4.2 Families of Programs

Overview of Chapter 4.2

- basic idea of families of programs
- . . . and what to do if the first version is due yesterday

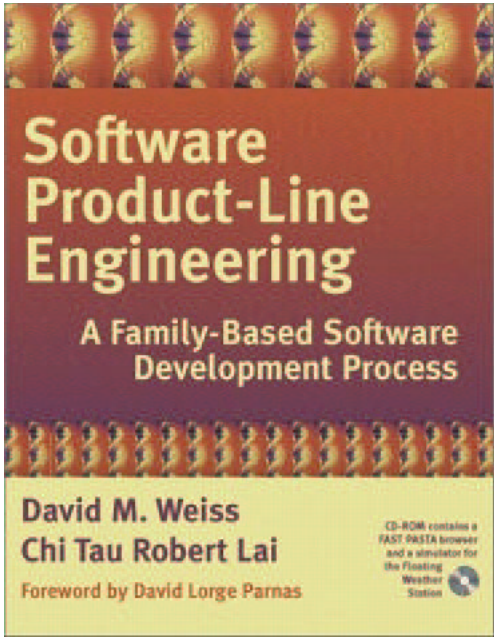
Text for Chapter 4.2

[Par76] Parnas, D. L. *On the design and development of program families*. IEEE Trans. Softw. Eng. **2**(1), 1–9 (Mar. 1976).

First paper to introduce families of programs explicitly. Presents the essentials very clearly.

[WeLa99] Weiss, D. M. and Lai, C. T. R. *Software Product Line Engineering – a Family-Based Software Development Process*. Addison Wesley Longman (1999).

Best current book on how to do software product line engineering (families of programs) in practice.

