Model-based Security Analysis for Mobile Communications

Jan Jürjens[1], Jörg Schreck[2], Peter Bartmann[3]

[1]Computing Department, The Open University, GB

[2]O2 (Germany)

[3]Univ. Augsburg, Germany

J.Jurjens@open.ac.uk

http://www.jurjens.de/jan

Mobile Communication Systems

Particularly complex and security-sensitive.

Various access media (WLAN, bluetooth, …), different standards, different security levels, with variations (e.g. “downwards compatible”)

Various enduser devices (laptop, mobile phone, …) with different OSs etc. Varying kinds of protection mechanisms.

Variations of security requirements (different architectural levels, strengths of protection, …).

Security challenges: Resource contraints. Not always online. Spontaneous usage.

➔ Several thousand combinations of the above. Need automated tools to analyze for security.

Industrial Application

Considered part of corporate security architecture and security policies for mobile communication systems at O_2 (Germany).

Modelled and analyzed security-critical parts using UMLsec and related tool-support.

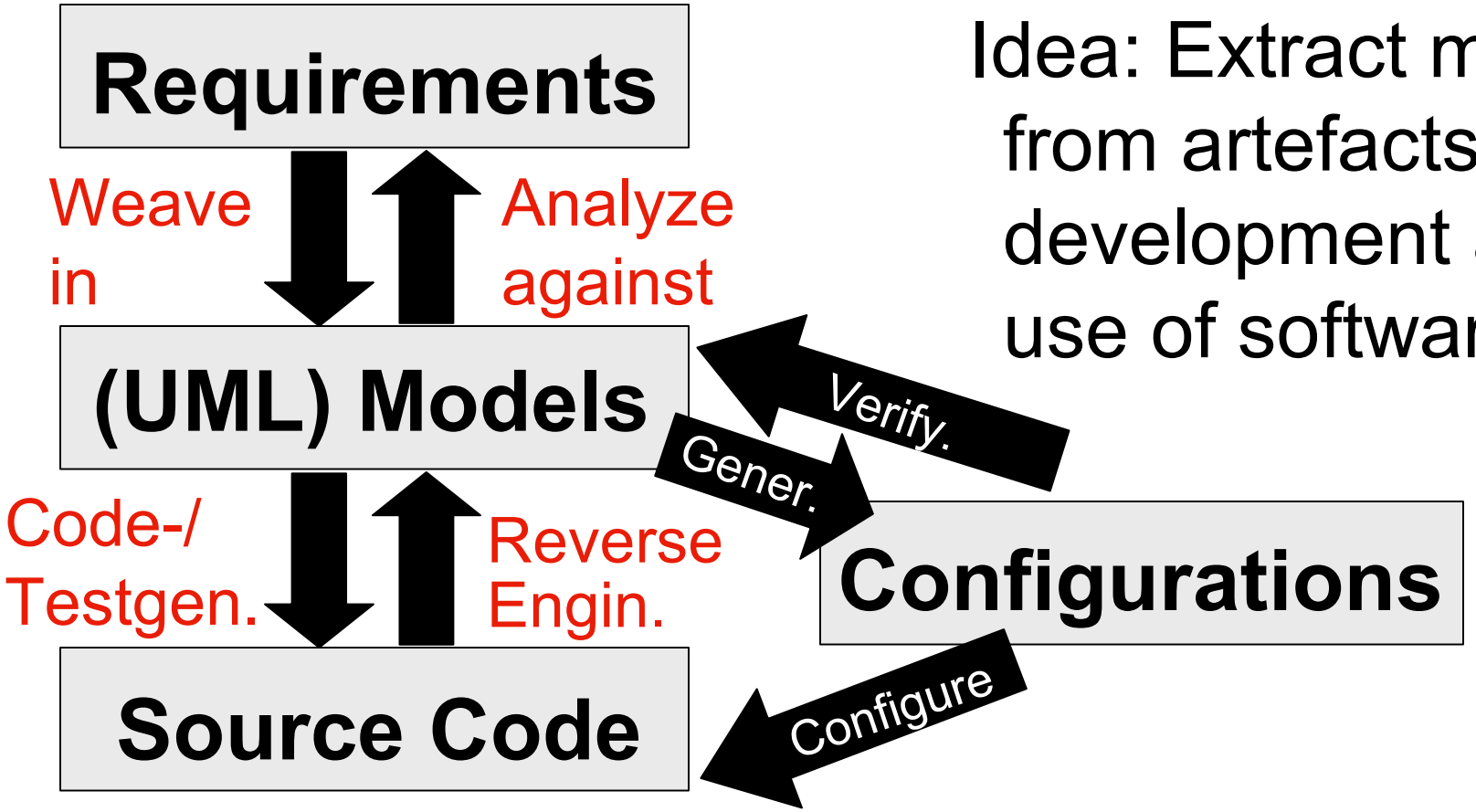
Scientific goal: investigate use of UMLsec in industrial telecommunications context, show benefits and limitations.

