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Corporate Technology

# Formal security analysis and security certification in industry

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Guest lecture on invitation by Prof. Peter Hartmann, Landshut Univ. of Appl. Sci., Germany, 08 Dec 2010

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## Overview

- **IT Security at Siemens Corporate Technology**
- Software distribution systems
- Common Criteria certification
- Formal security analysis
- Research project AVANTSSAR
- Example: Needham-Schroeder protocol

# Corporate Technology: Role within Siemens

Networking the integrated technology company

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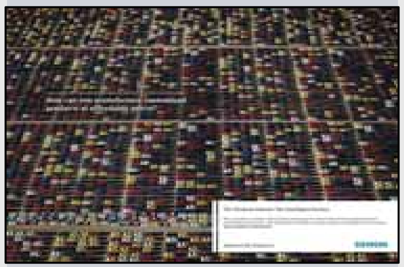
Customers

**Chief Technology Officer (CTO)**

- Review innovation strategies
- Drive technology based synergies
- Secure innovation power
- Technology assessments
- Governance and guidance

**Sectors / Divisions**

**Industry**



**Energy**

**Healthcare**

**Siemens IT Solutions and Services (SIS)**
**Siemens Financial Services (SFS)**

**Regions**

**Chief Technology Office (CT O)**

- Direct support of CTO

**Corporate Research and Technologies (CT T)**

- **Global Technology Fields** with multiple impact
- Pictures of the Future
- Accelerators

**Corporate Development Center (CT DC)**

- Software development partner for the Sectors

**Corporate Intellectual Property and Functions (CT I)**

- Intellectual Property services & strategy
- Standardization, environmental affairs
- Global information research

**Corporate Technology (CT)**

# Corporate Technology: around 3,000 R&D employees

Present in all leading markets and technology hot spots

# GTF IT-Security – Competences ensure innovation for secure processes and protection of critical infrastructure

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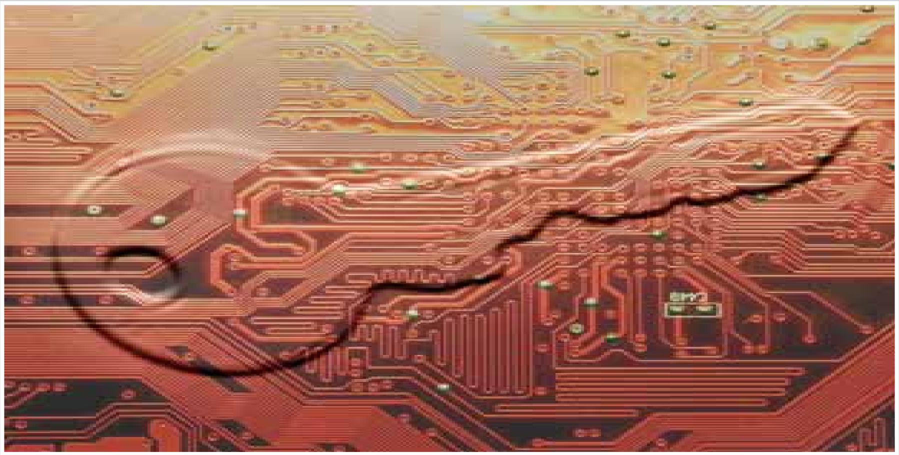
## Competences Areas



### Communication and Network Security

- Secure Communication Protocols and IP-based Architectures
- Sensor & Surveillance Security
- Security for Industrial Networks, Traffic Environments, and Building Technologies

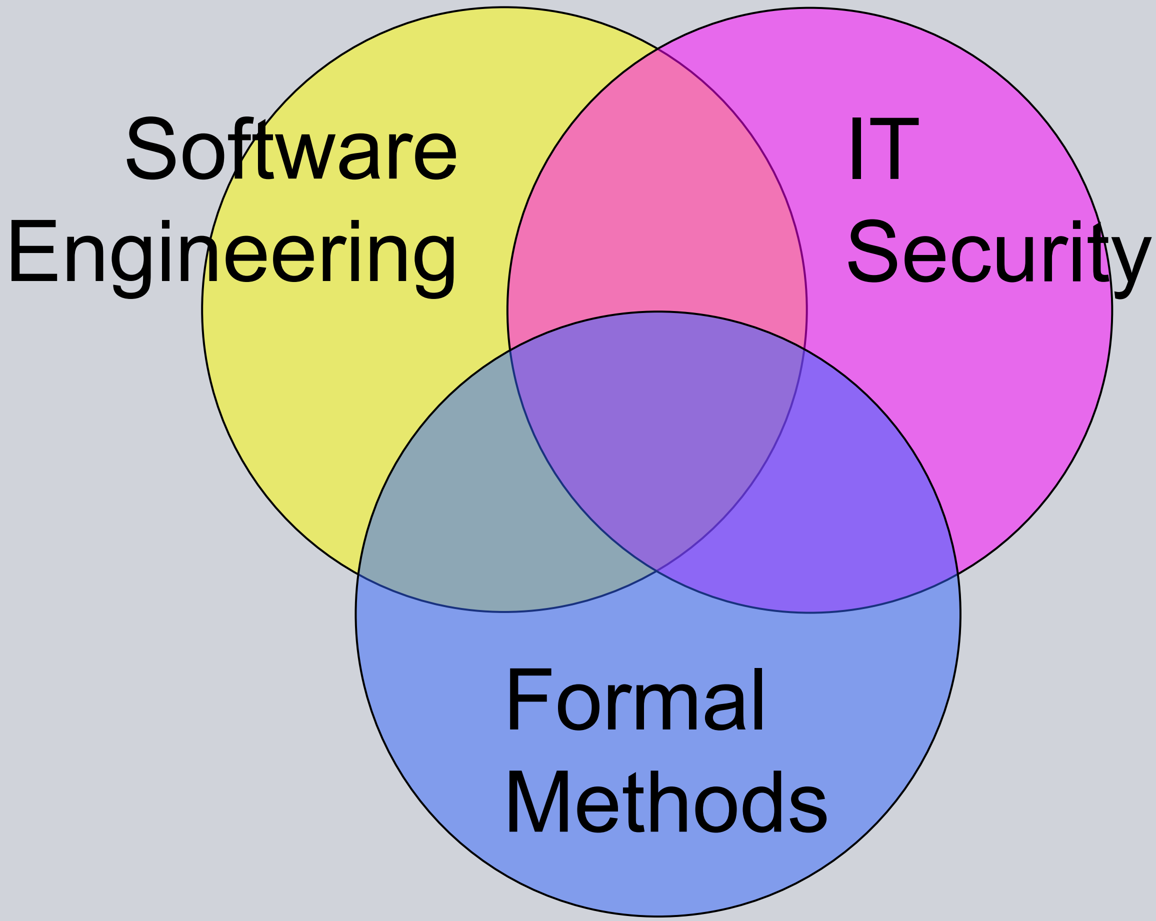
### Application Security & Methods

- Secure Service Oriented Architectures
- Enterprise Rights Management
- Trusted Computing
- Control Systems & SCADA Security
- Certification Support & Formal Methods

### Cryptography

- Security for Embedded Systems
- RFId Security
- Anti-counterfeiting / anti-piracy
- Side Channel Attack Robustness

