

**A New Foundation for Computing Science**  
**A Research & Experimental Engineering Programme**

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**Fredsvej 11, DK-2840 Holte, Denmark**

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**Programmiersprachen und Grundlagen der Programmierung**

# From Domain via Requirements to Software Design

## 1.1. The Compiler Development Approach

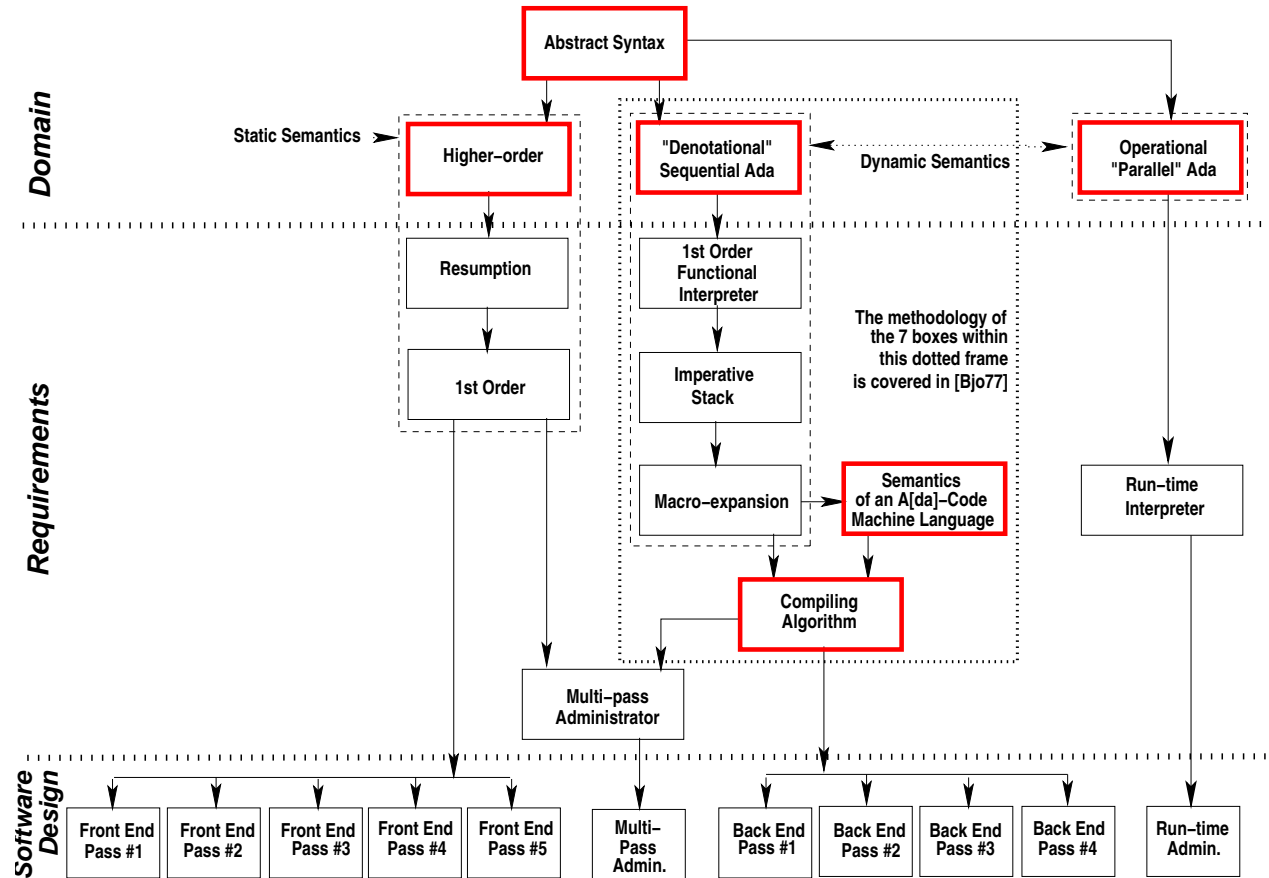


Figure 1: The Ada Compiler Software Development Graph [Bjø77]

