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Corporate Technology

Formal analysis of IT product security in industry

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Guest lecture on invitation by Prof. Peter Hartmann,
Landshut Univ. of Applied Science, Germany, 12 Jan 2012

Overview

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

Siemens Corporate Technology (CT)

Networking the integrated technology company

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Customers

Chief Technology Officer (CTO)

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

Sectors / Divisions

Energy

Healthcare

Industry

Infrastructure & Cities

Regions

Chief Technology Office (CT O)

- Direct support of CTO

Corporate Research and Technologies (CT T)

- 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 IP)

- Intellectual property
- Standardization and regulation
- Information research

Corporate Technology (CT)

Siemens corporate R&T: around 1,800 researchers

Present in all leading markets and technology hot spots

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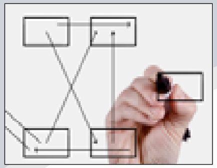
IT Security topics at Siemens Corporate Technology



Security lifecycle

Sustainable integration of IT security topics into product lifecycle processes

Security assessment

"Friendly" hacking and assessments of products, solutions, applications and processes

Security architectures

Domain specific security architectures, certification, and best practice use of COTS and Open Source security

Siemens product CERT

Incident handling and vulnerability management for Siemens products & solutions

IT Security @ Siemens CT

Embedded systems security

Optimized and adequate security for embedded systems

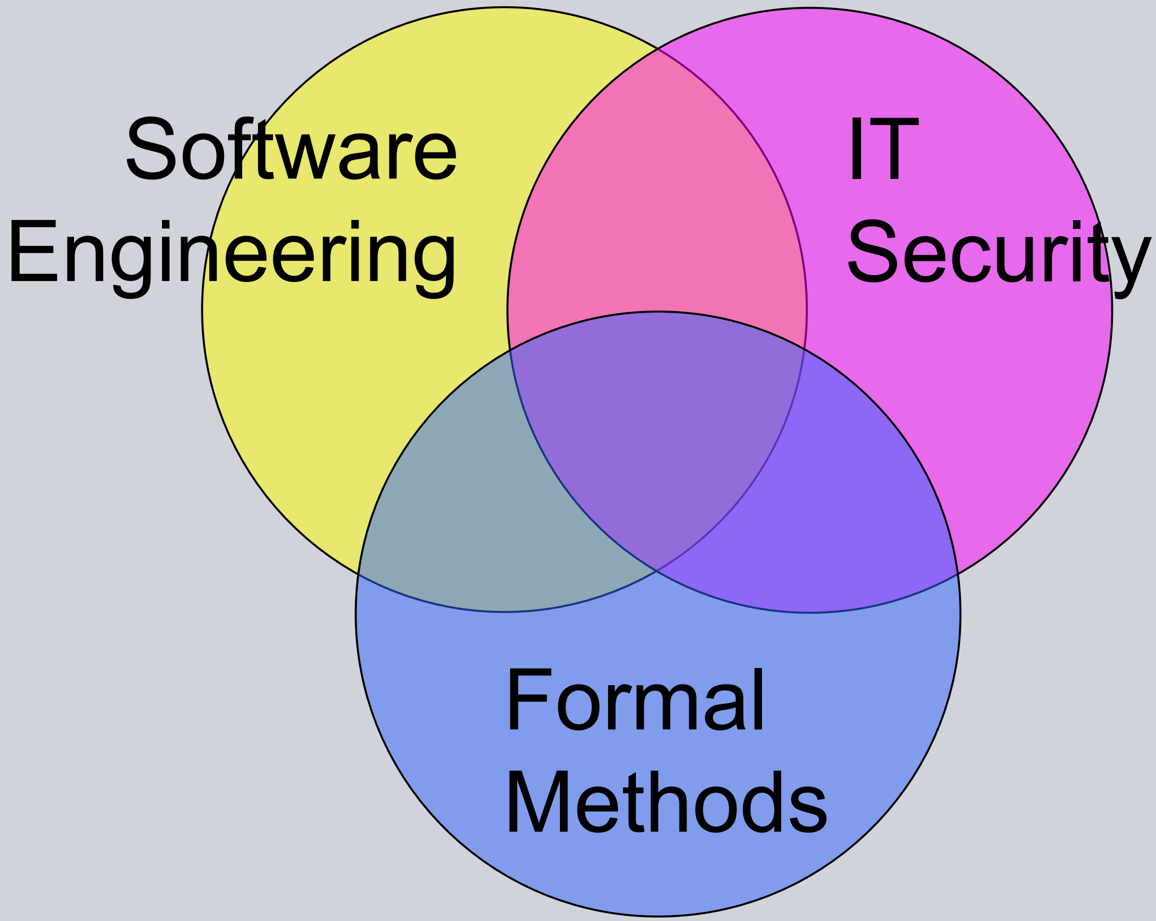
Computer Emergency Response Team (CERT)