# Fields



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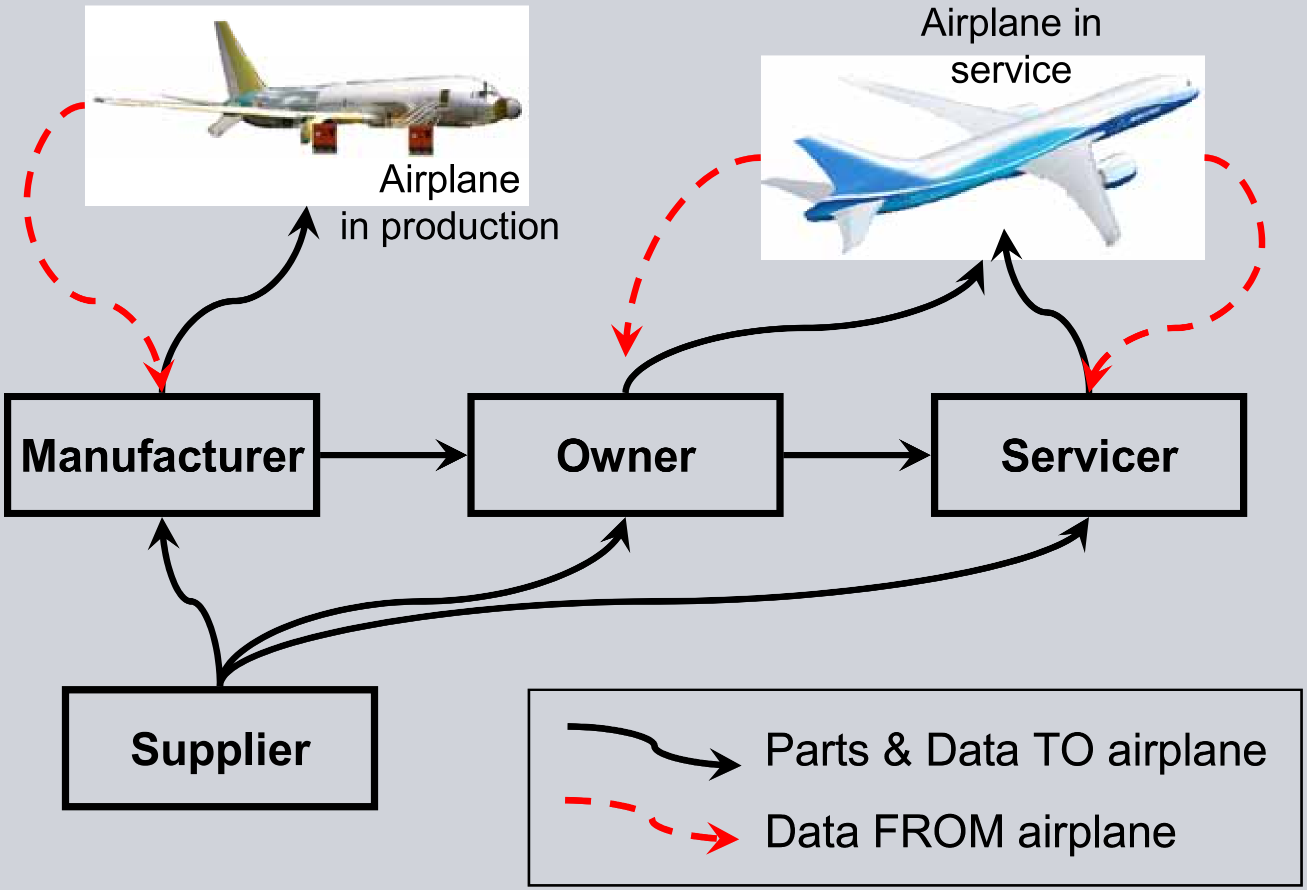
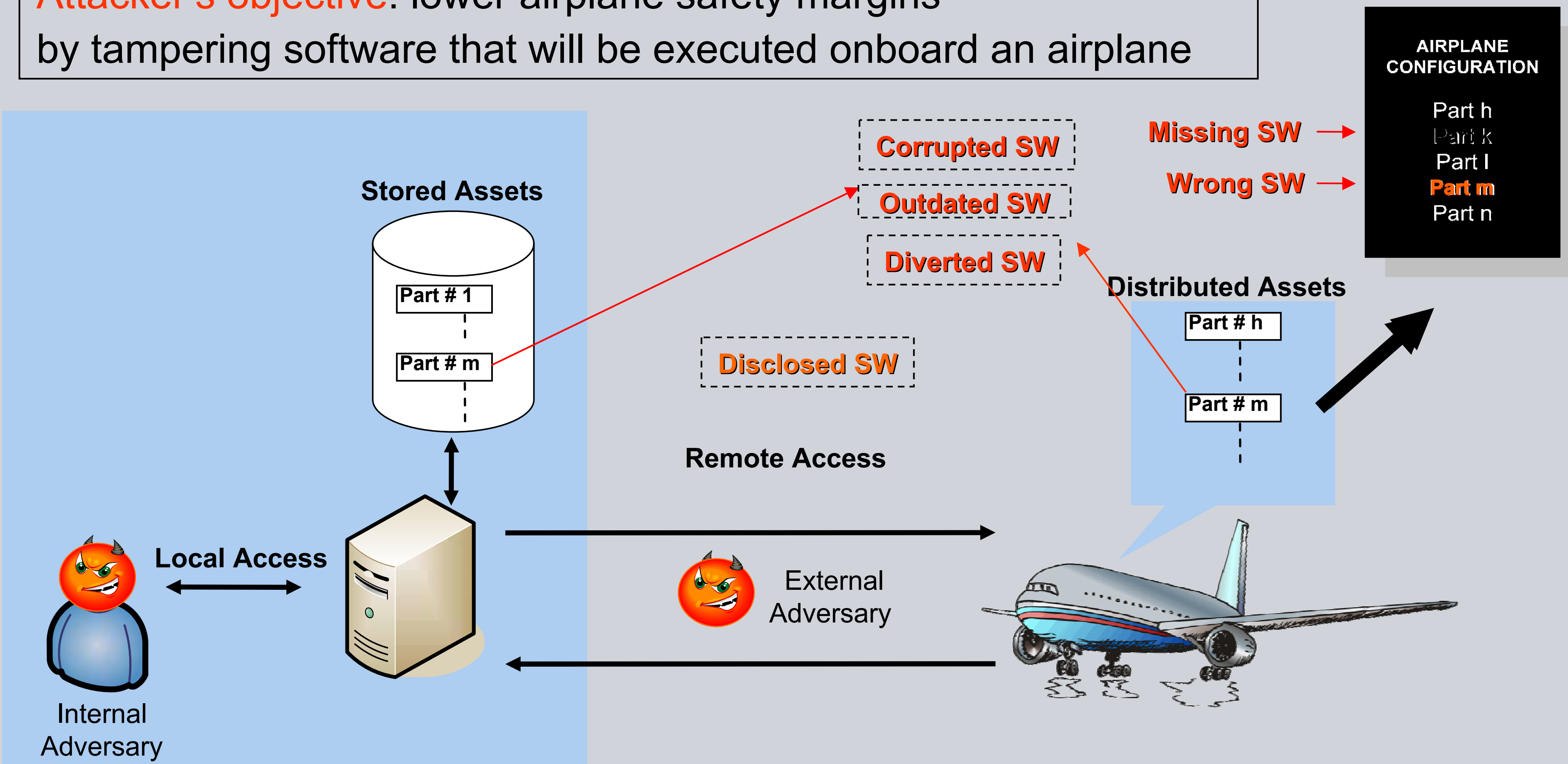
## Airplane Assets Distribution System (AADS)

AADS is a system for storage and distribution of airplane assets, including *Loadable Software Airplane Parts* (LSAP) and airplane health data



# Security threats at the AADS example

Attacker's objective: lower airplane safety margins
by tampering software that will be executed onboard an airplane




**Corruption/Injection** **Wrong Version** **Diversion** **Disclosure**

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## IT Security as a System Engineering Problem

- IT security aims at preventing, or at least detecting, unauthorized actions by agents in an IT system.