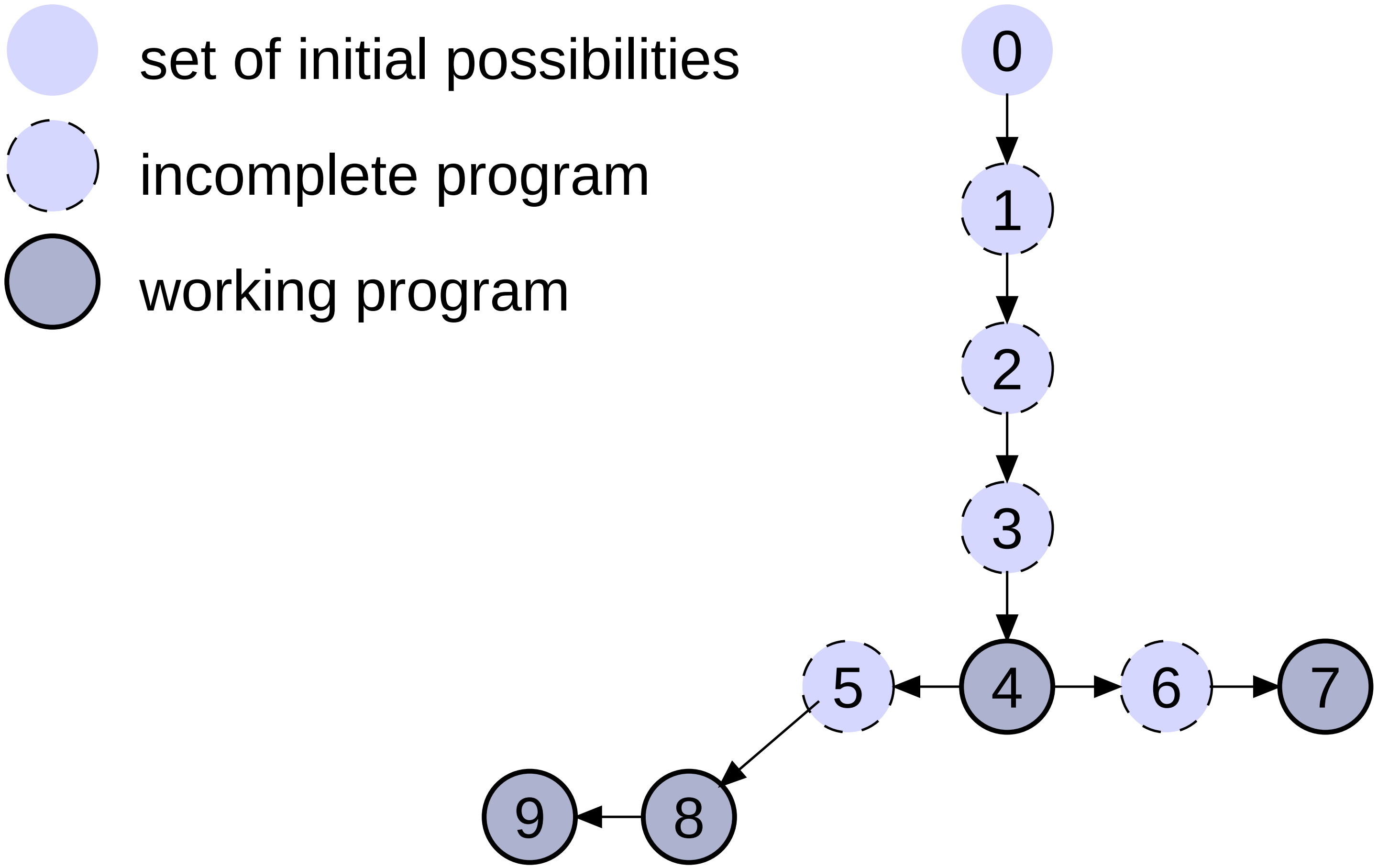


Definition of Program Family

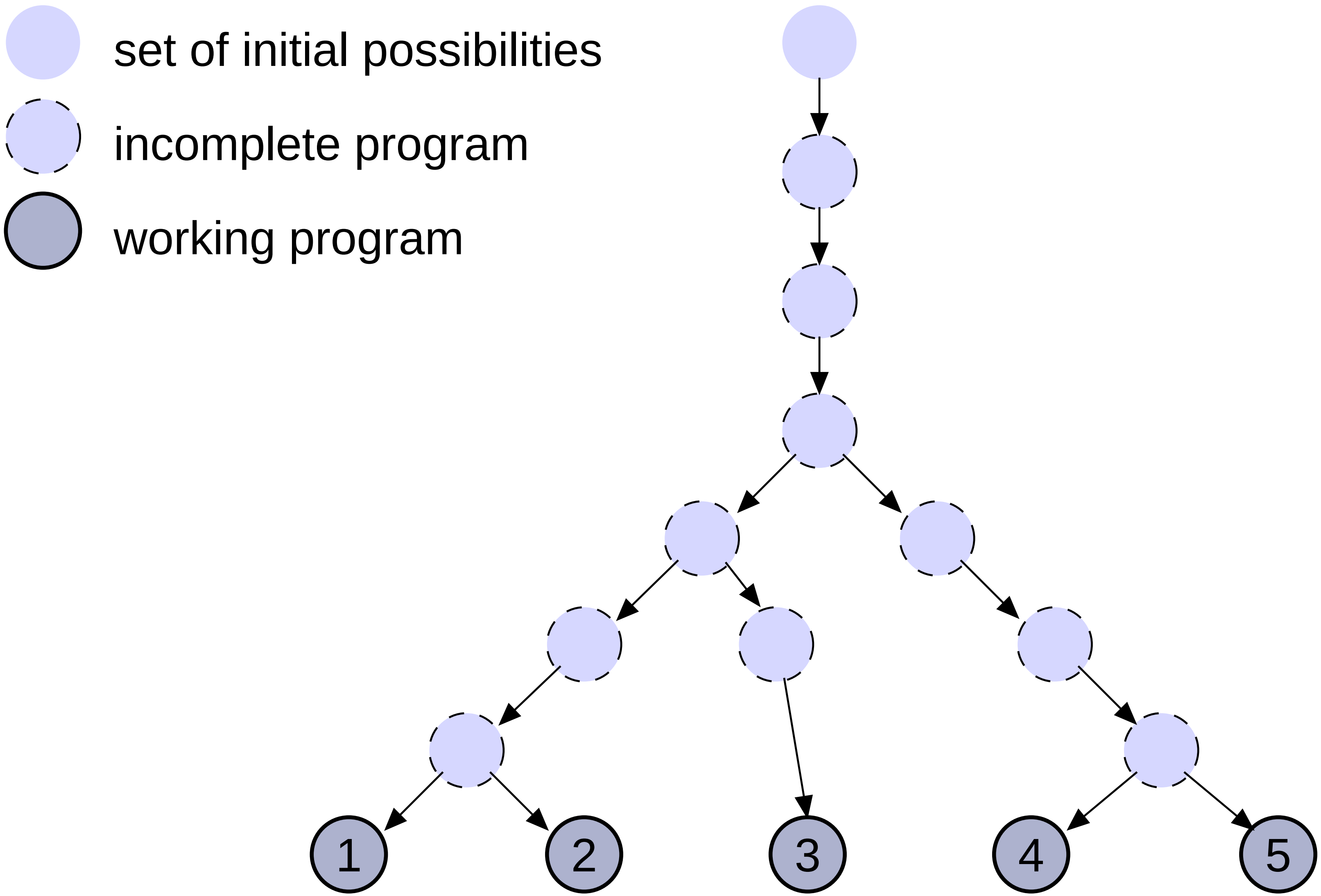
Definition 20 (Program family)
A set of programs constitutes a family whenever it is worthwile *to study programs from the set by* first *studying the common properties of the set and* then *determining the special properties of the individual family members.*

- examples:
  - the set of versions of an embedded software for different environments
  - the set of versions of a software over time

The “Classical” Method of Producing Program Families



Newer Techniques



Stepwise Refinement

- intermediate stages:
  - complete programs
  - except: certain operators and operand types only specified, not yet implemented
- next step: provide some more implementation, using more, newly introduced specifications as necessary
- linear sequence of steps towards one program
  - if a step must be taken back, all subsequent steps are lost

Module Specification

- intermediate stages:
  - black-box specifications of modules
  - *not* complete programs
- next step: add design decisions for a module, using newly introduced sub-modules as necesary
- steps taken in different modules are independent
  - any step taken back affects its sub-modules only
  - order of steps: more important
  - independent further development of modules

