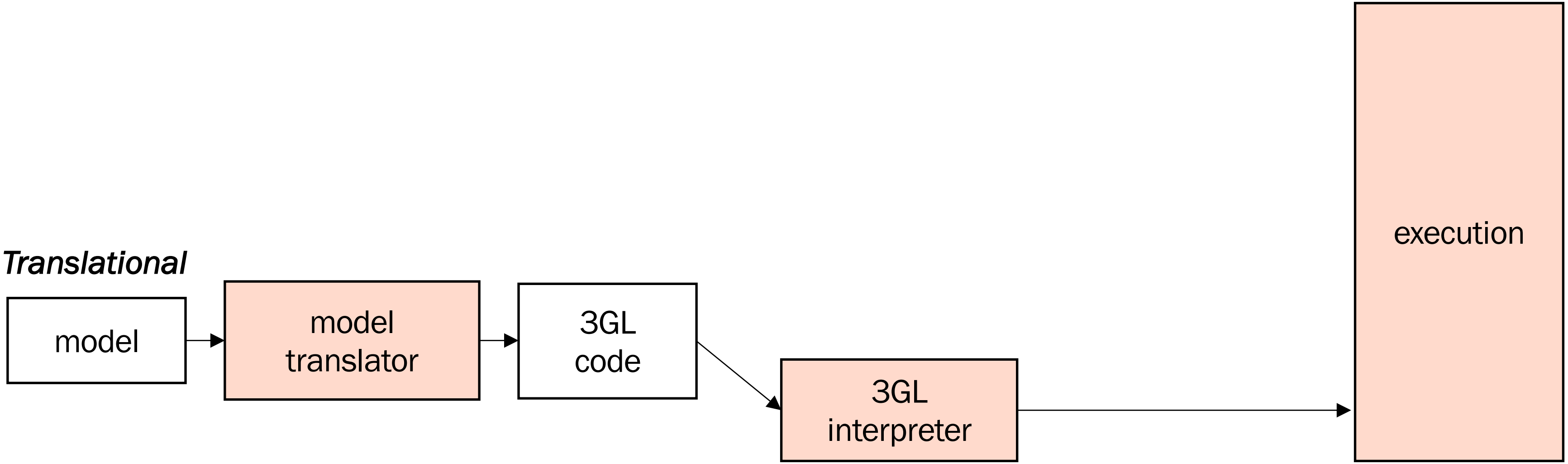


Model execution strategies

Translational



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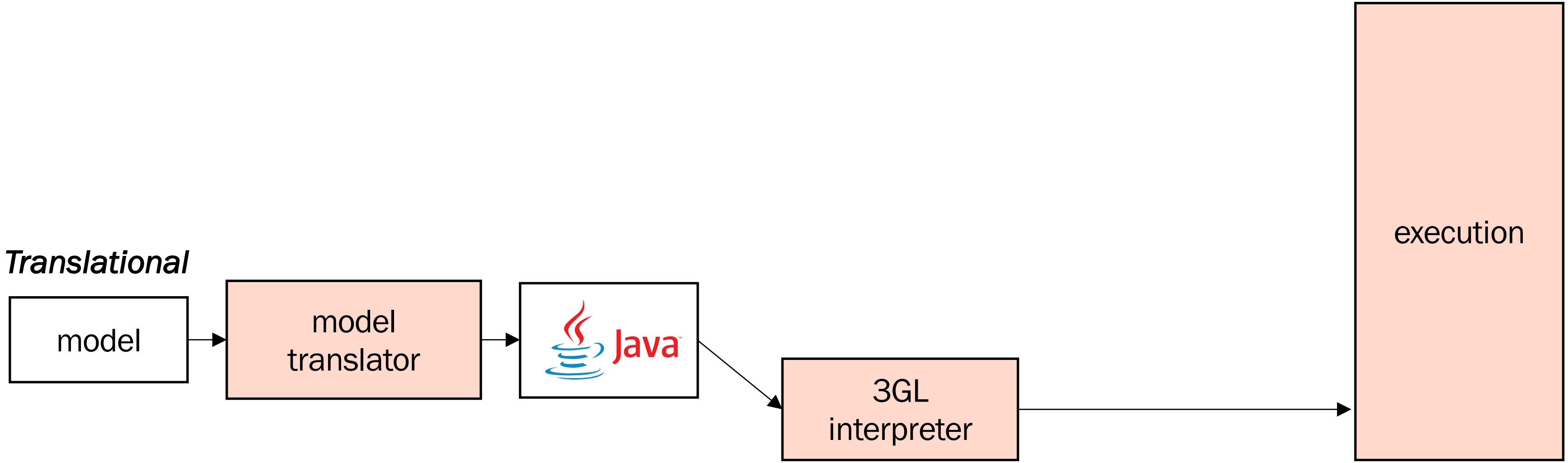

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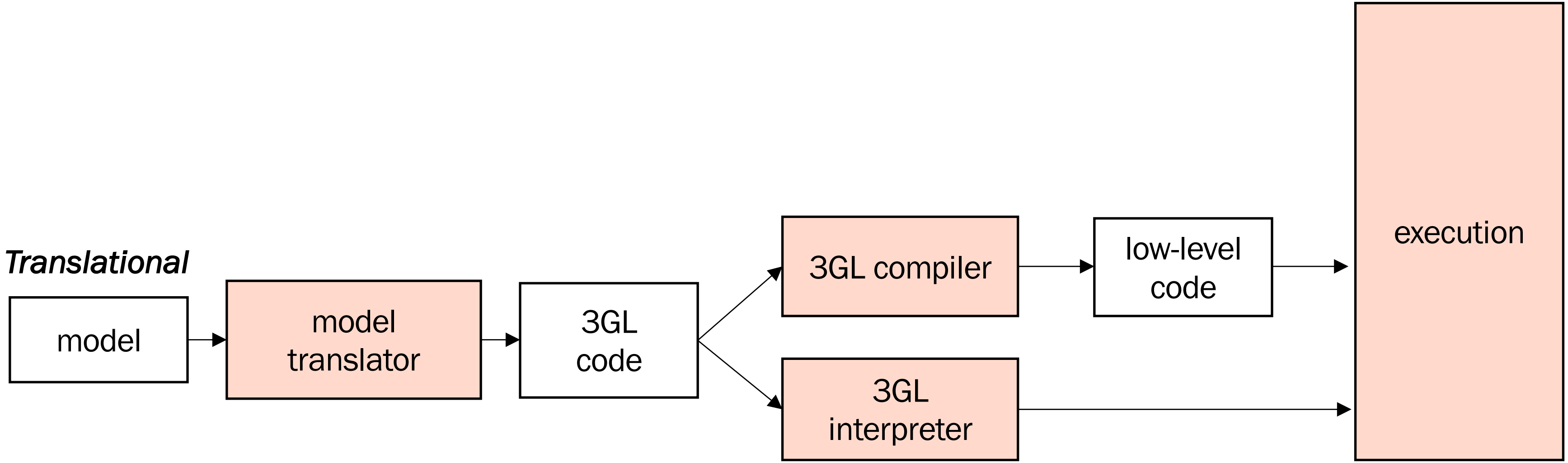

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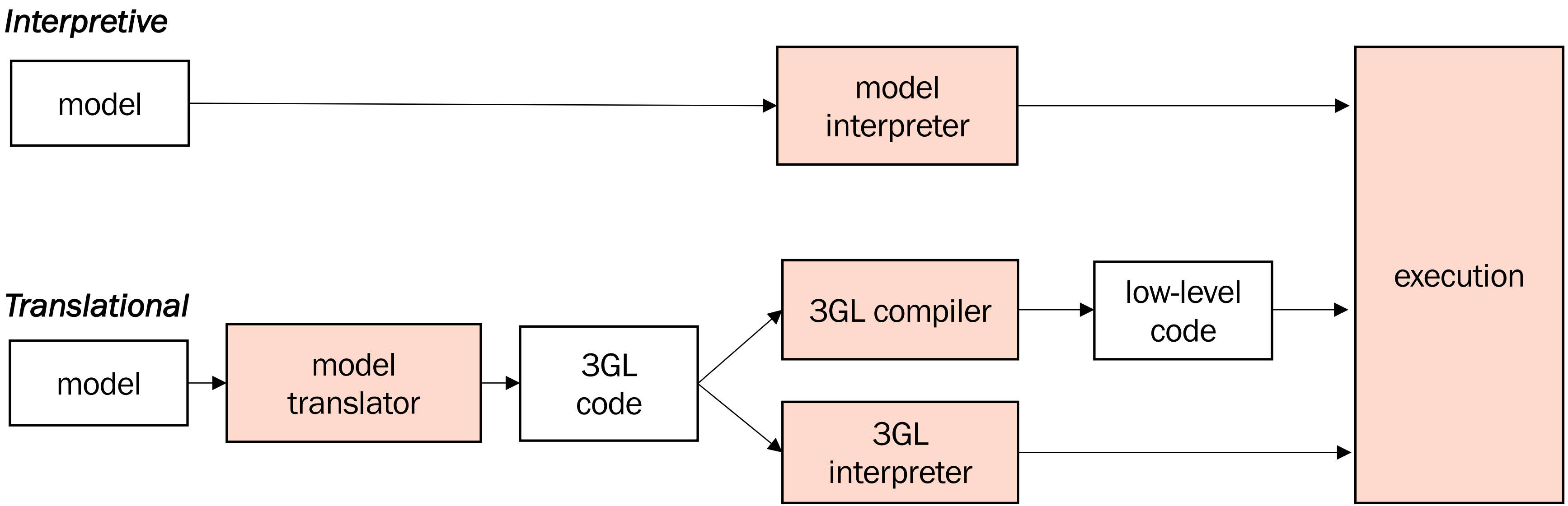
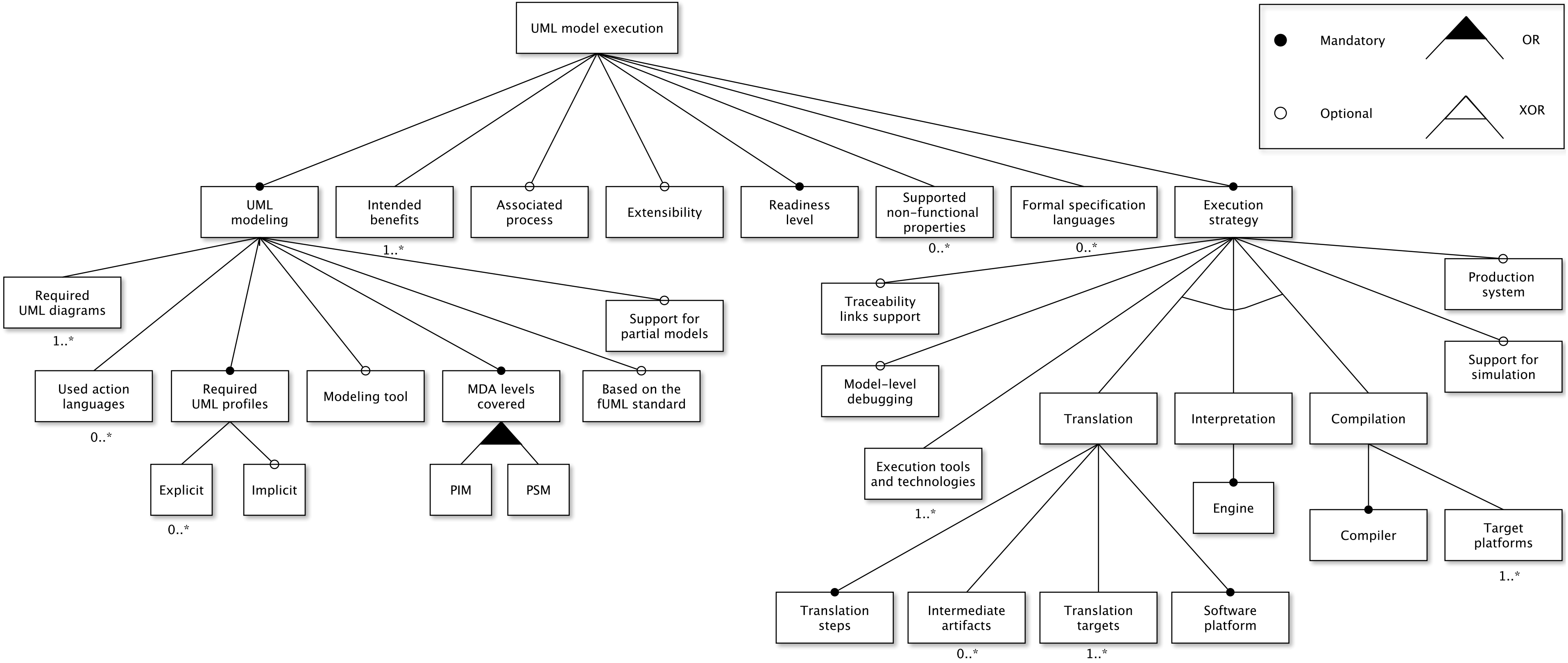


UML execution

- Systematic review of research and practice
    - Research articles
    - Tools
- Investigated >5400 items
- Included 63 articles and 19 tools
- Systematic search and data extraction

Execution of UML models: a systematic review of research and practice. Federico Ciccozzi, Ivano Malavolta, Bran Selic. Software & Systems Modeling (2019) 18:2313–2360

Classification of UML execution solutions



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- Execution strategy
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  - 15% based on fUML

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- Action languages
  - >90% use 3GLs
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- Action languages
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- Support for simulation
  - 59% provide some simulation feature

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Other interesting aspects..