In the AADS context, security is a prerequisite of safety.

- Safety aims at the absence of accidents (→ airworthiness)

Situation: security loopholes in IT systems actively exploited

Objective: thwart attacks by eliminating vulnerabilities

Difficulty: IT systems are very complex. Security is interwoven with the whole system, so very hard to assess.

Remedy: evaluate system following the Common Criteria approach

- address security systematically in all development phases
- perform document & code reviews and tests
- for maximal assurance, use formal modeling and analysis

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# Common Criteria (CC) for IT security evaluation

Common Criteria

product-oriented methodology

for IT security assessment

**ISO**/IEC **standard** 15408

Current version: 3.1R3 of Jul 2009

**Aim:** gain confidence in the security of a system

- What are the objectives the system should achieve?
- Are the measures employed appropriate to achieve them?
- Are the measures implemented and deployed correctly?

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## CC: General Approach

**Approach**: assessment of system + documents by neutral experts

- Gaining understanding of the system's security functionality
- Checking evidence that the functionality is correctly implemented
- Checking evidence that the system integrity is maintained

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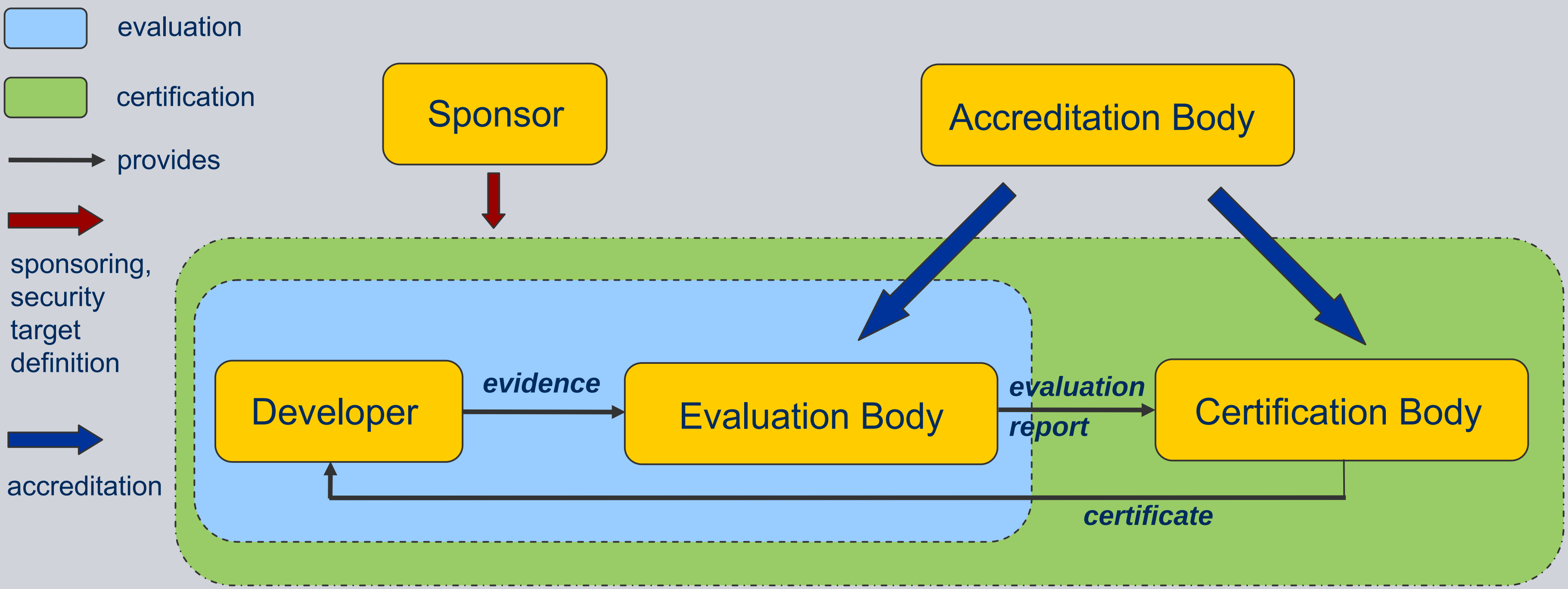
# CC: Process Scheme




Certification according to the Common Criteria is a rather complex, time consuming and expensive process.

A successful, approved evaluation is awarded a certificate.

## CC: Security Targets

**Security Target (ST)**: defines extent and depth of the evaluation
for a specific product called *Target of Evaluation (TOE)*

**Protection Profile (PP)**: defines extent and depth of the evaluation
for a whole class of products, i.e. firewalls

STs and PPs may inherit (‘*claim*’) other PPs.

ST and PP specifications use **generic** “construction kit”:

- Building blocks for defining *Security Functional Requirements (SFRs)*
- Scalable in depth and rigor: *Security Assurance Requirements (SARs)*
layered as *Evaluation Assurance Levels (EALs)*

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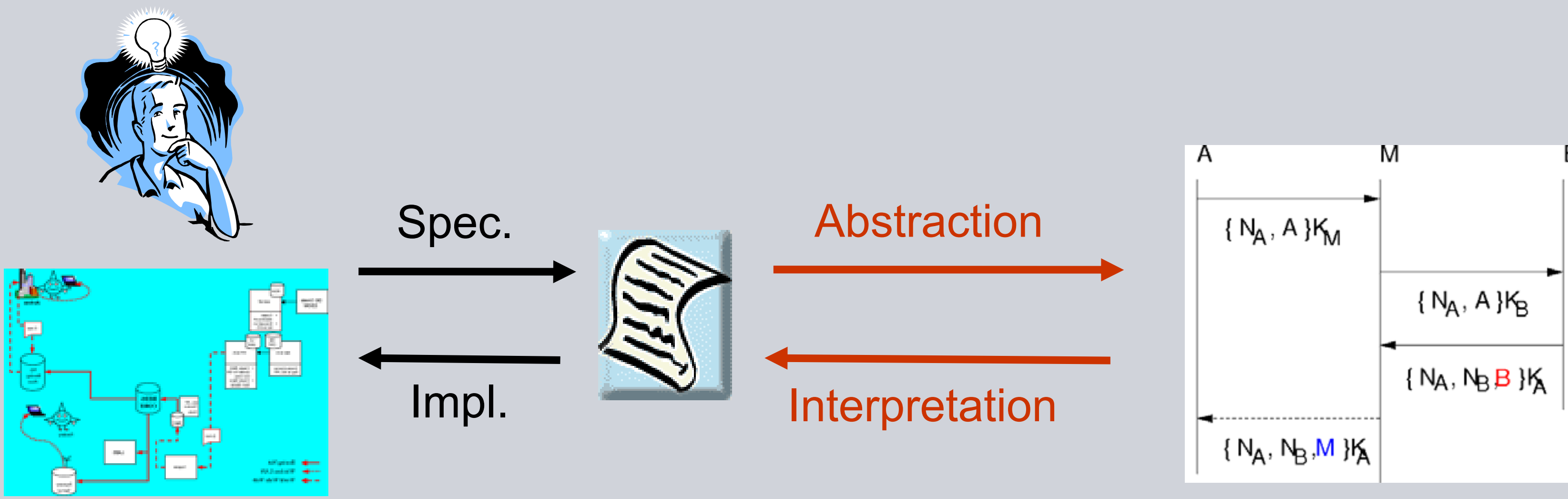
# Formal Security Analysis: Approach and Benefits

Mission: security analysis with maximal precision
Approach: formal modeling and verification




Improving the quality of the system specification

Checking for the existence of security loopholes

High-level protocol/system specification lang.
- Model checkers (AVANTSSAR tools)

HOL, Interacting State Machines, etc.
- Interactive theorem prover (Isabelle)