Evaluation Criteria (from Partner)

Goal: Evaluate security analysis approach under following criteria:

- Reproducability
- Delegatability
- Efficiency
- Parallelization
- Traceability
- Expressiveness

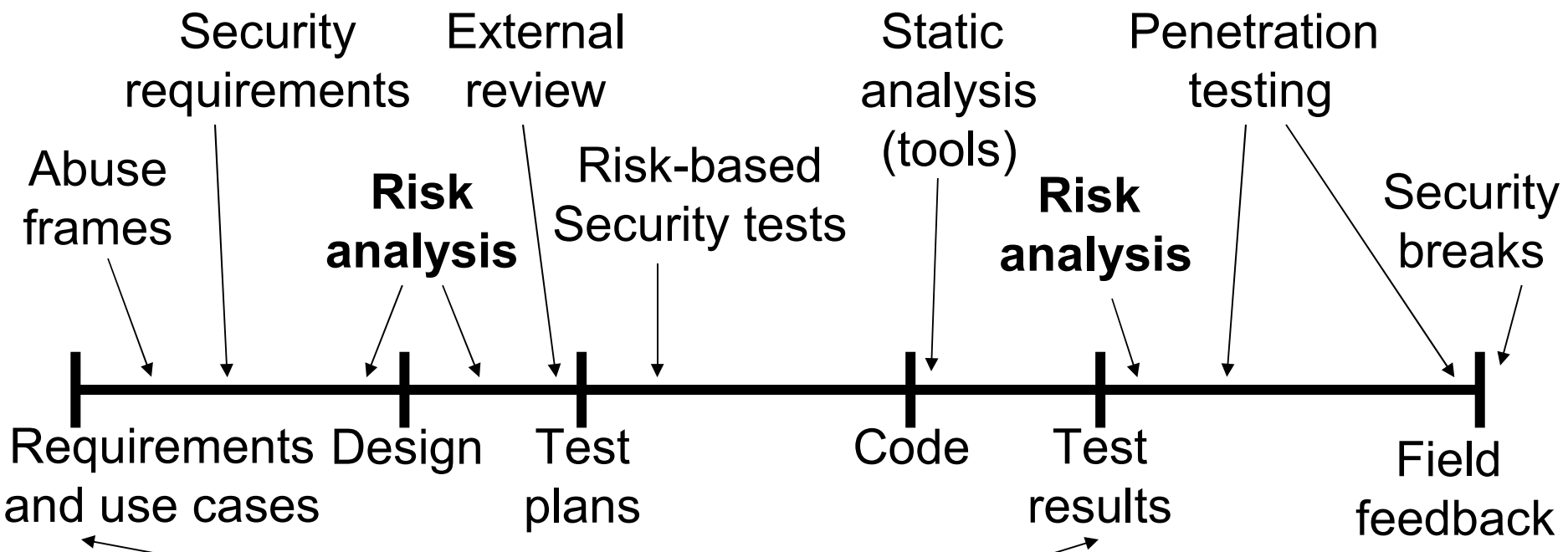
Model-based Security Engineering



Idea: Extract models from artefacts in development and use of software.

➔ Tool-supported, theoretically sound, efficient automated security design & analysis.

Secure System Lifecycle



Model-based Security Engineering

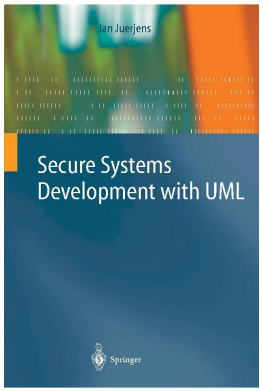
[McGraw 2003]

Design: Encapsulate prudent security engineering rules.
Analysis: Formally based, automated, efficient tools.
Note: emphasis on high-level requirements.