- Extensibility
  - 21% provide some sort of extension mechanism

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- Traceability (model-code)
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Other interesting aspects..

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- Traceability (model-code)
  - 18% provide some support for trace links
- Interactive debuggability
  - 25% provide debugging features at model-level

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In summary

- ***Translation*** outnumbers interpretation
- Interpretation is used for higher-level execution (e.g., simulation)
- Execution semantics from ***fUML is neglected*** in most cases
- Most solutions employ ***3GLs as action languages***
- Almost no model-level interactive debugging
- Little extensibility and customizability

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What about ”code generation” approach

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    - *Violate source models*
    - *Violate model-based analysis, optimisation and V&V*
    - *Get lost if source models change*

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- Not suitable for heterogeneous platforms (multiple 3GLs needed)

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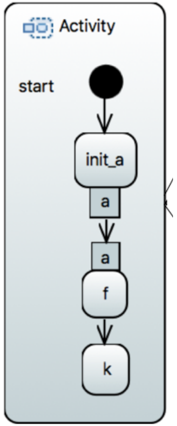

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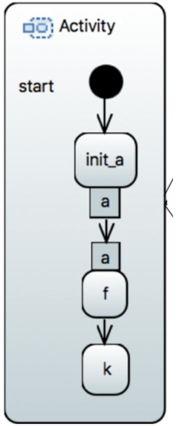
let a : A = null;
f(a); execution stops
k();
```



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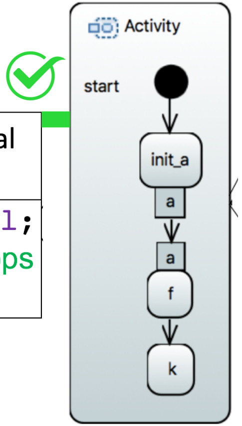

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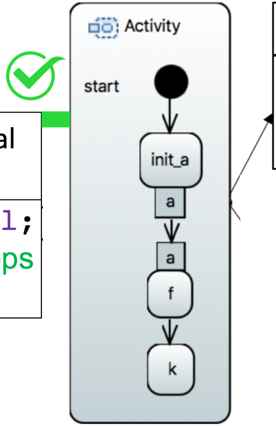

Java from code generator 1

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A a = null;
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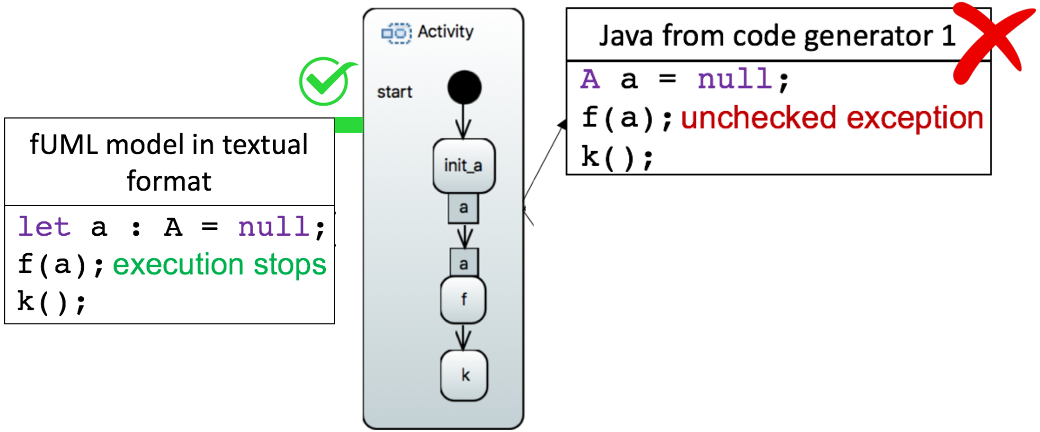

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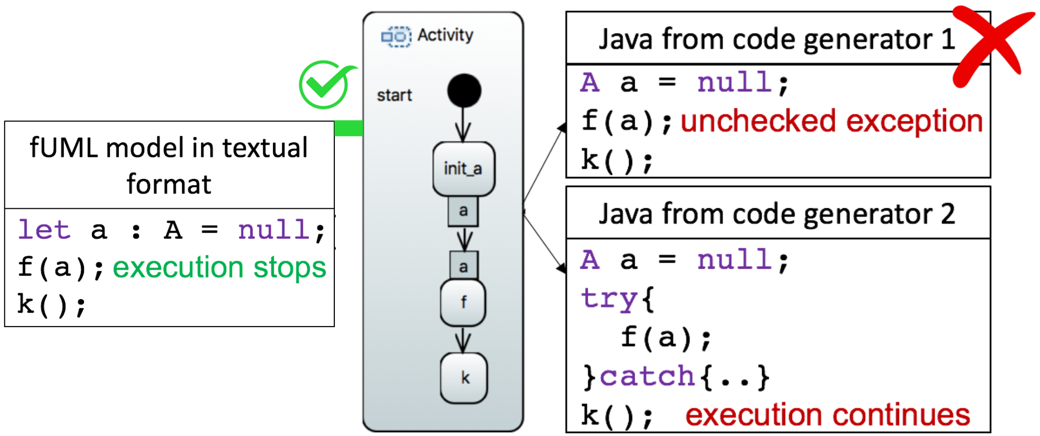

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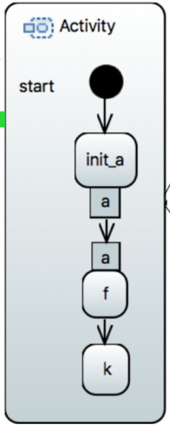

Java from code generator 1