## Formal Security Models

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- A security policy defines what is allowed (actions, data flow, ...) typically by a relationship between subjects and objects.
- A security model is a (+/- formal) description of a policy and enforcing mechanisms, usually in terms of system states or state sequences (traces).
- Security verification proves that mechanisms enforce policy.
- Models focus on specific characteristics of the reality (policies).
- Types of formal security models
  - Automata models
  - Access Control models
  - Information Flow models
  - Cryptoprotocol models

# Cryptoprotocol models

- Describe message exchange between processes or principals


- Take cryptographic operations as perfect primitives
- Describe system with specialized modeling languages
- State secrecy, authentication, . . . goals
- Verify (mostly) automatically using model-checkers

EU project AVISPA , AVANTSSAR

 

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AVANTSSAR

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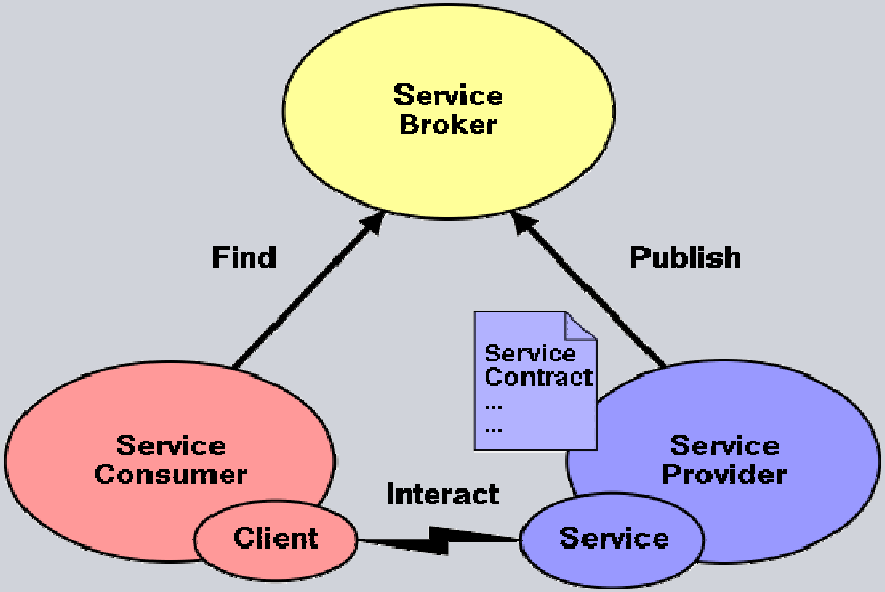
avantssar.eu

# Model-checking SOA security — research project AVANTSSAR[1]




[1] **A**utomated **V**alidatio**N** of **T**rust and **S**ecurity of **S**ervice-oriented **Ar**chitectures

***FP7-2007-ICT-1, ICT-1.1.4, STREP project no. 216471***
***Jan 2008 - Dec 2010, 590 PMs, 6M€ budget, 3.8M€ EC contribution***

# AVANTSSAR project motivation

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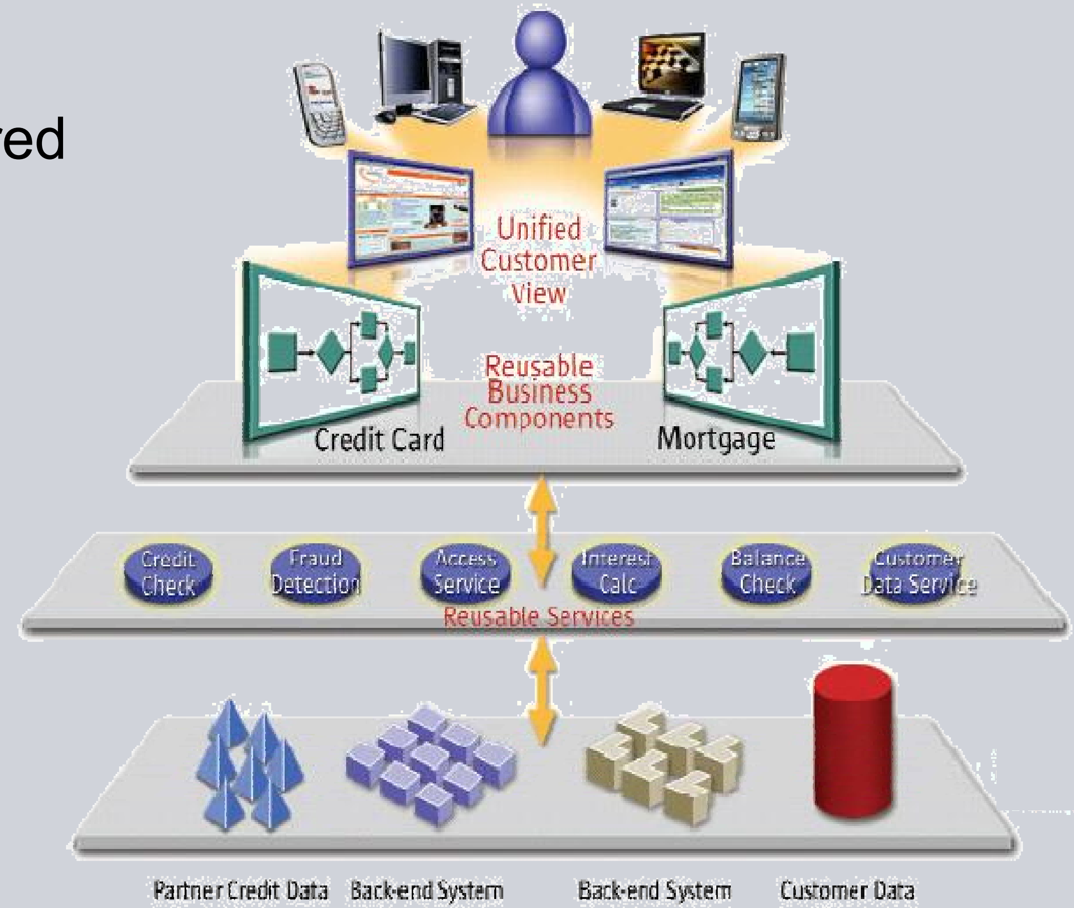
ICT paradigm shift: from components to services, composed and reconfigured dynamically in a demand-driven way.

Trustworthy service may interact with others causing novel trust and security problems.

For the composition of individual services into service-oriented architectures, validation is dramatically needed.