Corporate incident handling and technical policies

Cyber Security for specific regions

Regional Support focusing on specific security regulations and application topics like NERC-CIP, HIPAA, DIACAP (USA) or industrial control system security (Asia)

Fields



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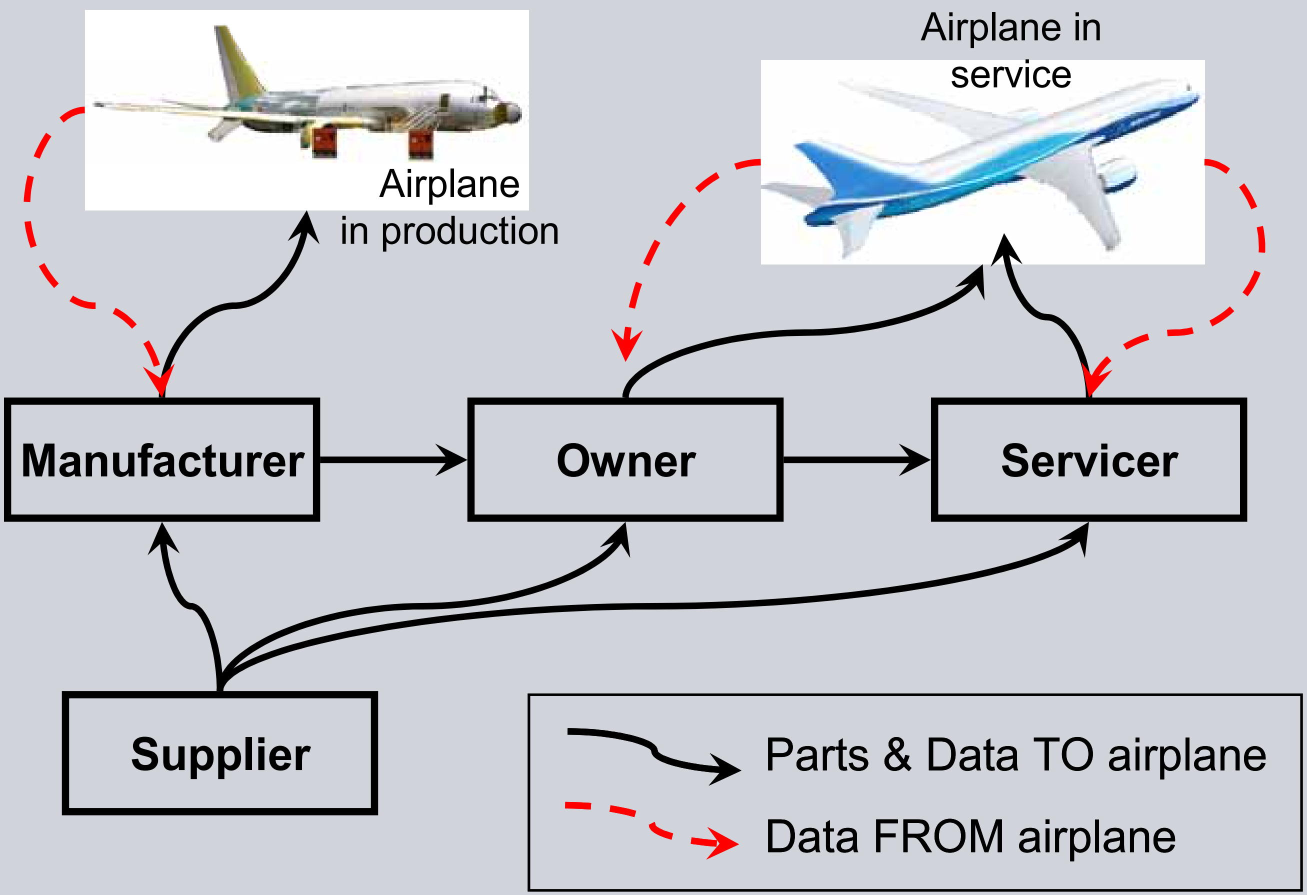
Airplane Assets Distribution System (AADS)