## 1.2. – as 5 MSc Thesis Projects for 6 Students

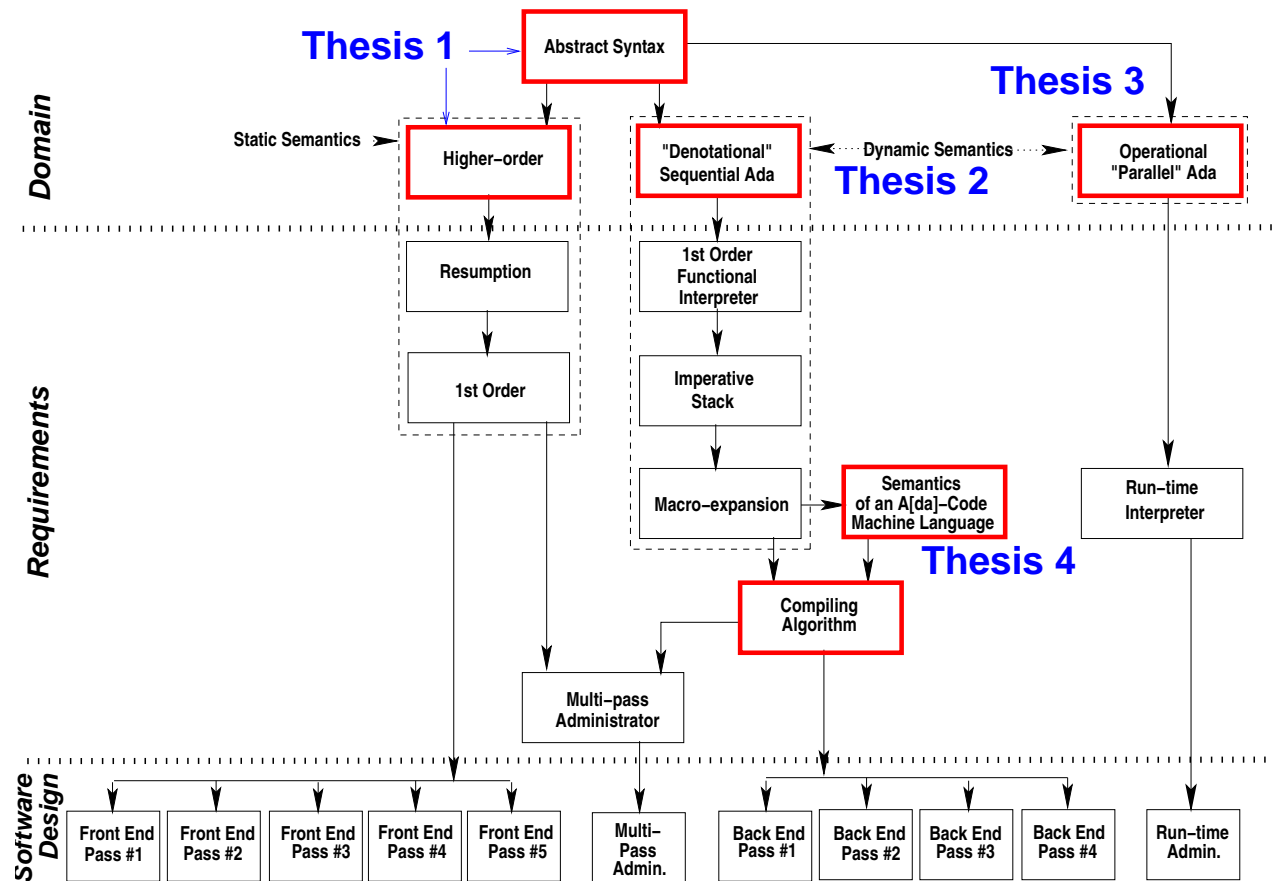


Figure 2: [BO80]

# 1.3. Domain Engineering

## 1.3.1. Denotational Semantics

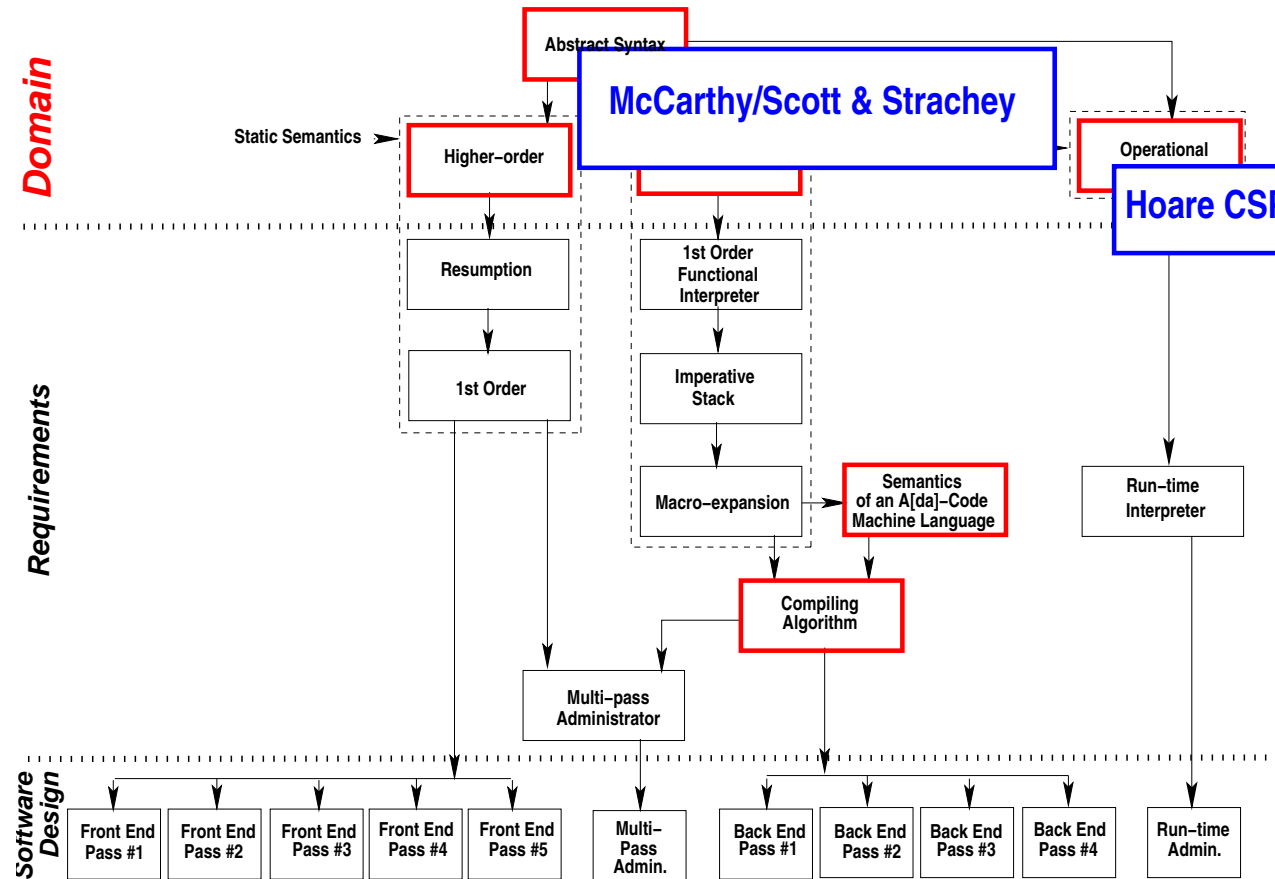


Figure 3: McCarthy [McC60, McC62], Strachey & Scott [Str68, Sco70, SS71, Sco72]