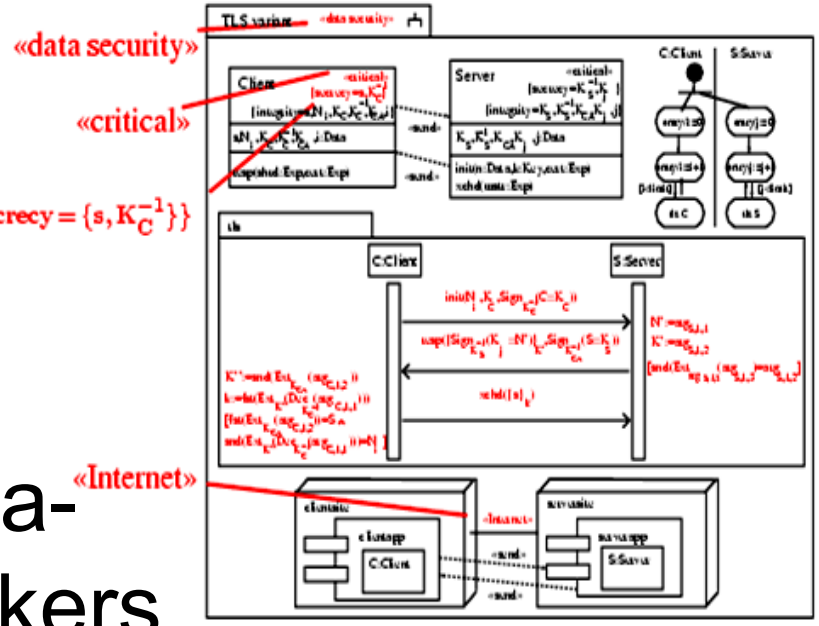
Model-based Security with UMLsec

Extension of the Unified Modeling Language (UML) for secure systems development.

- evaluate UML models for security
- encapsulate established rules of prudent secure engineering
- make available to developers not specialized in secure systems
- consider security requirements from early design phases, in system context
- can use in certification



UMLsec



Insert recurring security requirements, adversary scenarios, security mechanisms as predefined markers.

