22c181:
Formal Methods in Software Engineering

The University of Iowa

Spring 2008

Overview of the KeY System

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Contents of Second Part of Course

- **Overview of KeY**
- **UML and its semantics**
- **Introduction to OCL**
- **Specifying requirements with OCL**
- **Modelling of Systems with Formal Semantics**
- **Propositional & First-order logic, sequent calculus**
- **OCL to Logic, horizontal proof obligations, using KeY**
- **Dynamic logic, proving program correctness**
- **Java Card DL**
- **Vertical proof obligations, using KeY**
- **Wrap-up, trends**

Philosophy of KeY Tool

Formal Methods must *and can* be integrated into commercial processes, tools and languages for software development

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Integrated tool for

- **Modeling**
- **Development**
- **Formal specification**
- **Formal verification**

of object oriented programs

KeY Technologies Used in this Course

Standard language for Modeling of Software

- **Unified Modeling Language — UML** **(Borland Together)**

  Visual language for OO Modeling
  Standard of Object Management Group (OMG)

- **Object Constraint Language — OCL**

  Formal textual language for requirements specification
  UML sub-standard

Modern industrial programming language

Java (Card)

Logic, Automated Deduction

First-order logic, Dynamic Logic, Theorem proving

Other KeY Interfaces

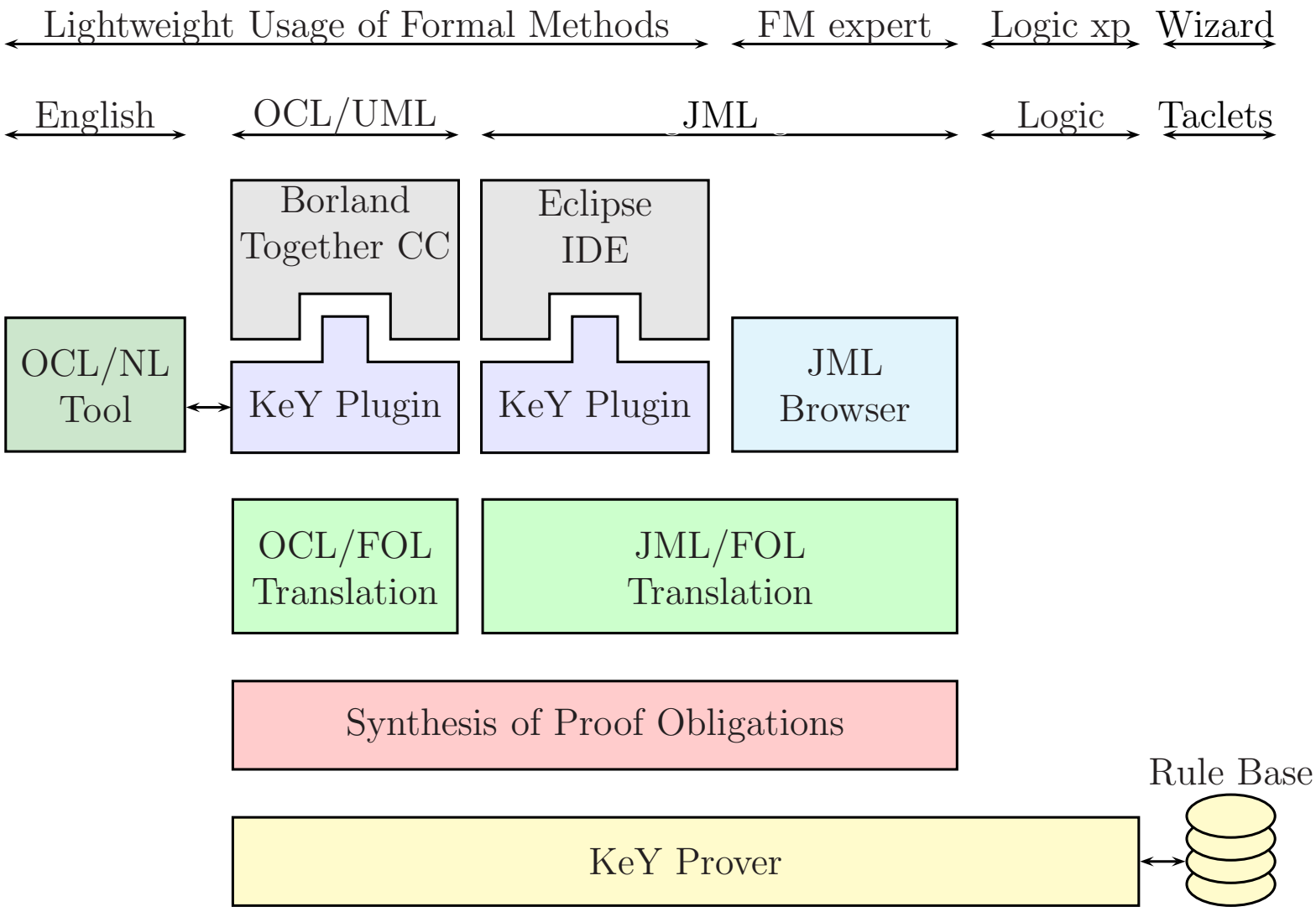
- **KeY plugin for Eclipse IDE**
- **Java Modeling Language — JML**

  Formal Interface Specification Language for Java
  Wide-spread in academic projects
- **Automatic Translation from OCL into English**

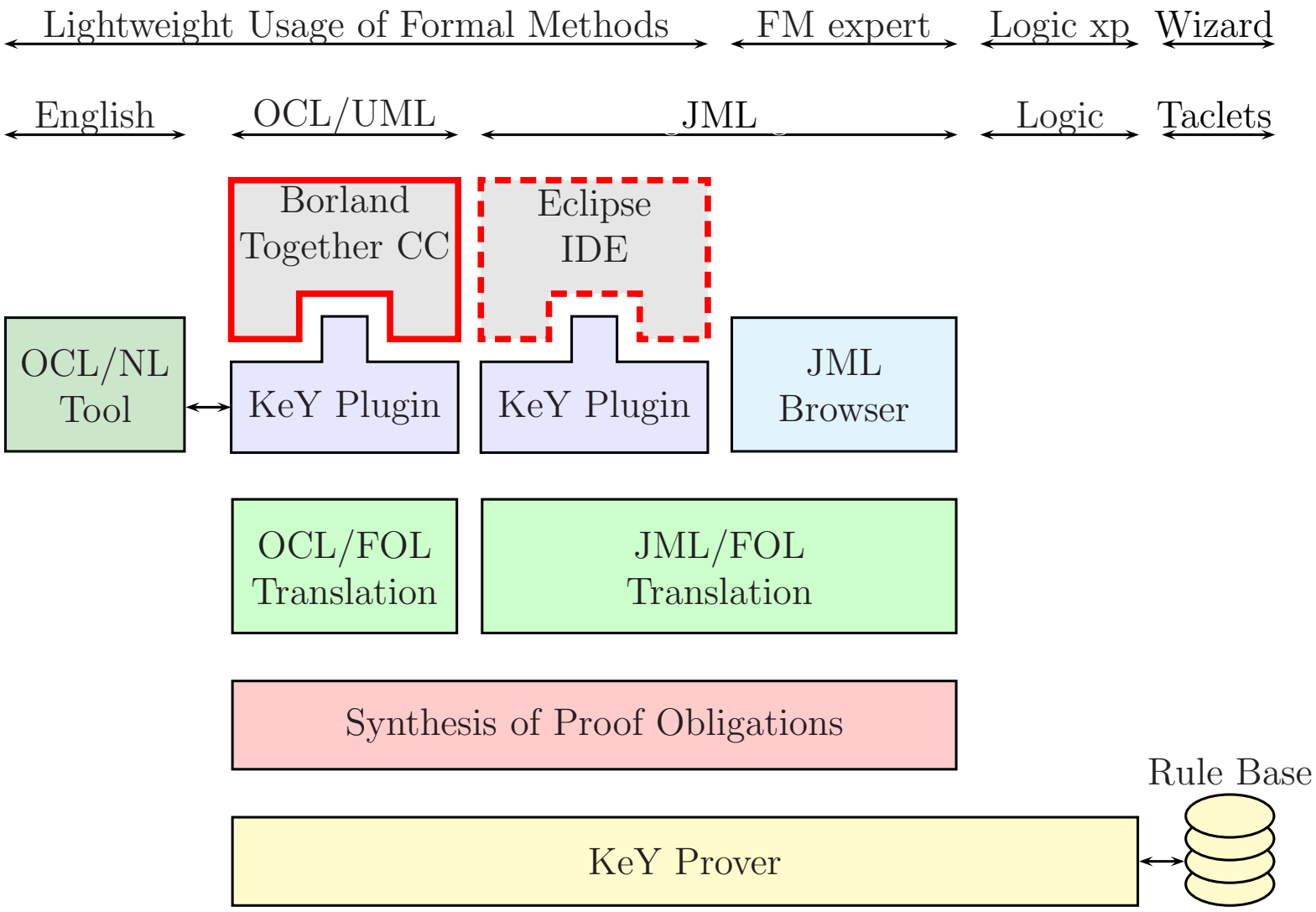
To come soon:

- **Visual symbolic debugger based on symbolic program execution**

The KeY System



The KeY System — UML Design, Java Coding



Target Language: Java Card

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Java Card

- **Sun's Java dialect for smart cards and embedded systems**

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Java Card

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Java Card is relevant target language for verification:

- Restrictions admit complete coverage (more later)
- Applications smallish

Feasability

Target Language: Java Card

Java Card

- Sun's Java dialect for smart cards and embedded systems

Java Card is relevant target language for verification:

- Restrictions admit complete coverage (more later)
- Applications smallish

- Applications safety & security critical
- Often impossible to update smart cards/embedded systems

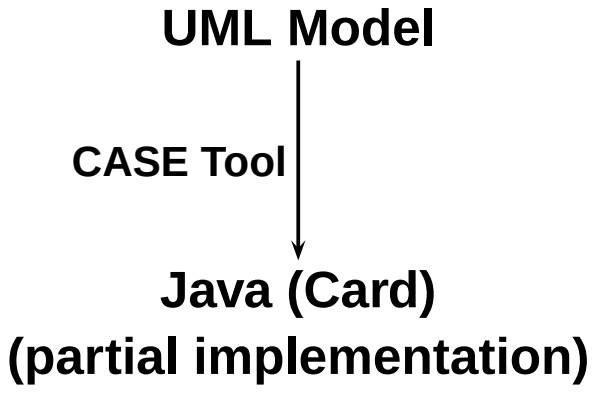
Significance Feasability

How KeY Works

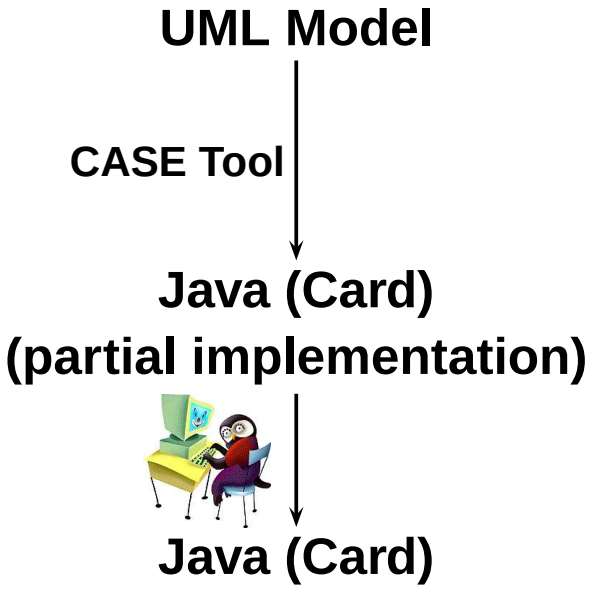
Conventional CASE-Based Development

UML Model

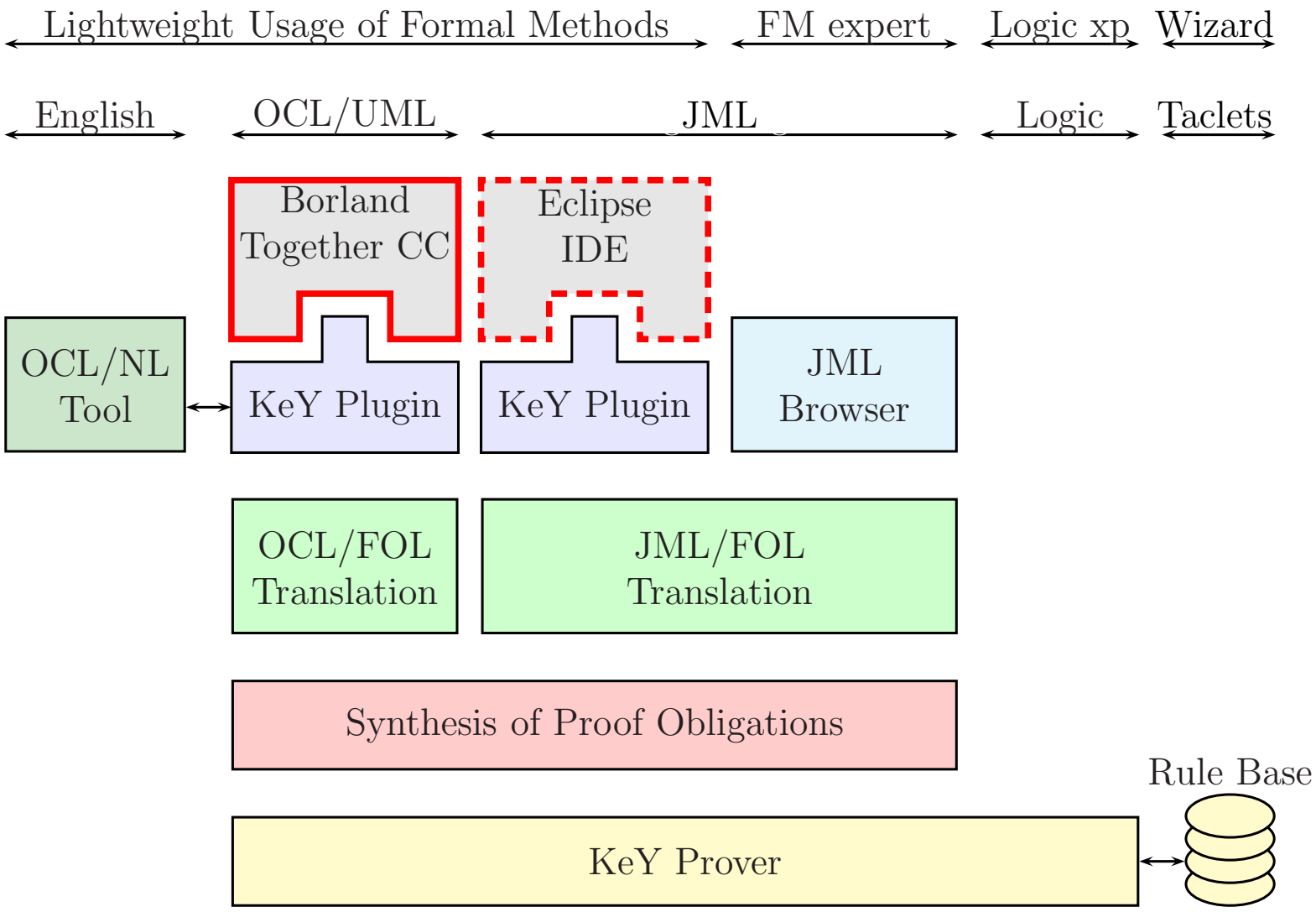
Conventional CASE-Based Development



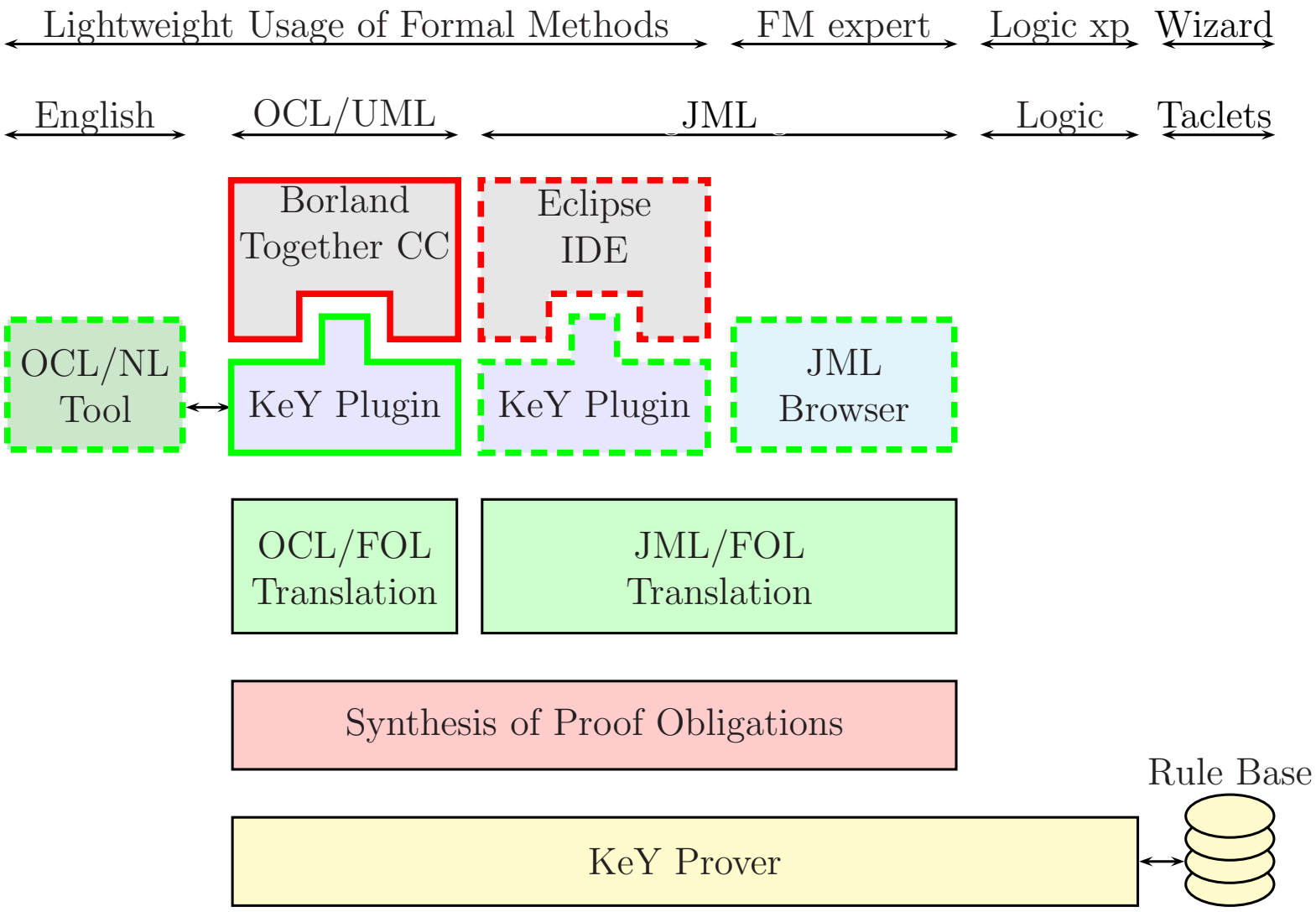
Conventional CASE-Based Development



The KeY System



The KeY System — Formal Specification



Specification Language: OCL

UML has textual specification language as sub-standard:

Object Constraint Language (OCL)

- **OOP-like syntax, ASCII**
- **designed for easy navigation within UML class diagrams, etc.**
- **strongly typed**
- **formal semantics: translation to typed FOL**

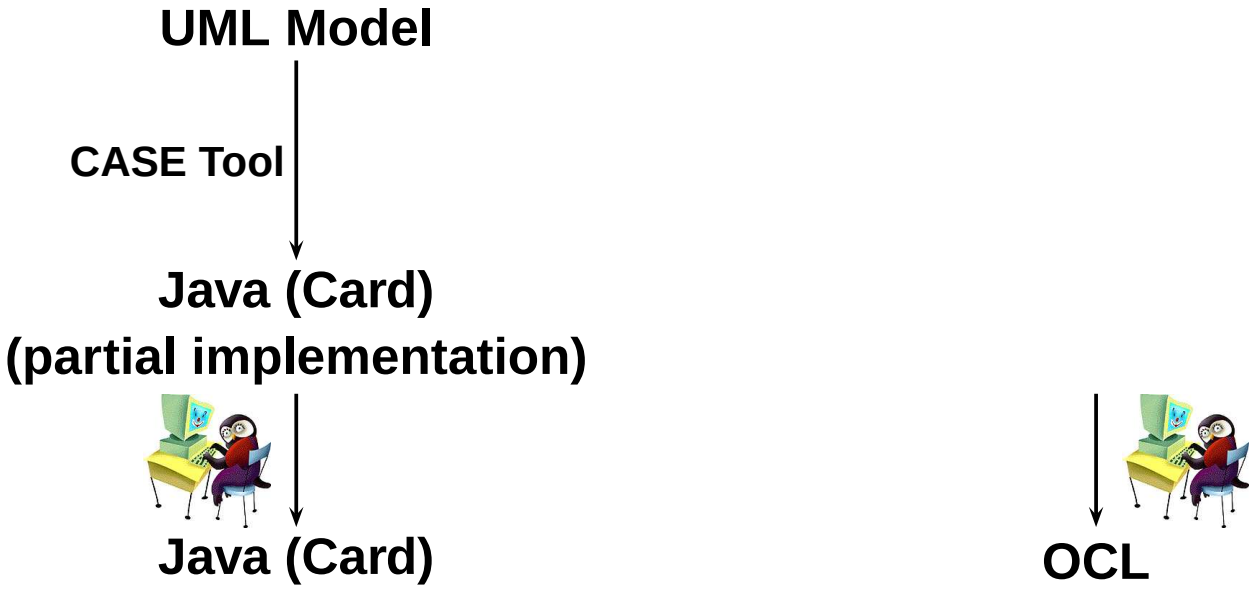
OCL expressions reduce legal instances of underlying UML diagram

- **Class invariants**
- **Pre-/postconditions of operations and methods**

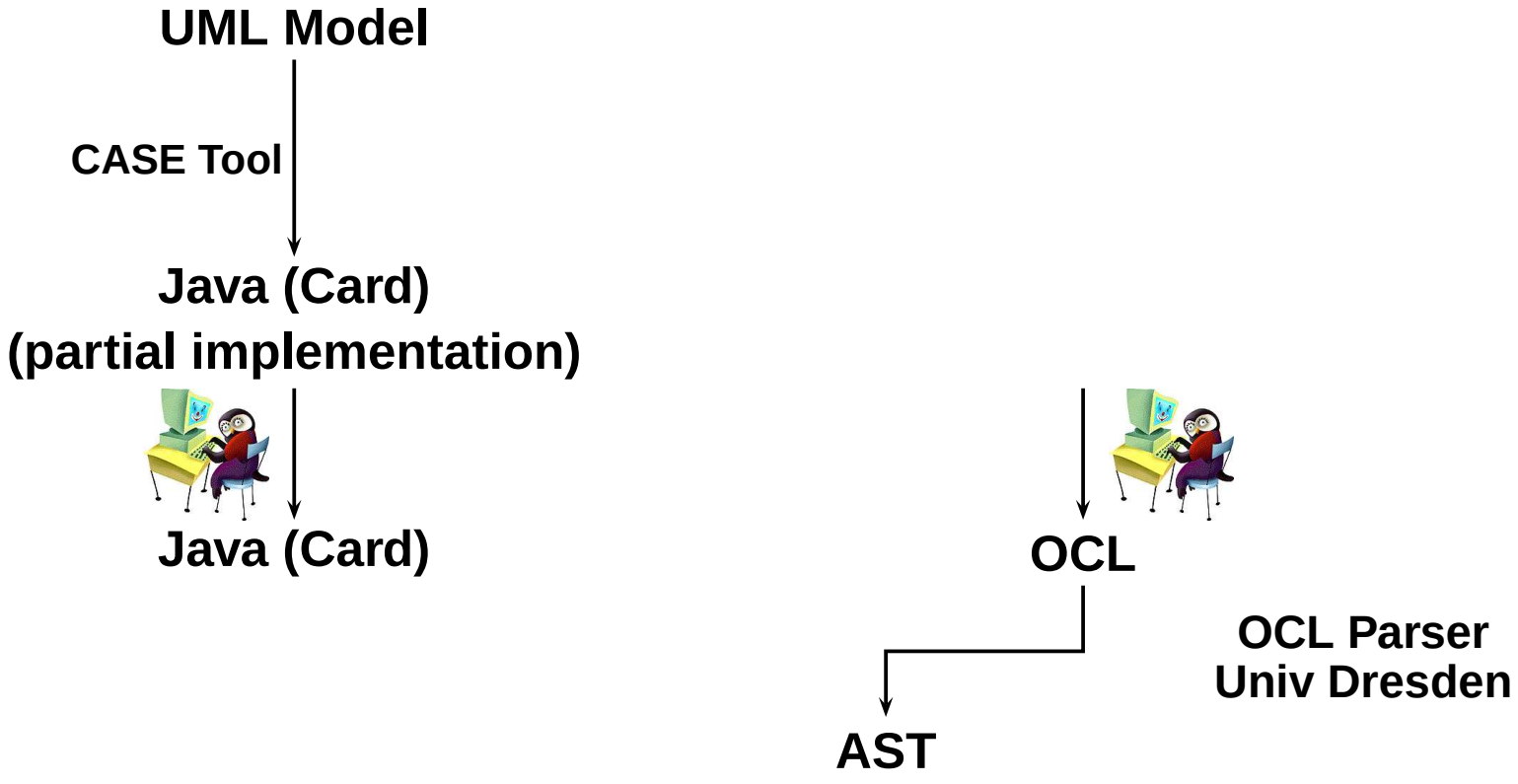
Permits formal specification of functional requirements

Other specification languages: *Alloy*, *JML*, *RSL*, . . .