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



Safety-related security threats at the AADS example

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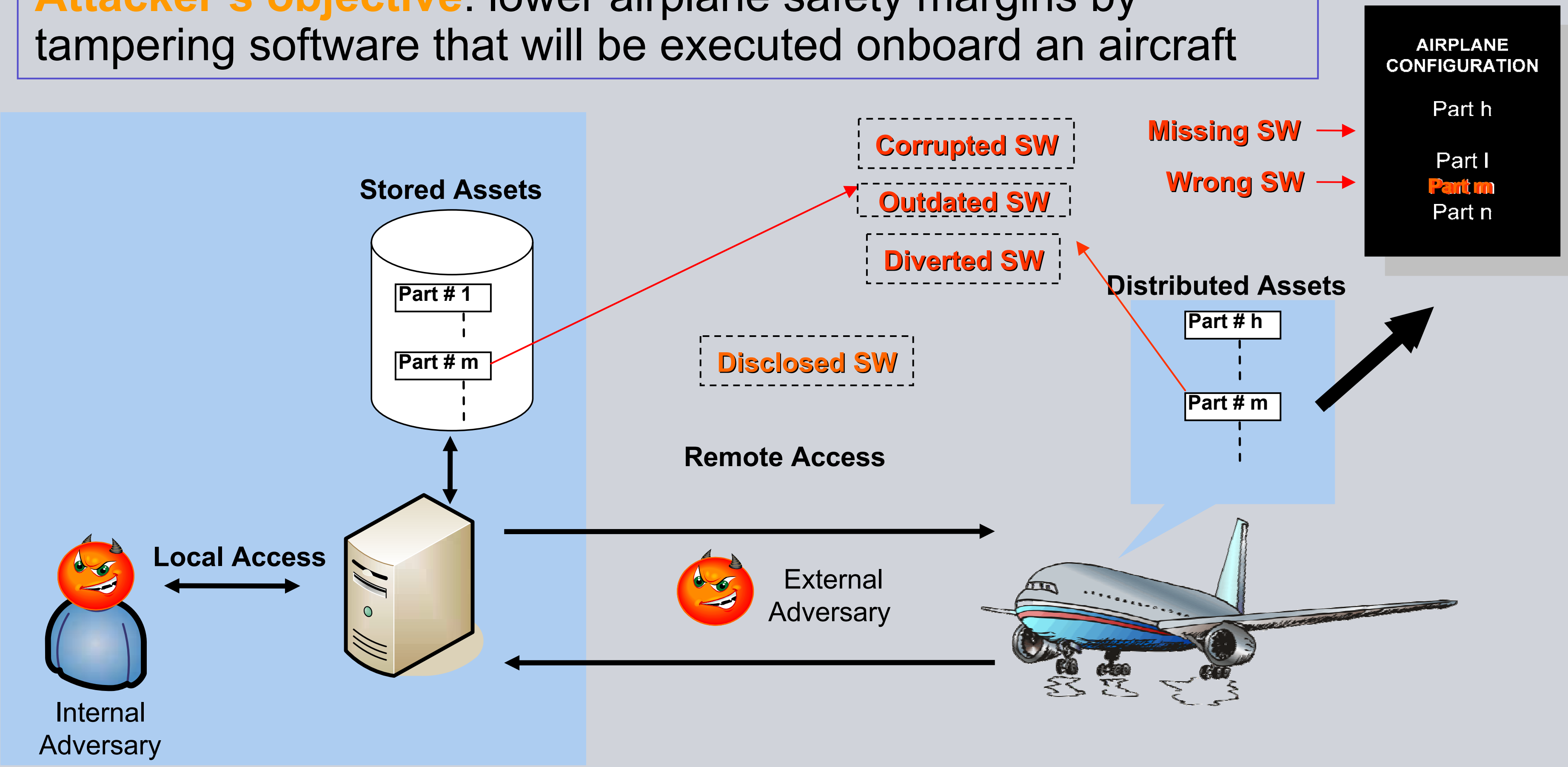
Attacker's objective: lower airplane safety margins by tampering software that will be executed onboard an aircraft