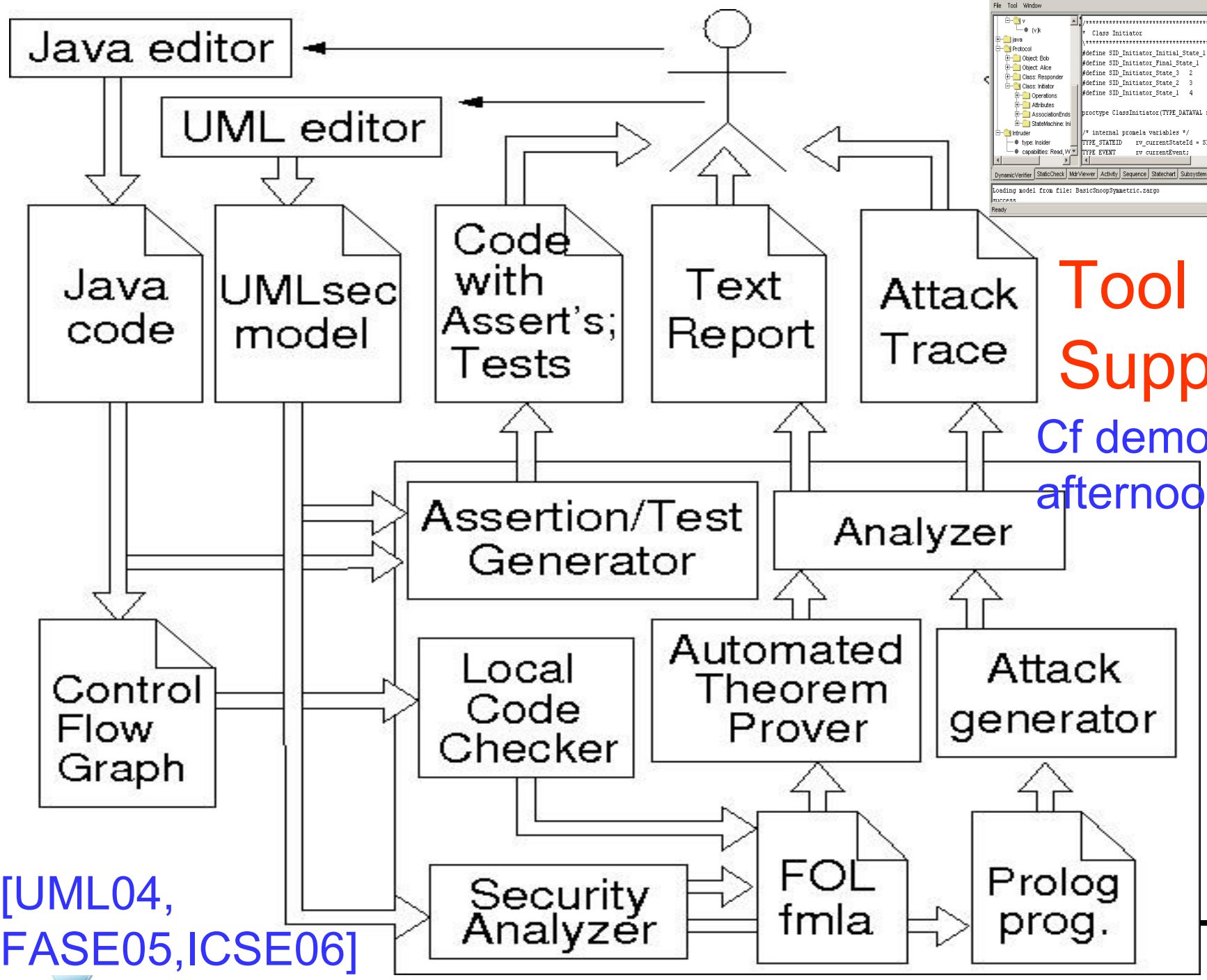
Use associated logical constraints to verify specifications using model checkers and ATPs based on formal semantics.

Ensures that UML specification enforces the relevant security requirements wrt Dolev-Yao type adversaries. [FASE01,UML02,ICSE05]

Tool Support

For example:

- consistency checks
- mechanical analysis of complicated requirements on model level (bindings to model-checkers, constraint solvers, automated theorem provers, …)
- code generation
- test-sequence generation
- configuration data analysis against UML.