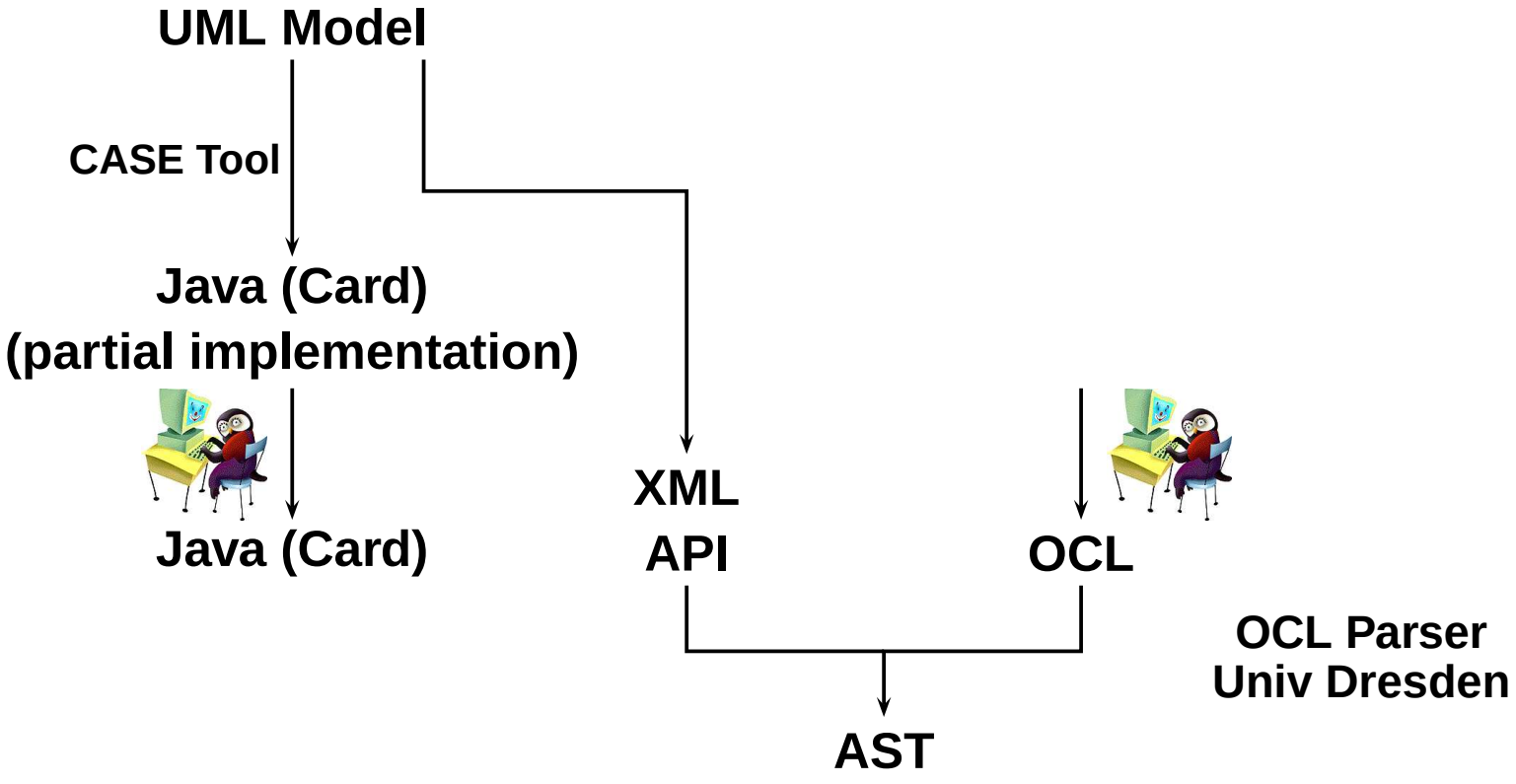
Formal Specification in OCL



Parsing OCL


UML Model
CASE Tool
Java (Card)
(partial implementation)
Java (Card)
OCL
OCL Parser
Univ Dresden
AST

Parsing OCL


UML Model
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Java (Card)
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XML
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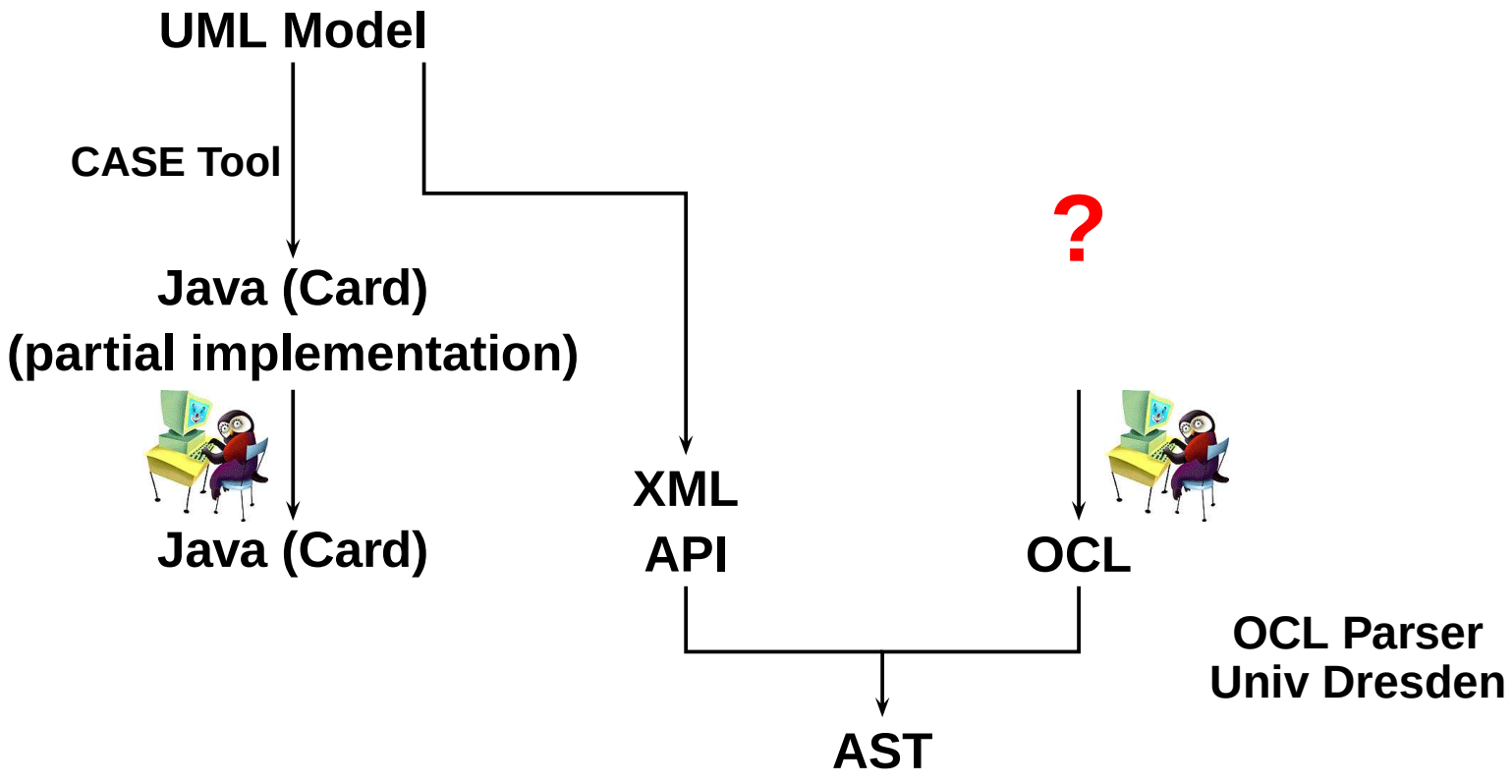
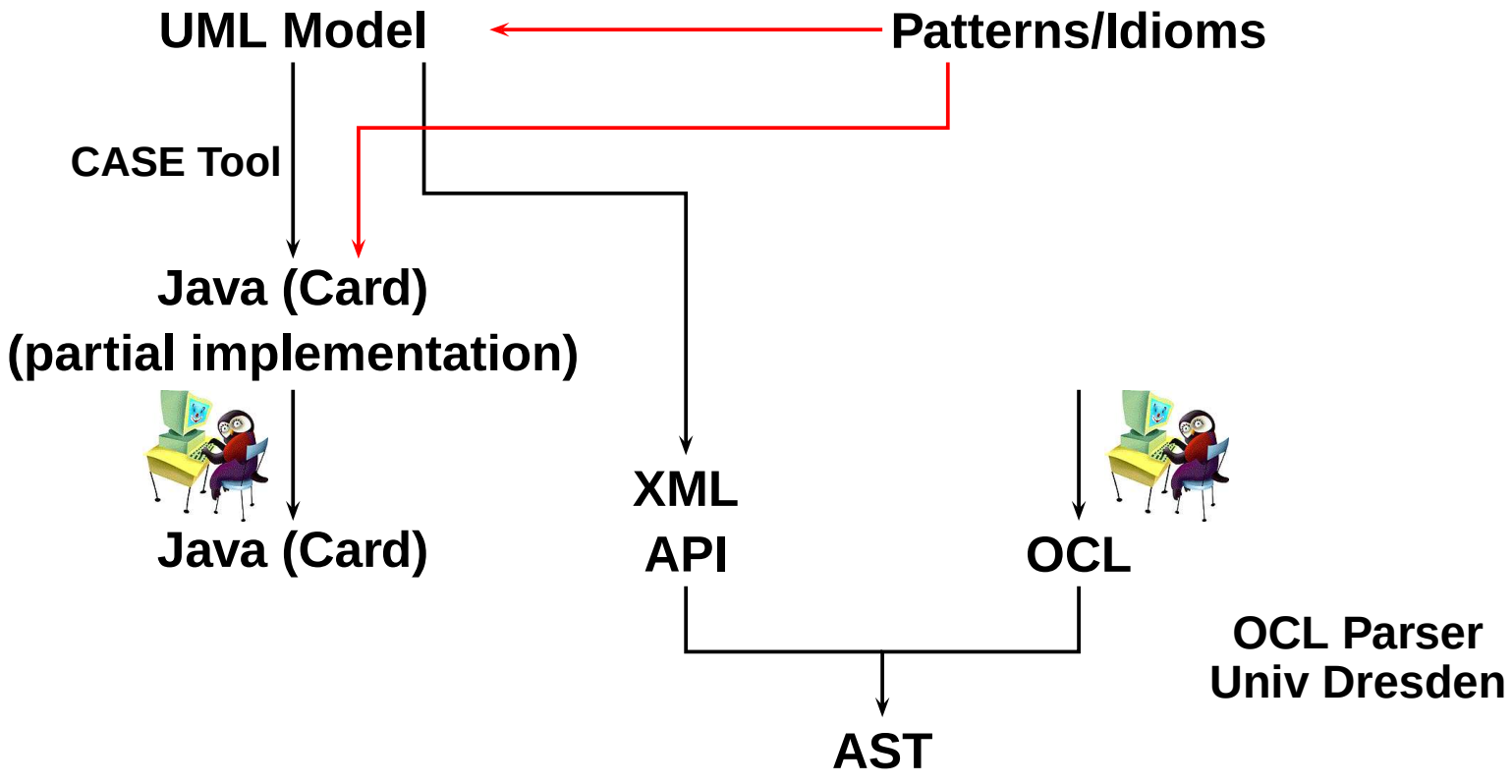
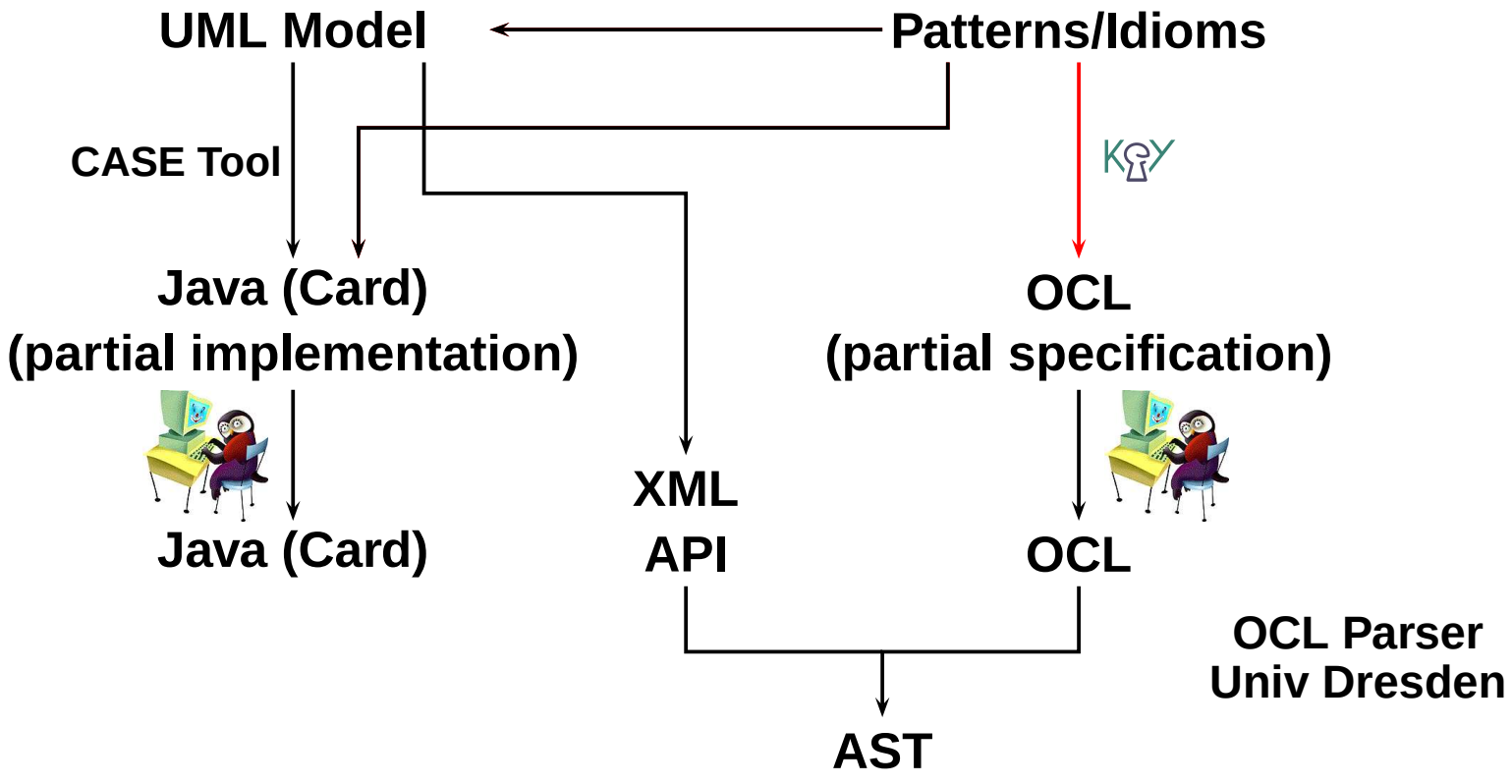
Where to Take Formal Specification from?