Discussion of Both Development Approaches

- both based on same basic ideas:
  - represent intermediate stages precisely
  - postpone certain decisions
- extra effort to design first family member:
  - stepwise refinement: none
  - module specification: significant
- effort to design next family members:
  - stepwise refinement: high, if early step taken back
  - module specification: low, as long as low uses-level modules affected

Dilemma: Careful Engineering vs. Rapid Production

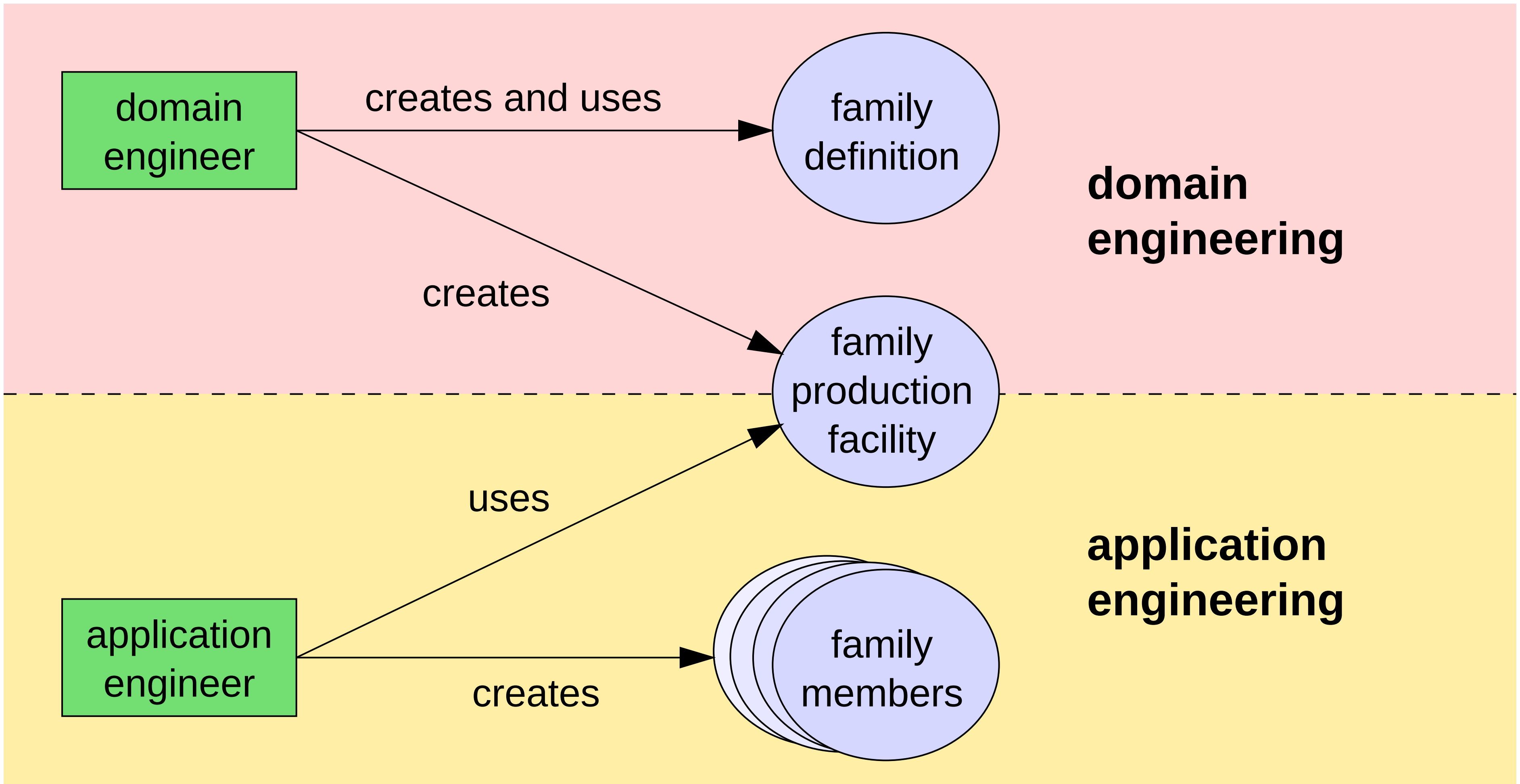
- careful engineering:
  - attractive functionality
  - ease of use
  - reliability
  - easy to enhance
- rapid production:
  - market it ahead of competition

A Solution in Other Fields

- fields:
  - aerospace
  - automotive
  - computer hardware
  - . . .
- idea: *a family of products produced with a single production facility*

- family: set of items
  - common aspects (e.g., chassis)
  - predicted variabilities (e.g., engine)
- def. *product line*: a family of products

Family-Oriented Abstraction, Specification, and Translation (FAST)



Applications of FAST

- developed and in use within Lucent Technologies (development: Bell Labs)
- many product lines already created there