```
A a = null;
f(a); unchecked exception
k();
```

Java from code generator 2

```
A a = null;
try{
  f(a);
}catch{..}
k();   execution continues
```

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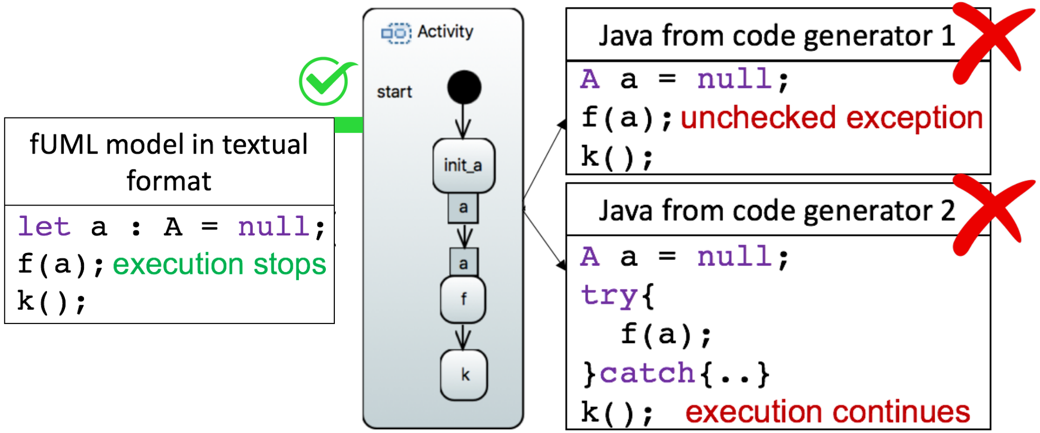
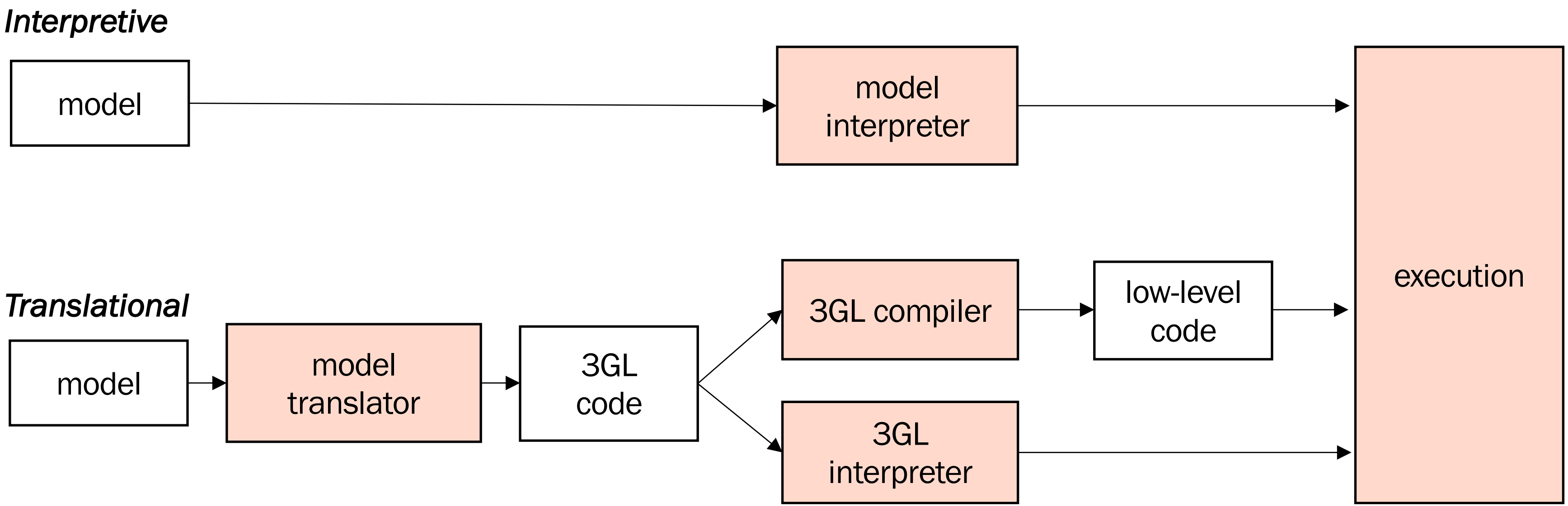


Some of the issues

- *Predictability*
- *Validity of MB-analysis*
- *Consistency model-code*
- *Bidirectional traceability*
- *Co-simulation*
- *Co-debugging*

Model execution strategies



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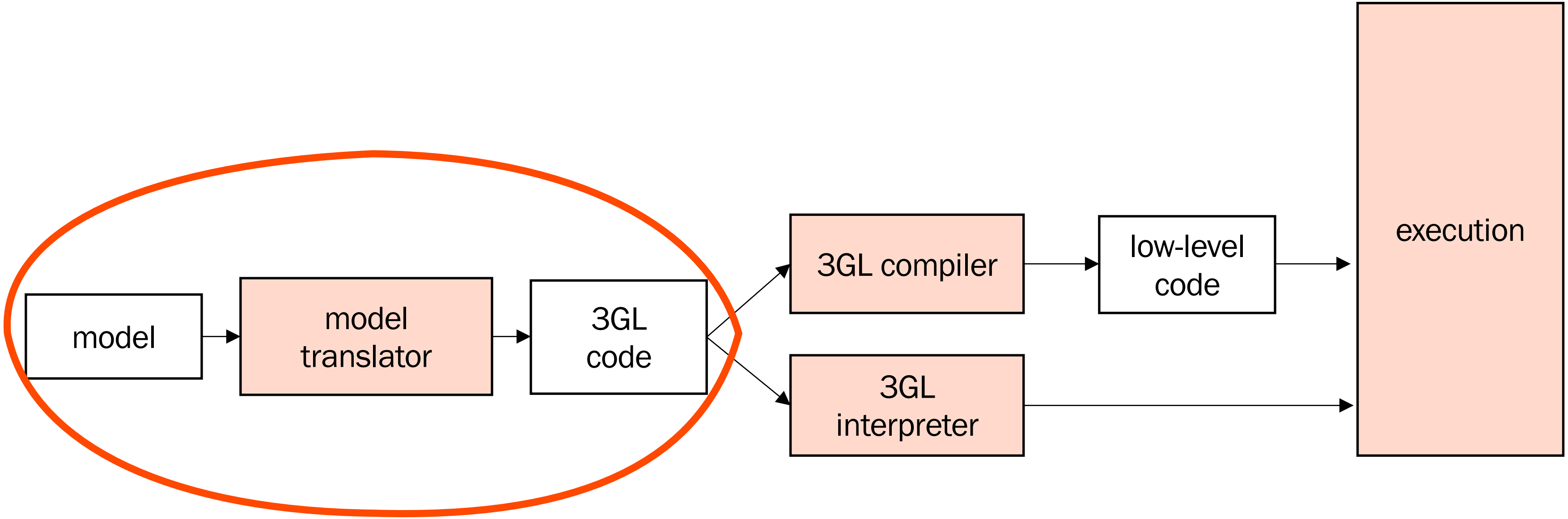