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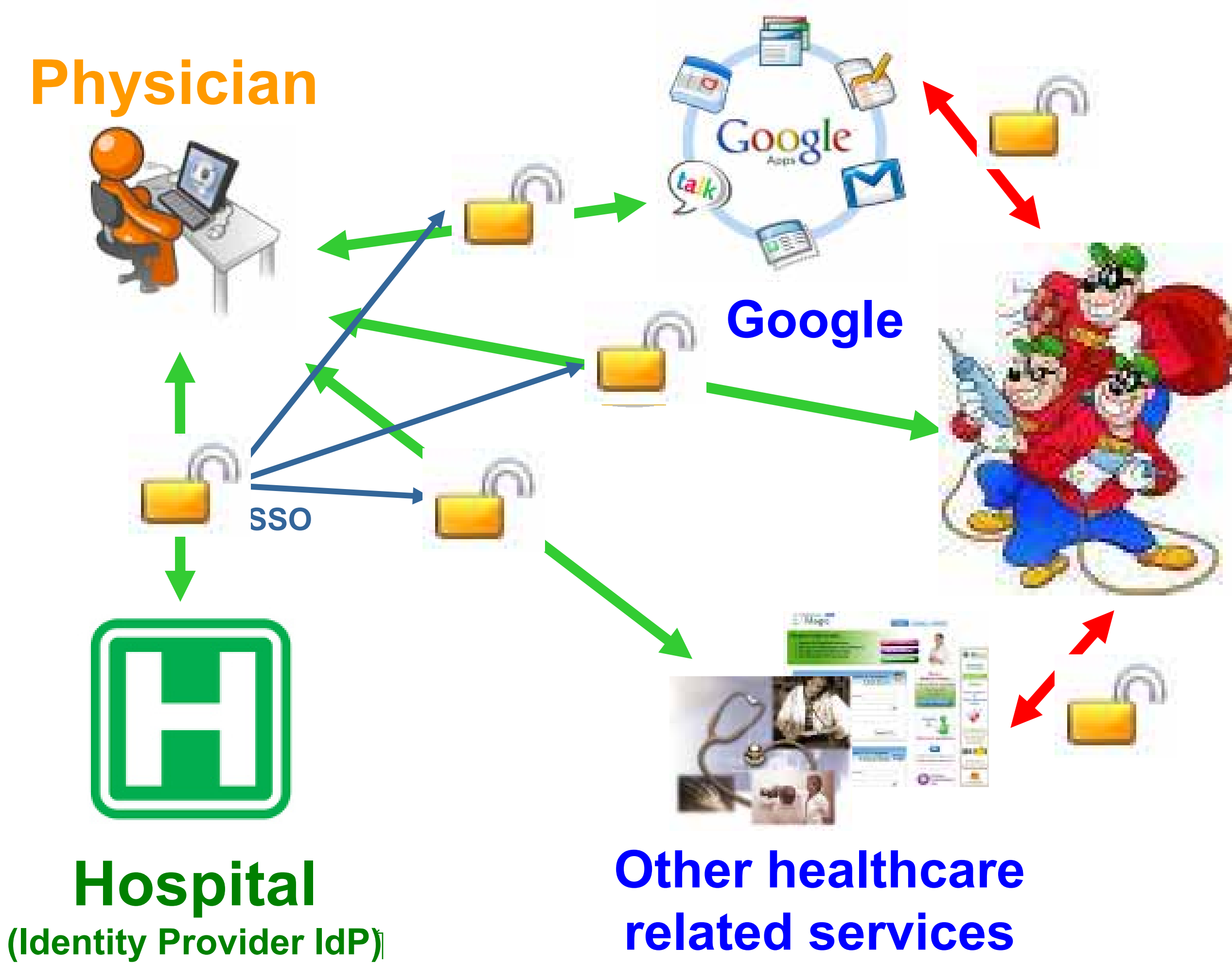
# Example 1: Google SAML-based Single Sign-On (SSO)




**A malicious service provider can access the data of the physician located at all other services connected via Google SSO**

# Example 1: Google SAML SSO protocol flaw

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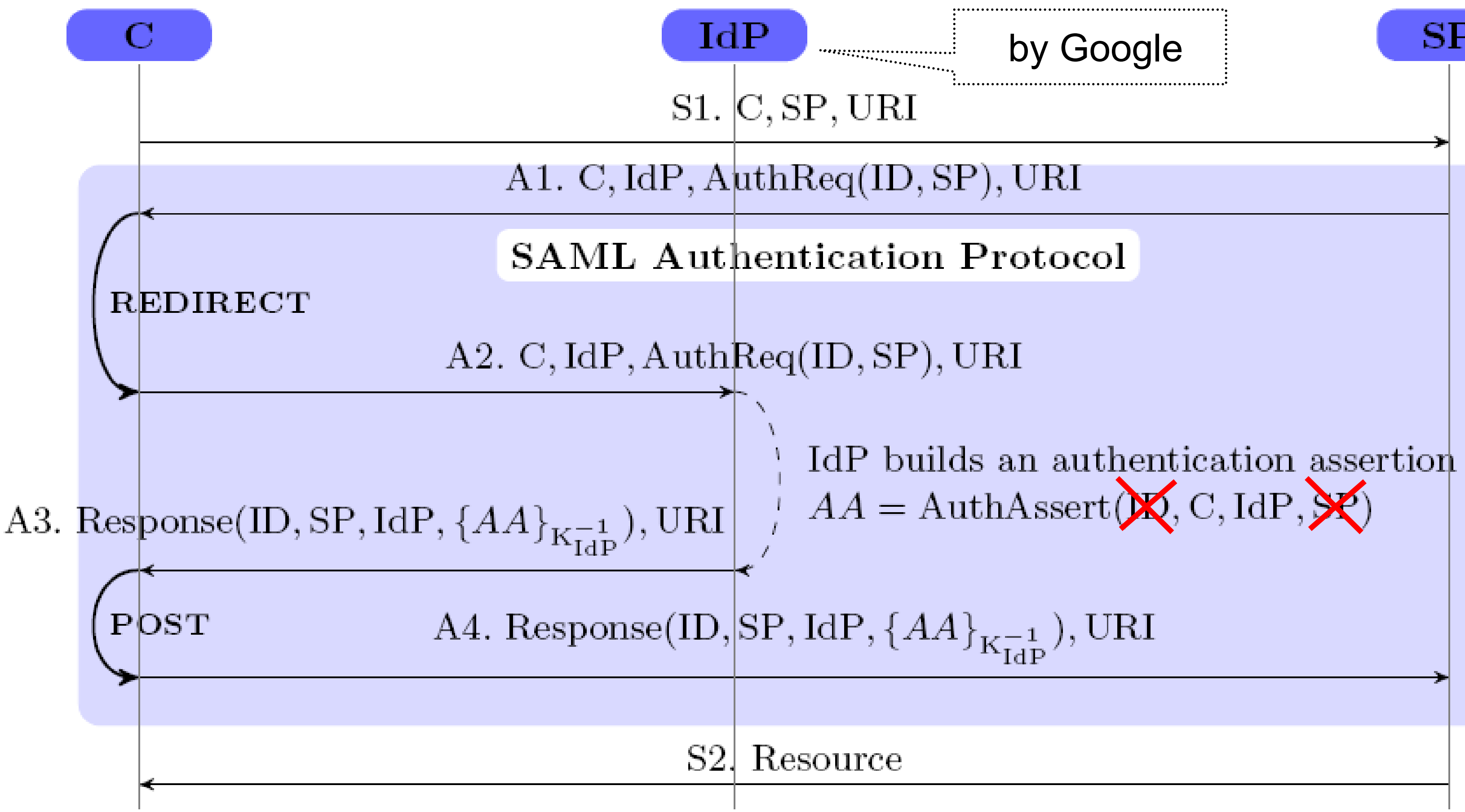


**Fig. 1.** SP-Initiated SSO with Redirect/POST Bindings

# AVANTSSAR consortium

**Industry**

*SAP Research France, Sophia Antipolis*

*Siemens Corporate Technology, München*

IBM Zürich Research Labs (initial two years)

OpenTrust, Paris

**Academia**

Università di Verona

*Università di Genova*

*ETH Zürich*

*INRIA Lorraine*

UPS-IRIT, Toulouse

IEAT, Timişoara

**Expertise**

Service-oriented enterprise architectures

Security solutions

Standardization and industry migration

Security engineering

Formal methods

Automated security validation

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# AVANTSSAR main objectives and principles

**AVANTSSAR product: Platform for formal specification and automated validation of trust and security of SOAs**

- Formal language for specifying trust and security properties of services, their policies, and their composition into service-oriented architectures
- Automated toolset supporting the above
- Library of validated industry-relevant case studies

**Migration of platform to industry and standardization organizations**

- Speed up development of new service infrastructures
- Enhance their security and robustness
- Increase public acceptance of SOA-based systems