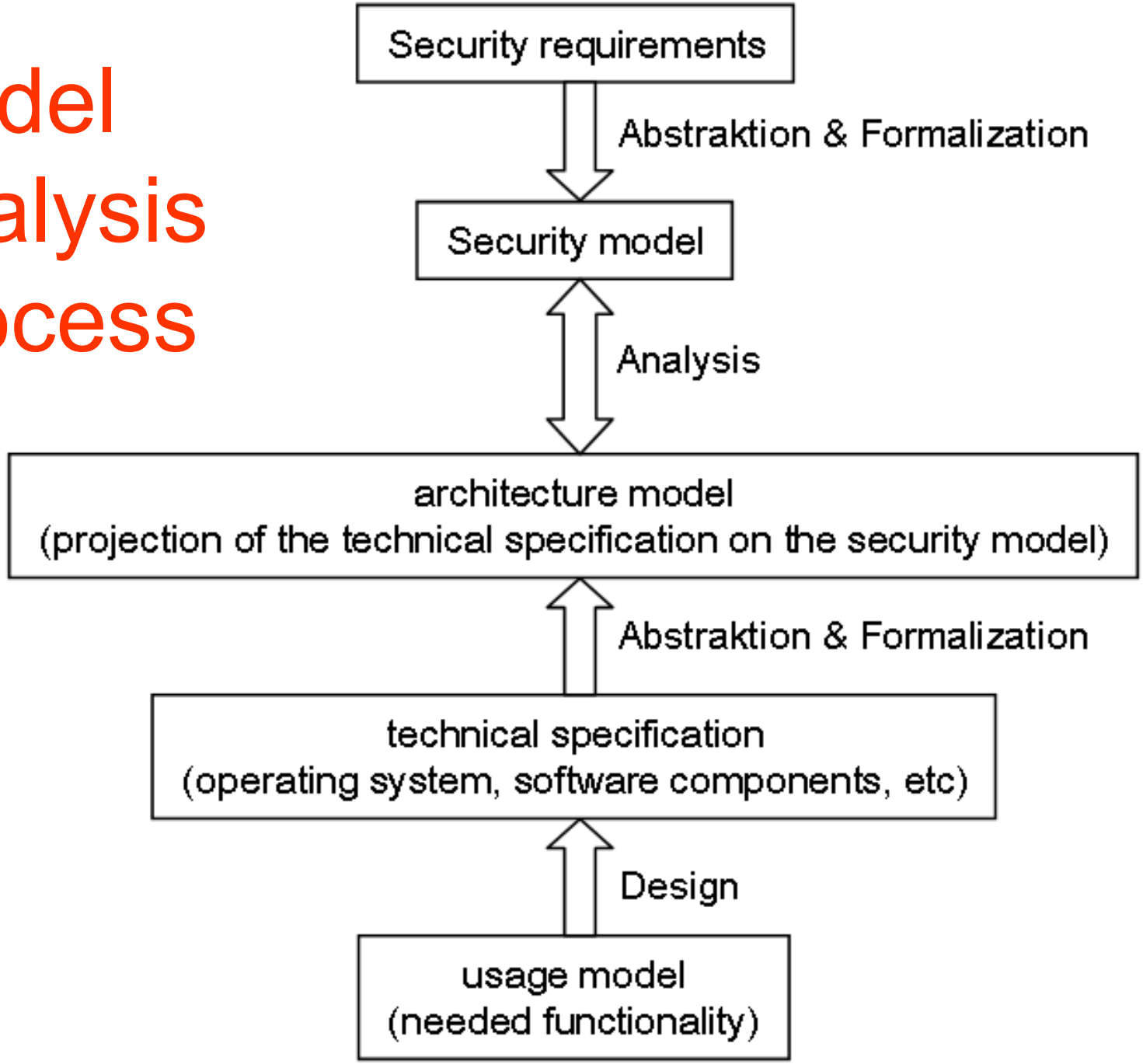


Tool Support

Cf demo this afternoon

[UML04, FASE05,ICSE06]