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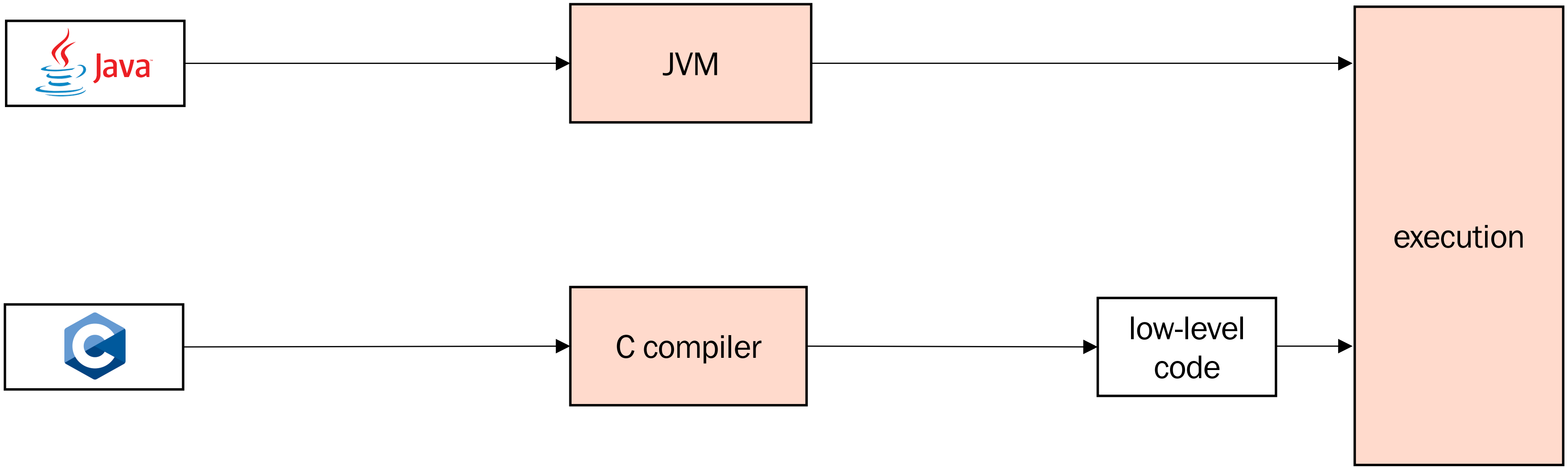

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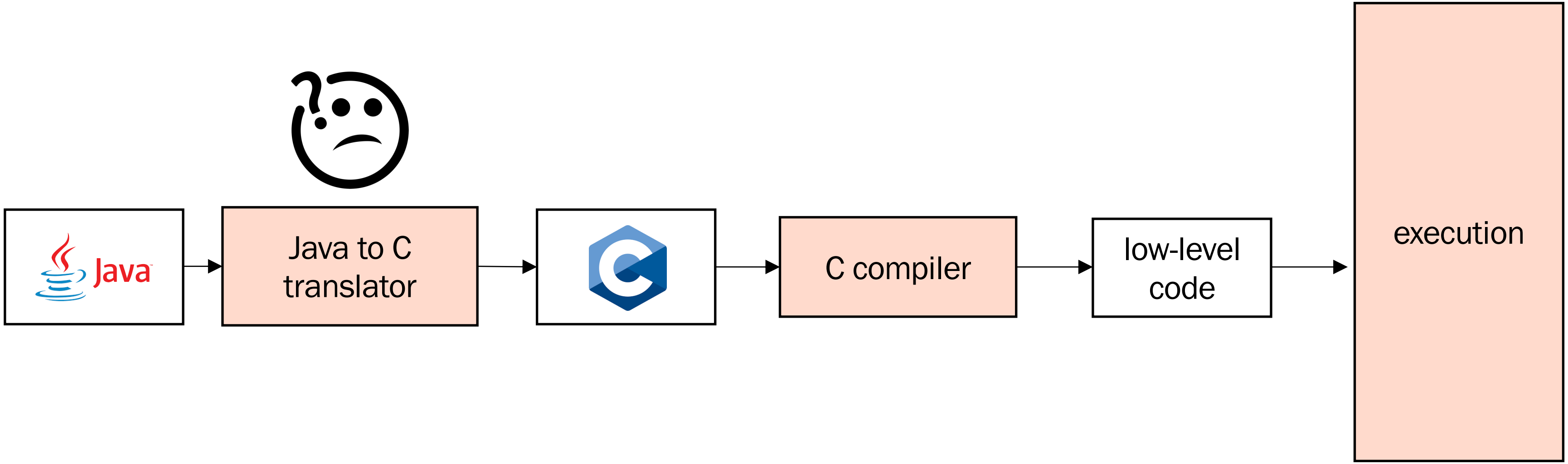
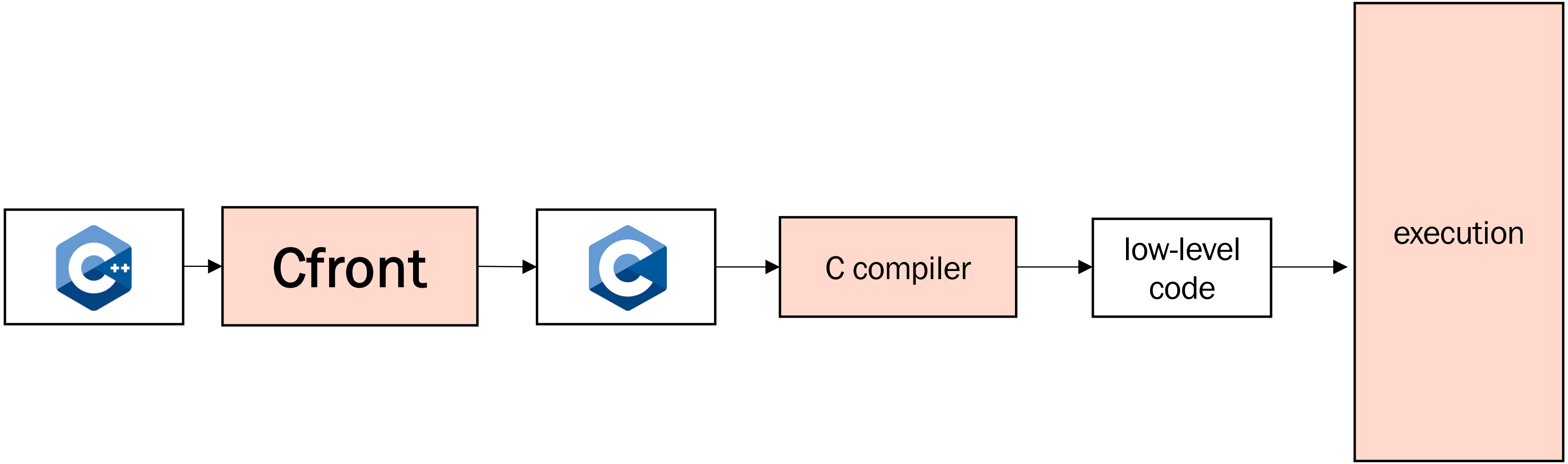
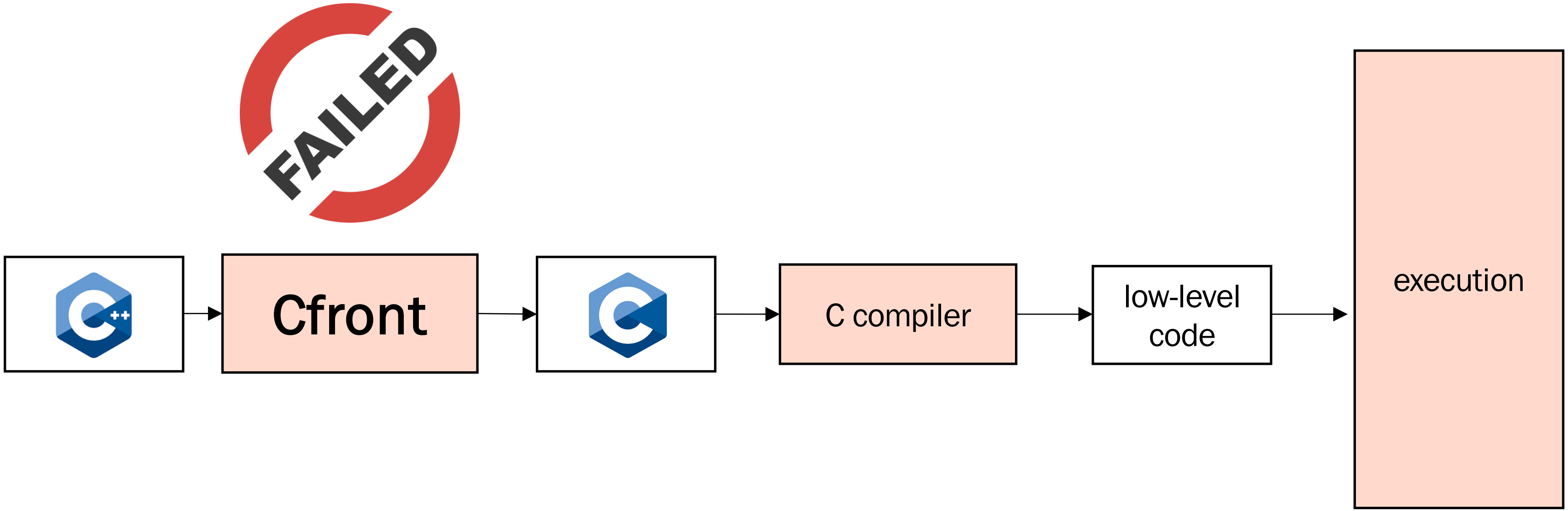


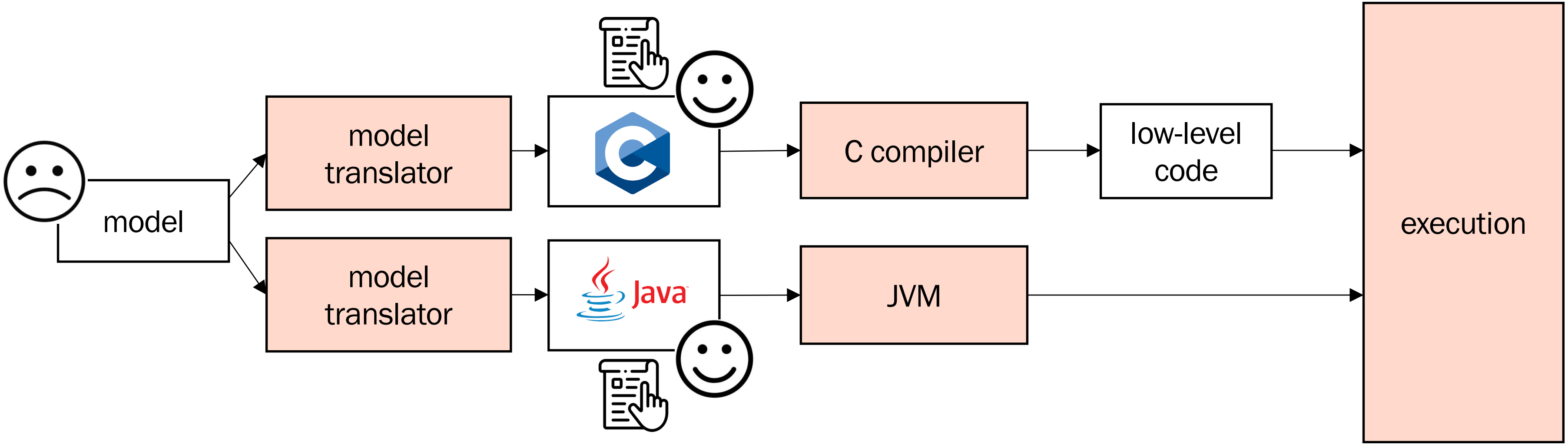
We have tried before..

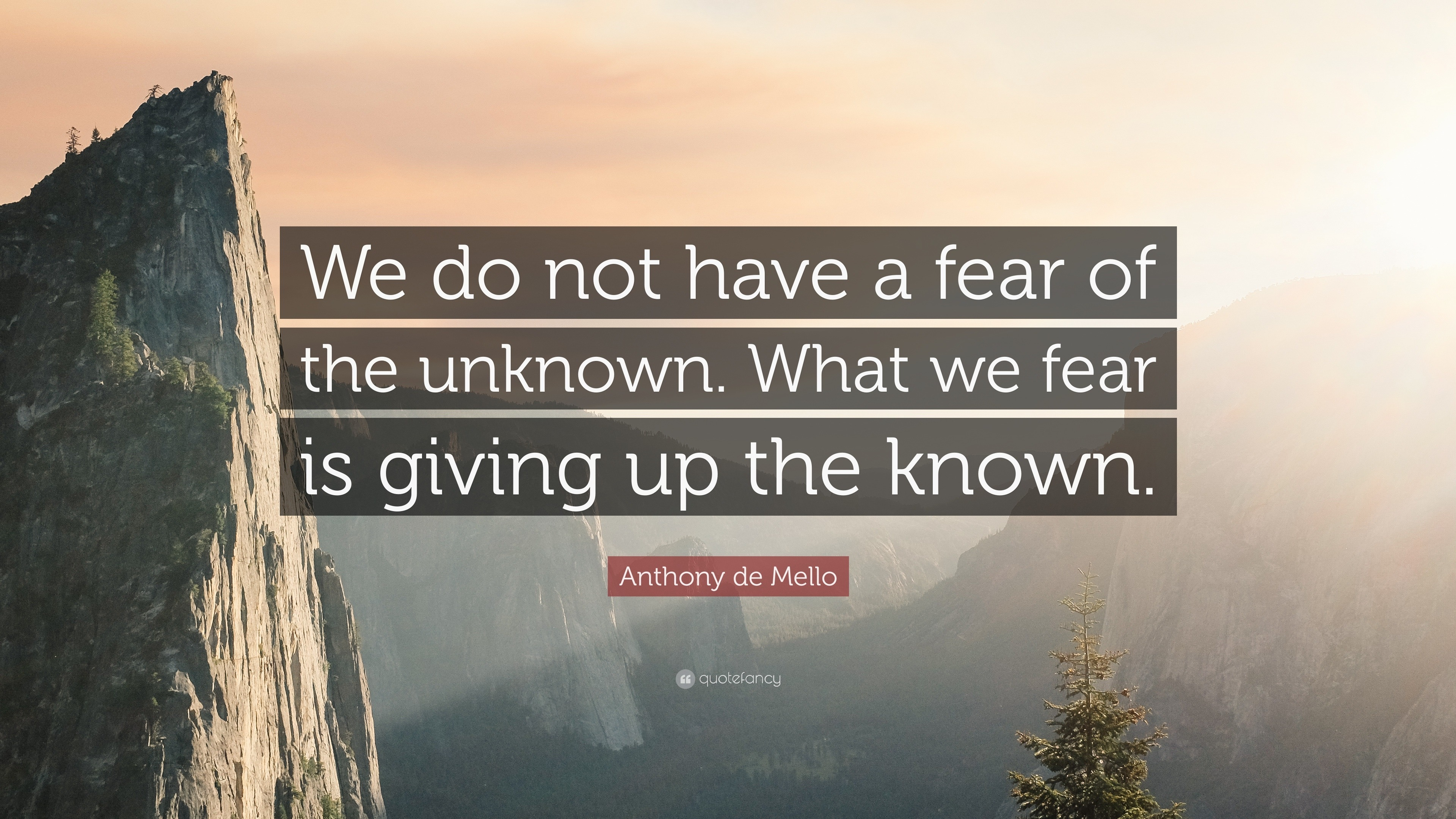


.. And not succeeded

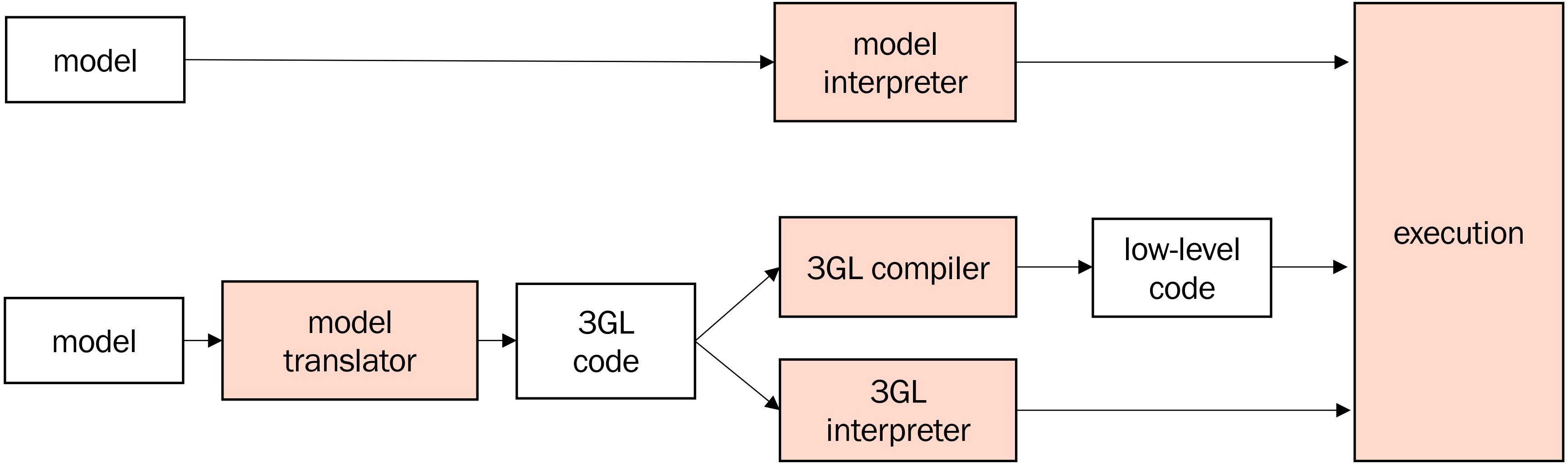


Code generation.. why



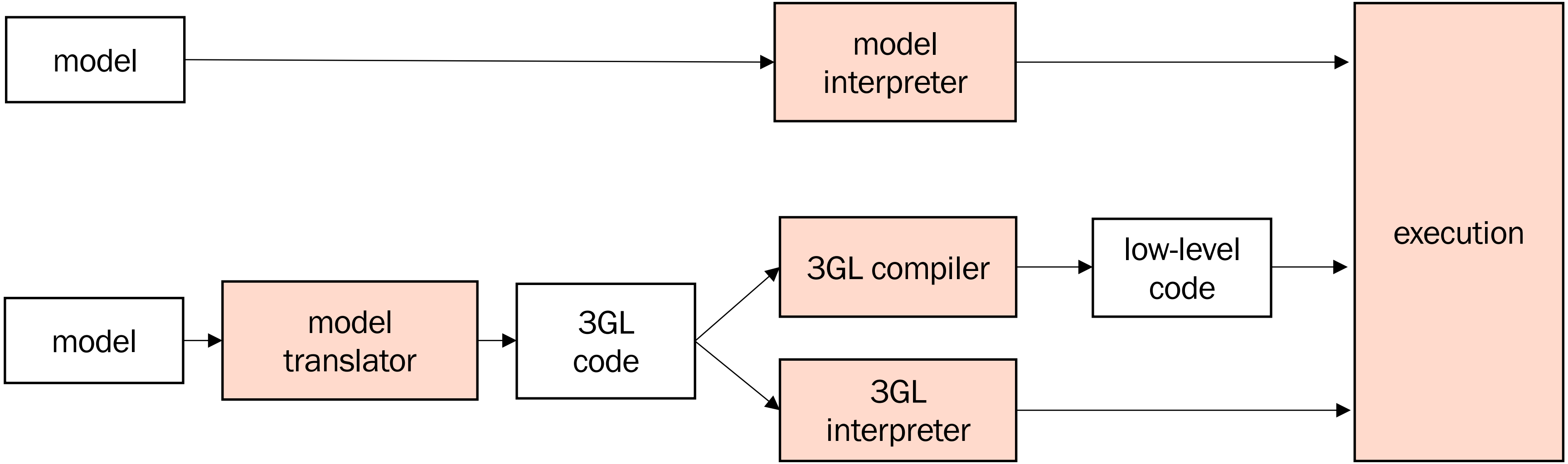

We do not have a fear of the unknown. What we fear is giving up the known.
Anthony de Mello
quotefancy