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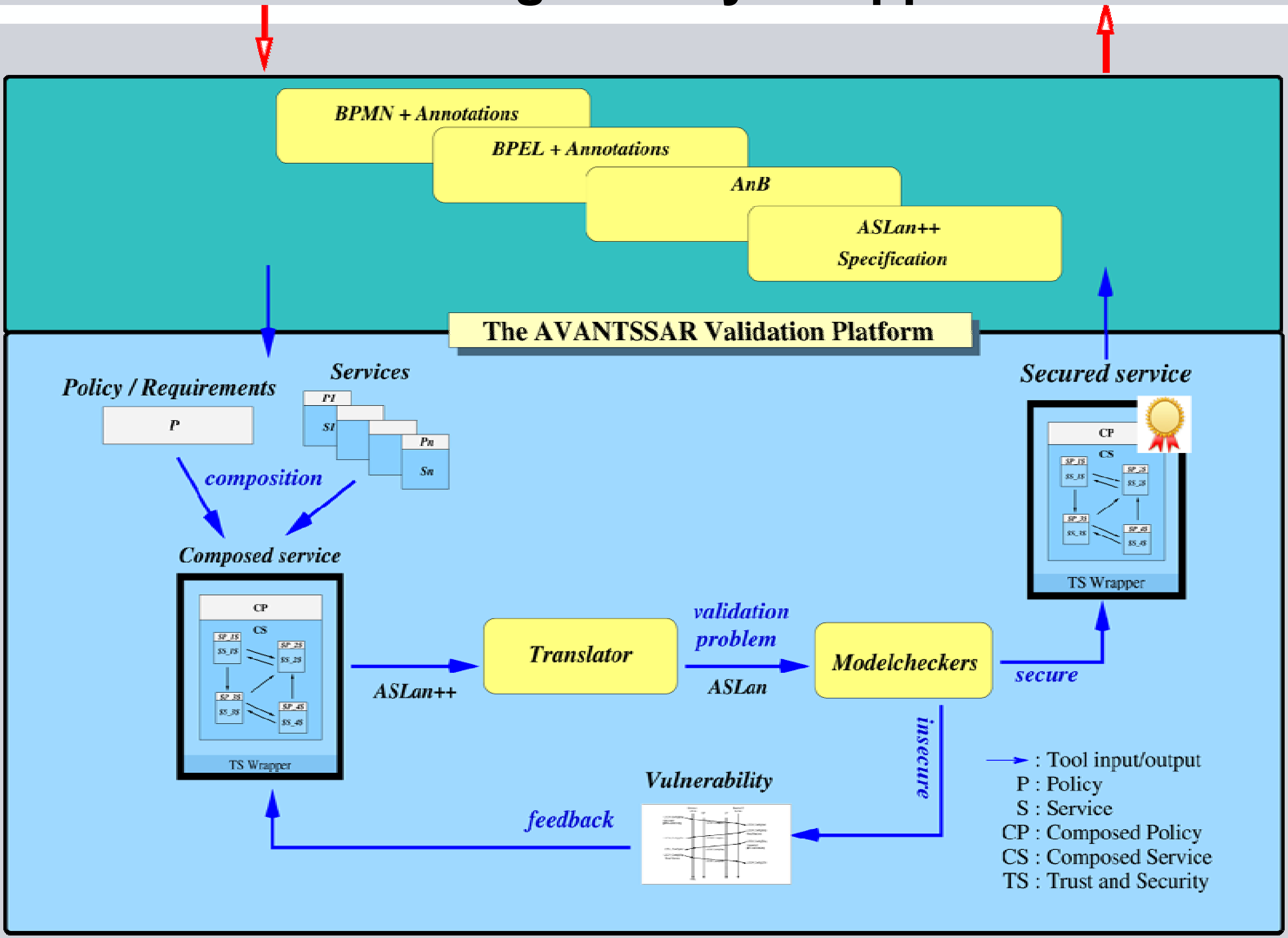
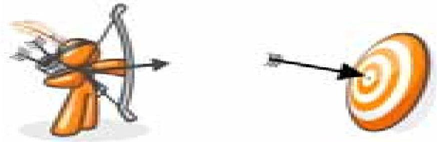
# AVANTSSAR modeling & analysis approach with ASLan++



# AVANTSSAR: current status



**WP2: ASLan++** supports the formal specification
of trust and security related aspects of SOAs, and
of static and dynamic service and policy composition

**WP3**: Techniques for: satisfiability check of policies,
model checking of SOAs w.r.t. dynamic policies,
attacker models, compositional reasoning, abstraction

**WP4:** Second prototype of the **AVANTSSAR Platform**

**WP5:** Formalization of **industry-relevant problem cases**
as ASLan++ specifications and their validation

**WP6: Ongoing dissemination and migration**
into scientific community and industry

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# AVANTSSAR: conclusion and industry migration

Contemporary SOA has complex structure and security requirements including dynamic trust relations and application-specific policies.

On integration of the AVANTSSAR Platform in industrial development, a rigorous demonstration that the security requirements are fulfilled will:

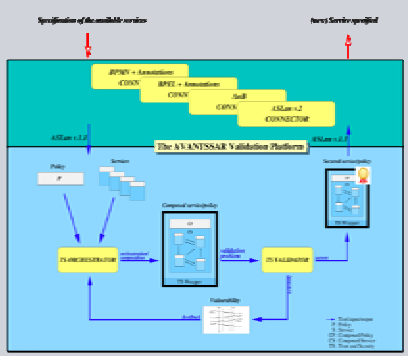
- assist developers with security architecture, analysis and certification
- increase customers' confidence in modern service-oriented architectures

**The AVANTSSAR Platform advances the security of industrial vendors' service offerings: validated, provable, traceable.**

AVANTSSAR will thus strengthen the competitive advantage of the products of the industrial partners.

E-Business

Infrastructure



Citizen Portals

Health care

# Example 2: Process Task Delegation (PTD)

**Authorization and trust management via token passing**

There are three roles in the protocol (**C, A, TS)**
and potentially several instances for each role

The ***client*** **C** (or *user*) uses the system for
authorization and trust management, e.g. SSO

Each ***application*** **A** is in one domain,
each domain has exactly one active ***trust server*** **TS**

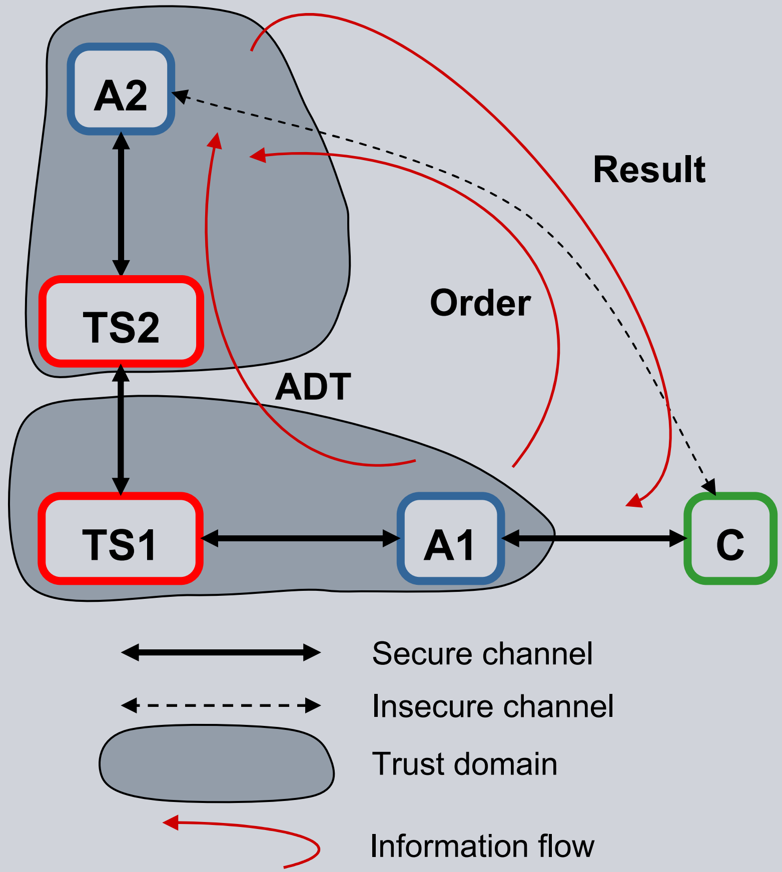
**A1** uses the system to pass to **A2** some **Order**
and an **ADT (Authorization Decision Token)**

