7. Language Families and Composition of Tools (Structure of M2 in a Technical Space)

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1) Problem of Tool Composition
2) Data definition languages
3) Query languages
4) Constraint languages
5) Reuse languages
6) Transformation and Restructuring languages
7) Behavior specification languages
8) Language families in several technical spaces
9) .. and all together now...

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Obligatory Literature

- http://en.wikipedia.org/wiki/List_of_UML_tools
- [HRC-MM] The SPEEDS project. Deliverable D.2.1.5. SPEEDS L-1 Meta-Model, Revision: 1.0.1, 2009
  - http://speeds.eu.com/downloads/SPEEDS_Meta-Model.pdf
- [HRC-Kit] The SPEEDS project. SPEEDS Training Kit.
  - http://www.speeds.eu.com/downloads/Training_Kit_and_Report.zip
  - Training_Kit_and_Report.pdf: Overview
  - Contract-based System Design.pdf: Overview slide set
  - ADT Services Top level Users view.pdf: Slide set about different relationships between contracts

References

- [Vered Gafni] Presentation Slides about the Heterogeneous Rich Component Model (HRC).
- [CSL] The SPEEDS Project. Contract Specification Language (CSL)
  - http://www.speeds.eu.com/downloads/D_2_5_4_RE_Contract_Specification_Language.pdf
- G.Gößler and J.Sifakis. Composition for component-based modeling. Science of Computer Programming, 55(1-3):161–183, 2005.

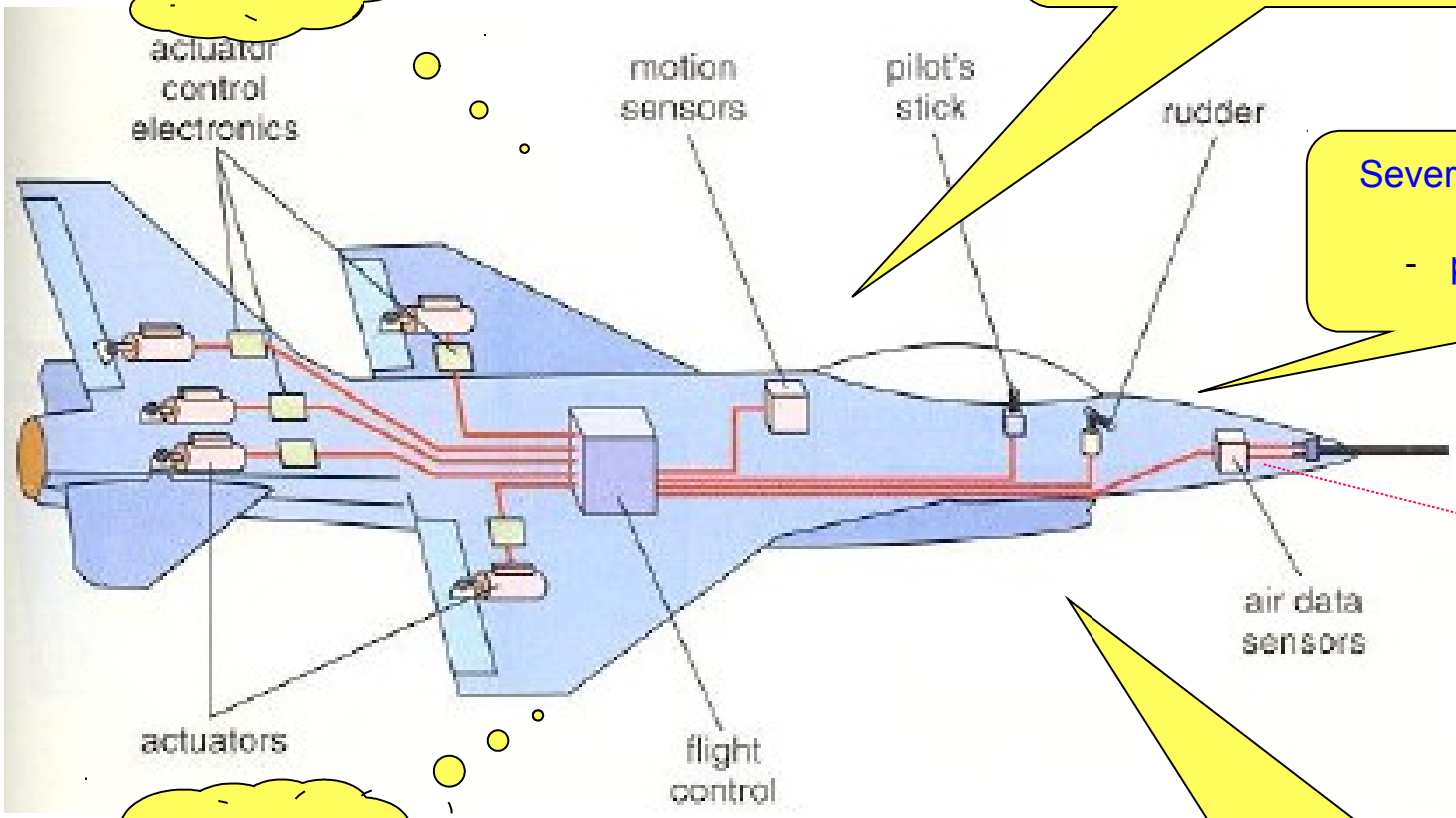
Other Literature

- Informatik Forum http://www.infforum.de/
- Data-Flow Diagrams:
  - De Marco, T.: Structured Analysis and System Specification; Yourdon Inc. 1978/1979. Siehe auch Vorlesung ST-2
  - McMenamin, S., Palmer, J.: Strukturierte Systemanalyse; Hanser Verlag 1988
- Workflow languages:
  - ARIS tool (IDS Scheer, now Software AG)
    - http://en.wikipedia.org/wiki/Architecture_of_Integrated_Information_Systems

Big CASE IDE

- MID Innovator (insbesondere für Informationssysteme)
  - http://www.modellerfolg.de/
- MagicDraw http://www.nomagic.com/

Big MDSD tool chain for automotive and aearial systems: www.speeds-project.eu



Large Scale

composed of physical specific subsystems developed concurrently

Several quality aspects:
- cost,
- performance,…

Embedded System

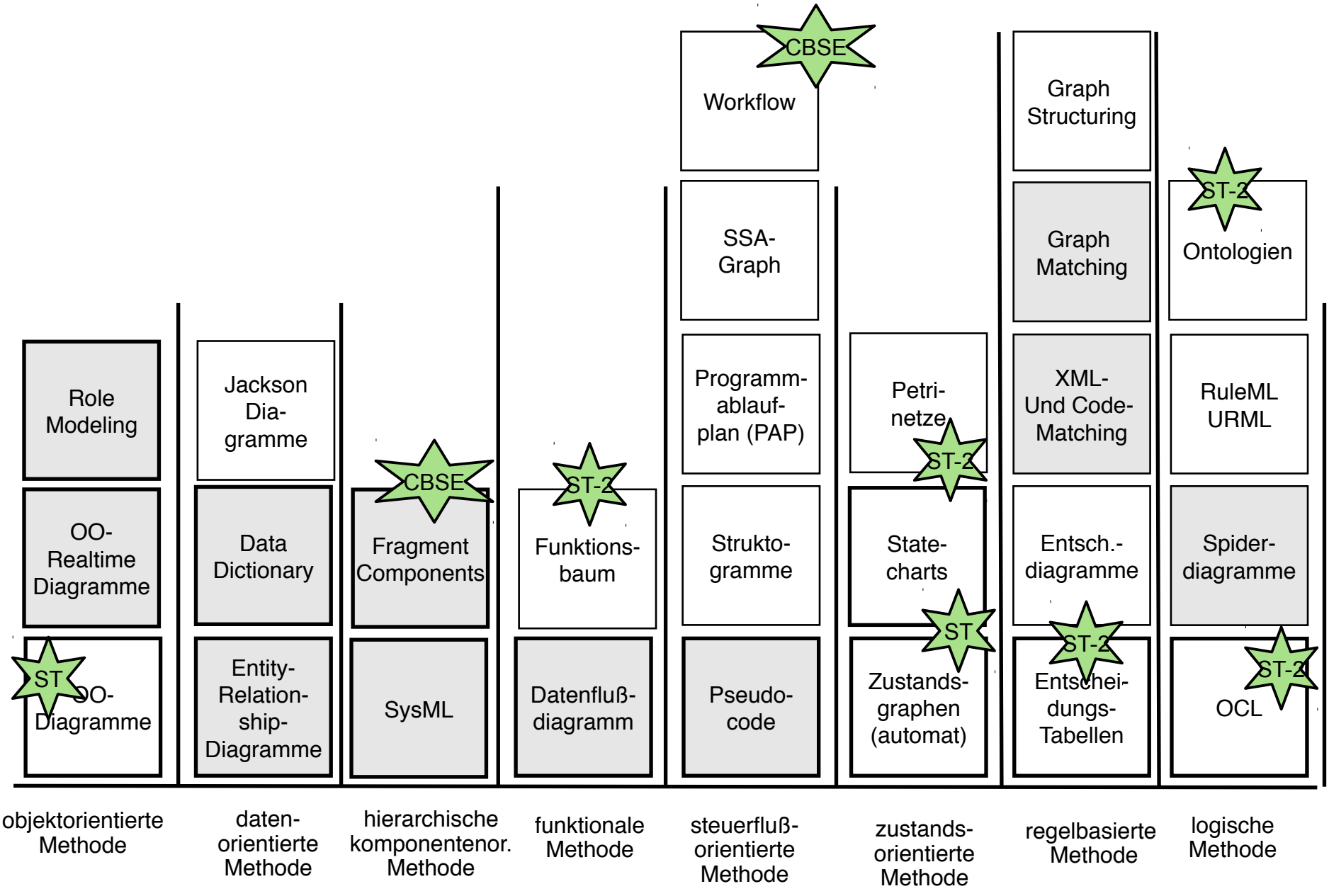
Reliability is critical

involve several disciplines (e.g., aerodynamics, mechanical, control)