Model execution strategies

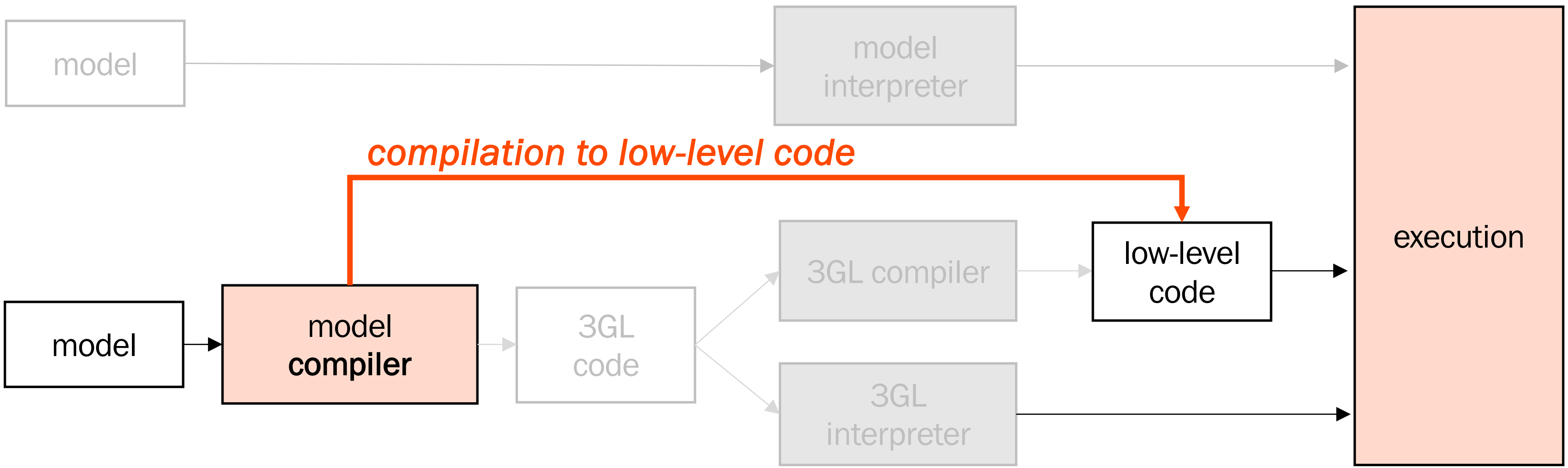


Model execution strategies

In H2020 SPACE-10-TEC-2020, ***new model execution*** *approaches regarded as the* ***most urgent software engineering*** *need in the* ***space*** *industry*

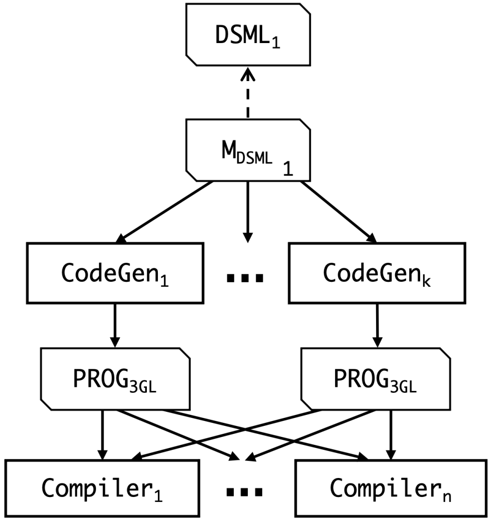


Model compilation



Model compilation

- 3GL code generators are specific to source DSML and target 3GL



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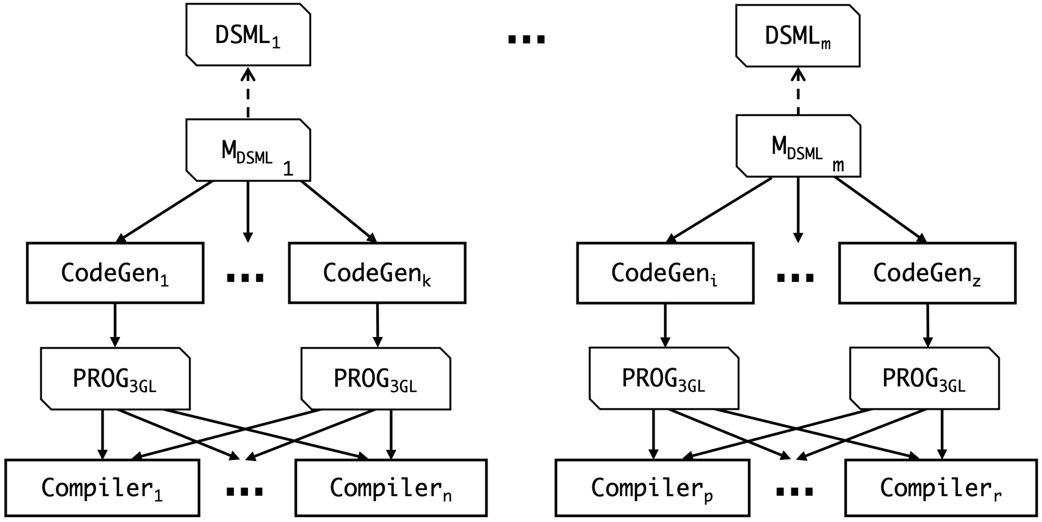

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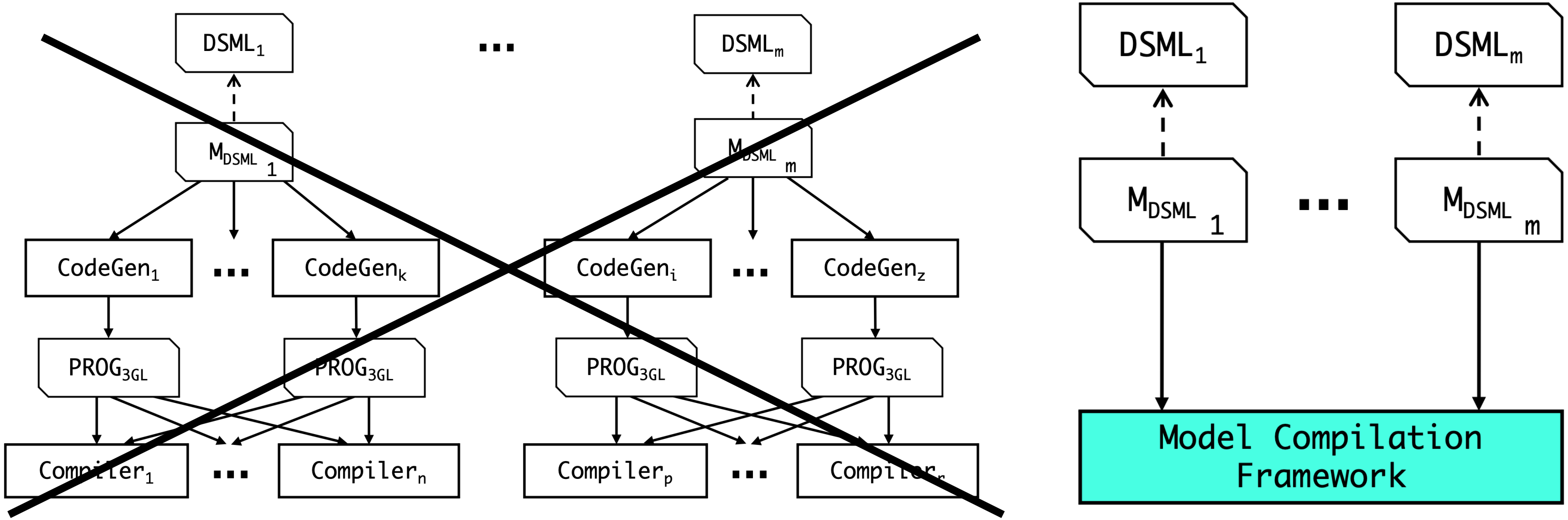