# 1.4. Requirements Engineering

## 1.4.1. The Landin SECD Machine and Reynolds Closures

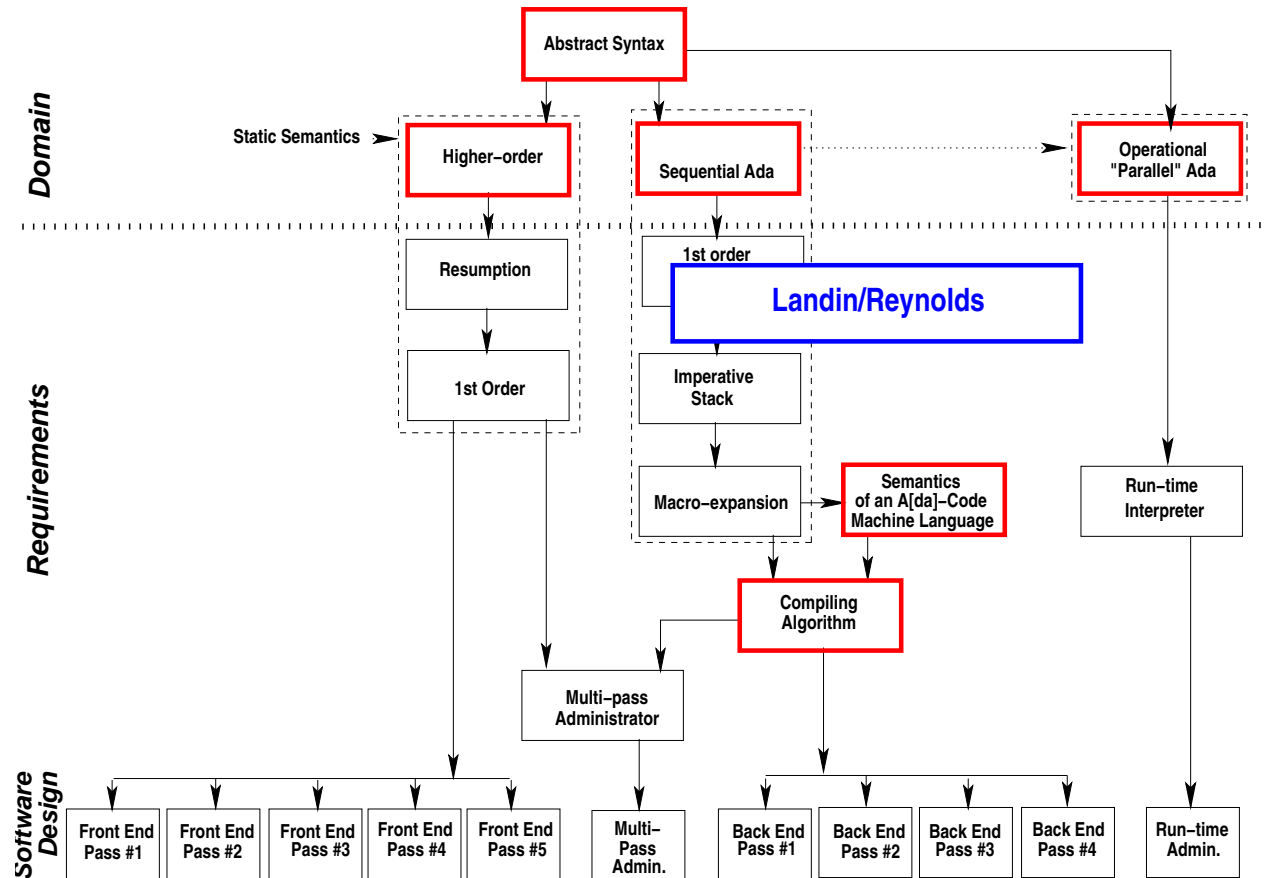


Figure 4: Landin [Lan64, Lan65a, Lan65b], Reynolds [Rey70, Rey72]

## 1.4.2. Macro-Expansion Semantics

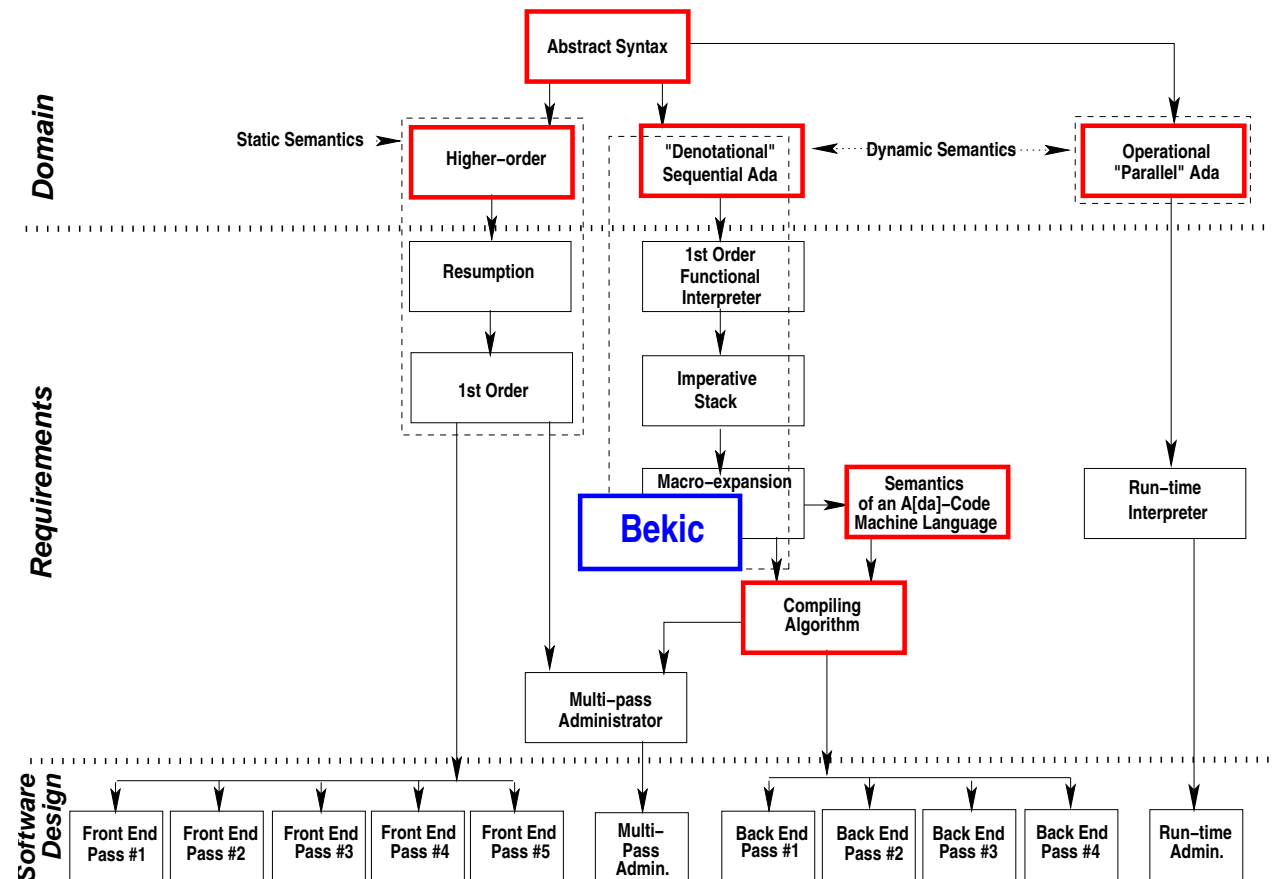


Figure 5: Bekič [Bek84]