7.1 Basic Techniques of Software Engineering, Language Families, and Tool Composition

Basic Techniques and Languages for Modeling

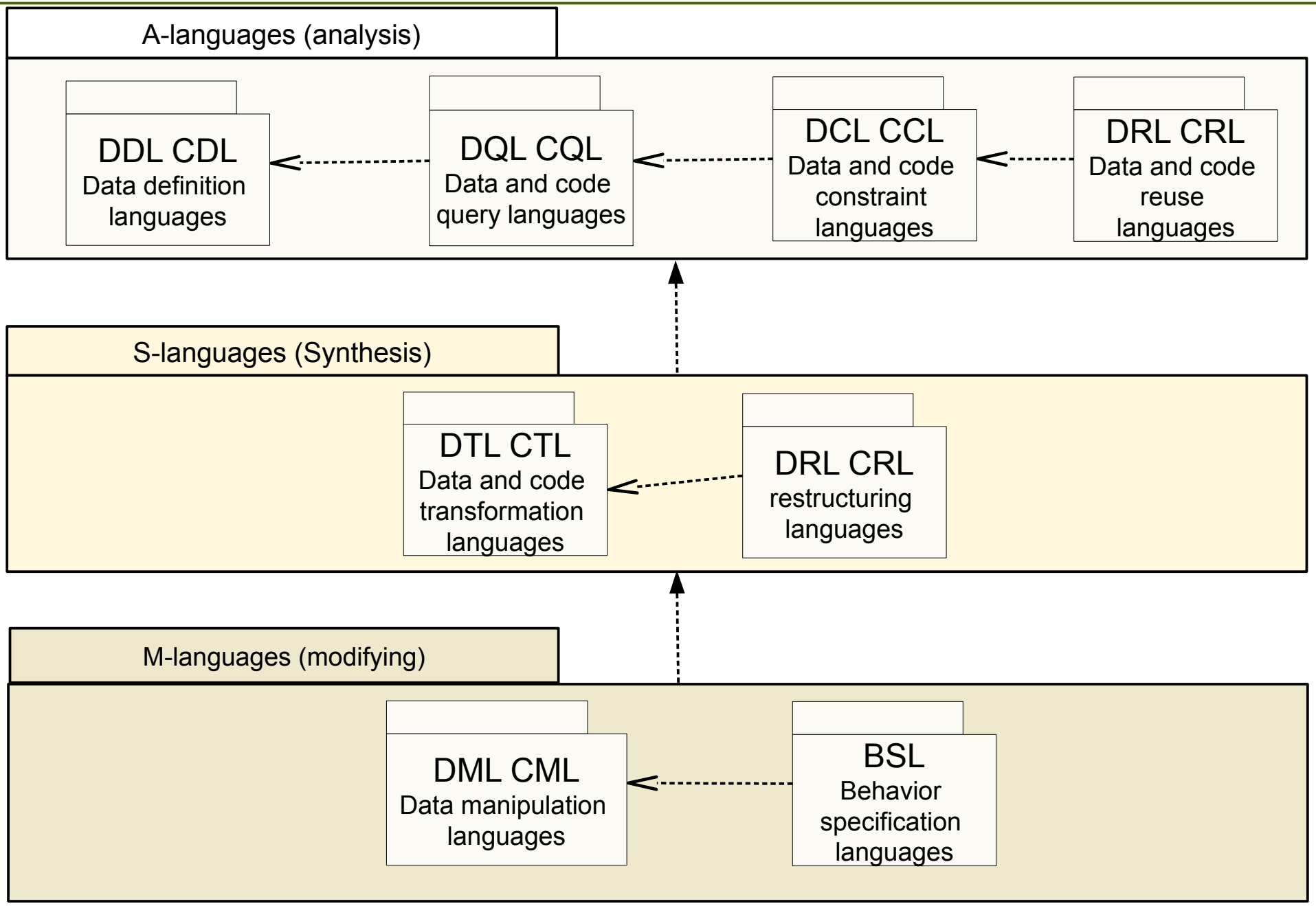
Derived from [Balzert]



Metamodel Layering

- M2 can systematically be divided into **M2 layers**
- The layers contain metamodel packages, which can be varied so that **language families** result:
  - Language engineering by composition
  - Tool construction by composition
  - Basic technique composition from several languages
  - Method engineering by method composition of basic techniques
- Productivity of Process
- Reliability of Software

Basic Language Families (Layer Structure of M2)



Basic Language Families (Structure of M2)

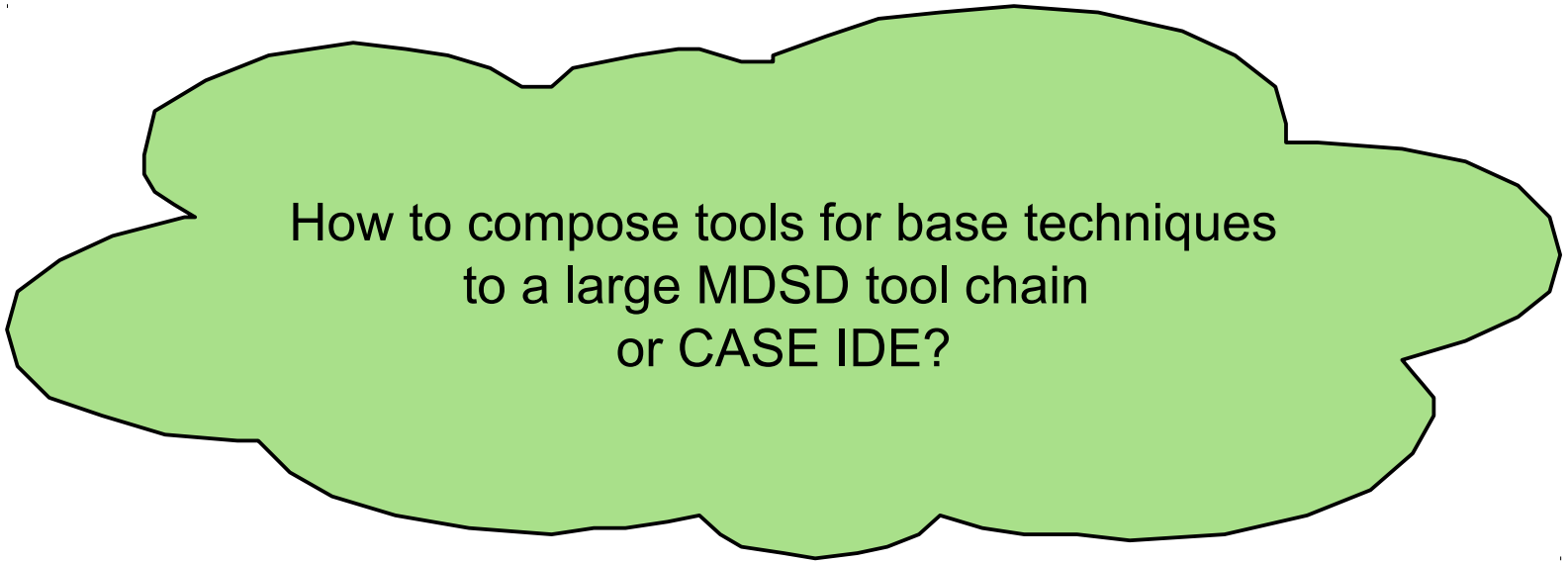
- In the metahierarchy, code covers M3-M0, because M0 is populated by objects of the dynamic semantics
  - Data does not have dynamic semantics, so it only covers M3-M1 (or M2-M0); however, when data is loaded as code, it changes its nature.
- **Data and code modeling with definition languages (DDL, CDL)**
  - DDL form the basci packages of M2 to be imported by all other packages
  - Ex.: MOF → UML-CD → UML-Statecharts
  - Ex: lifted metamodels, such as EBNF-Grammars, Relational Schema (RS), Entity-Relationship-Diagrams (ERD), UML-CD, SysML-Component diagrams
- **Analysis languages (A-languages):**
  - Queries with **query languages** (DQL, CQL)
  - Consistency checking with data and code **constraint languages** (DCL, CCL) on wellformedness of data and code
  - **Reuse languages: Contract languages and composition languages**
    - Architectural description languages (ADL)
    - Template-Sprachen (template languages, TL)
    - → course CBSE

Basic Language Families (Structure of M2) (ctd.)