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

IT Security as a System Engineering Problem

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- 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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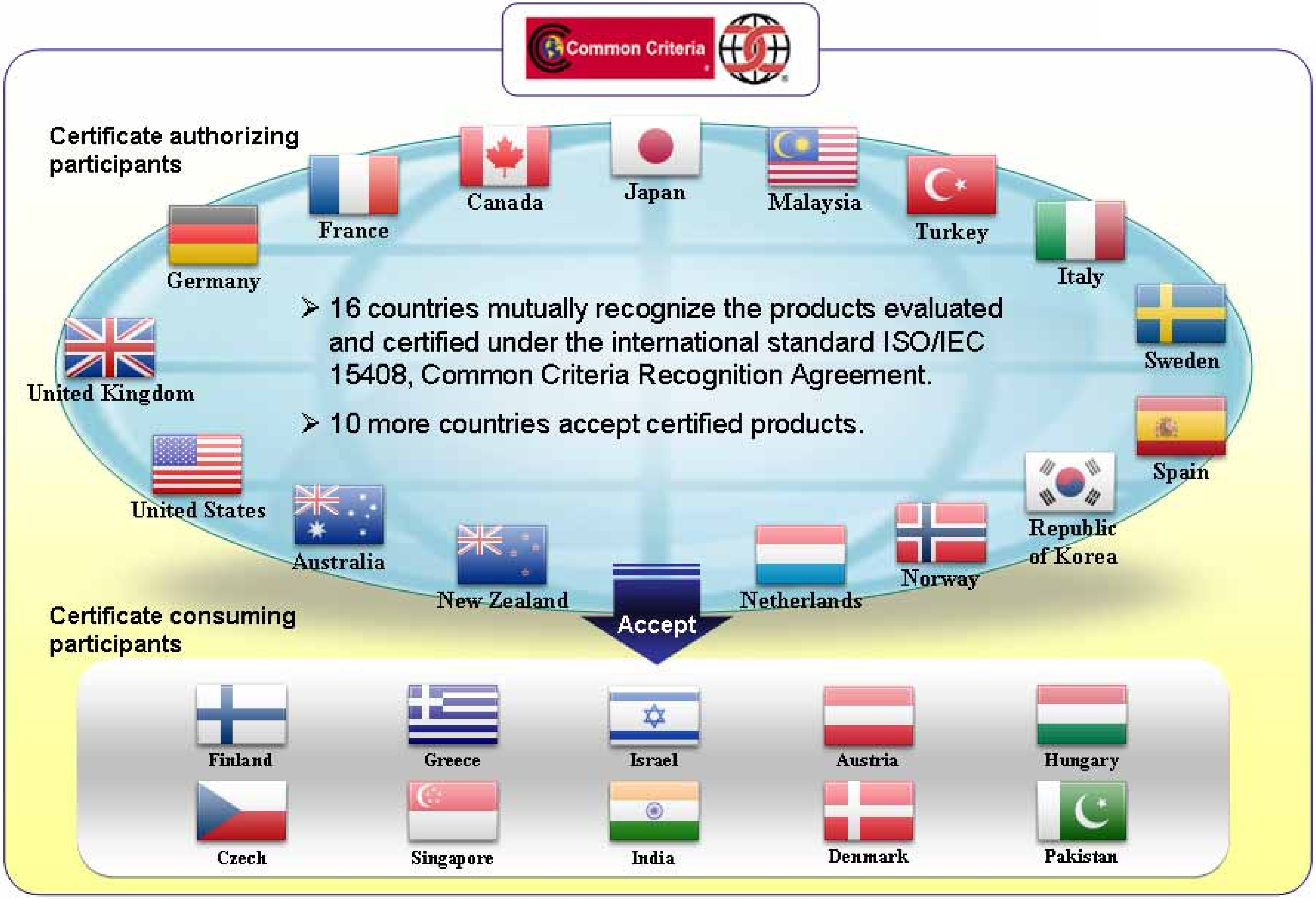
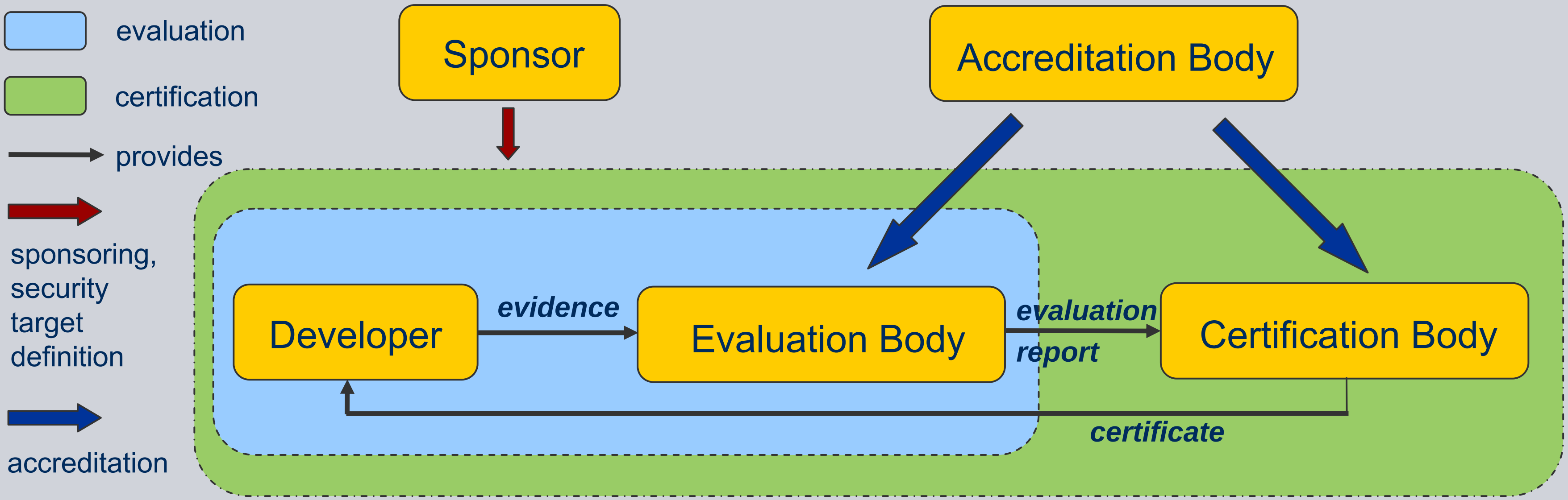
International recognition of Common Criteria certificates