Basic Assumptions

- redevelopment hypothesis
- oracle hypothesis
- organizational hypothesis

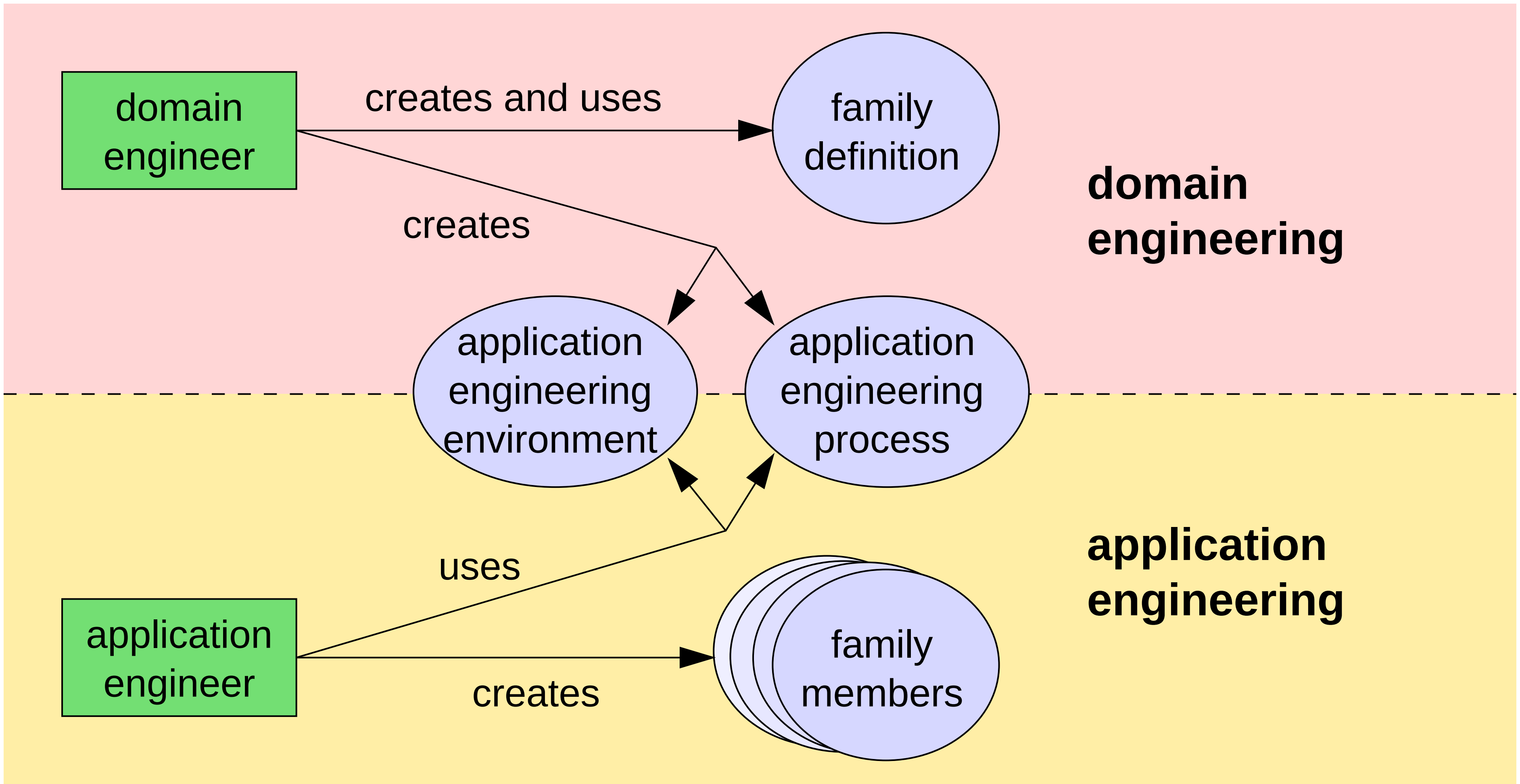
Stages Towards an Engineered Family

1. potential family
   - one suspects sufficient commonality
2. semifamily
   - common and variable aspects identified
3. defined family
   - semifamily + economic analysis of exploiting it
4. engineered family
   - defined family + investment in processes, tools, resources

FAST Strategies

- identify collections of programs
  that can be considered families
- design the family for producibility
- invest in family-specific tools
- create a family-specific way to model family members
  - for validating the requirements by exploring the behaviour
  - for generating code and documentation