- **Synthesis languages** (S-languages)
  - **Declarative Transformation Languages** (DTL, CTL)
    - Data flow diagrams (DFD)
    - Term- und graph rewrite systems
    - XML transformation languages
  - **Restructuring** (data and code restructuring languages, DRL, CRL)
    - **Wide Spectrum Languages** for refinement **(broadband languages, Breitbandsprachen)**
    - **Data exchange languages** (data exchange languages)
- Data and State **Manipulation Languages** (M-languages)
  - (non-declarative) Data manipulation languages (DML)
    - Workflow Languages, Petri Nets
    - Imperative languages
- Languages for **behavior specification language** (BSL)
  - Action-based state transition systems (finite automata and transducers)
  - Condition-Action-languages, Event-Condition-Action-languages (ECA)
  - → course Softwaretechnologie-2

Software Engineering vs Programming

- A complex MDSD tool chain or Software IDE uses many base techniques and languages
- There is no homogeneous software construction



Basic Techniques and Languages for Modeling

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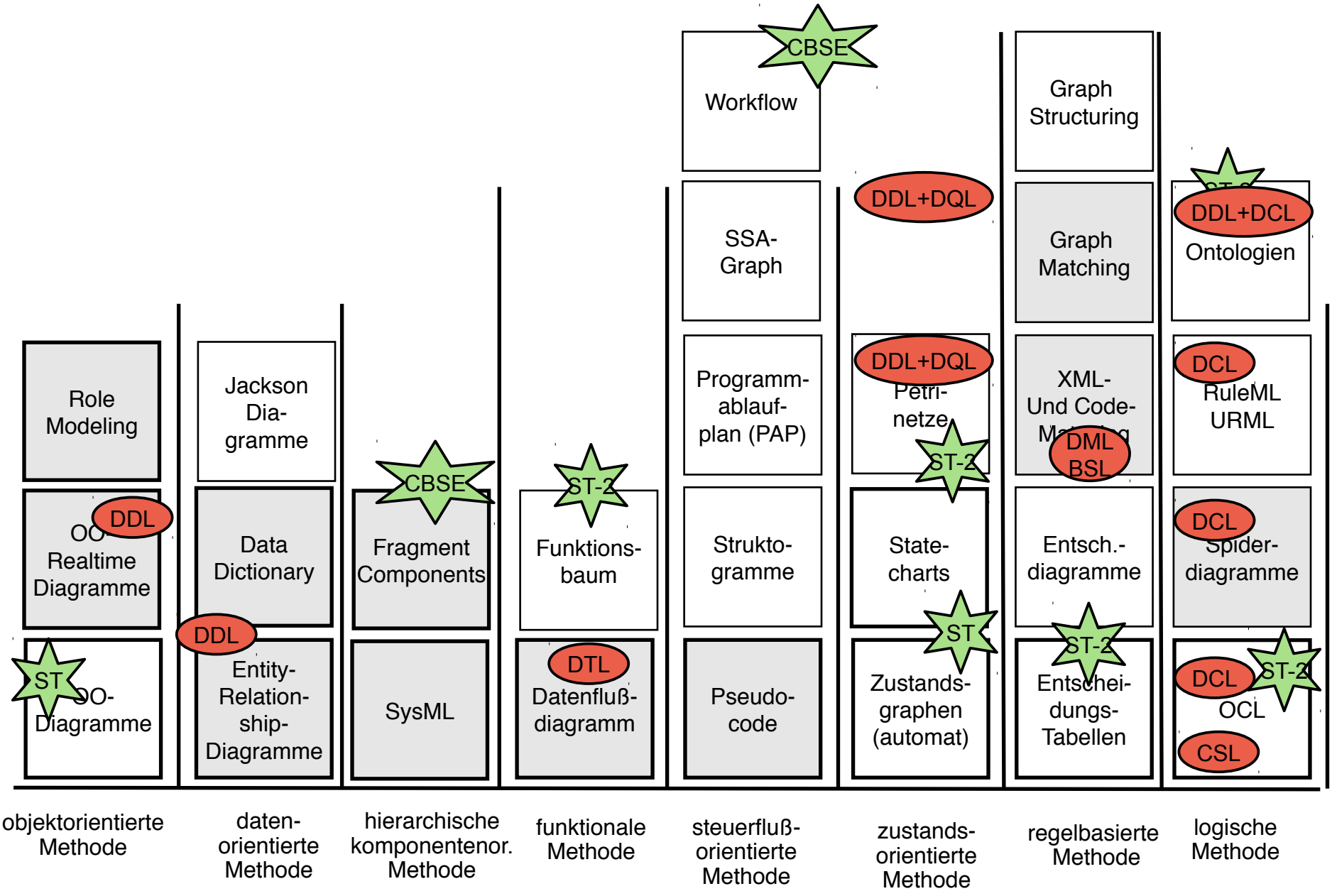


7.2 Data Definition Languages (DDL) and Code Definition Languages (CDL)

The basic layer of M2

All materials are shaped by a DDL or CDL

Data Dictionaries (Data Catalogues) as Basis for all Tools and IDE

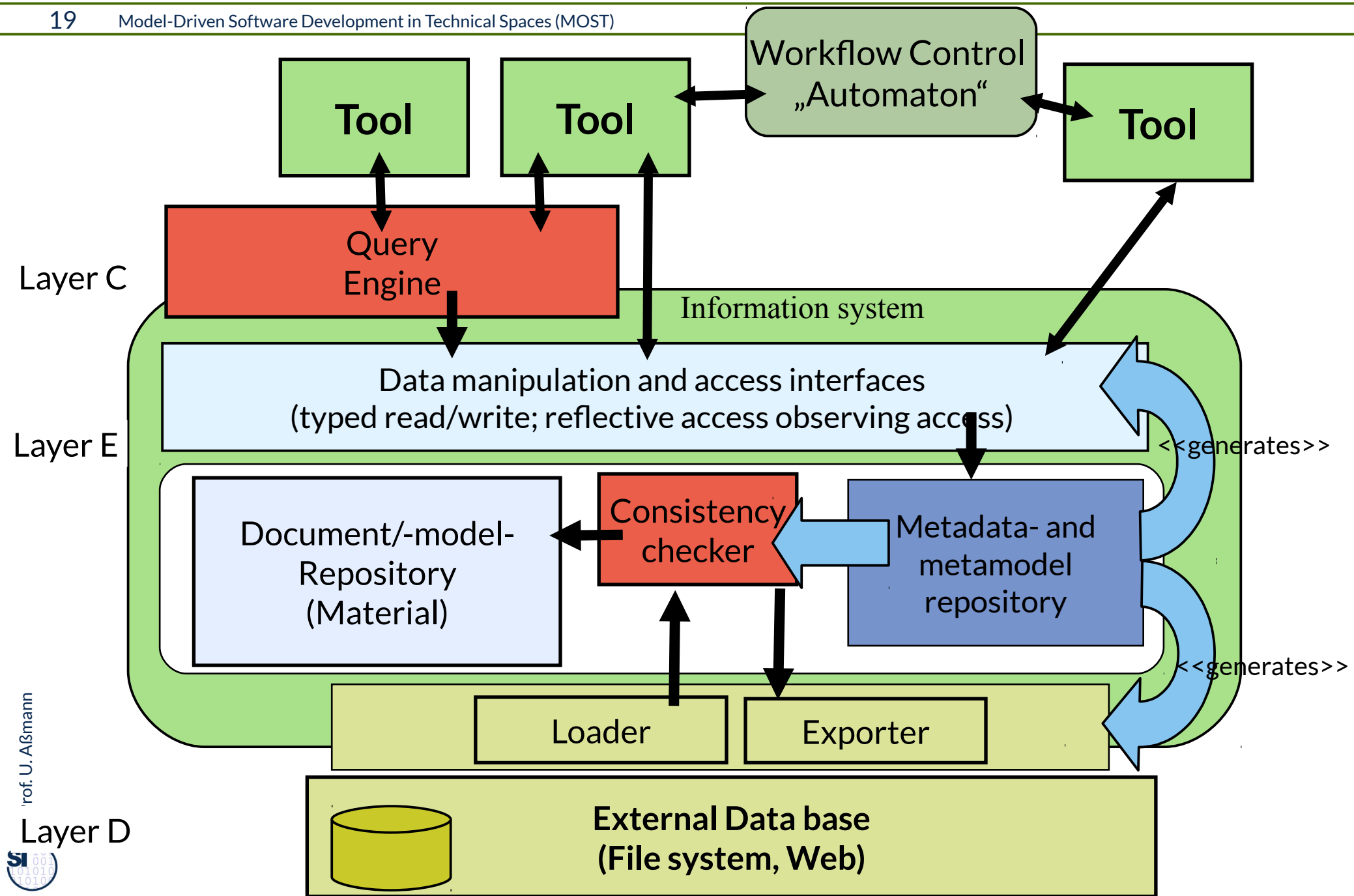
- A **data dictionary (data schema)** contains all types of data flowing through a system, including those stored in a repository
  - Scope: local for an application, for several applications, for an entire company or even for a supply chain
  - A data dictionary is a special kind of model repository
  - If the data are models, it is called **metamodel repository**
- A **homogeneous data dictionary** is specified in a DDL
  - EBNF definies text languages (sets of text types)
  - Relational Schema (RS) defines relations and tabels
  - XML Schema (XSD) defines tree languages
  - ERD or UML-CD define graph languages
- A **heterogeneous data dictionary** is specified in several DDL
  - Usually, MDSD tool chains and Software IDE maintain heterogeneous metamodel repositories

Information Systems

- An **information system** is a software system conducting data analysis about a repository
  - Data warehouses, business intelligence, data analytics
- A **stream-based information system** is a software system conducting data analysis on a set of data streams

- Every software tool, every IDE relies on an information system
  - maintaining artefacts (data, programs, models, documents)
  - giving information about them
  - typed by the types in a data dictionary
- The data dictionary is described in a data definition language
- The repository and the data streams are queried and analyzed by A-languages

Q7: Tool Architecture with Data Sharing in a Metamodel-Driven Repository



7.3 Query Languages (QL)

DQL – Data Query Languages

CQL – Code Query Languages

All materials are queried by technical tools shaped by a DQL or CQL.