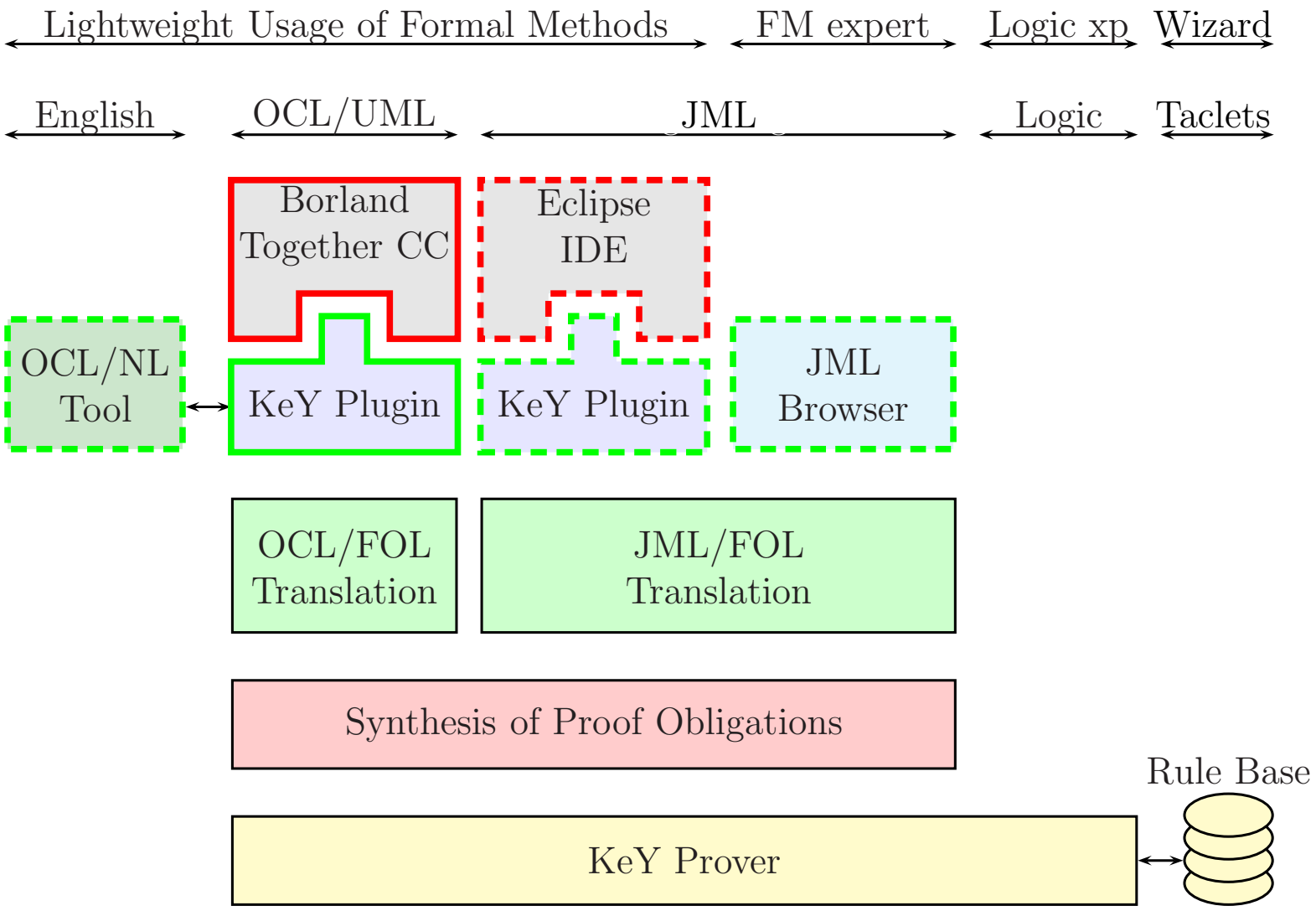
(Library of Patterns and Idioms)