Common Criteria process overview



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

A successful, approved evaluation is awarded a certificate.

Lifetime of certificates is theoretically not bounded, but their applicability is limited by technical progress (→ re-certification).

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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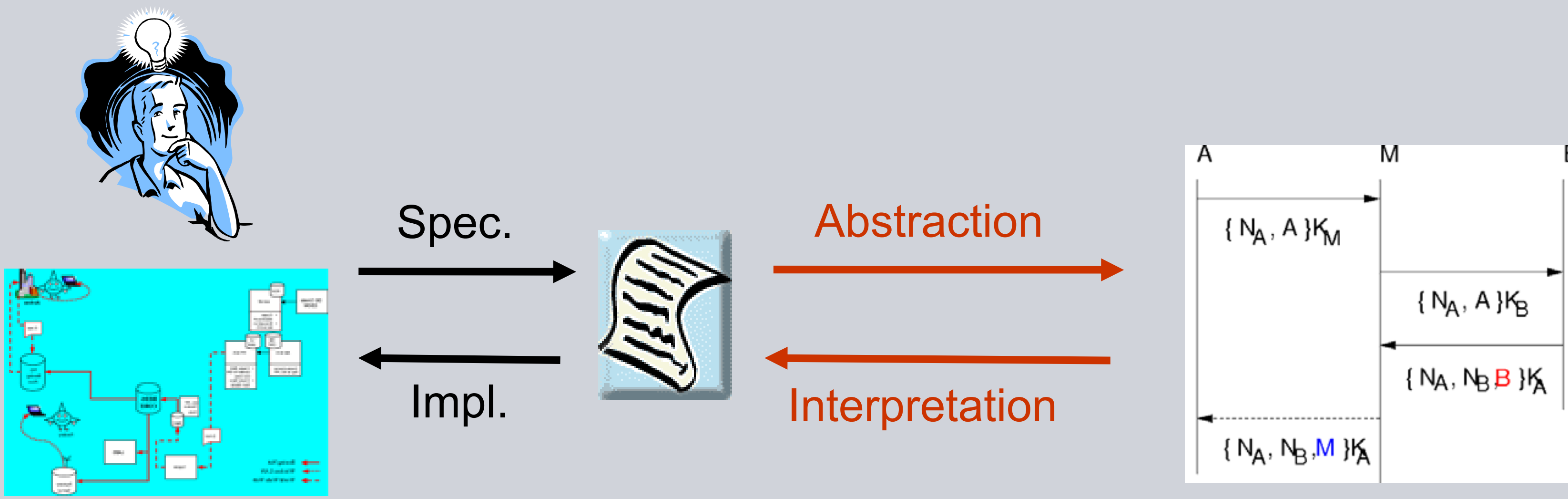
Formal Security Analysis: Approach and Benefits

Mission: security analysis with maximal precision

Approach: formal modeling and verification



Improving the quality of the system specification

High-level protocol/system specification lang.

Model checkers (e.g., AVANTSSAR tools)

Checking for the existence of security loopholes

HOL, Interacting State Machines, etc.