DQL and CQL

- Querying
  - Pattern matching of structural patterns
  - Joining information
  - Reachability queries
- Metrics : counting of patterns
- Analysis: Deeper knowledge (implicit knowledge)
  - Program and model analyses on value and type flow

7.4 Constraint Languages (DCL,CCL) for Consistency Checking

All materials are constraint-checked by technical tools shaped by a DCL or CCL.

Well-formedness of Models

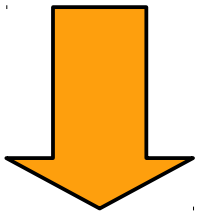
A model is **well-formed (consistent)**, if it fulfils the context-sensitive constraints (integrity rules, consistency rules) of its metamodel.

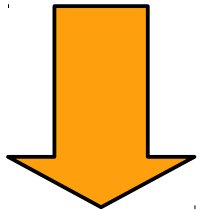
- Wellformedness is checked by **semantic analysis (context analysis)**:
  - **Name analysis (Namensanalyse)** finds the meaning of a name
    - **Type analysis (Typananalyse) f**inds the meaning of a type
  - **Type checking** checks the use of types with their definition
  - **Invariant checks**
    - **Range checks** (Bereichsprüfungen) test the validity of variables in ranges
    - **Structuring** of data structures: Acyclicity, layering, connected components, reducibility
  - **Forbidden combinations**
  - **Replicated definitions**

Well-formedness of Metamodels and Data Dictionaries

A **model** is **well-formed (consistent)**, if it fulfils the context-sensitive constraints (integrity rules, consistency rules) of its metamodel.

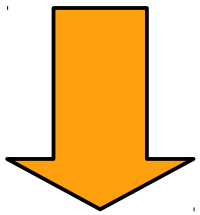
A **metamodel** is **wellformed**, if it fulfils the context-sensitive constraints of its metametamodel.

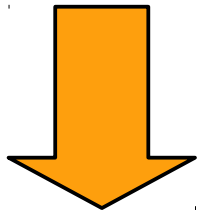




A **data dictionary** is **wellformed**, if all contained models fulfil its context-sensitive constraints.

A **metamodel repository** is **wellformed**, if it fulfils all its context-sensitive constraints.





A **megamodel** is **wellformed**, if it fulfils all its context-sensitive constraints. Then it is called a **macromodel.**

Reuse Languages and Contract Languages

A reuse language is a (sub-)language) controlling the reuse of program or model elements.

Examples:

- **Contract languages** check whether components, modules, classes, procedures and methods are applied correctly
- **Component model definition languages** define reuse languages and contract languages [Johannes-PhD]

7.5 Data Transformation Languages (DTL)

Text, XML, Term, and Graph Rewriting

see separate Chapter

DTL and DML

- Mit DML (Datenmanipulationssprachen) formt man Daten um.
- **Declarative DTL (Datentransformationssprachen, DTL)** consist of declarative rule systems transforming a repository
  - Term rewriting for trees, terms, link trees, and XML trees
  - Graph rewriting for graphs
- **Imperative DML (general DML)** know states and side effects.

Restructuring Languages (DRL)

- **Restructuring** means to transform while to retain invariants.
- A **restructuring language** gives guarantees about the transformed materials.
- Languages for **Refinement**:
  - Refinement means that a transformed program *implies the semantics* of the original
  - A **wide spectrum language** transforms programs by refinement, generating more and more versions *implying* the requirements specification (the original)

7.6. Behavior Specification Languages (BSL)

All automata (workflow engines) in a TS execute workflows written in a BSL.

Automaten, Petri-Nets, DFD and Workflow Languages

- **State-oriented Behavior specification languages** enable the specification of **interpreters (operational dynamic semantics)**
  - Automata, Transducers, Statecharts → course Softwaretechnologie-I
  - DFD, Petri-Nets and Workflow languages → course Softwaretechnologie-II
  - Appendix: DFD

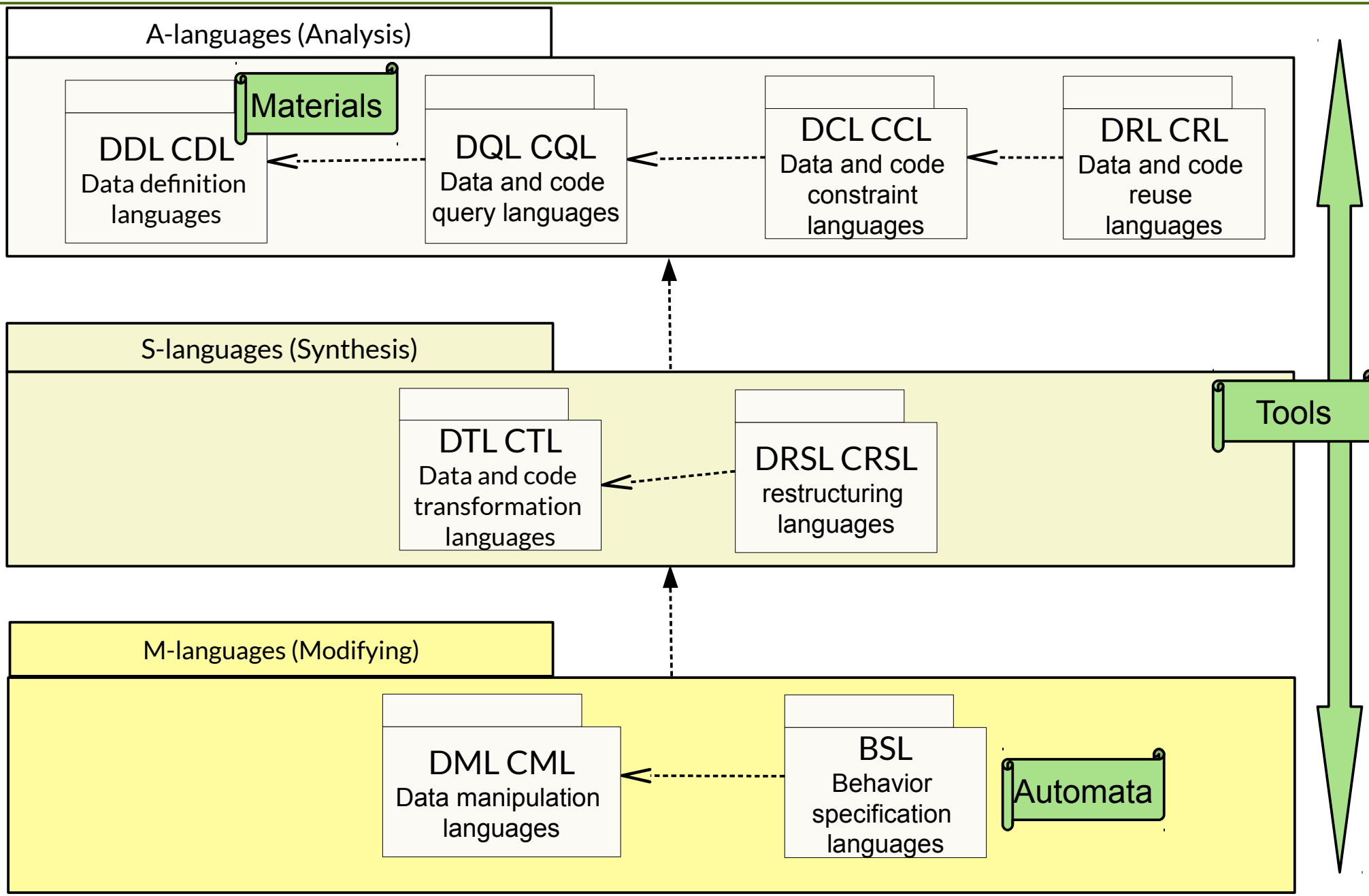
7.7 Language Families on the M2 Layers

Every technical space has a language hierarchy on M2 with a similar, layered structure.