# 1.4.3. Compiling Algorithm

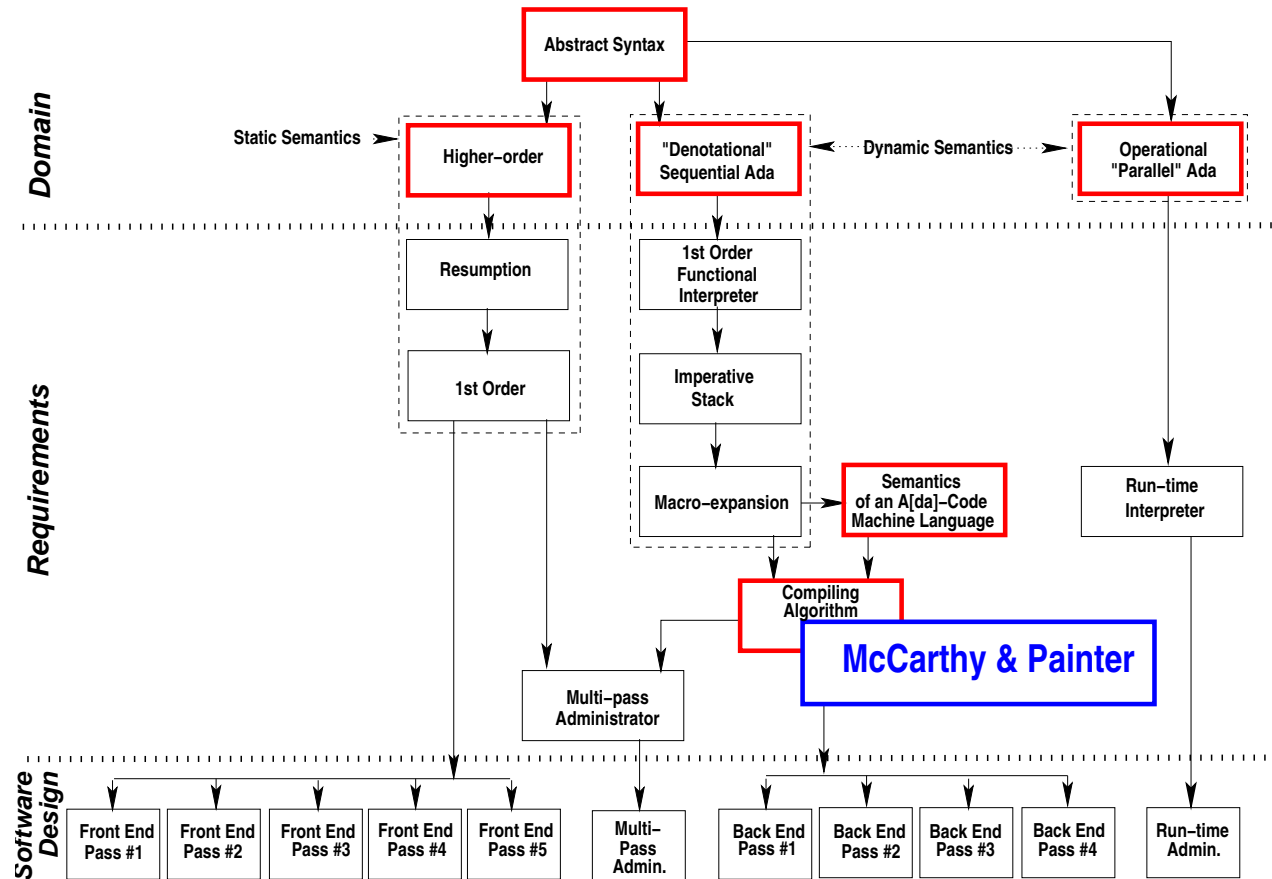


Figure 6: McCarthy & Painter [MP66]