Interactive theorem provers (e.g., Isabelle)

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Formal Security Models

- 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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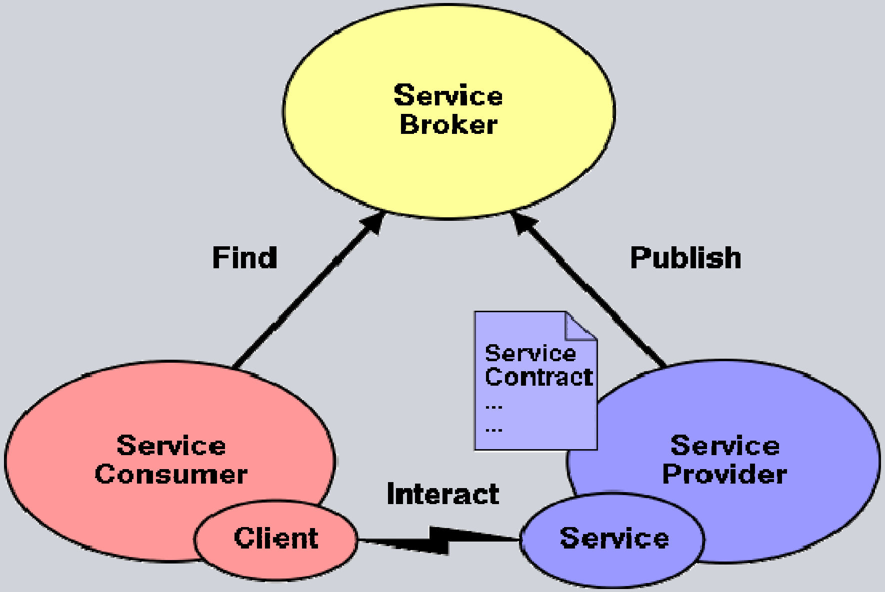
avantssar.eu

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

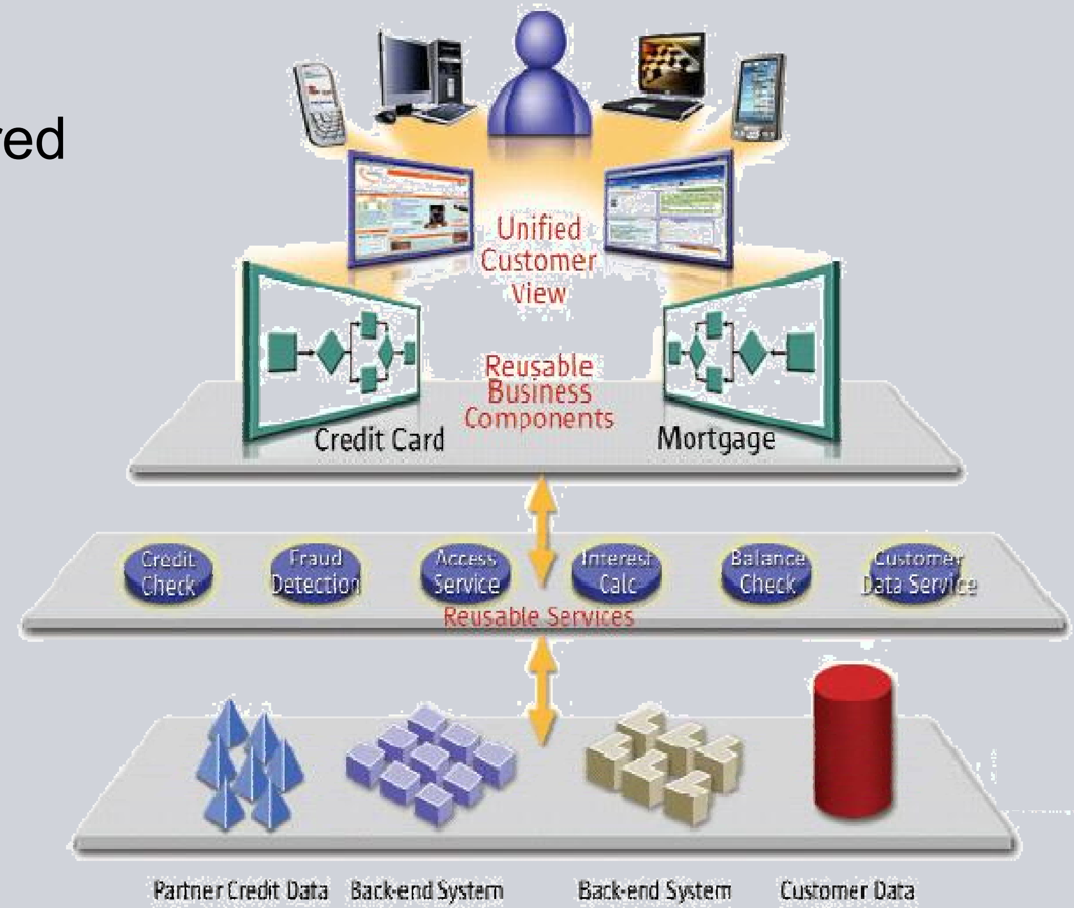
FP7-2007-ICT-1, ICT-1.1.4, STREP project no. 216471
Jan 2008 - Dec 2010, 590 PMs, 6M€ budget, 3.8M€ EC contribution