- **Order** contains:
  - workflow task information
  - application data
  - information about the client **C** and his current activity

  to be delivered securely (integrity and confidentiality)

- **ADT** is mainly authorization *attributes* and *decisions*
  - sent via **TS1** and **TS2**, who may weaken it
  - must remain unaltered, apart from weakening by **TS**
  - must remain confidential among intended parties

**C**, **A1**, and **A2** must be authenticated among each other




**Security prerequisites**:
PKI used for **A** and **TS**, username & passwd for **C**
The **TS** enforce a strict time-out

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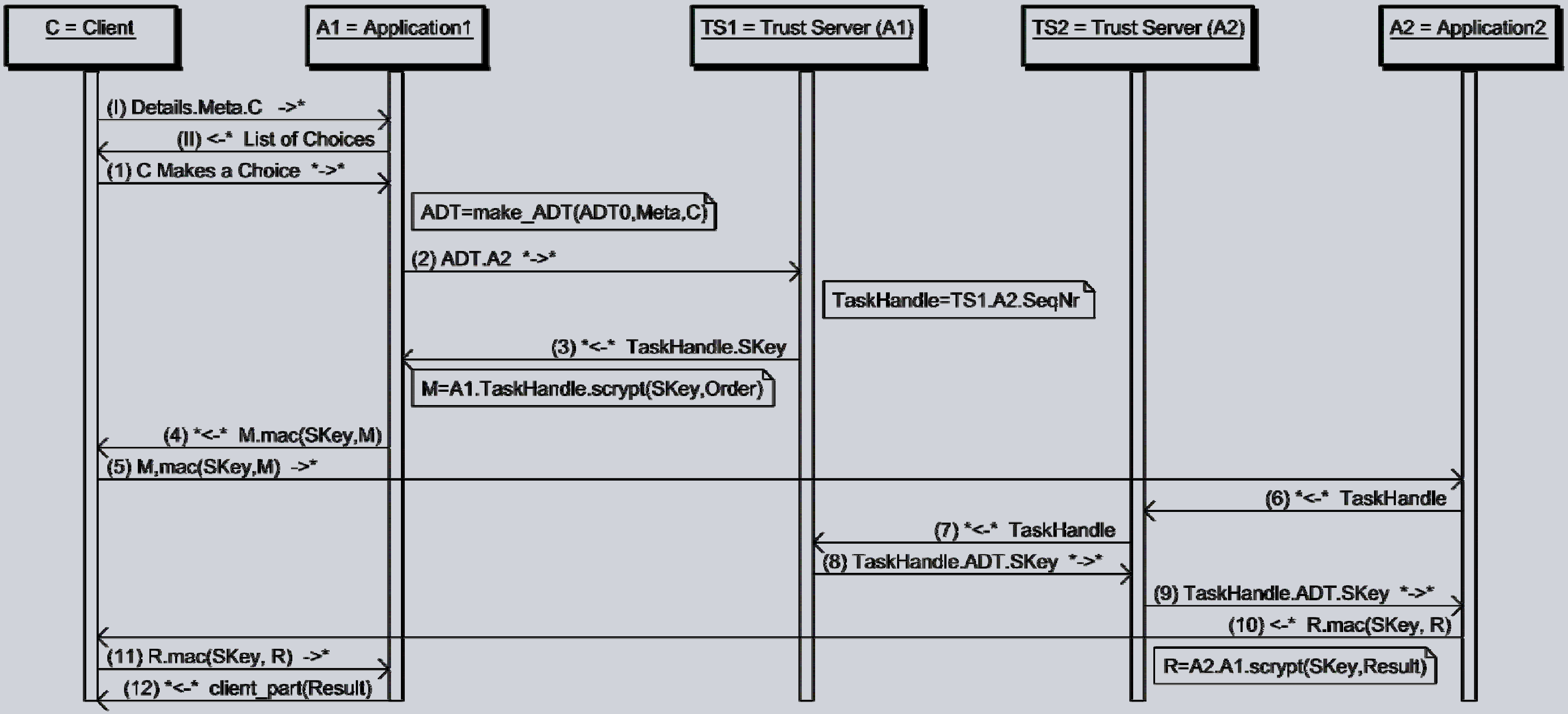
# Example 2: Message Sequence Chart of PTD



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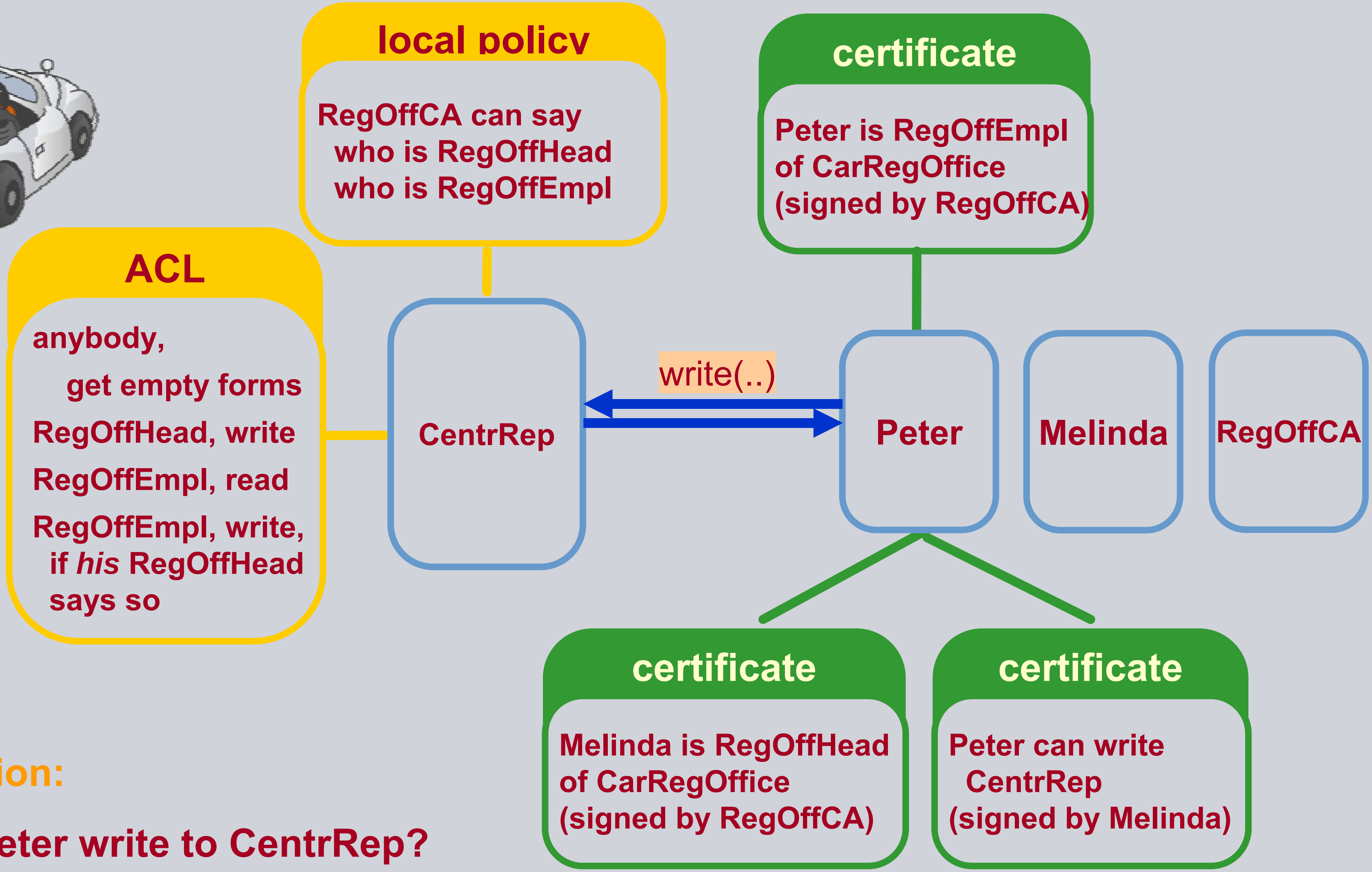
# Example 2: ASLan++ model of PTD Application A2

```
entity A2 (Actor: agent, TS2: agent) {    % Application 2, connected with Trust Server 2
  symbols
    C0,C,A1: agent;
    CryptedOrder, Order, Details, Results, TaskHandle, ADT, MAC: message;
    SKey: symmetric_key;
  body { while (true) {
    select {
      % A2 receives (via some C0) a package from some A1. This package includes encrypted and
      % hashed information. A2 needs the corresponding key and the Authorization Decision Token.
      on (?C0 -> Actor: (?A1.Actor.?TaskHandle.?CryptedOrder).?MAC): {
        % A2 contacts its own ticket server (TS2) and requests the secret key SKey and the ADT.
        Actor *->* TS2: TaskHandle;
      }
        % A2 receives from A1 the SKey and checks if the decrypted data corresponds to the hashed data
      on (TS2 *->* Actor: (?ADT.?SKey).TaskHandle  & CryptedOrder = scrypt(SKey,?,?Details.?C)
           & MAC = hash(SKey, A1.Actor.TaskHandle.CryptedOrder)): {
        % A2 does the task requested by A1, then sends to A1 via C the results encrypted with the secret key.
        Results := fresh();  % in general, the result depends on Details etc.
        Actor -> C: Actor.C.A1. scrypt(SKey,Results);
   }}}
  goals
    authentic_C_A2_Details: C  *-> Actor: Details;
    secret_Order: secret (Order, {Actor, A1});
}
```