## 1.4.4. Machine Requirements

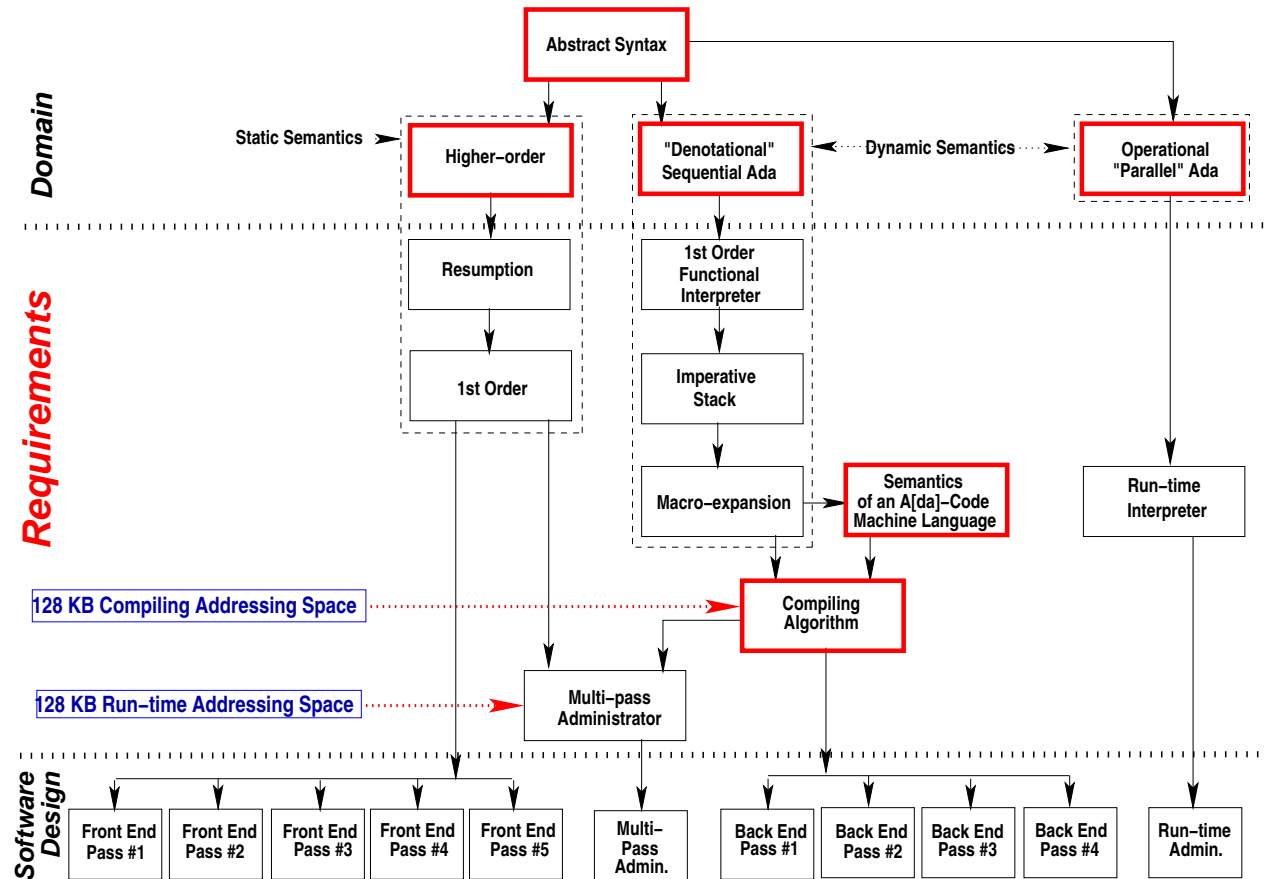


Figure 7: The Ada Compiler Software Development Graph



# 1.5. Lines of [VDM+comment] Specifications and Man Years

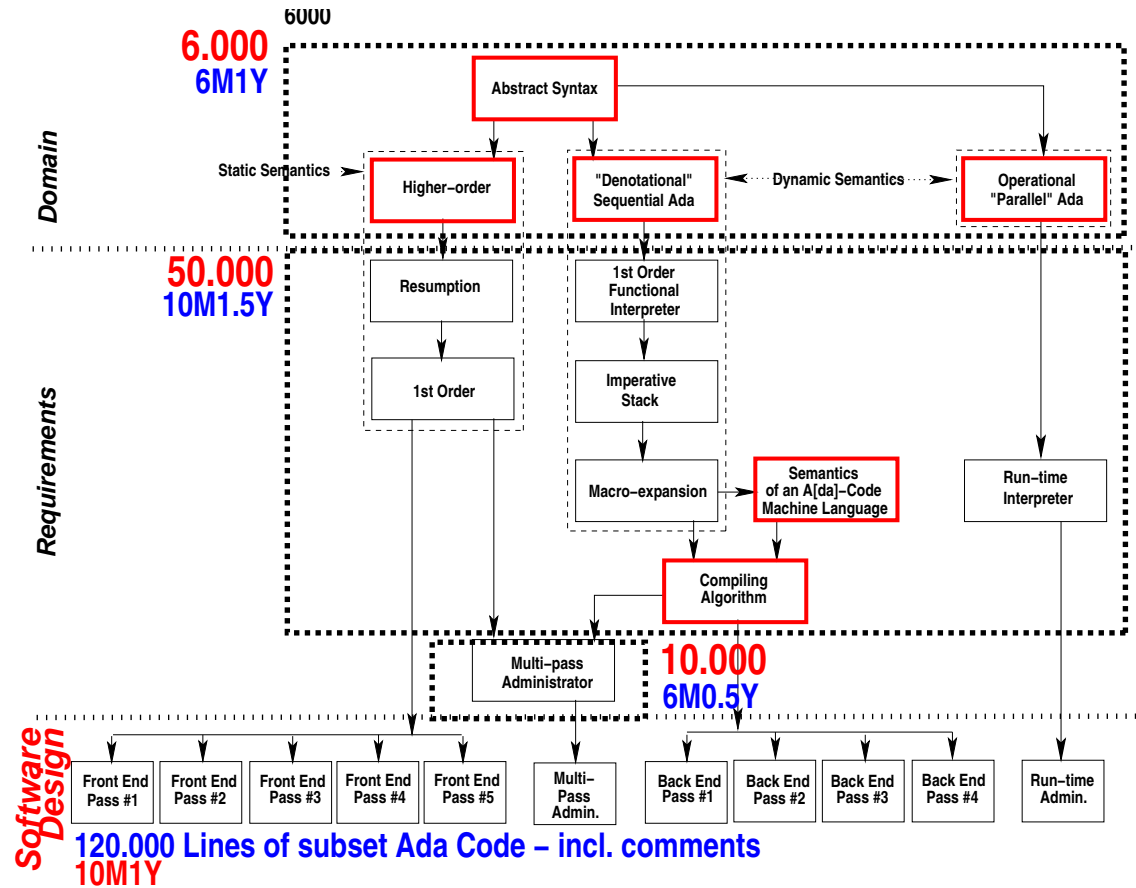


Figure 8: The Ada Compiler Software Development Graph

## The Thesis of This Talk

- To describe a *D*omain is to give semantics to its endurants and perdurants.
  - ❖ That is, a *D*omain is viewed as a language.
  - ❖ Description emphasis is put on semantic domains
- To prescribe *R*equirements is to “derive” these from a domain description.
  - ❖ The *R*equirements are for an interpretive machine.
- To specify a/the *S*oftware design is to refine it from the requirements prescription.

- To verify correctness of the software design is to
  - ◇ formally test,
  - ◇ model check and
  - ◇ prove property theorems.
- $\mathcal{D}, \mathcal{S} \models \mathcal{R}$
- $\mathcal{S} \models \mathcal{R}$  helps ensure correctness.
- $\mathcal{D}, \mathcal{S} \models \mathcal{R}$  helps ensure that product meets client expectations.

# The Development Dogma

## 3.1. The Specification Dogma

- In order to develop *S*oftware  
we must have a reasonable understanding of the requirements.
- In order to understand the *R*equirements  
we must have a reasonable understanding of the domain.
- In order to understand the *D*omain  
we must analyse & describe it.

## 3.2. The Verification Dogma

- In order to have trust in the *S*oftware  
it must be related formally to a *R*equirements.
- In order to have trust in the *R*equirements  
it must be related formally to a *D*omain description.