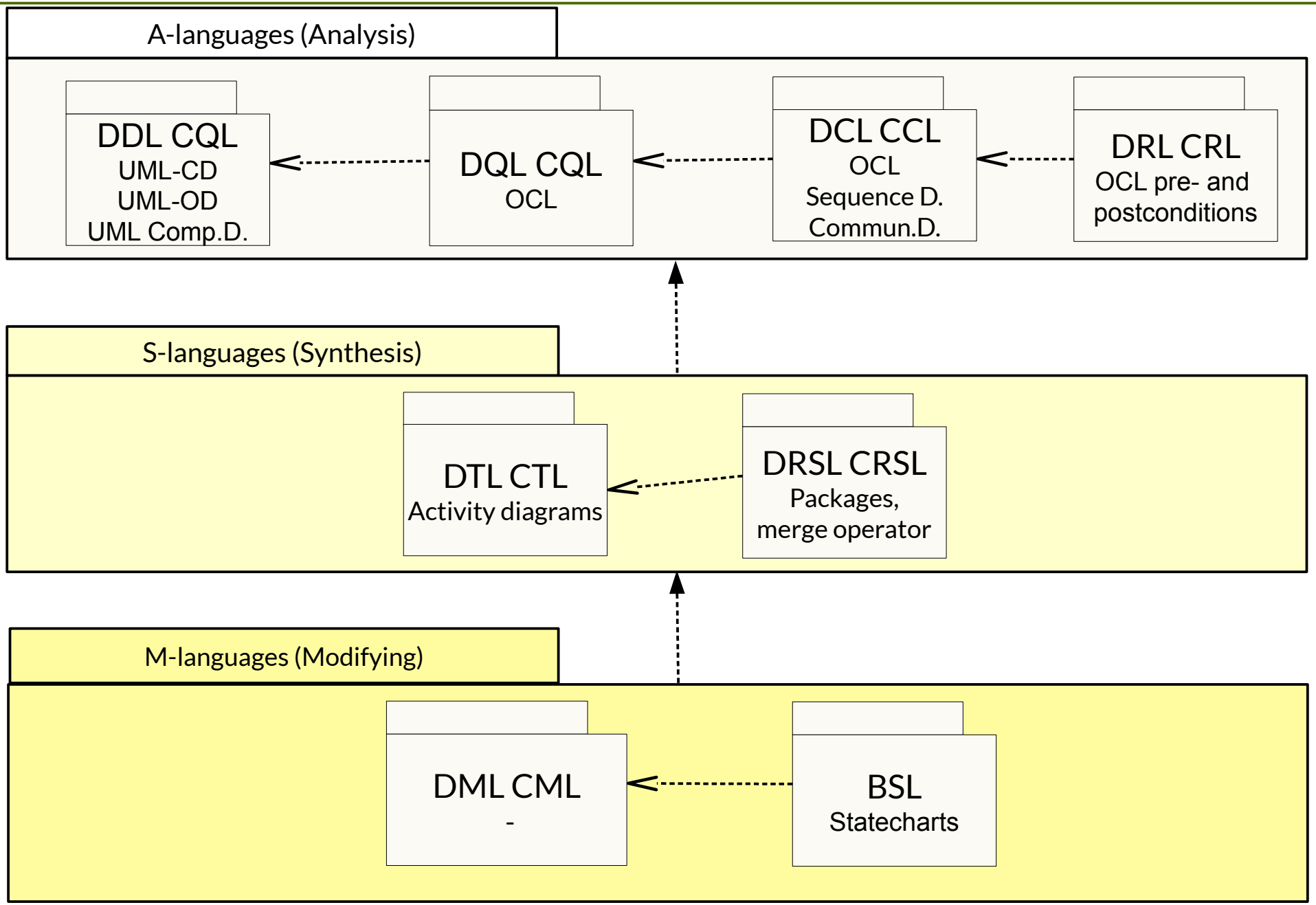
All tools have an underlying language family.

Every IDE has an underlying language family.

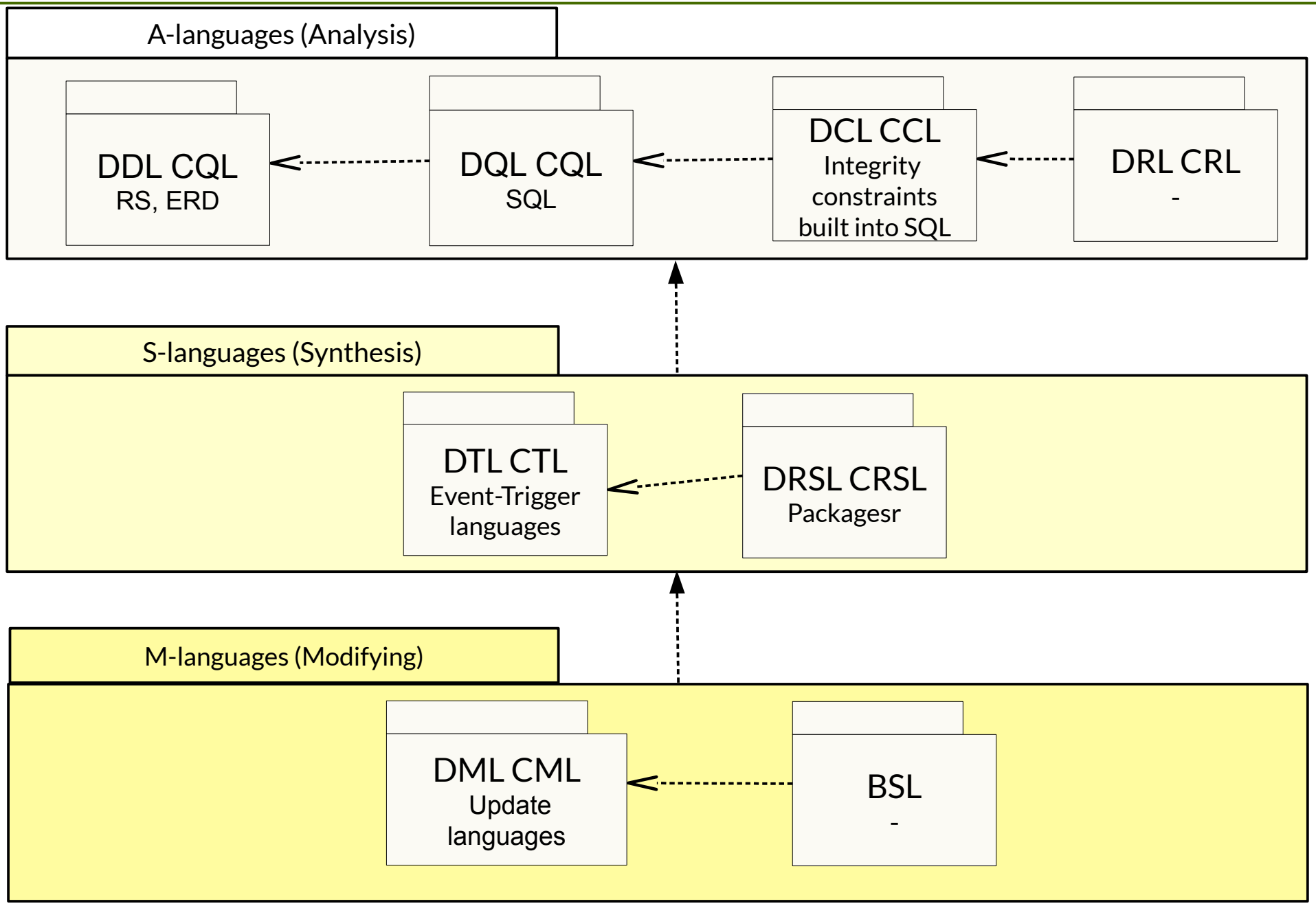
Basic Language Families (Layer Structure of M2)