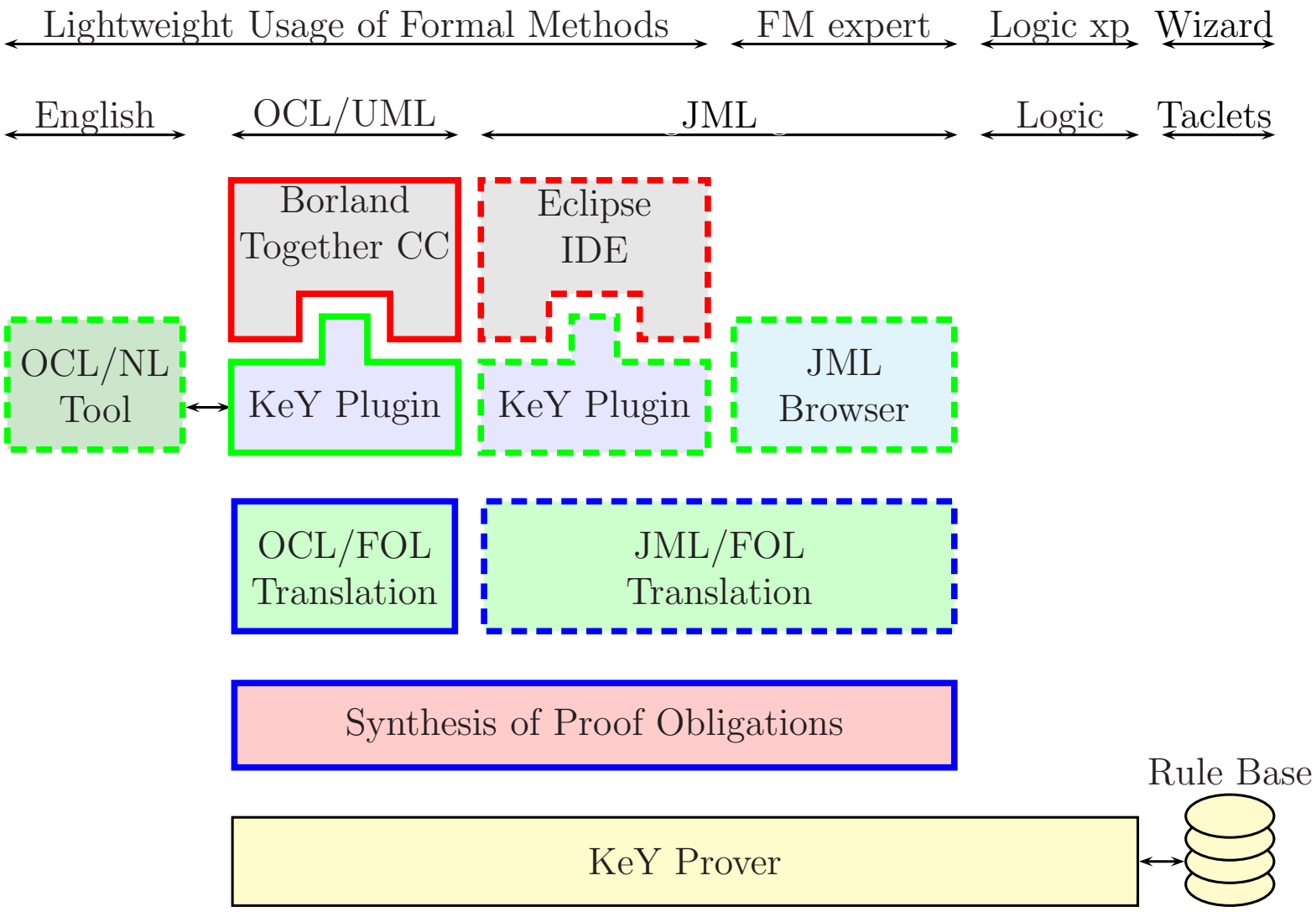
(KeY OCL Library)



The KeY System



The KeY System — Verification



Tasks of Verification Component

Tasks of Verification Component

- **Translation OCL $\Rightarrow$ logic**

Need to simplify resulting formulas

Tasks of Verification Component

- **Translation OCL $\Rightarrow$ logic**
- **Synthesize FOL formulas from horizontal verification tasks**

Eg, structural subtyping

Tasks of Verification Component

- **Translation OCL $\Rightarrow$ logic**
- **Synthesize FOL formulas from horizontal verification tasks**
- **Synthesize Java Card DL formulas from vertical verification tasks**

Eg, method invariants, total correctness

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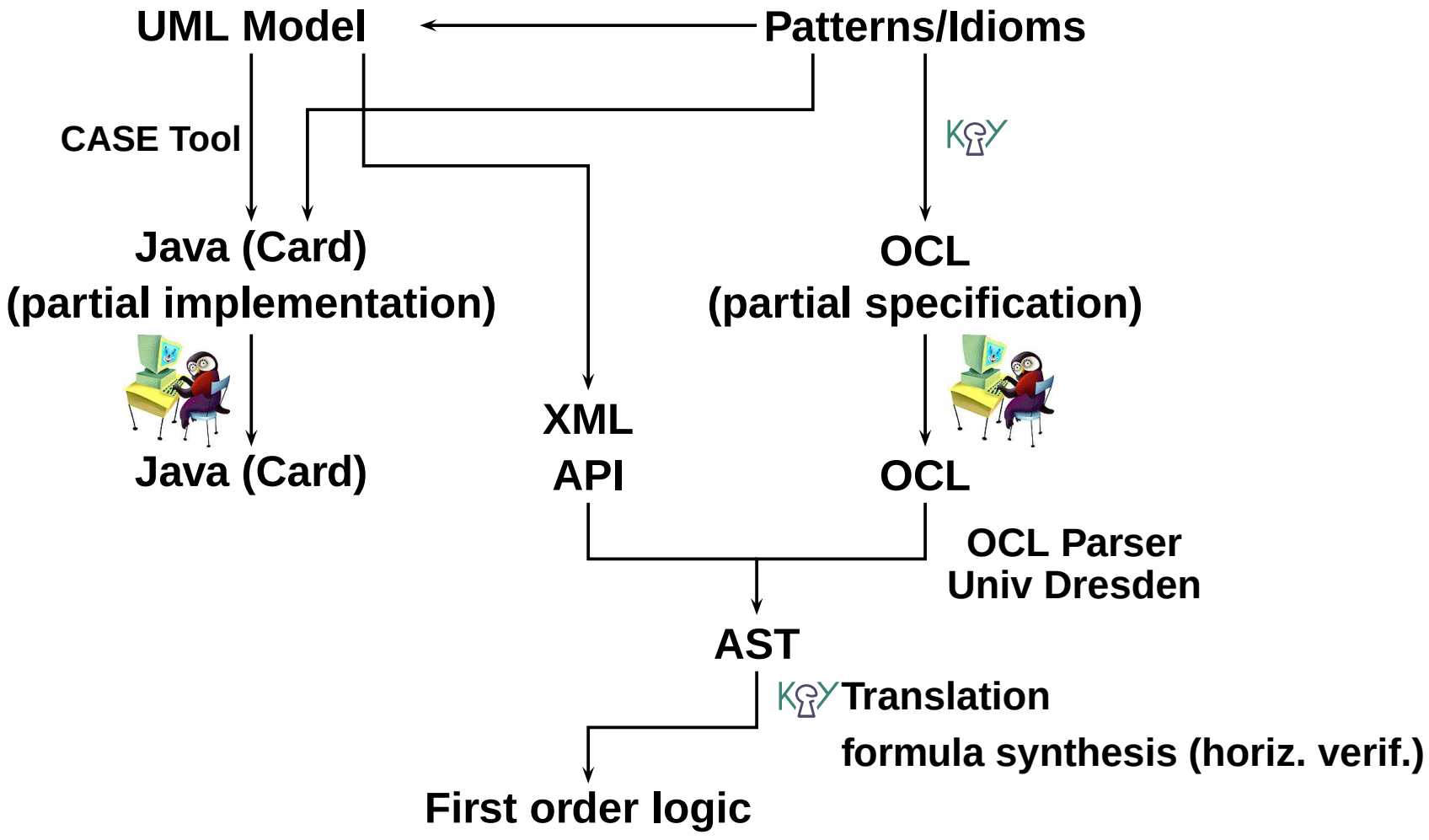
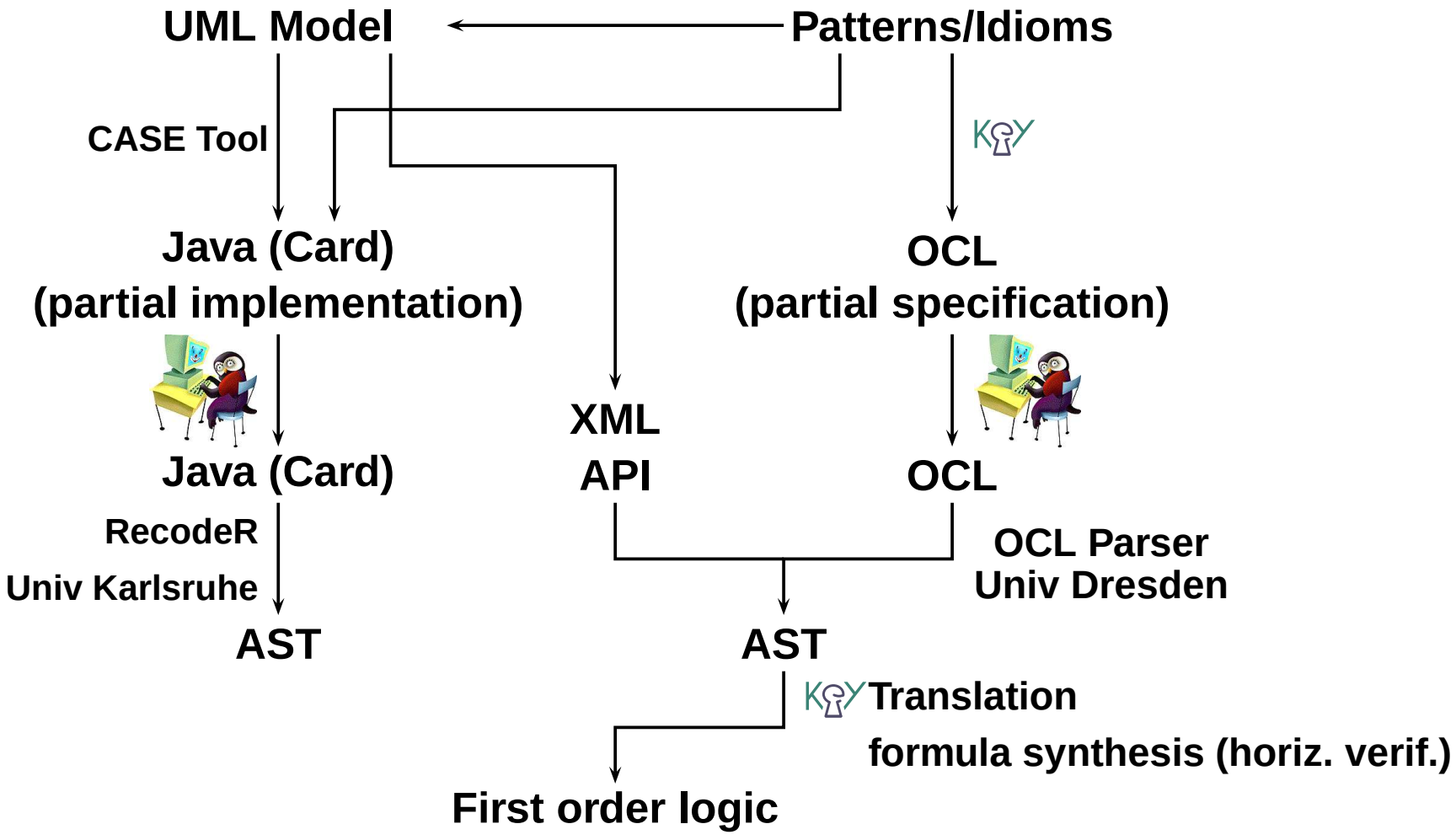
- **Driving the deduction component**
- **Correctness management**