AVANTSSAR project motivation

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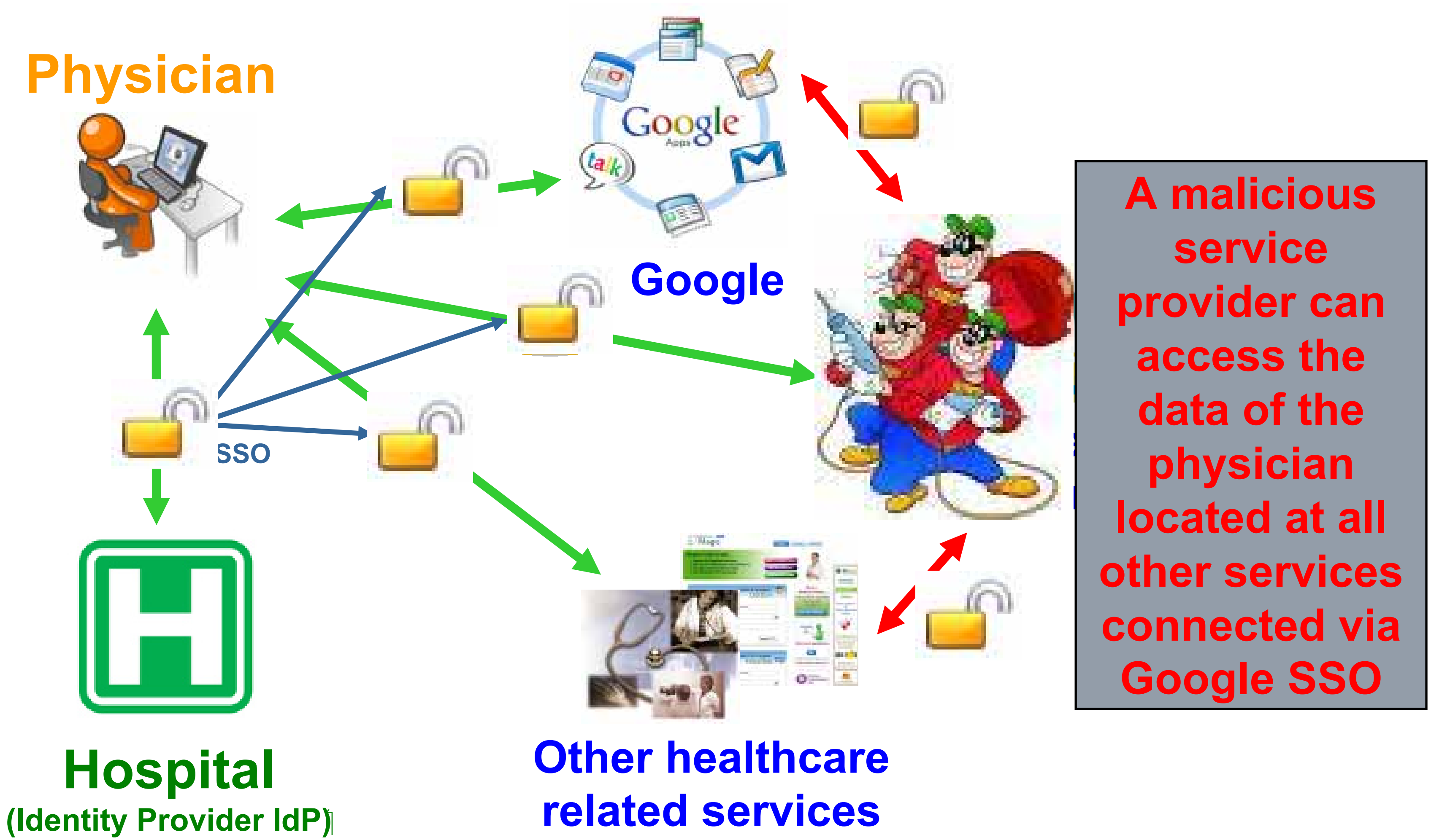
Example 1: Google SAML-based Single Sign-On (SSO)