Outputs from Domain and Application Engineering



Predicting Change

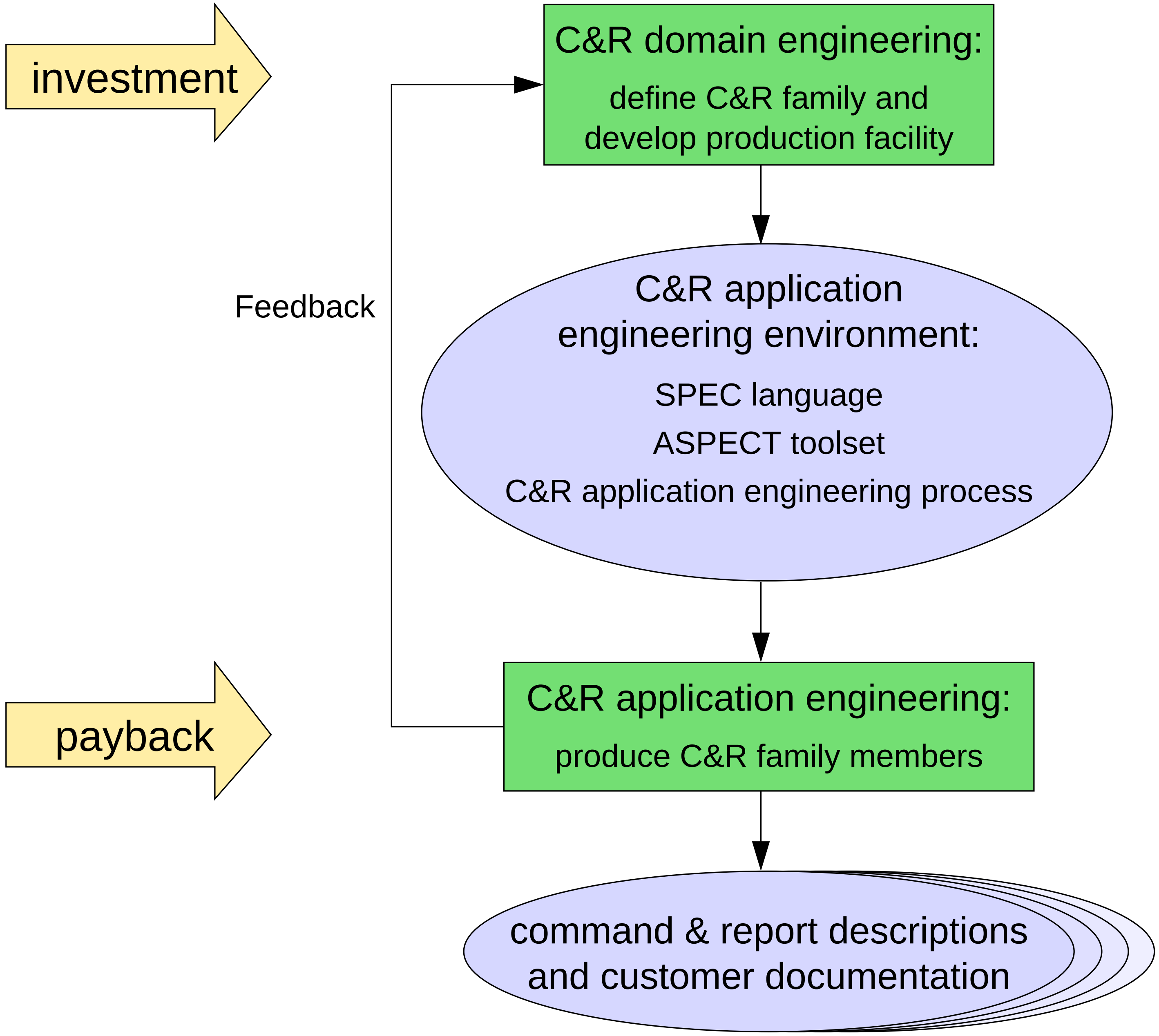
- is critical
  - but is not all-or-nothing
- confidence should rule size of investment
- FAST: explicitly bounds change (oracle hypothesis)
  - allows for common abstractions
- good guides for future change:
  - past change
  - your marketing organization
  - early adopters
  - experienced developers

Organizational Considerations

- reorientation of software development around domains may need change in organization of development
  - e.g., one sub-organization for each domain
  - e.g., a product line composed out ouf several sub-domains
    - ▷ example: protocol stack

Example:
FAST Applied to Commands and Reports

- C&R: part of Lucent's 5ESS telephone switch
- technicians monitor and maintain running switch
  - issue commands
  - receive status reports
- voluminous documentation
- command set: thousands of commands and report types


investment
payback
Feedback
C&R domain engineering:
define C&R family and
develop production facility
C&R application
engineering environment:
SPEC language
ASPECT toolset
C&R application engineering process
C&R application engineering:
produce C&R family members
command & report descriptions
and customer documentation

Defining the C&R Family

- identify potential family members, characterize commonalities and differences
- 5ESS command:
  - always command code followed by parameters
    - ▷ command code: action and an object
      - example: report status of a line connected to the switch
  - the particular actions, objects, parameters vary
    - ▷ over reasonably well-defined sets
    - ▷ certain combinations not included in family
      - example: remove clock is not included, but set clock is included

C&R Commonality Analysis Document

- introduction
  - purpose of the commonality analysis
- overview
  - brief overview of C&R domain
- dictionary
  - defines technical terms for the C&R domain used
- commonalities
  - assumptions true for every member
- variabilities
  - assumptions about how members may vary

- parameters of variation
  - the value space for each variability
  - the time at which the value must be fixed
- issues
  - issues that arose during analysis / how resolved

Excerpts from Dictionary Section

Command code	Unique identifier of an *input command*, consisting of a *verb* and an *object*.
Input command	A command entered by an office technician that acts as a stimulus to the 5ESS to perform tasks. Such tasks include changing the state or reporting the state of the 5ESS.
Input command definition	A specification of all the information needed to identify and produce an *input command* or a set of *input commands* with common structure and contents.
Input command manual page	Documentation of an *input command* for the customer's use.
Output report	An information message that is printed on an output device.
Output report definition	A specification of all the information needed to identify and produce an *output report* or a set of *output reports* with common structure and contents.