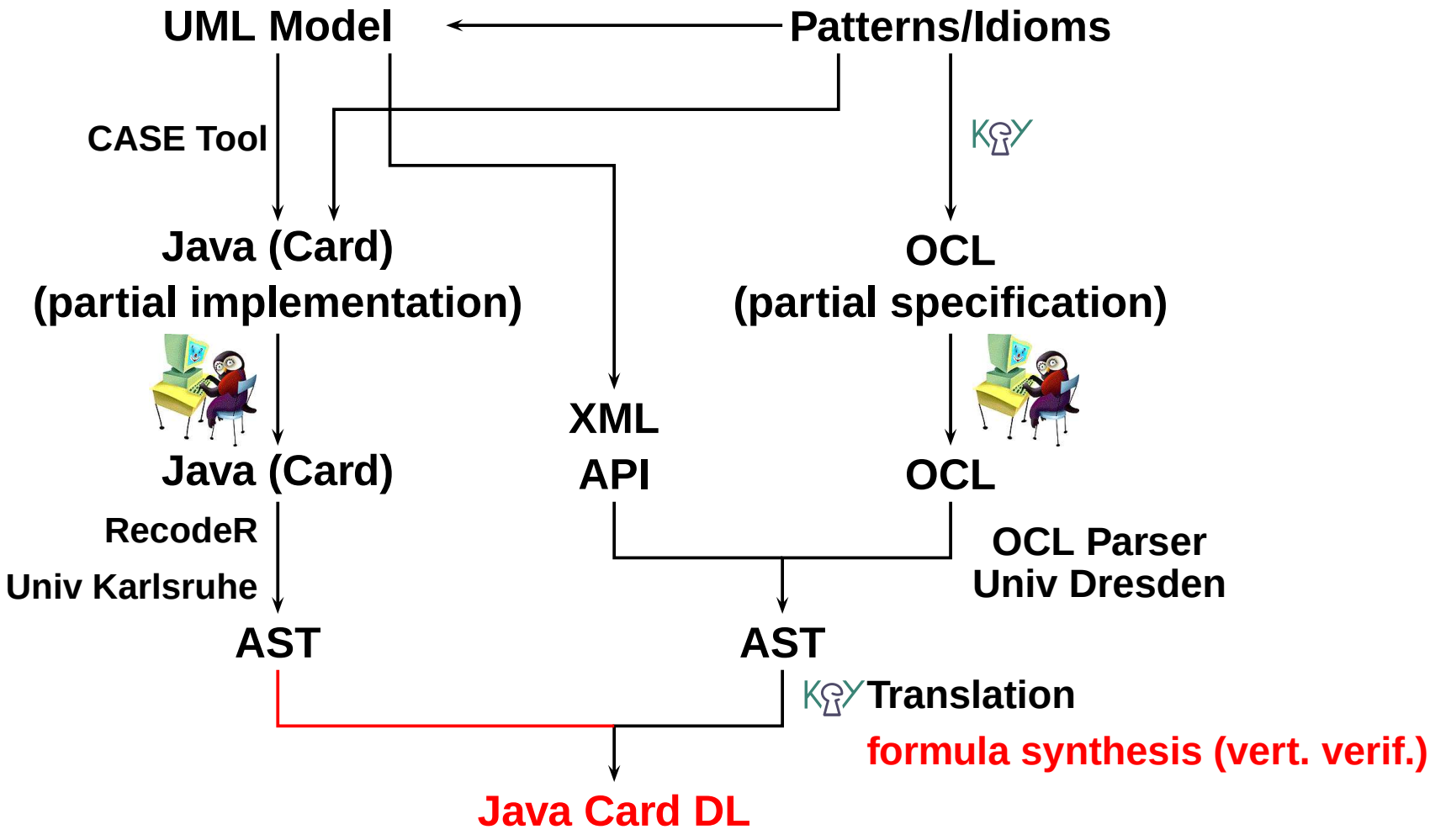
Translation, Horizontal Verification



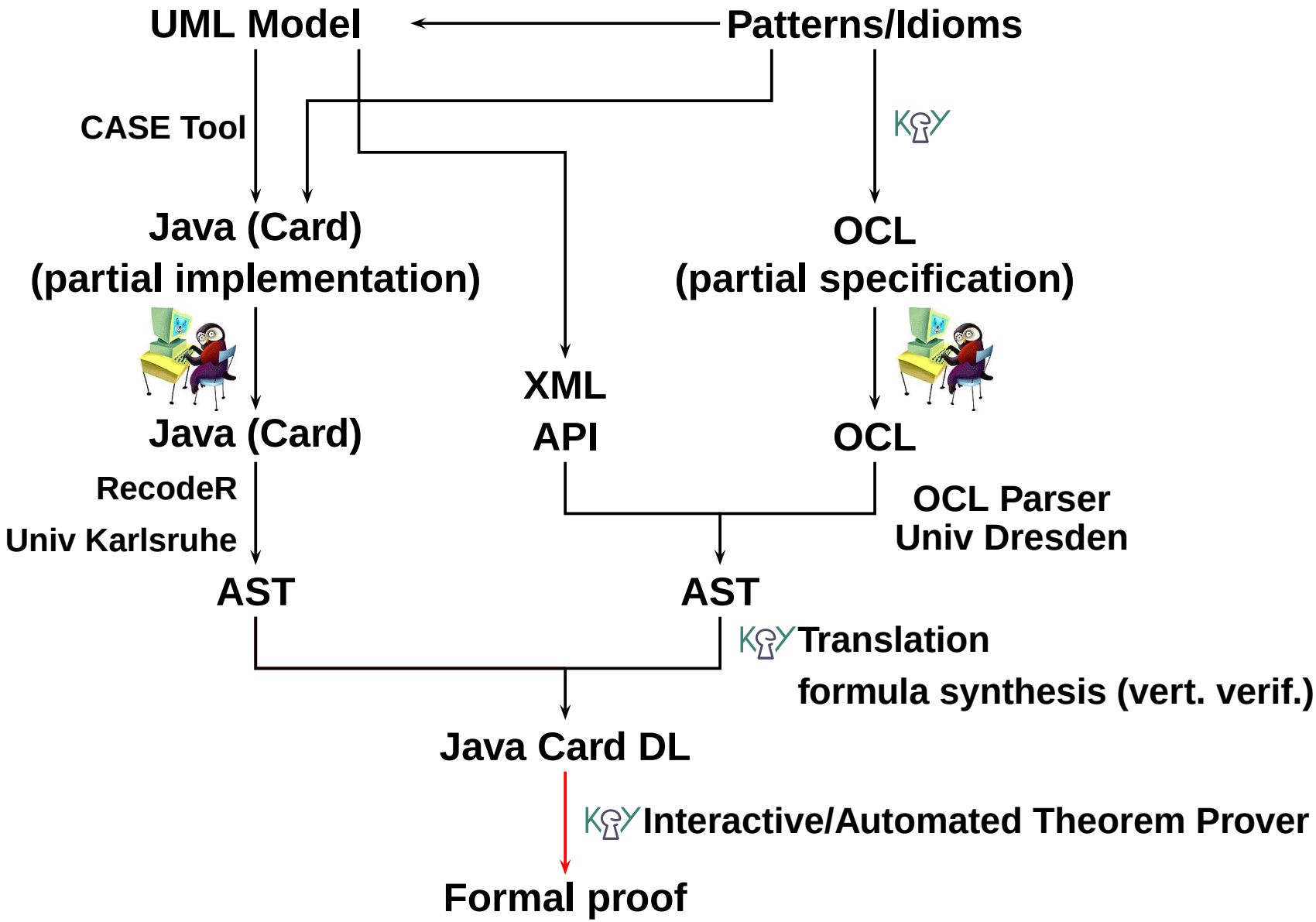
Parsing Java



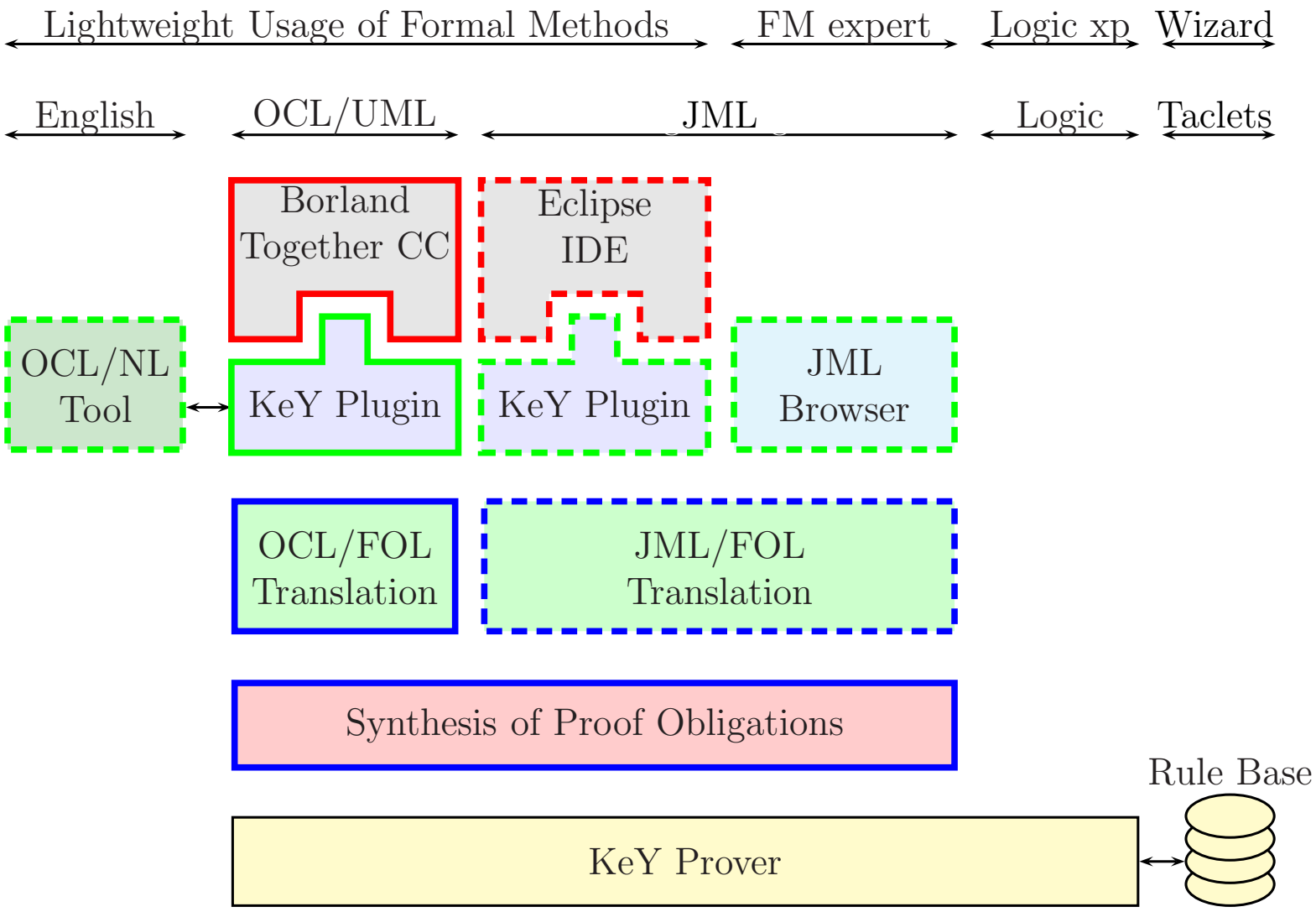
Translation, Vertical Verification



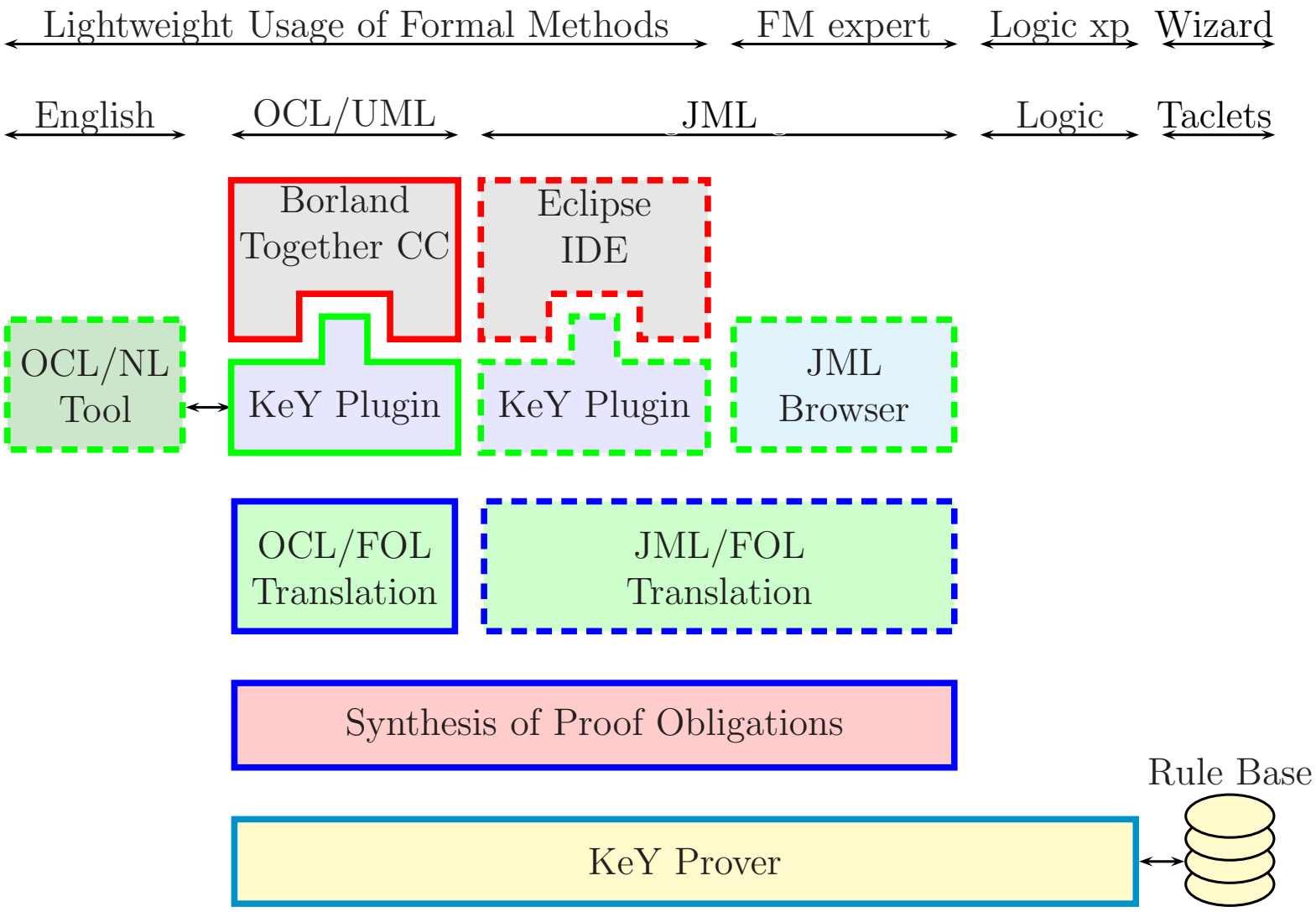
Deductive Verification



The KeY System



The KeY System — Proving



The Program Logic: Dynamic Logic

Syntax

- **Modal operators $[p]$ and $\langle p \rangle$ for each Java (Card) program p**
- **Statements about *final state* of p**

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- **Modal operators $[p]$ and $\langle p \rangle$ for each Java (Card) program p**
- **Statements about *final state* of p**

Semantics

- $[p]\ F$: **If p terminates normally, then F holds in the final state**
  (partial correctness)
- $\langle p \rangle\ F$: **p terminates normally *and* F holds in the final state**
  (total correctness)

Java vs. Java Card

Java features that are not present in Java Card

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- **Threads**

  unrestricted concurrency

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  IEEE standard 754 is huge . . .

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  Implementation must be known before verification

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- **Graphical/buffered I/O**

  formal specification Swing classes?

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