Model Analysis Process

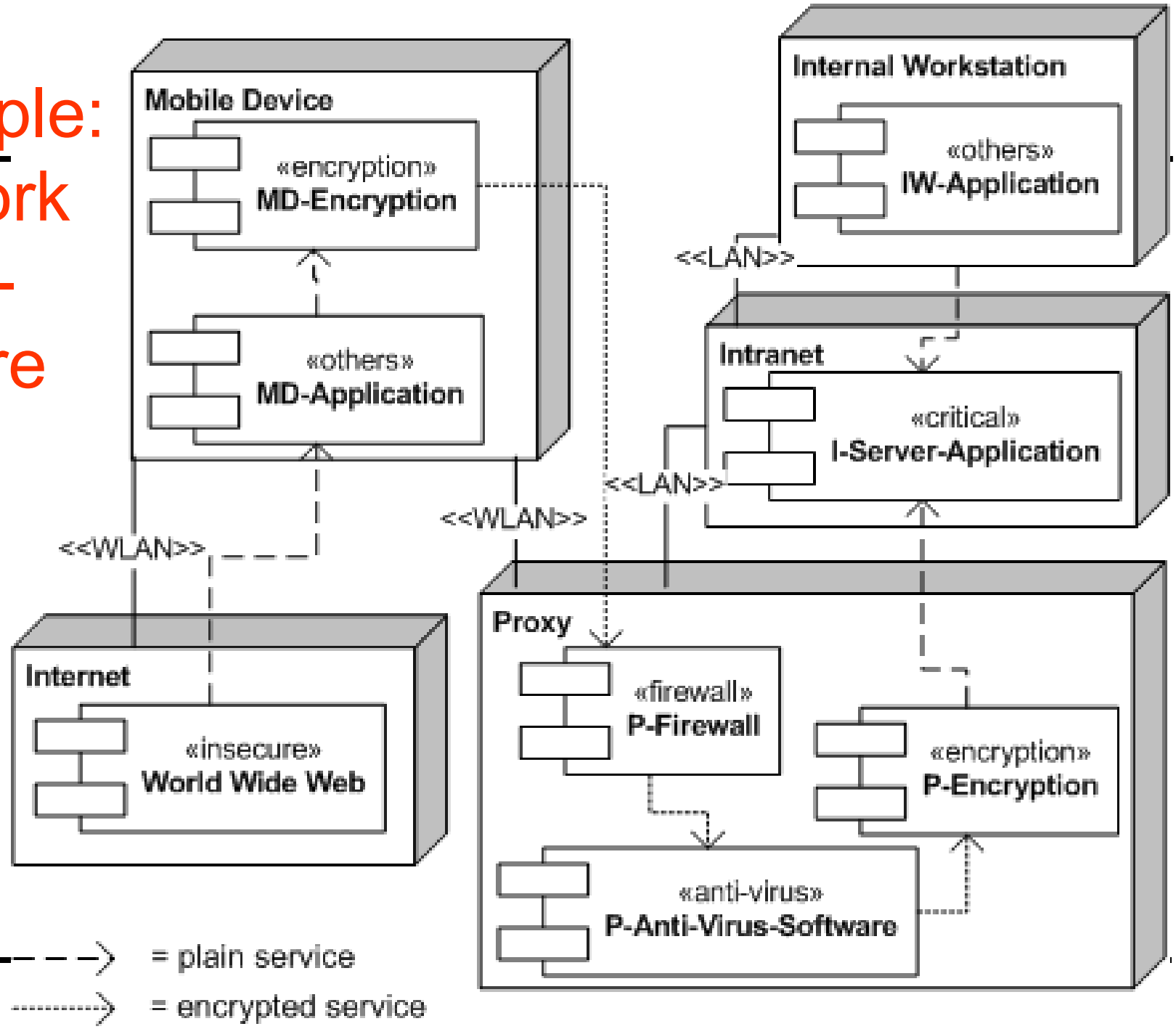


Analysis

Extracted 62 security requirements from security policy documents.

- 21 process-related requ. captured in 8 activity diagrams using stereotypes <<fair exchange>> and <<provable>>
- 10 requ. regarding secrecy and integrity of data on physical layer, in 1 deployment diag.
- 3 requ. regarding RBAC
- 15 requ. regarding security of network services / dataflow wrt. use of firewalls / anti-virus software (extension to UMLsec)
- 13 requ.: no appropriate representation in UMLsec

Example: Network Archi-tecture



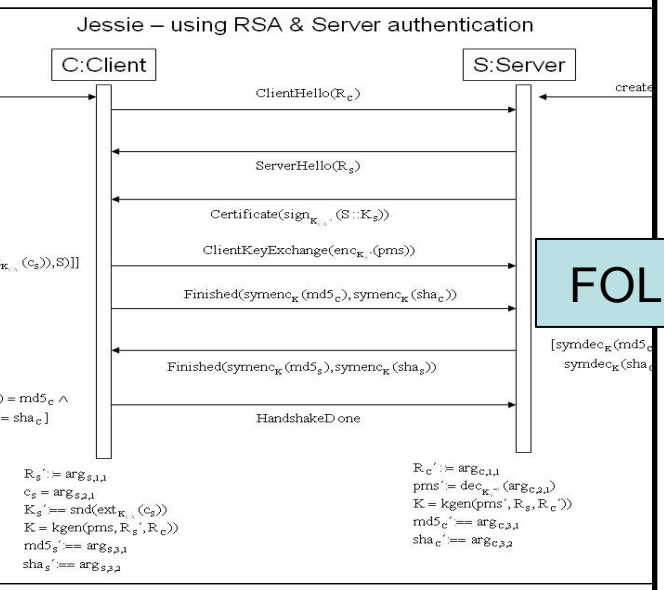
Architecture, Data Flow, Sec. Req. in FOL

```
input_formula(network_architecture_model,axiom,(
  is_component_of(internal_workstation,iw-application) &
  is_component_of(intranet,i-server-application) &
  type_of_component(iw-application,others) &
  type_of_component(i-server-application,critical) &
  access_media_availability(internal_workstation,lan) &
  access_media_availability(intranet,lan) &
  service_on_access_media(http,lan) &
  connection(service,iw-application,i-server-application,
    http,plaindata))).

input_formula(connection_of_service_to_connection_of_dataflow,axiom,(
! [ComponentX,ComponentY,Service,DataEnc] : ( (
  connection(service,ComponentX,ComponentY,Service,DataEnc) ) => (
    connection(dataflow,ComponentX,ComponentY,Service,DataEnc) &
    connection(dataflow,ComponentY,ComponentX,Service,DataEnc))))).


input_formula(requirement_1,conjecture,(
? [ComponentX,ComponentY,Service] : (
  connection_without_firewall_regulation
    (dataflow,ComponentX,ComponentY,Service,plaindata)&
  type_of_component(ComponentX,insecure) &
  type_of_component(ComponentY,critical)) )).
```