Purpose	*Customer documentation* that describes the use of an *input command*.
Verb	The name of the action indicated by an *input command*.

Excerpts from Commonality Section

COMMONALITIES

The following are basic assumptions about the domain of *input commands*, *output reports*, and *customer documentation*.

INPUT COMMANDS

C1. Each *input command* is uniquely determined by its *command code*. When an *input command definition* is used to define more than one *input command*, it defines multiple *command codes*, all of which share the same set of *input parameters*.

C2. Each *input command* is described on exactly one *input manual page*.

C3. The following *administrative data* are required in an *input command definition*: *msgid, process, ostype, schedule*, and *auth*. Each *input command* has exactly one value for each of these fields.

C4. A *verb* is an *alpha-string* with a maximum length.

C5. There is a fixed maximum number of *input parameters* permitted for *input commands*.

C6. An *input parameter description* consists of a *parameter name* and a *value specification*. The *value specification* defines the range of values that an office technician may use for the *input parameter*.

OUTPUT REPORTS

C7. *Output reports* appear in three different contexts as follows.

a. Runtime: At runtime an *output report* may appear on an output device, such as the printer.

b. Report definition: The set of *output reports* that a 5ESS switch may produce at runtime, and the meaning of each possible *output report*, must be defined before building the software for the switch.

c. Output report documentation: Each *output report* must be documented for customer use. The documentation of *output reports* must include all the information that the office technician needs to know to understand the report and determine the reason for its appearance at runtime.

C8. An *output report* contains the report type – spontaneous or solicited – and the text of the report.

C9. There is a fixed maximum number of characters in a line of an *output report*.

C10. Each *output report* is described on exactly one *output manual page*; however, an *output manual page* may describe more than one *output report*.

C11. An *output report definition* is a sequence of *text block definitions*.

DOCUMENTATION

C12. An (*input command* or *output report*) *manual page* consists of several fixed sections. It may also reference an *appendix*.

C13. An (*input command* or *output report*) *manual page* documents one or more *input commands* or *output reports*.

SHARED COMMONALITIES

C14. All the information needed to define an *input command*, the associated *solicited output report*, and the associated *manual pages* must be describable as one specification. It must be possible to generate from such a specification all the files and data needed to process *input commands* and produce *output reports* at runtime and to generate either (1) the *input command* and *output manual pages* or (2) files and data that can be used to generate the *input command manual pages* and *output manual pages*.

Excerpts from Variabilities Section

The following statements describe how *input commands*, *output reports*, and *customer documentation* may vary.

VARIABILITIES

INPUT COMMANDS

V1. The maximum length of a *verb*, *object*, *parameter name*, or *enumeration* value.

V2. The domain for *verbs*.

V3. The maximum number of *input parameters*.

V4. The *Csymbol* used to designate a *msgid*.

OUTPUT REPORTS

V5. The maximum number of characters in a line of an *output report*.

DOCUMENTATION

V6. The representation of an *input command* on an *input manual page*, particularly the following in the syntactic template for the *input command*:

a. The separators used between the *command code* and the list of *input parameters*

b. The terminator for the representation of the *input command*

c. The separator used between the *verb* and the *object*

Typical *input command* representations appear as follows:

<command code rep><separator1><input parameter rep><input terminator>

<command code rep><input terminator>

<verb><separator2><object>

V7. Typographic distinguishers for command templates.

Sample Command Template, Written in SPEC

```
COMMAND {
  TEMPLATE {
    abt-task:tlws;
    purpose: "Aborts an active trunk and line workstation
             (TLWS) maintenance task.";
    warning: "Once this command is entered, the
             consistency of all hardware states and data
             in use by the task is questionable.";
    }
}
```

Formatted Generated Documentation

ABT-TASK:TLWS=a;

Warning: Once this command is entered, the consistency of all hardware states and data in use by the task is questionable.

- Purpose

  Aborts an active trunk and line workstation (TLWS) maintenance task.

- Explanation of Parameters

  a = Task identifier given to active TLWS maintenance tasks by the OP-JOBST command.

- Responses

  Only standard system responses apply.

Sample Parameter Definition

```
COMMAND {
  ..........

  PARAM tlws {
     TYPE {
          domain: num;
          min: 0;
          max: 15;
          default: 0;
          }
     desc: "Task identifier given to active TLWS
            maintenance tasks by the OP-JOBST command.";
     csymbol: task_id;
     }
}
```

A Parameterized Version of TLWS

```
PARAM lib_tlws( x ) {
   TYPE {
        domain: num;
        min: 0;
        max: 15;
        default: 0;
        }
   desc: "Task identifier given to active TLWS
          maintenance tasks by the OP-JOBST command.";
   csymbol: x;
   }
```