# Example 3: Electronic Car Registration policies




**Question:**

**May Peter write to CentrRep?**

# Example 3: On-the-fly inferences via Horn clauses

**DKAL-style trust inference**, e.g. trust application:

```
trustapp(P,Q,AnyThing):
  P->knows(AnyThing) :-
    P->trusts(Q,AnyThing) &
    P->knows(Q->said(AnyThing));
```

**Basic facts**, e.g. the central repository fully trusts the CA

```
centrRepTrustCA(AnyThing):
  centrRep->trusts(theCA,AnyThing);
```

**State-dependent (evolving) facts**, e.g. department head manages a set of trusted employees:

```
trustedEmplsCanStoreDoc(Head): forall Empl.
  Head->knows(Empl->canStoreDoc) :-
    contains(TrustedEmpls, Empl);
```

**Use of certificates**, e.g. the central repository trusts the department head on employee's rights:

```
centrRepTrustHead(Head,Empl):
  centrRep->trusts(Head,Empl->canStoreDoc) :-
    centrRep->knows(theCA->said(Head->hasRole(head))) &
    centrRep->knows(theCA->said(Empl->hasRole(employee)));
```

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## Example: Needham-Schroeder Public Key Protocol

# [Needham-Schroeder 1978]

$$A \longrightarrow B: \{Na.A\}_{pk(B)}$$
$$B \longrightarrow A: \{Na.Nb\}_{pk(A)}$$
$$A \longrightarrow B: \{Nb\}_{pk(B)}$$

Goal: strong mutual authentication

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# Example: ASLan++ model of NSPK_Cert (1): Alice & Bob

```
specification NSPK_Cert
  …
  entity Alice (Actor, B: agent) {
    symbols
     Na, Nb: message;
    body {
      if(trusted_pk(B)) {
        Na := fresh();
        Actor -> B: {secret_Na:(Na).Actor}_pk(B);
        B -> Actor: {Alice_strong_auth_Bob_on_Na:(Na).secret_Nb:(?Nb)}_pk(Actor);
        Actor -> B: {Bob_strong_auth_Alice_on_Nb:(Nb)}_pk(B); } }
  }
  entity Bob (Actor: agent) {
    symbols
      A: agent;
      Na, Nb: message;
    body {
      ?A -> Actor: {secret_Na:(?Na).?A}_pk(Actor); % Bob learns A here!
      if (trusted_pk(A)) {
        Nb := fresh();
        Actor -> A: {Alice_strong_auth_Bob_on_Na:(Na).secret_Nb:(Nb)}_pk(A);
        A -> Actor: {Bob_strong_auth_Alice_on_Nb:(Nb)}_pk(Actor); } }
  } …
}
```

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# Example: ASLan++ model of NSPK_Cert (2): certificates

```
specification NSPK_Cert channel_model CCM
entity Environment {

  symbols
    trusted_pk(agent): fact;
    trusted_agent(agent): fact;
    root_ca, ca: agent;
    issued(message): fact;

  macros
    A->signed(M)   = {M}_inv(pk(A)).M;
    C->cert(A,PK) = C->signed(C.A.PK); % no validity period etc.

  clauses
    trusted_pk_direct(C):
      trusted_pk(C) :-
      trusted_agent(C);

    trusted_pk_cert_chain(A,B):
      trusted_pk(A) :-
      trusted_pk(B) & issued(B->cert(A,pk(A)));
```

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# Example: ASLan++ model of NSPK_Cert (3): sessions

```
entity Session (A, B: agent) {
  entity Alice (Actor, B: agent) {…}
  entity Bob (Actor: agent) {…}
  body {
    issued(ca->cert(A,pk(A)));
    issued(ca->cert(B,pk(B)));
    new Alice(A,B);
    new Bob(B);
  }
  goals
    secret_Na: {A,B};
    secret_Nb: {A,B};
    Alice_strong_auth_Bob_on_Na: B *->> A;
    Bob_strong_auth_Alice_on_Nb: A *->> B;
}
body { % need two sessions for Lowe's attack
  trusted_agent(root_ca);
  issued(root_ca->cert(ca,pk(ca))); % root-signed CA certificate
  issued(     ca->cert(i ,pk(i ))); % CA-signed intruder cert
  any A B. Session(A,B) where A!=B;
  any A B. Session(A,B) where A!=B; } }
```

 

# Example: Lowe’s attack on NSPK

## [Lowe 1995] Man-in-the-middle attack

```
1.1   A   -  {Na.A}_pk(i)  ->  i
2.1                            i(A)   -  {Na.A}_pk(B)   ->  B
2.2                            i(A)  <-  {Na.Nb}_pk(A)   -  B
1.2   A  <-  {Na.Nb}_pk(A)  -  i
1.3   A   -  {Nb}_pk(i)  --->  i
2.3                            i(A)   -  {Nb}_pk(B)    -->  B
```

In the first session, Alice talks with some Chuck who happens to be the intruder.
In the second session, Bob wants to talk with Alice but actually talks to the intruder.
Therefore, also the nonce Nb gets leaked.