## 3.3. Domain Engineering

### 3.3.1. Domain Analysis: Manifest & Non-manifest Phenomena

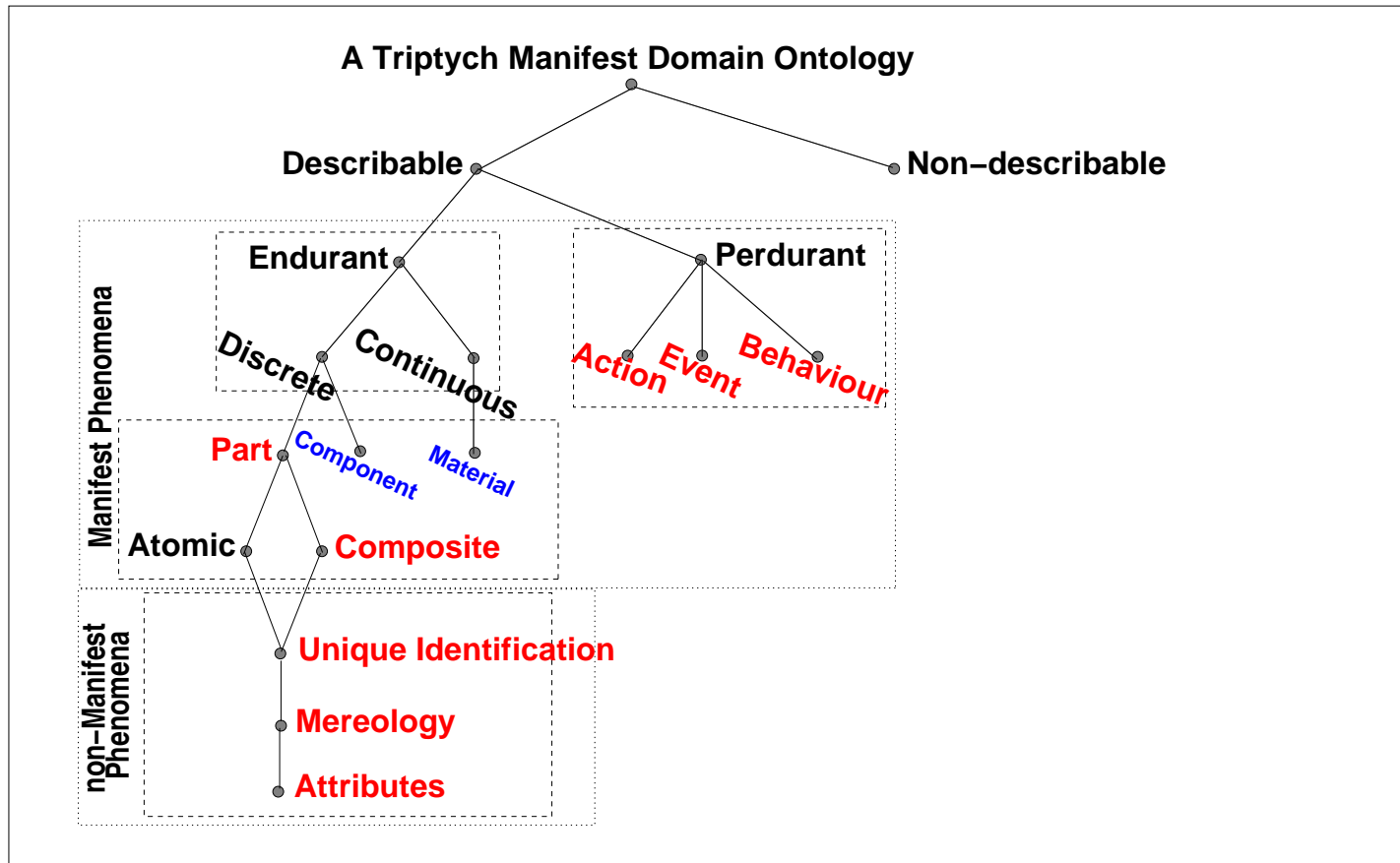


Figure 9: An **Ontology** of Manifest & Non-manifest Phenomena

## 3.3.2. Domain Analysis Prompts

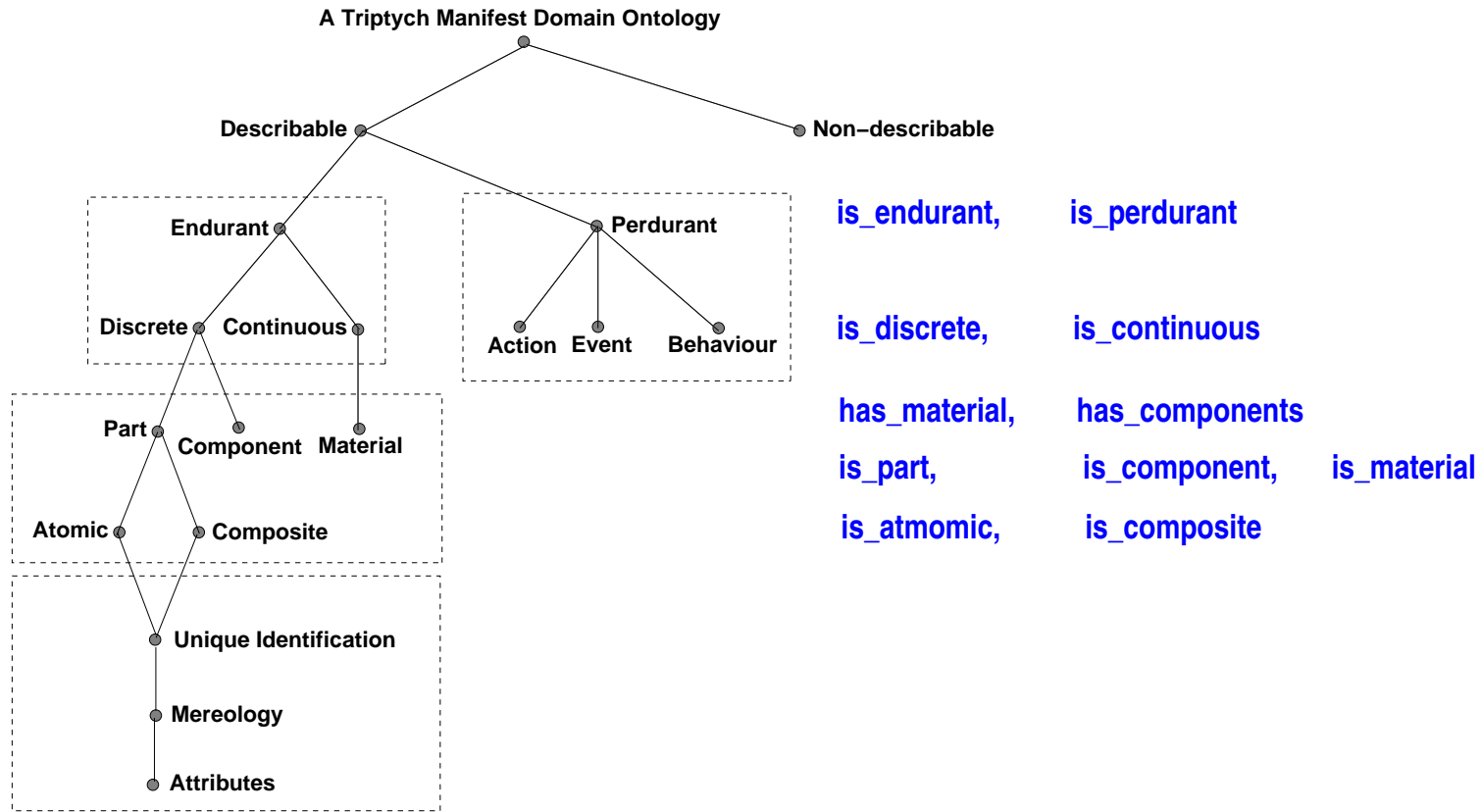


Figure 10: Analysis Prompts

### 3.3.3. Domain Description Prompts

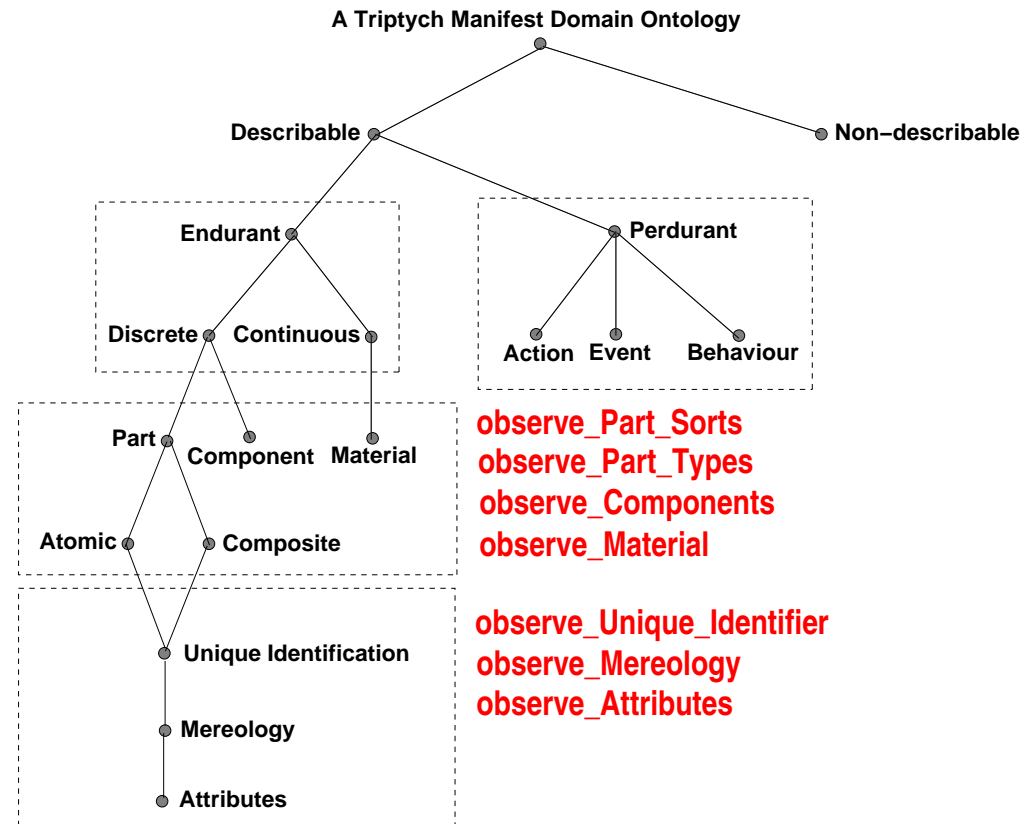


Figure 11: Description Prompts



### 3.3.4. Domain Analysis: Non-manifest Properties

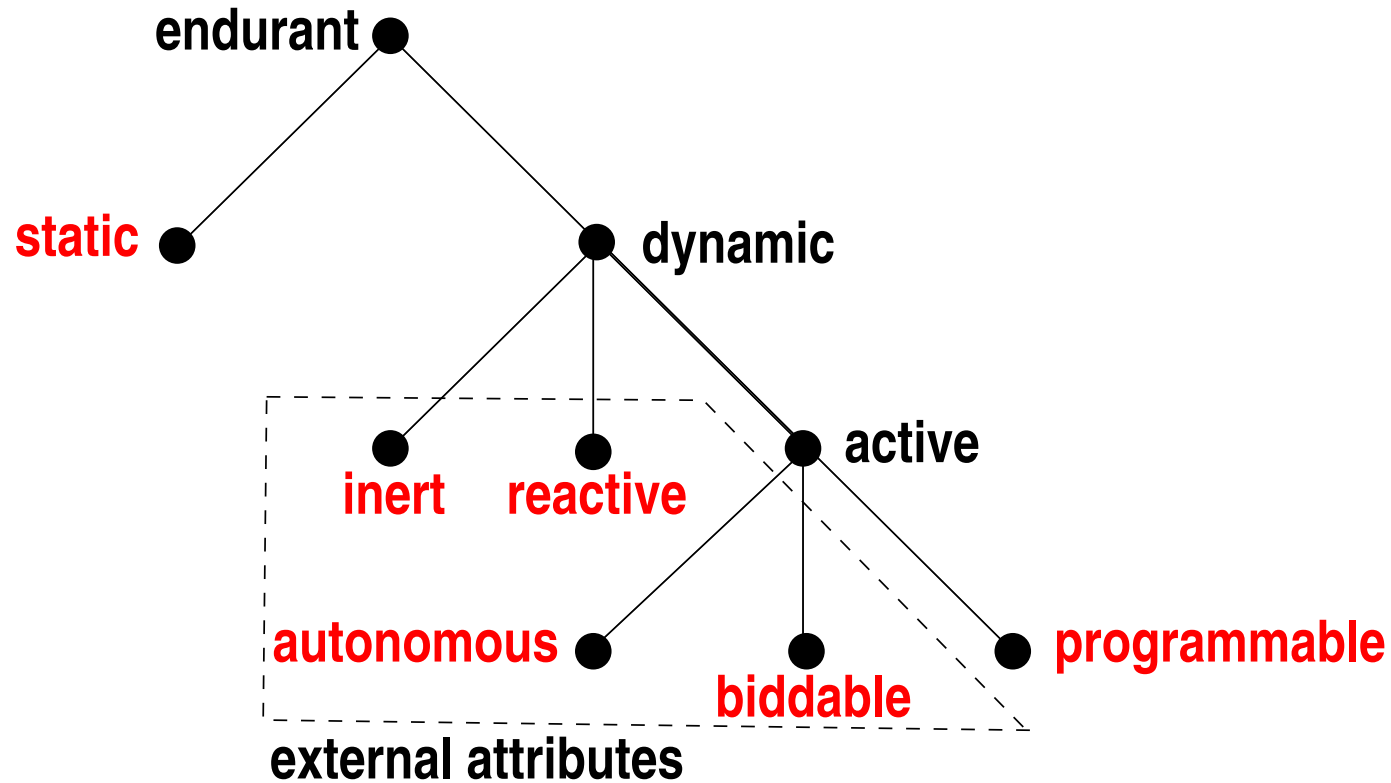


Figure 12: Attributes Analysis Prompts

## 3.4. Requirements Engineering

- Three Stages

- ❖ *D*omain *R*equirements
- ❖ Interface *R*equirements
- ❖ Machine *R*equirements

- *D*omain *R*equirements

- ❖ Projection
- ❖ Instantiation
- ❖ Determination
- ❖ Extension
- ❖ Fitting

- Interface *R*equirements

- ❖ Shared Phenomena
- ❖ Shared Endurants
- ❖ Shared Actions
- ❖ Shared Events
- ❖ Shared Behaviours

## So What's at Stake ?

### 4.1. “States-of-Affairs”

- It seems that compiler development using formal methods
  - ❖ such as in the DDC Ada Project (1981–1984)
  - ❖ is still **not developed** the right way in industry
  - ❖ and is also **not taught** that way at very, very many universities.
  