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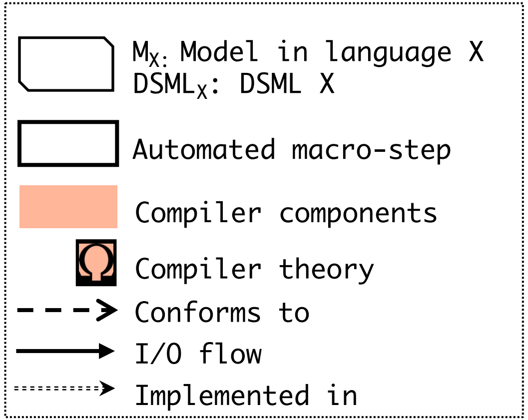
- Use of model compilation for AI/ML purposes

Envisioned model compilation approach



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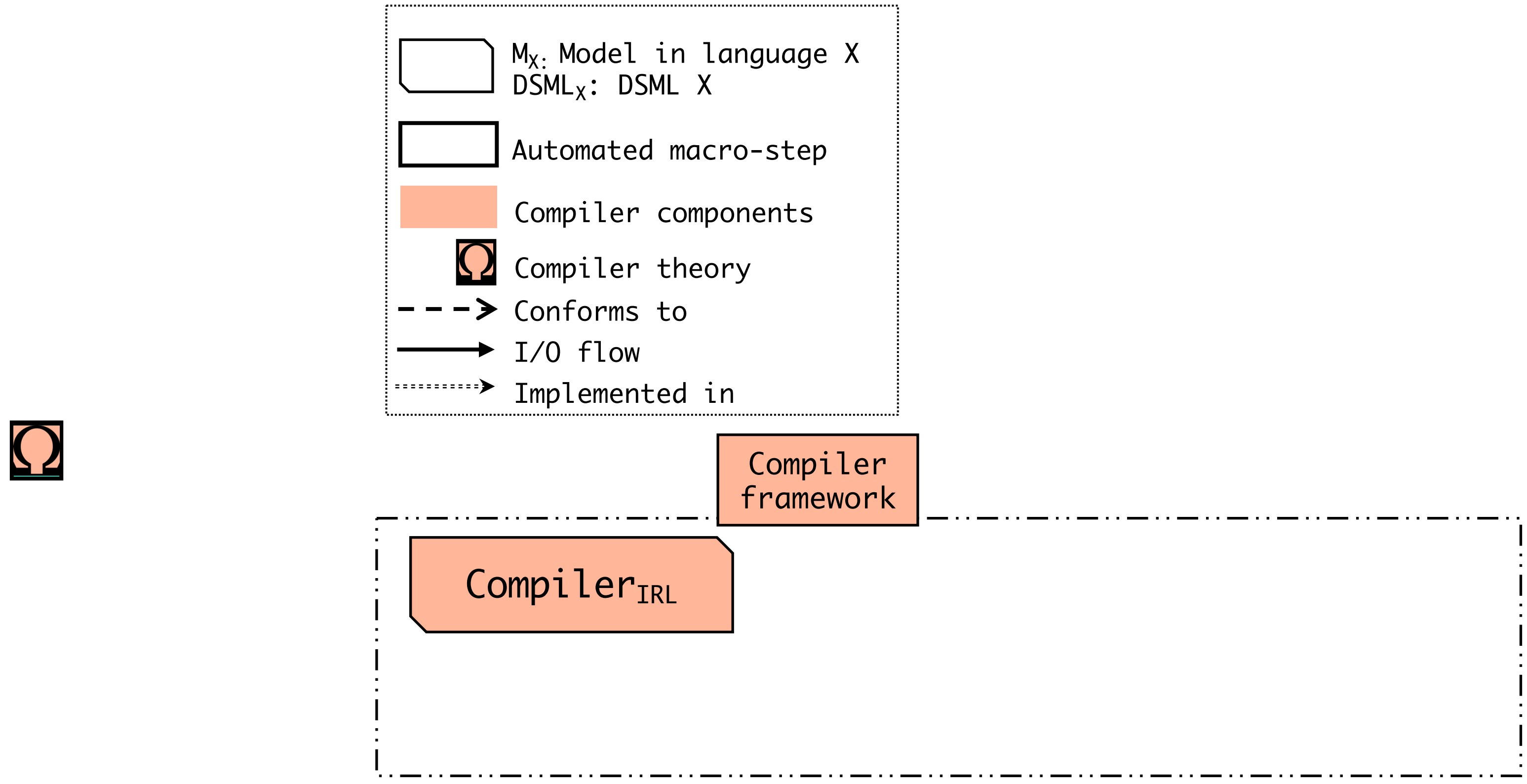

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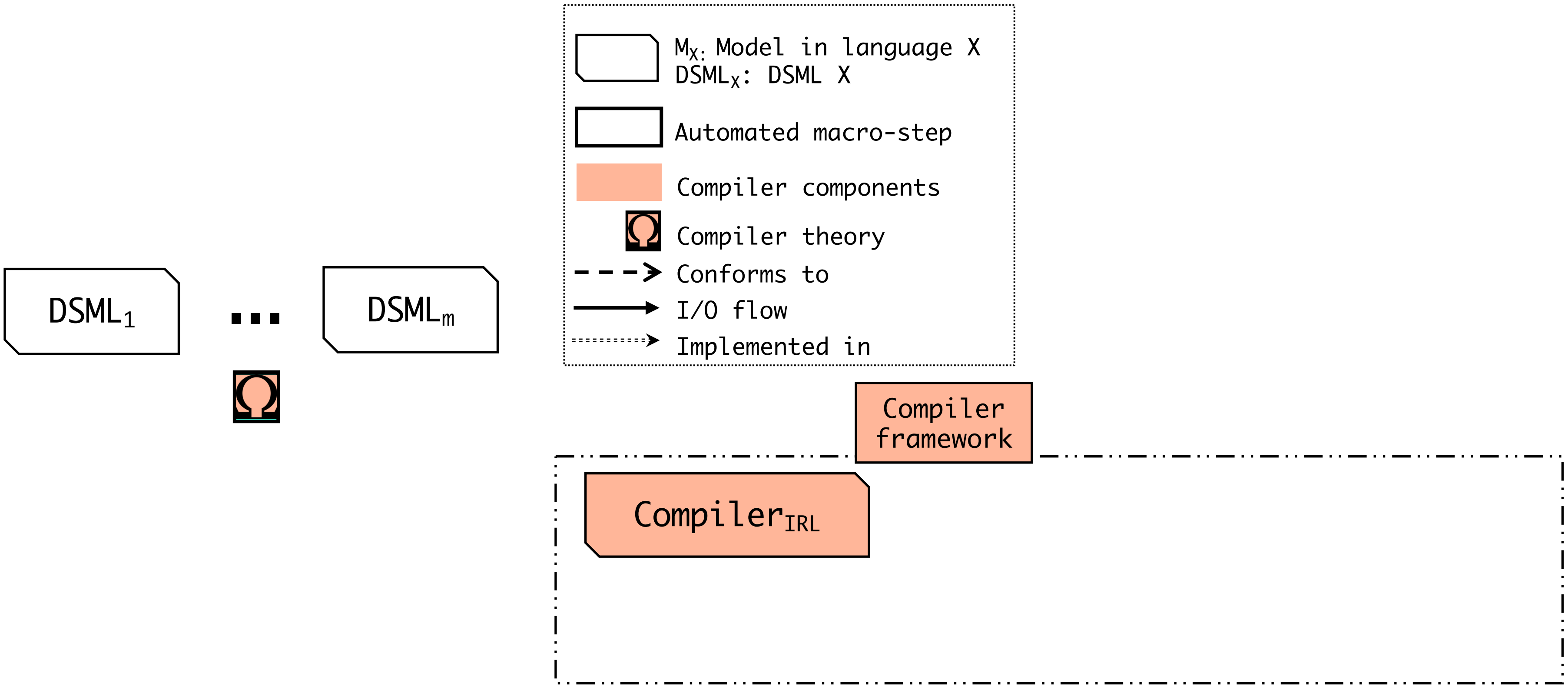

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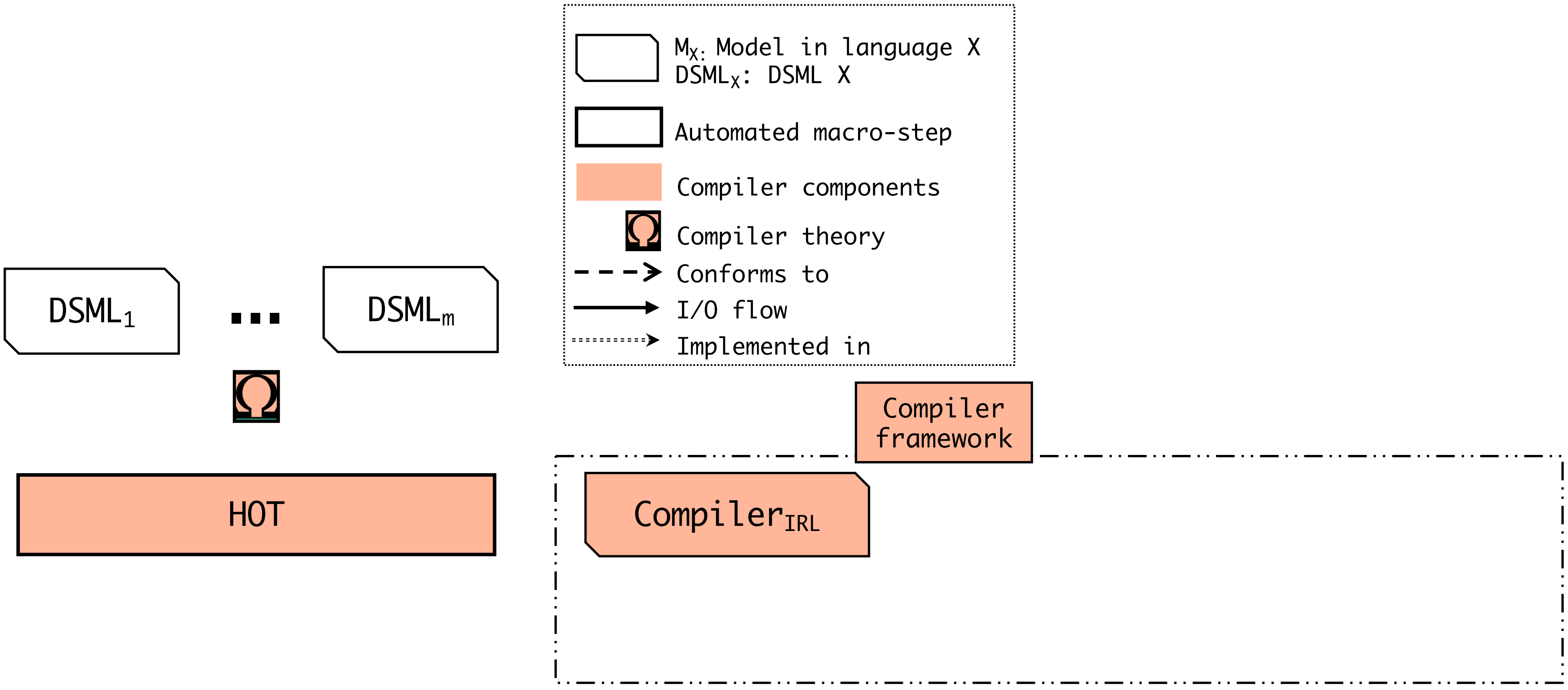

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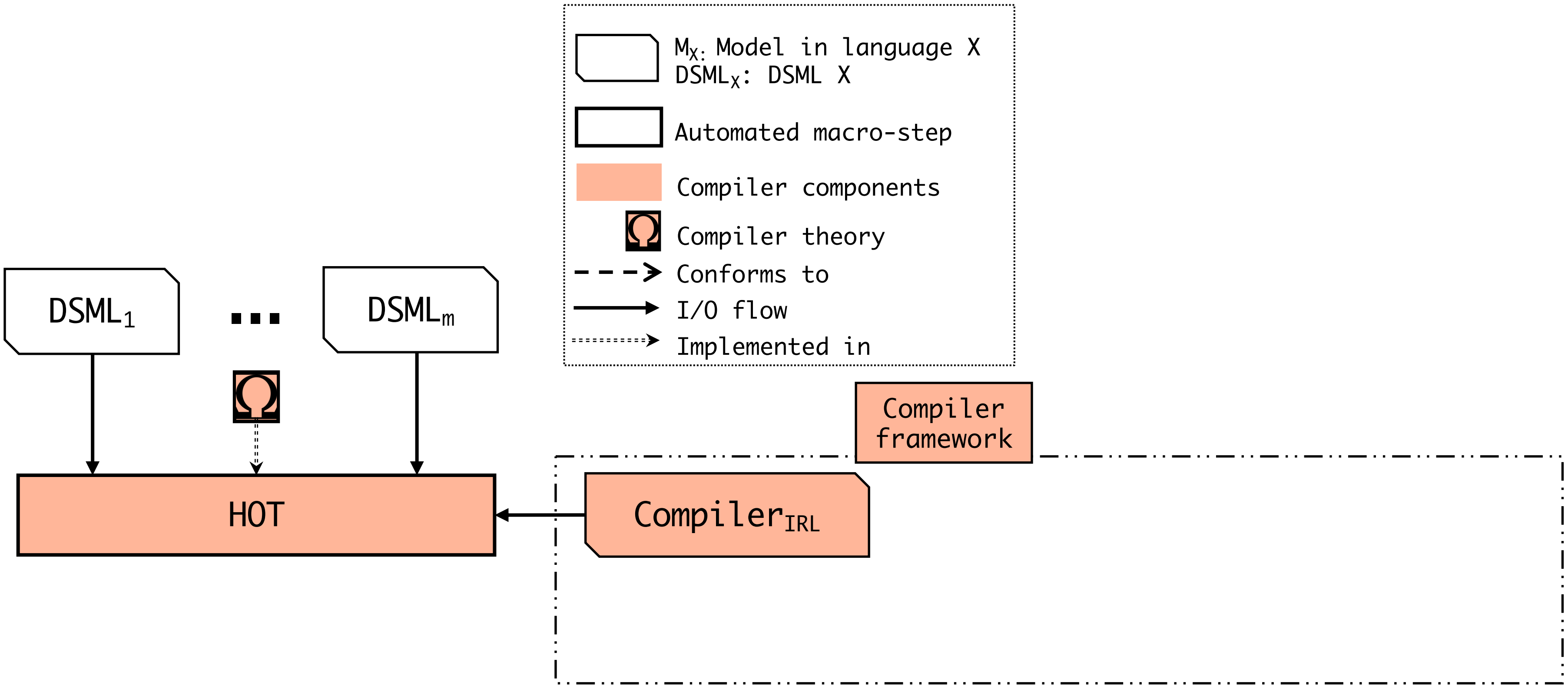