Formal Security Analysis



FOL

```
...
((
  knows(ArgC_3)
  & (equal(fst(ArgC_3), type_serverkeyexchange))
  & (equal(snd(ext(snd(snd(ArgC_3)), k_ca)), skey))
  & (equal(snd(ext(snd(ArgC_2), k_ca)), fst(snd(ArgC_3))))
)
=>(
  ((knows(ArgC_4_1)
    & equal(ArgC_4_1, type_serverhellodone))
    =>(
  ( ( true & equal(ClientKeyExchange, enc(premasterkey, skey))
)
...
%------------------------ Conjecture --

input_formula(attack,conjecture,(
   knows(mastersecret) )).
```

ATP

```
analyzing results ...
model found/total failure
time limit information: 19 total / 18 strategy
(leaving wrapper).
task myUML_PID1491 on atbroy1 has status SUCCESS
(model found by strategy 300) consuming 1 seconds
deleting temporary files.
e-SETHEO done. exiting
```

Security Analysis Results

The security properties that were considered were found to be enforced (examples with details in paper).

Note: 100% security proof is impossible for principled reasons. Goal is optimal cost effectiveness for finding weaknesses in highly security-critical system parts.

Revisit Evaluation Criteria

Evaluated security analysis approach under following criteria:

- Reproducability
- Delegatability
- Efficiency
- Parallelization
- Traceability
- Expressiveness

Some Insights

- Model-based development with notations such as UML does incur effort.
- That effort seems manageable when applied to core critical parts of the system.
- It seems to be justifiable in case of high assurance needs (e.g. in security).
- We believe it to compare favorably with traditional assurance methods offering a similar degree of trustworthiness.
- UMLsec seems to be well-suited for the domain of mobile communication systems.

Possible Improvements

Experiences indicated potential improvements:

- extend notation further (e.g. to cover remaining 13 requirements)
- provide tool support for these extensions
- improve simplicity of parts of the existing tool support

Link models to code using model-based monitor generation or testing [cf SESS talk tomorrow].

Some Other Applications

Analyzed designs / implementations / configurations for

- biometry, smart-card or RFID based identification
- authentication (crypto protocols)
- authorization (user permissions, e.g. SAP systems)

Analyzed security policies, e.g. for privacy regulations.

T··Systems·

Allianz

Deutsche Bank

HypoVereinsbank

CEPS™

BMW Group

msg systems

Münchener Rück
Munich Re Group

Bundesministerium für Bildung und Forschung

Bundesministerium der Verteidigung

O2

infineon

Bundesministerium für Wirtschaft und Technologie

Some Related Work

Other applications of UMLsec:

- Apvrille, Pourzandi (IEEE Security & Privacy, 2005)
- Best, Jurjens, Nuseibeh (ICSE 2007)

Other approaches for UML + security:

- RBAC: Fernandez et al., Basin et al., Breu et al., Koch/Parisi-Presicce, …
- Aspect-Oriented Modeling (France et al.)
- Model-based Risk Assessment (CORAS project, Stoelen, Houmb et al.)
- Agents: Yoshioka, Honiden, Finkelstein
- Misuse cases: Whittle (earlier this conf.)
- …

Conclusions

Application of the UMLsec approach in industrial setting.

Model-based security analysis of mobile communications architecture and related security policies. Benefits were:

- consideration of security goals within a standard industrial design technique
- automated security analysis

The approach was found to be applicable with justifiable training and time effort.