- It also seems that most other “application software”
  - ❖ is mostly not developed properly:
  - ❖ from domain descriptions
  - ❖ via (therefrom derived) requirements prescriptions
  - ❖ to software design etc.

## 4.2. What Would it Take ?

### 4.2.1. Computer Science

- By **computer science** we understand the study and knowledge of the artifacts that can exist inside computers.

### 4.2.2. Computing Science

- By **computing science** we understand the study and knowledge of how to construct those artifacts.

### 4.2.3. Formal Method

- By a **formal method** we understand a set of **principles** for **selecting** and **applying techniques** and **tools** for constructing an artifact — where the tools and techniques can be formalised, i.e., given a **logic/algebraic** basis.

## 4.2.4. A Remedy

- This speaker suggests, as far as universities are concerned,
  - ⊗ that we put more emphasis on **computing science**,
  - ⊗ that we do more **research** into and **teach** more **formal methods**,
  - ⊗ that we **research** and **teach**
    - ⊗ **domain science & engineering** and
    - ⊗ **domain, interface & machine requirements**.
  - ⊗ and that we
    - ⊗ do **experimental research** into
    - ⊗ and **pathfinder develop** **domains** and **domain applications**.

## 4.3. Justification

- The Dansk Datamatik Centers Ada Compiler project demonstrated that using formal methods can lead to trustworthy software: Less than 3% of original resources spent on corrective, perfective and adaptive maintenance since 1984.
- So for programming languages we know how to do it.
- But for application domain categories such as government systems: taxation, policing, social services, etc. we repeatedly hear of **“IT scandals”**.
- I am sure that many of the abstractions, concepts and ideas of programming languages and interpreter/compiler development can form a strong basis for **domain science & engineering**.

## Relevant Publications & Reports

- **[Bjø16b, 2015]** is the definitive paper on  
**Manifest Domains: Analysis & Description**
- **[Bjø16a, 2015]** is the definitive paper on  
**From Domain Descriptions to Requirements Prescriptions  
– A Different Approach to Requirements Engineering**

## 5.1. Further Domain Science & Engineering Papers

- Web page [www.imm.dtu.dk/~dibj/domains/](http://www.imm.dtu.dk/~dibj/domains/) lists the published papers and reports mentioned below.
- I have thought about domain engineering for more than 25 years.
- But serious, focused writing only started to appear as from **[Bjø06, Part IV]** — with **[Bjø03, Bjø97]** being exceptions:
  - ◆ **[Bjø07, 2007]** suggests a number of domain science and engineering **research topics**;
  - ◆ **[Bjø10a, 2008]** covers the concept of **domain facets**;
  - ◆ **[BE10, 2008]** explores **compositionality** and **Galois connections**.



- ❖ **[Bjø08, Bjø10b, 2008,2009]** show how to systematically, but, of course, not automatically, “derive” **requirements prescriptions from domain descriptions;**
- ❖ **[Bjø11a, 2008]** takes the triptych software development as a basis for outlining principles for **believable software management;**
- ❖ **[Bjø09, Bjø14a, 2009,2013]** presents a model for **Stanisław Leśniewski’s** [CV99] concept of **mereology;**
- ❖ **[Bjø11b, 2010]** presents, based on the TripTych view of software development as ideally proceeding from domain description via requirements prescription to software design, concepts such as software **demos and simulators;**

- ❖ **[Bjø13, 2012]** analyses the TripTych, especially its domain engineering, approach, with respect to **Maslow's Theory of Human Motivation**. Psychological Review 50(4) (1943):370-96; and **Motivation and Personality**, (Third Edition, Harper and Row Publishers, 1954.) and Peterson's and Seligman's **Character strengths and virtues: A handbook and classification**. (Oxford University Press, 2004);
- ❖ the first part of **[Bjø14b, 2014]** is a precursor for **[Bjø16b, 2015]** with its second part presenting a first **formal model of the elicitation process of analysis and description** based on the prompts more definitively presented in the current paper; and
- ❖ **[Bjø14c, 2014]** focus on **domain safety criticality**.

## 5.2. Some Domain Descriptions

### 5.2.1. 1990s: UNU-IIST

#### 1 **Scheduling and Rescheduling of Trains (China)**

[BGP95, BGH<sup>+</sup>97]

#### 2 **Ministry of Finance (Vietnam)**

[DCT<sup>+</sup>96] and [VGJM02, Chapter 5]

#### 3 **Radio/Telecommunications System (The Philippines)**

[DG96, LM97] and [VGJM02, Chapter 4]

#### 4 **Airlines (Vietnam)** [AM96]

#### 5 **Manufacturing: Production Processes** [VGJM02, Chapter 7]

#### 6 **Travel Planning** [VGJM02, Chapter 8]

#### 7 **Enterprise Management** [JA97]

## 5.2.2. 2000s and on ...

- 8 **A Railway Systems Domain**  
`http://euler.fd.cvut.cz/railwaydomain/` (2003)
- 9 **Models of IT Security. Security Rules & Regulations**  
`it-security.pdf` (2006)
- 10 **A Container Line Industry Domain**  
`container-paper.pdf` (2007)
- 11 **The “Market”:  
Consumers, Retailers, Wholesalers, Producers**  
`themarket.pdf` (2007)

## 12 **What is Logistics ?**

logistics.pdf (2009)

## 13 **A Domain Model of Oil Pipelines**

pipeline.pdf (2009)

## 14 **Transport Systems**

comet/comet1.pdf (2010)

## 15 **The Tokyo Stock Exchange**

today/tse-1.pdf and today/tse-2.pdf (2010)

## 16 **On Development of Web-based Software. A Divertimento**

wdfftp.pdf (2010)

## 17 **Documents (incomplete draft)**

doc-p.pdf (2013)

## Conclusion

- So, welcome to a **wonderful world** of
  - ❖ **Domain Science & Engineering** !
- **What is there to wait for !?**
- Bring your Computing/Computer Science group up to speed!
- Your students will love it.
- Young researchers will thrive.

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