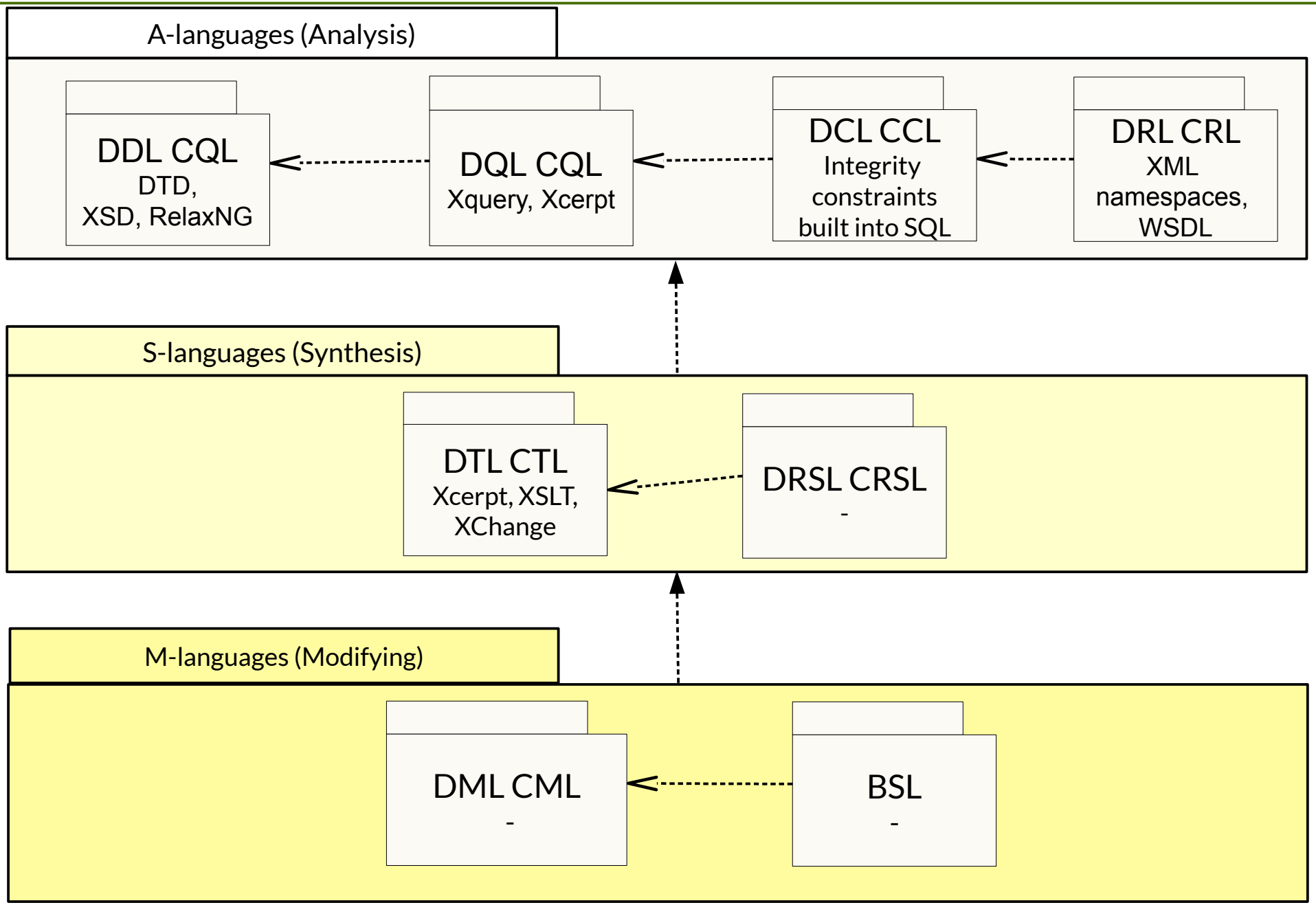
UML Language Family in the ModelWare TS



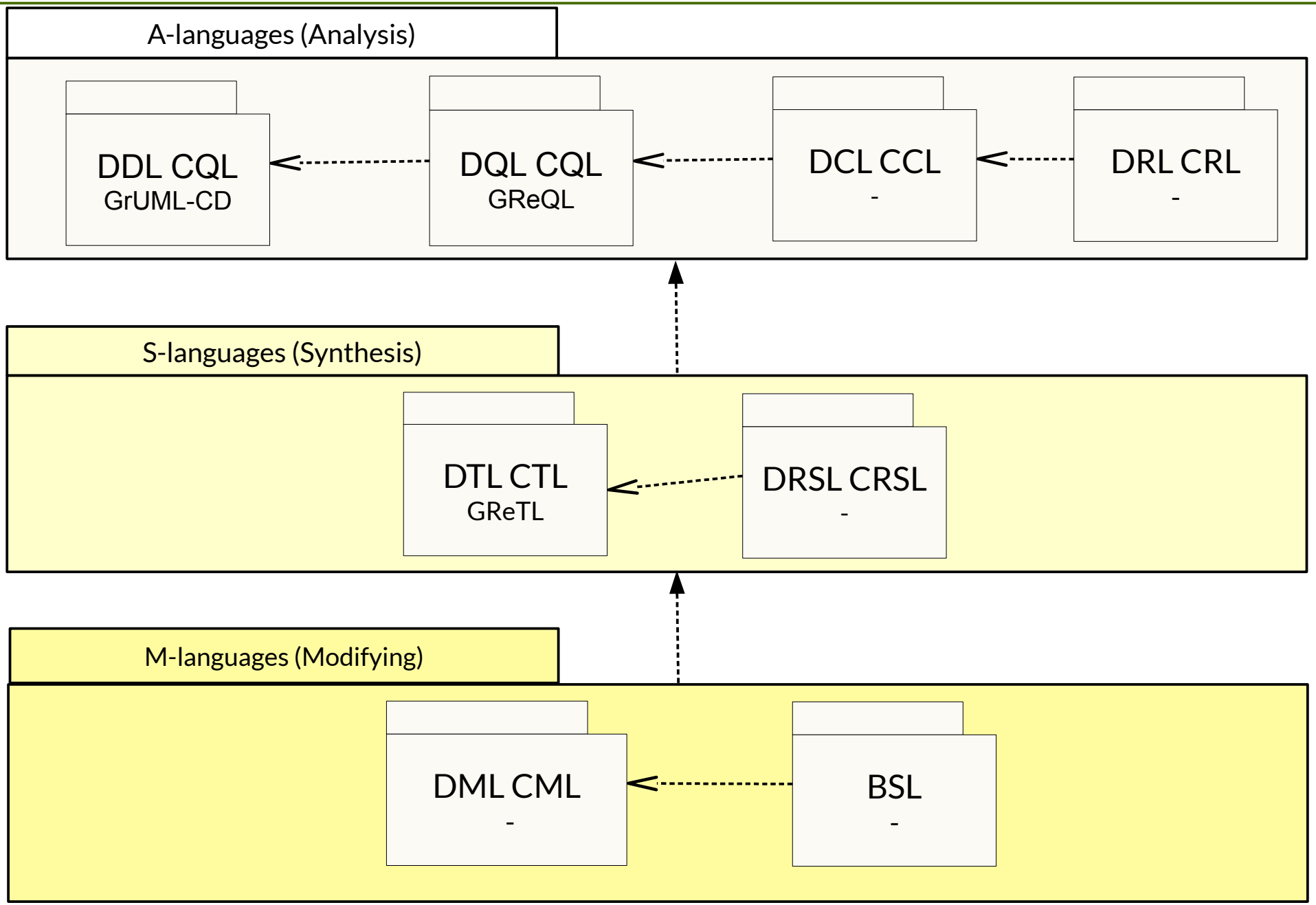
ERD/RS Language Family in the Relational TS



XML Language Family in the Link Tree TS



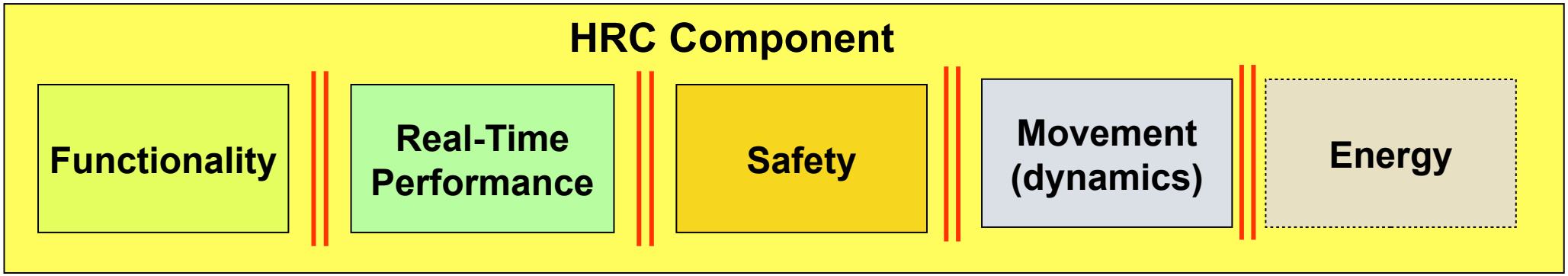
GrUML Language Family [Ebert]



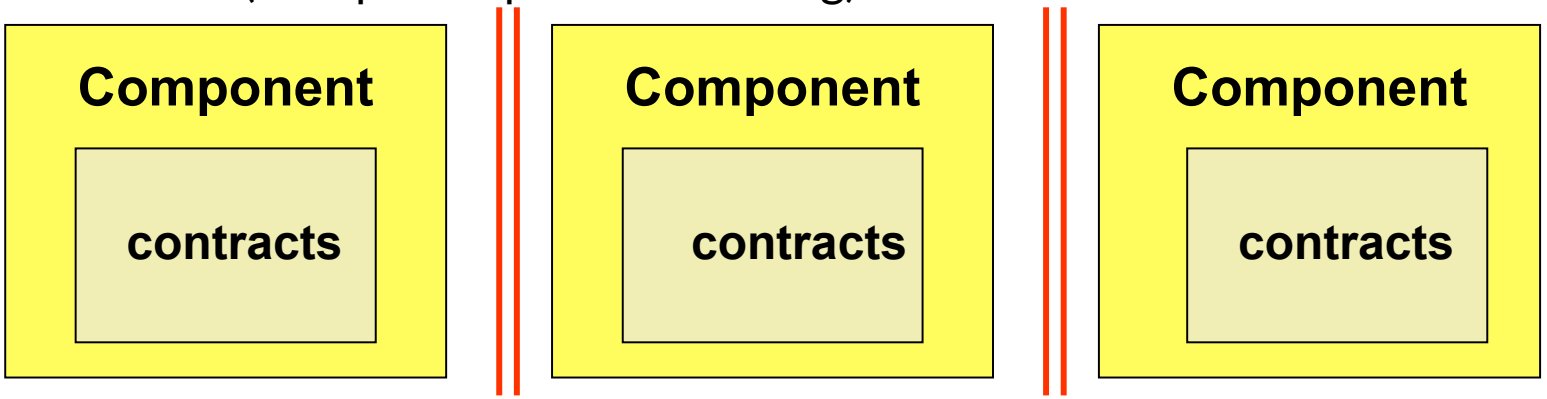
7.8. … and all together now...