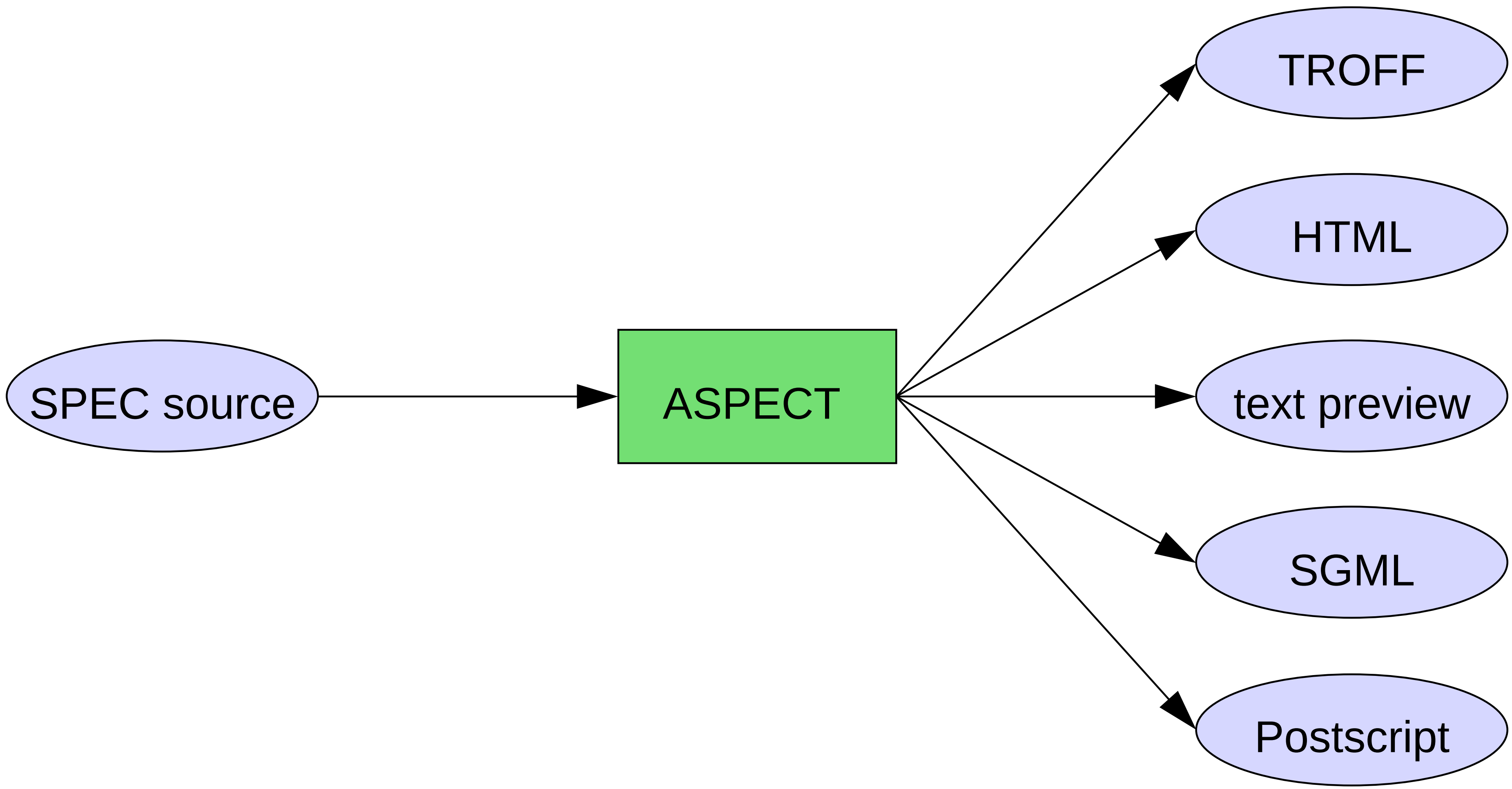
Reuse of TLWS

```
COMMAND {
  TEMPLATE {
    abt-task:tlws;
    purpose: "Aborts an active trunk and line workstation
             (TLWS) maintenance task.";
    warning: "Once this command is entered, the
             consistency of all hardware states and data
             in use by the task is questionable.";
    }

  PARAM tlws use lib_tlws( task_id )

}
```

Producing Multiple Documentation Formats



Designing the Translators

- existing parser generator tools used
- principles of software family development applied
- combined with SCR design process
- minimal toolset:
  - command translator
  - report translator
  - command documentation generator
  - report documentation generator
- much overlap between translators expected (commonalities)

Using the SCR Design Process

- information hiding hierarchy
  - module guide
  - uses relation
- ASPECT:
  - external interface module
    - ▷ . . .
  - behaviour hiding module
    - ▷ . . .
  - software decisions module
    - ▷ . . .
- result: substantial code reuse

ASPECT External Interface Module

- output drivers module
  - command format module
  - report format module
  - documentation format module
- library reference module
- device drivers module
  - text module
  - HTML module
  - formatter macros (TROFF) module
  - Postscript module
  - SGML module