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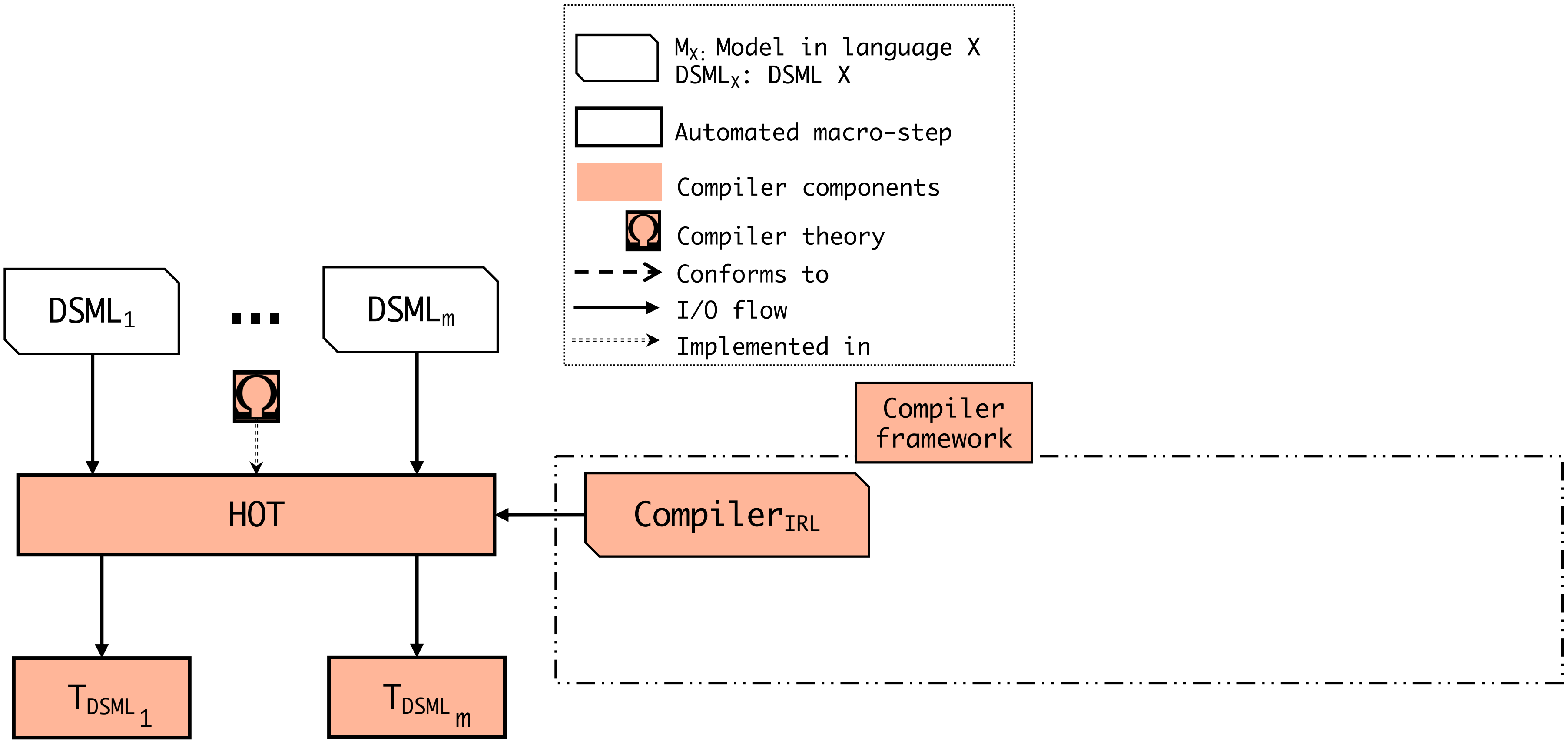

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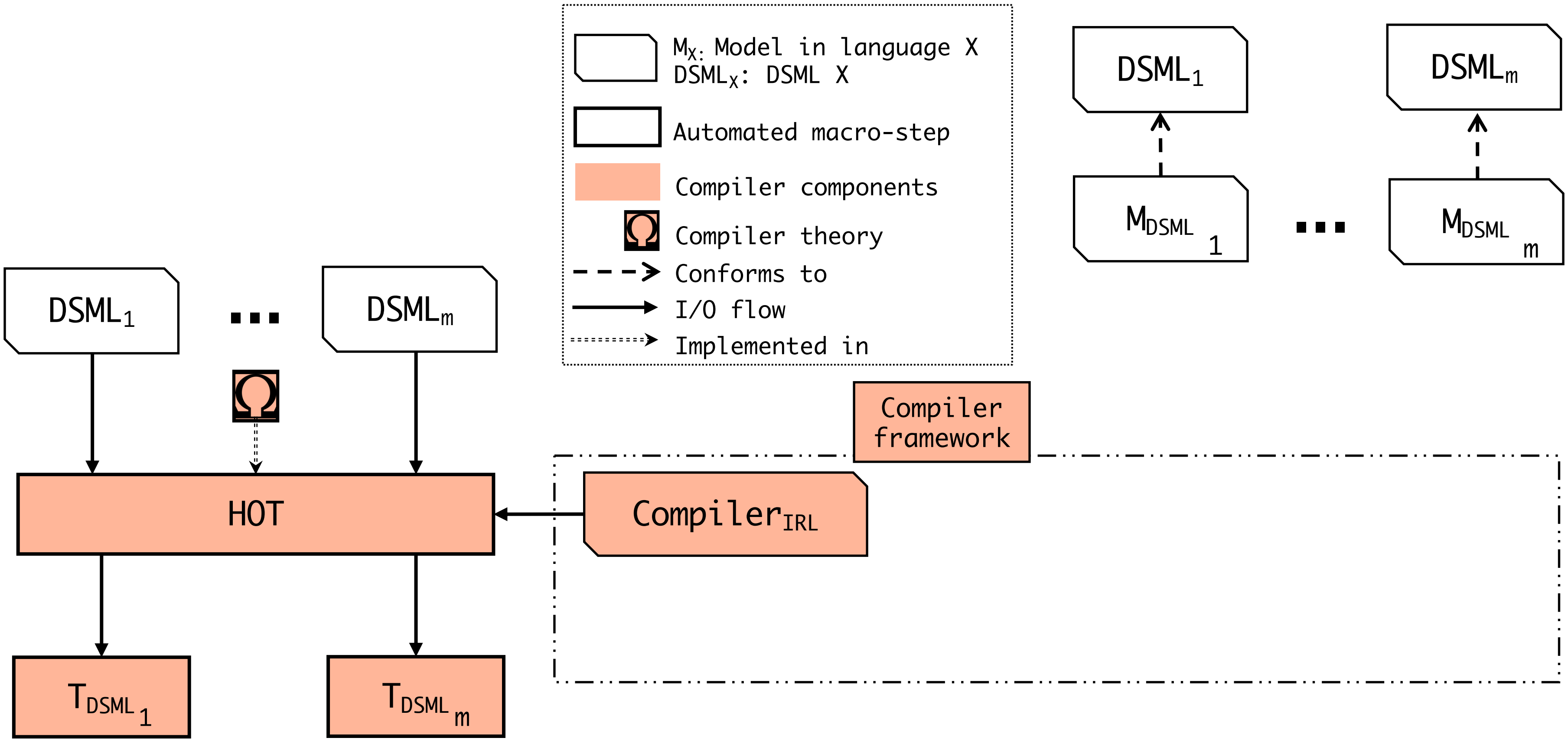

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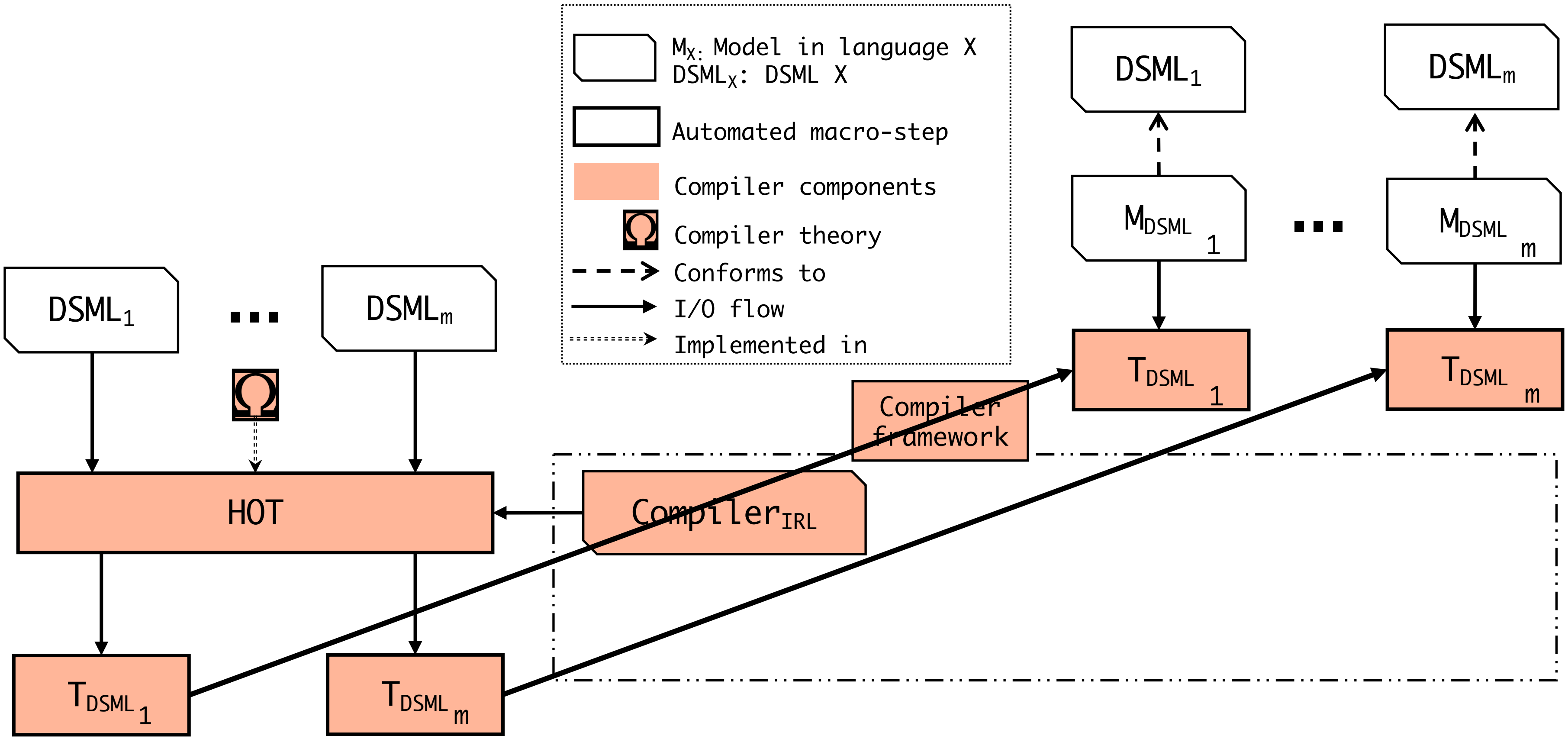

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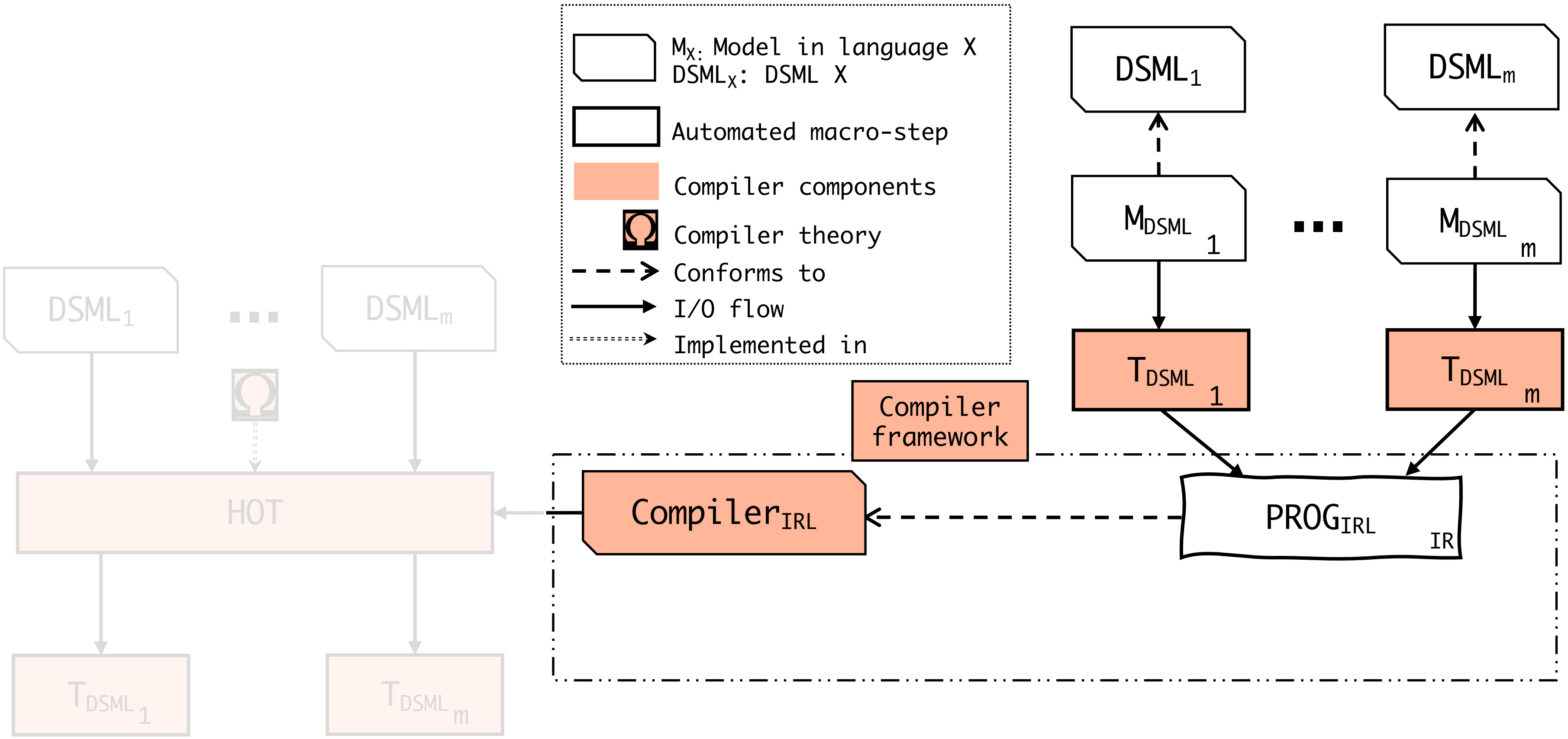

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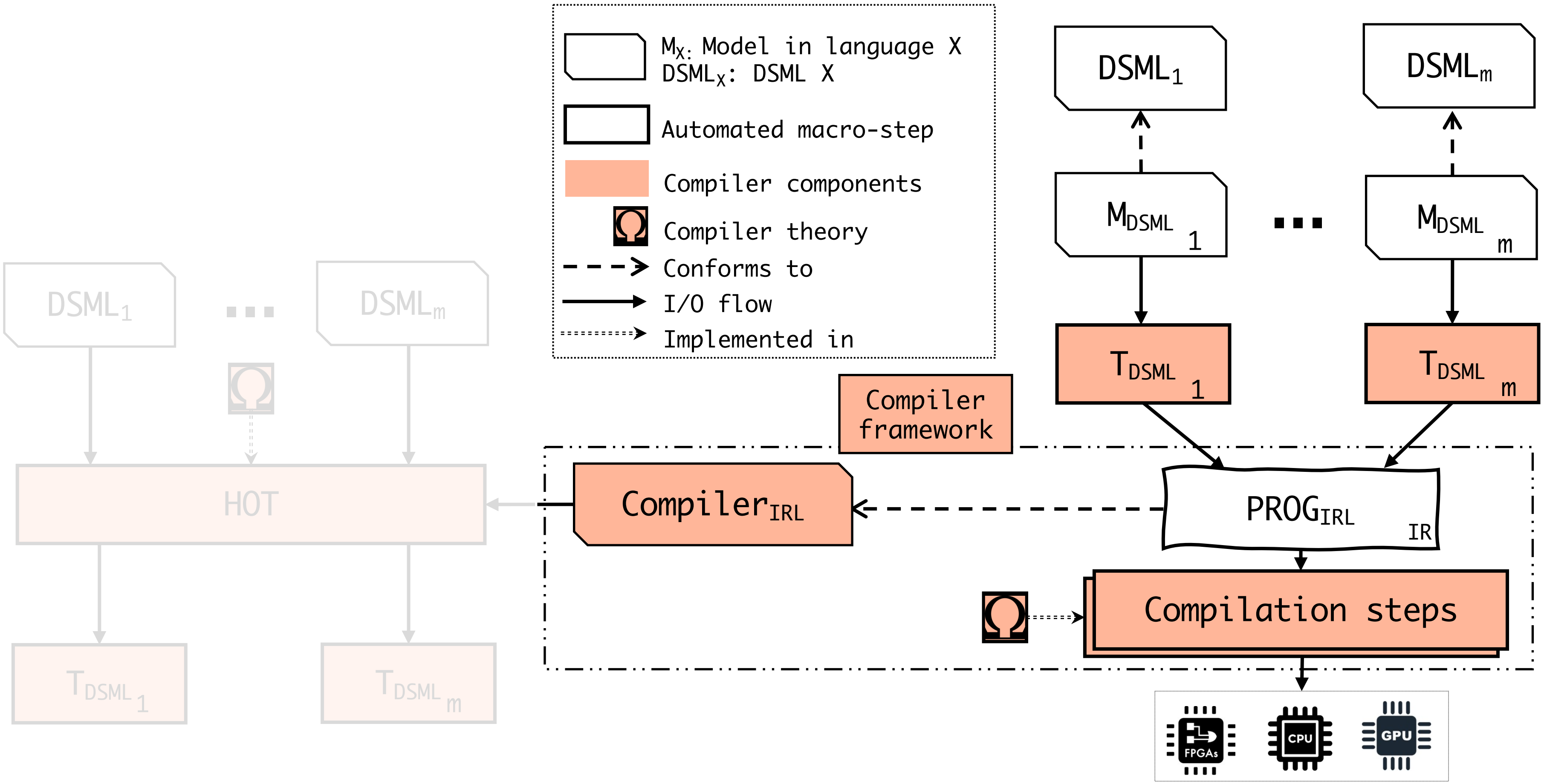

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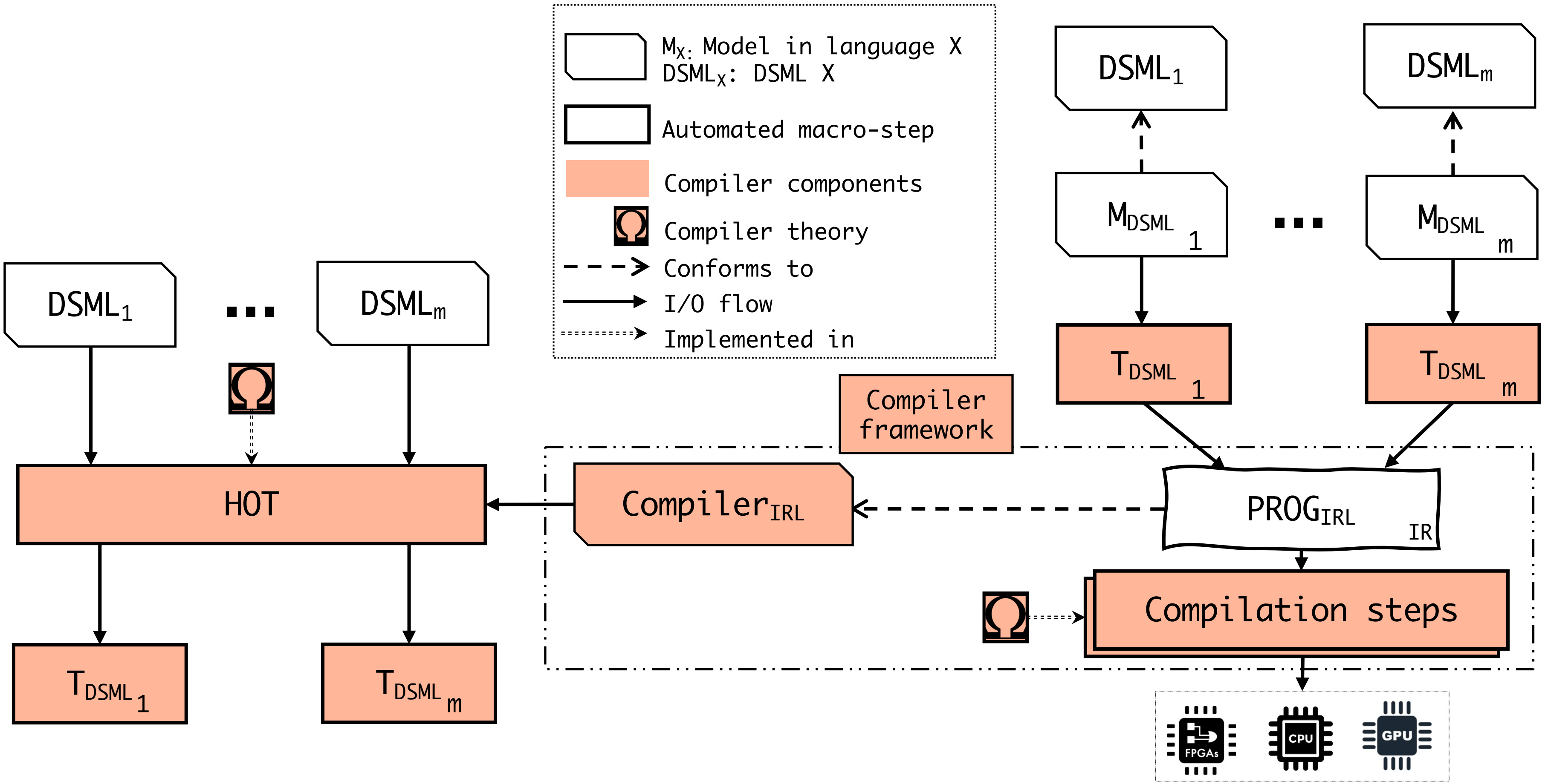
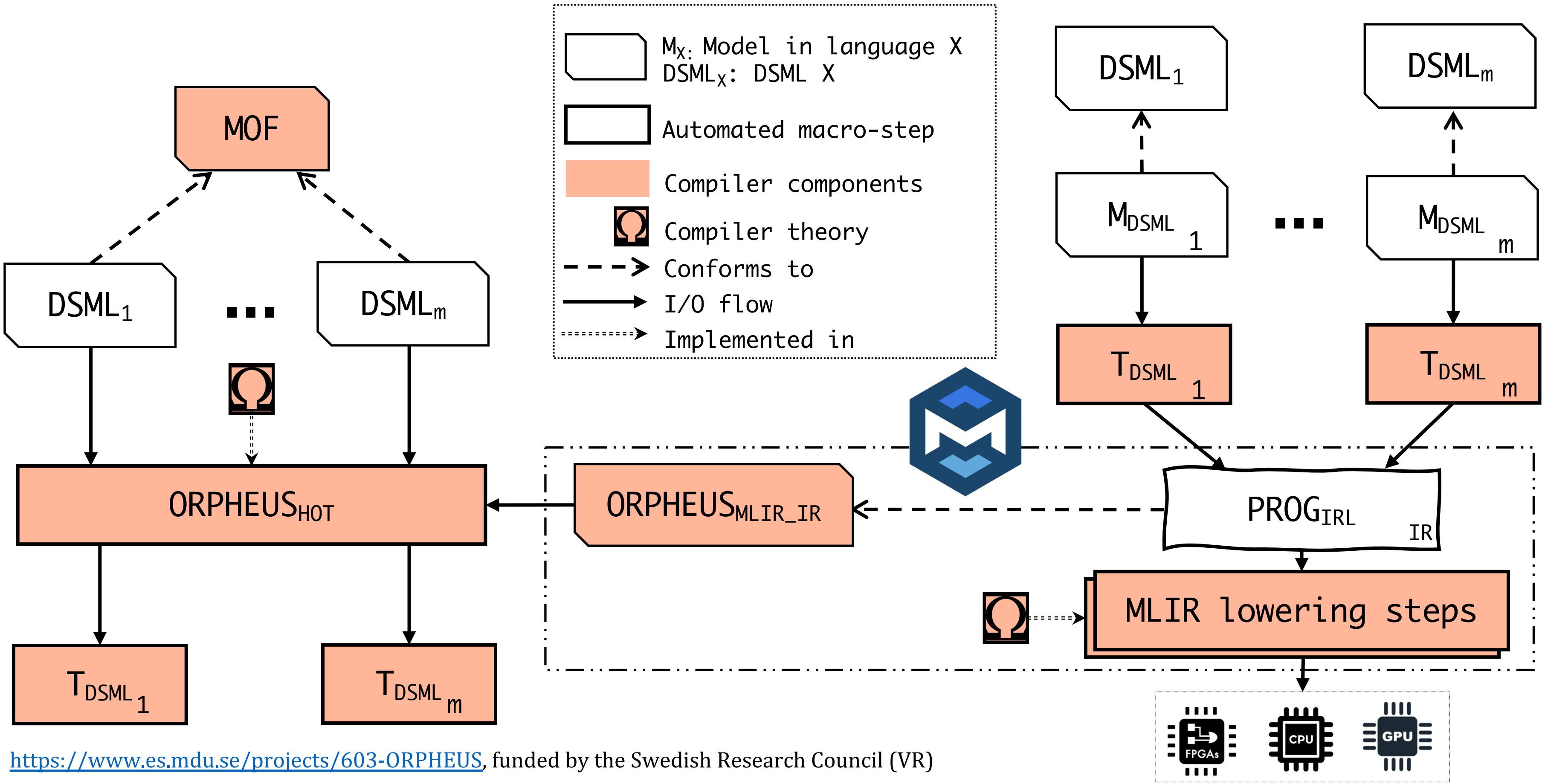


ORPHEUS model compilation approach



https://www.es.mdu.se/projects/603-ORPHEUS, funded by the Swedish Research Council (VR)

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- UML model execution
  - Compliance to fUML execution semantics
  - Support for UML-compliant action languages
  - Support for executing models based on UML profiles

.. and..

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Let’s not forget that **modelling**, for sketching, communication, and brainstorming purposes, is..

.. *fun, useful, and very valuable!*


Design adds value
faster than it adds cost.
Joel Spolsky
quotefancy

Thank you!