Composition of Contracts in the HRC (Heterogeneous Rich Components) MDSD Tool Chain for Complex Embedded Systems

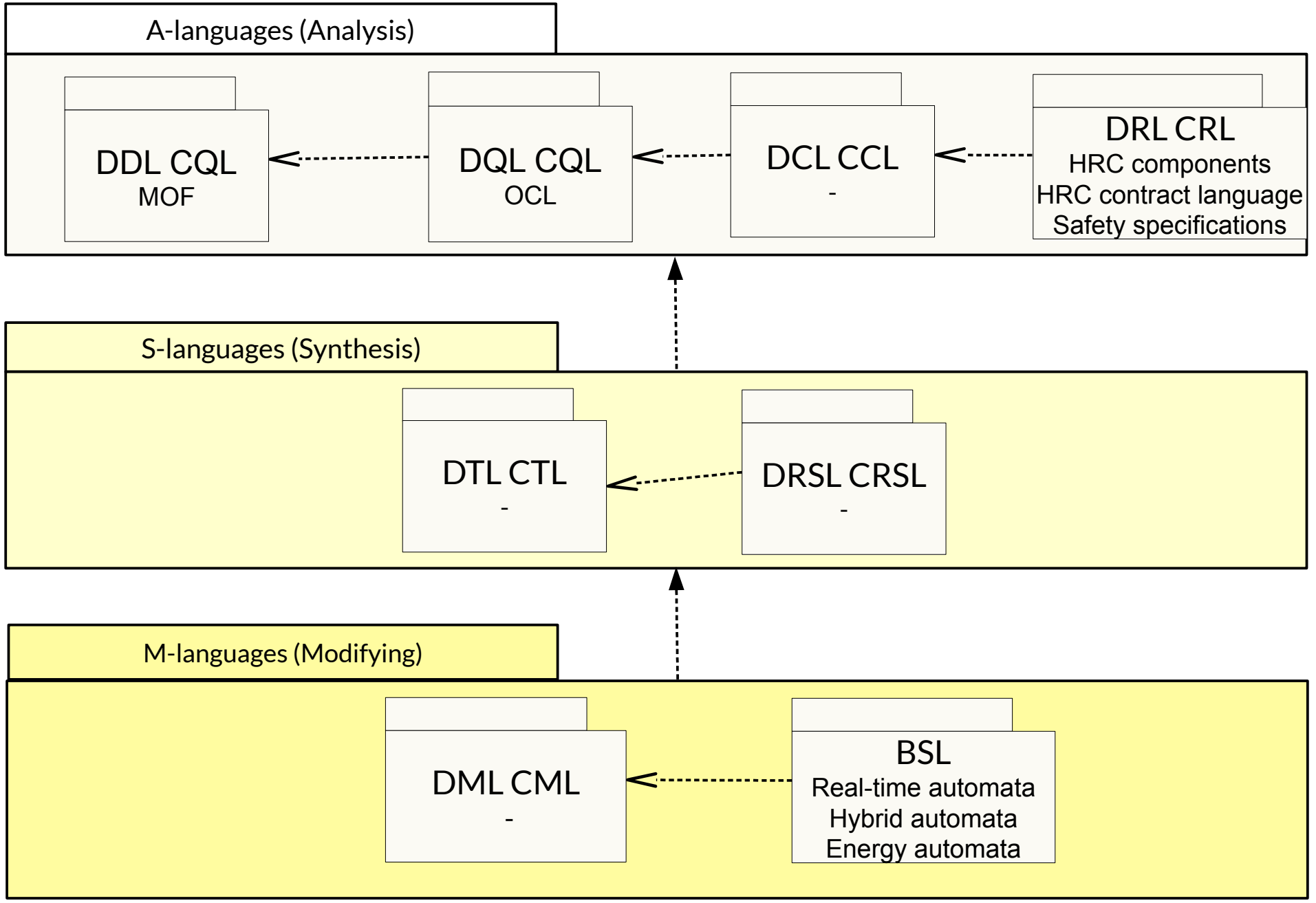
- Within a HRC component, contracts *in different views* can be synchronized (synchronized token-based modeling)
  - The real-time assertions can be coupled with functional, real-time, safety, physical movement (dynamics), and energy view
  - Every contract has a different contract language



- Between different components, the contracts of a certain viewpoint can be composed and checked (viewpoint-specific modeling)



HRC Language Family for Safety-Critical Embedded Software



Why is it Important to Know about the M2-Layers?

MDSD Tool Chains and Software IDE
very often combine different languages from
several layers of M2 (**M2-Mix**)

- ERD – MOF – XSD – UML-CD
- Xquery – XSLT – SQL – SPARQL
- OCL – SpiderDiagrams – OntologyLanguages
- Java – C++ – C#
- Petrinets – DFD – WorkflowNets – BPMN

Domain-specific languages always consist of an M2-Mix

Basic techniques (Basistechniken) also

Methods also

Why is it Important to Know about the M2-Structure?

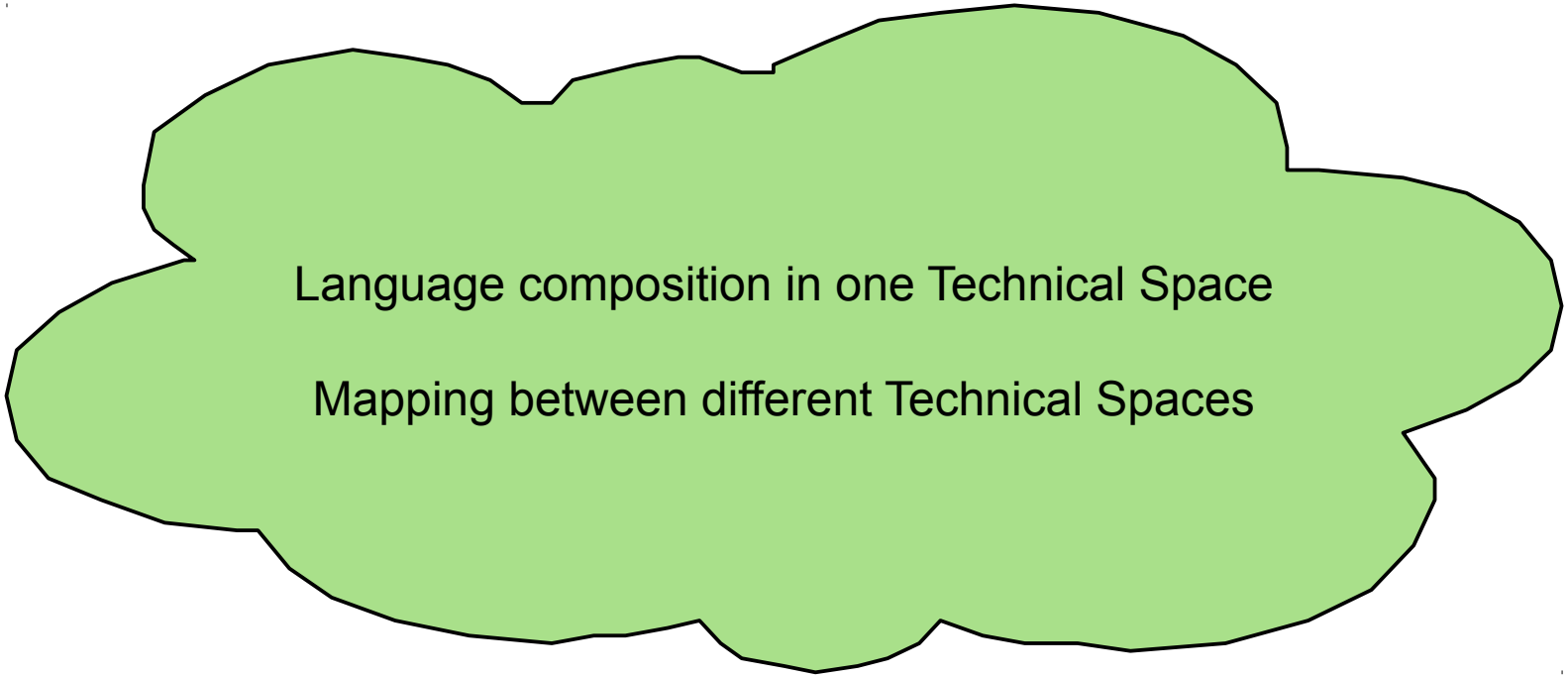
How can we compose metamodels for tool composition?