ASPECT Behaviour Hiding Module

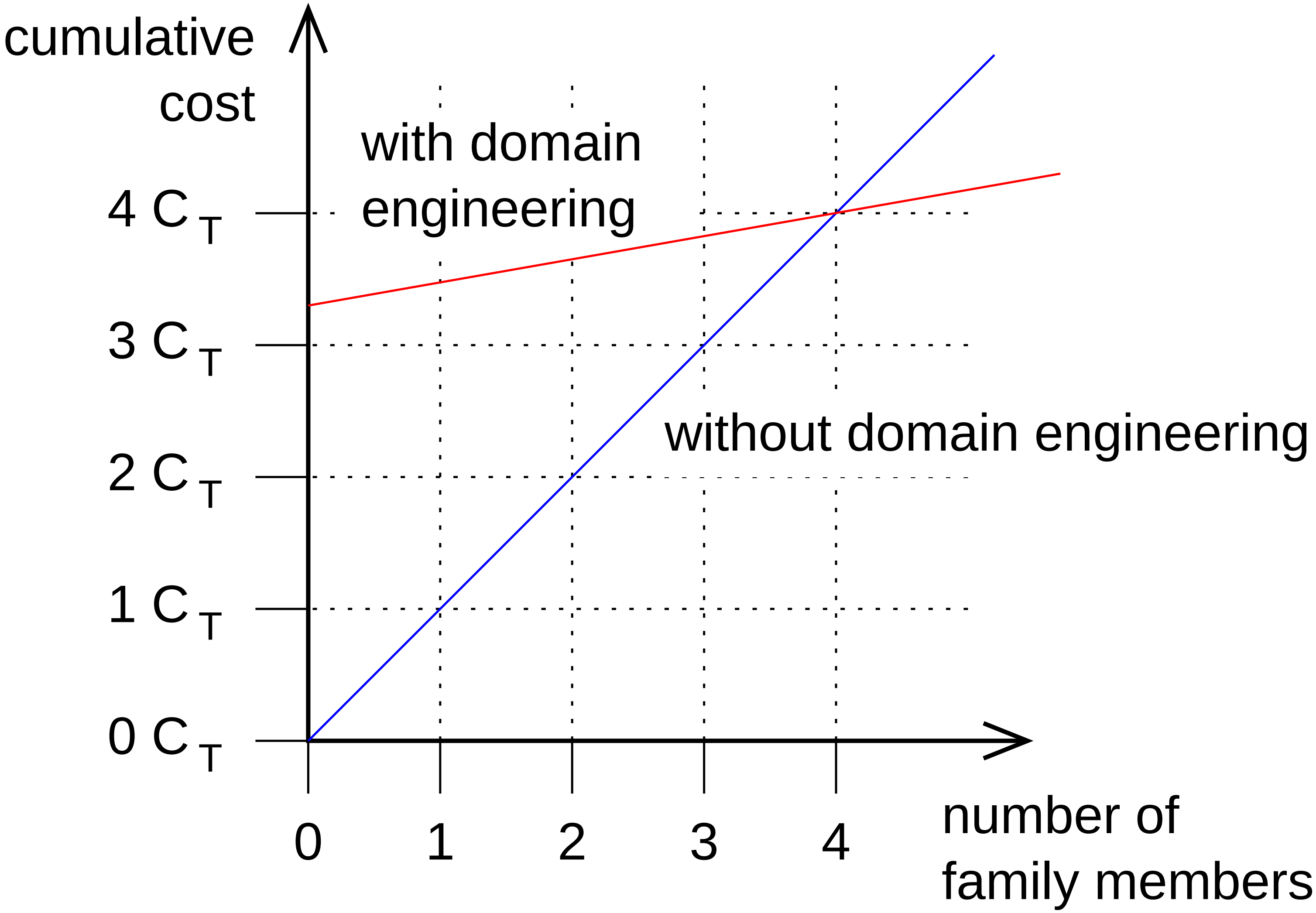
- tool builder module
- input command traversal module
- output report traversal module
- command documentation traversal module
- report documentation traversal module
- shared services module

ASPECT Software Decisions Module

- cross reference module
- database module
- domain translator module
- error recorder module
- global context module
- preprocessors module
  - alter structure module
  - alter syntax module
  - random access module

- semantic verification module
  - completeness module
  - consistency module
  - placement module
- specification expander module
- symbol reference module
- text function module
- text translation module
- global language data module
- system interface module
- transversal module

The Economics of FAST



Modelling the FAST Process

- there is a precise model for the FAST process
  - see [WeLa99]
- description of process models: PASTA approach (Process and Artifact State Transition Abstraction)
  - see [WeLa99]

Finding Domains where FAST is Worth Applying

- usually apply to legacy systems
- look for domain with
  - frequent, continuing change
  - change at high cost
  - predictable change
  - (quick change needed)
- do an informal or formal economic analysis

Applying FAST Incrementally

- early activities of FAST:
  better understanding of market, customers, requirements
  - facilitates communication, staff training, member design
  - modest cost
- later activities of FAST:
  make effective use of information and understanding
- apply FAST iteratively, e.g.:
  1. commonality analysis only, to make design more flexible
  2. introduce a rudimentary language
     to generate data structures changing most often
  3. expand language to generate majority of code

Transitioning to a FAST Process

- FAST process allows for gradual introduction into company
- early: staff learns to think in terms of families
  - test: can they predict future changes?
- later: use this thinking
- one way to start:
  - pick a few, high-leverage, well-understood domains
  - apply a simple version of FAST
  - several iterations
  - if you understand it and if it works,
    spread to more domains and more parts of company
- you might have to reengineer your organization later