- Language families can be arranged in M2 layers
  - Many languages on upper layers can be composed with languages on lower layers
- If everything is in one Technical Space, composition of tools relies on the composition of languages
  - For that we need Model Composition Systems (forthcoming, → course CBSE)
    - Example: UML-Package Merge-Operator

Language composition: Compose new language constructs from layers further down

How Can We Compose Tools for Base Techniques for MDSD Tool Chains and Software IDE?

- If we have to treat several Technical Spaces, Bridges between TS have to be built



The End

- Why can we compose different DQL with a given DDL?
- How is it possible to apply a graph query language on XML trees?
- Why is UML such a complex language?
- A MDSD tool chain such as the HRC IDE for embedded systems works with many languages in different technical spaces. Explain some ingredients of such a complex IDE.

A.1 Data Flow Diagrams (Datenflussdiagramme, DFD)

Repetition from course ST-II

DFD are special Petri nets resp. Workflow languages without global state

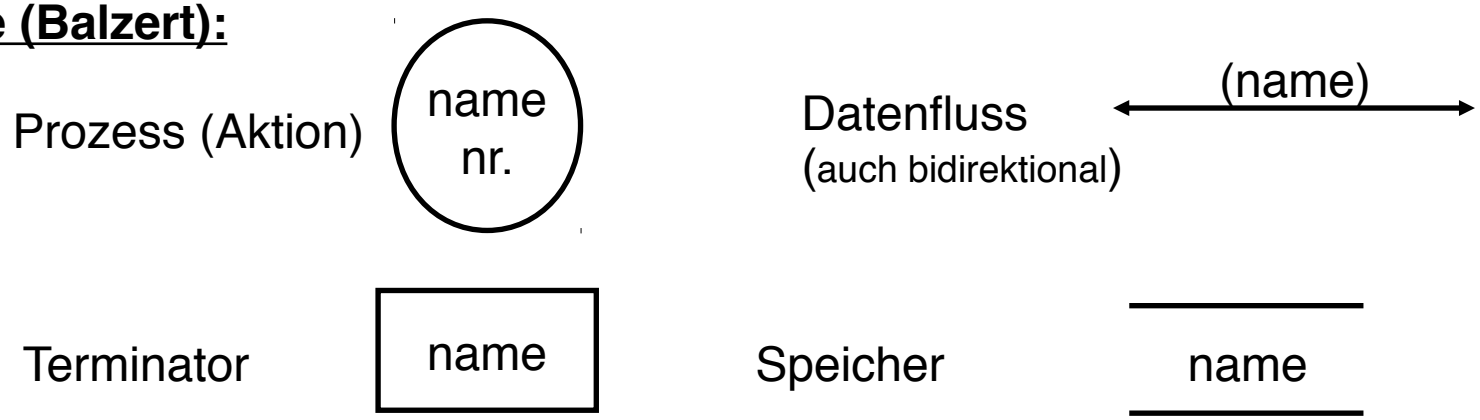
Datenflußmodellierung

- **Datenfluss-Modellierung:** Prozesse (Iterierte Aktionen) auf Datenflüssen, ohne gemeinsames Repository
  - Datenfluss (Datenströme, streams, channels, pipes) zwischen Prozessen (immerwährenden Aktivitäten auf einem Zustand)
  - Datenflussdiagramme werden für strukturierte Prozesse (Geschäftsprozesse, technische Prozesse, Abläufe in Werkzeugen) eingesetzt
- Datenfluss-Modellierung ist Hauptbestandteil der **Strukturierten Analyse (SA)**

DFD-Modellierung

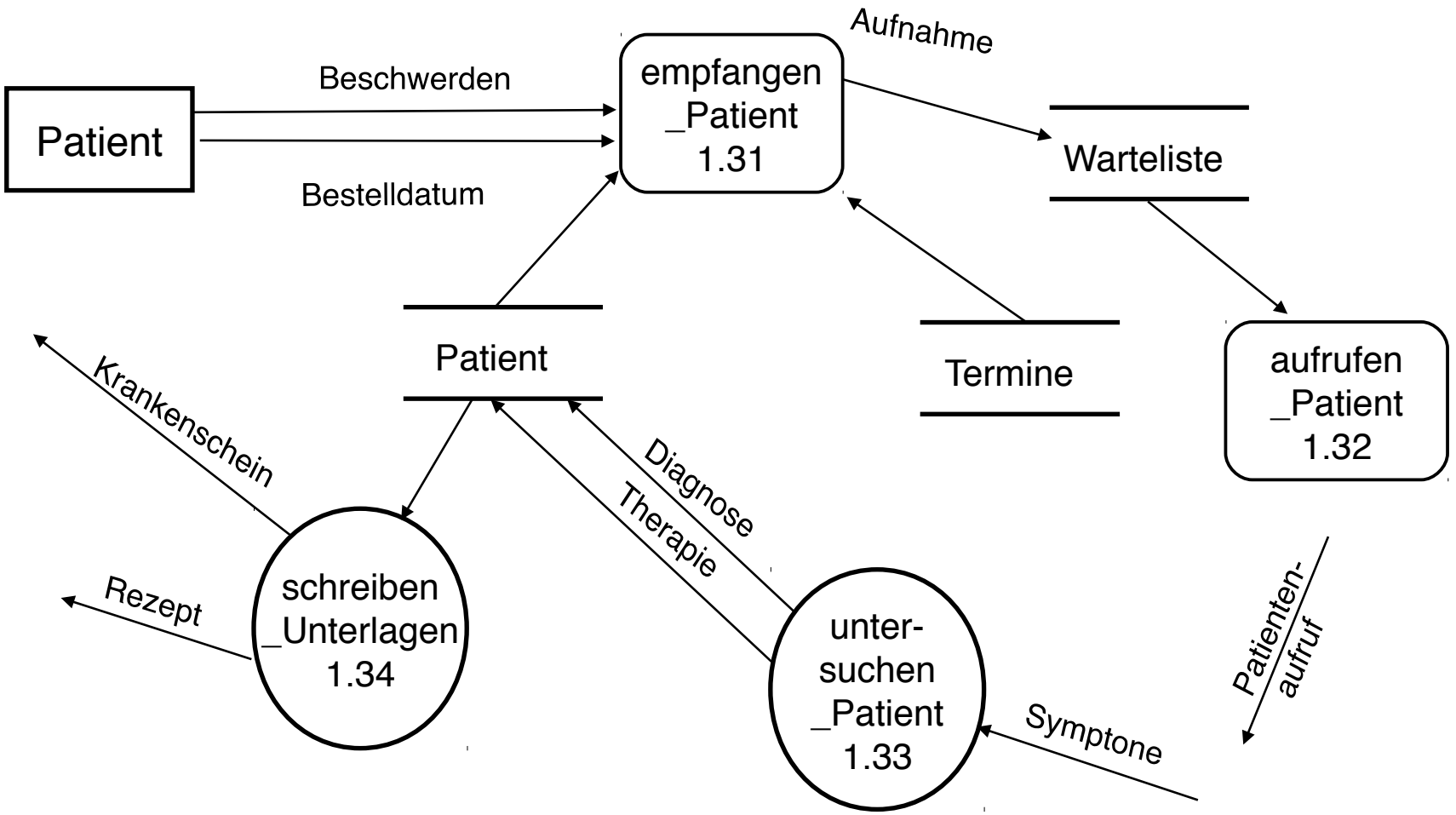
- Hierarchische (reduzible) Prozessspezifikationen:
  - Kontextdiagramm (oberstes Diagramm, mit Terminatoren)
  - Parent-Diagramme
  - Child-Diagramme (Verfeinerte Prozesse)
- Datenkatalog wird benutzt zur Typisierung (spezifiziert in einer DDL)
- Minispezifikationendienen der Beschreibung der in Elementarprozessen durchzuführenden Transformationen.
  - mit Pseudocode
  - mit einer Transformationssprache wie Xcerpt

Symbole (Balzert):



DFD-Beispiel "behandeln_Patient"

- Prozesse auf Datenströmen, auch Geschäftsprozesse
- Kein zentrales Repositorium, lokale Daten, explizite Definition des Datenflusses
- UML notiert Aktivitäten und Prozesse mit Ovalen, SA/Balzert mit Kreisen



DFD als BSL mit privaten Daten

- DFD verzichten auf ein globales Repositorium, sondern spalten die Daten in “private” Speicher auf,
  - für die explizit spezifiziert wird, wohin ihre Daten fließen
- DFD sind sehr gut geeignet für die Spezifikation von Werkzeugverhalten
  - Datenabhängigkeiten sind immer klar, da explizit spezifiziert
  - Natürliche Parallelität
  - Einfache Komposition durch Anfügen von weiteren Datenflüssen und Teilnetzen