Example 1: Google SAML SSO protocol flaw

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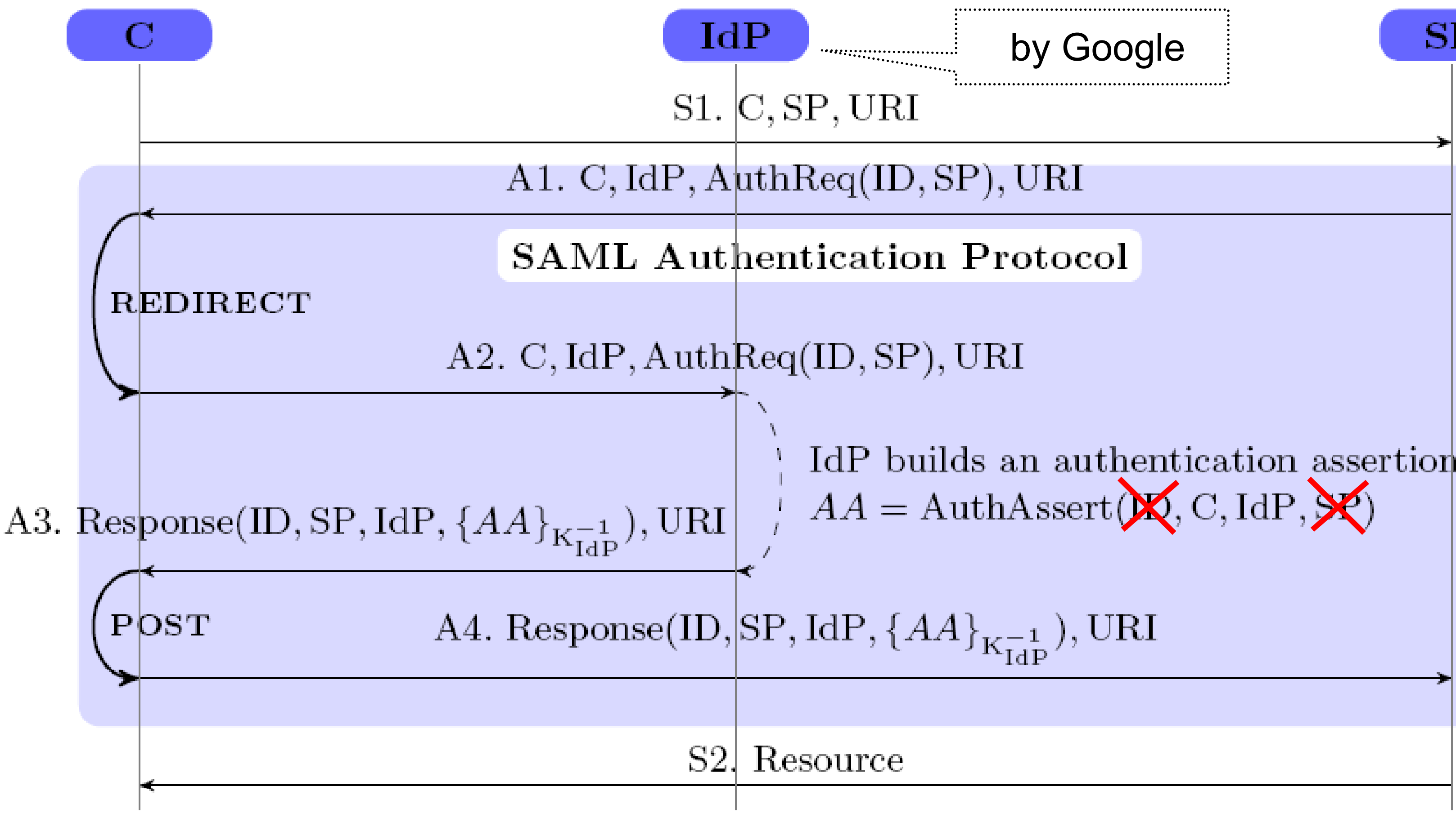


Fig. 1. SP-Initiated SSO with Redirect/POST Bindings

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

AVANTSSAR main objectives and principles

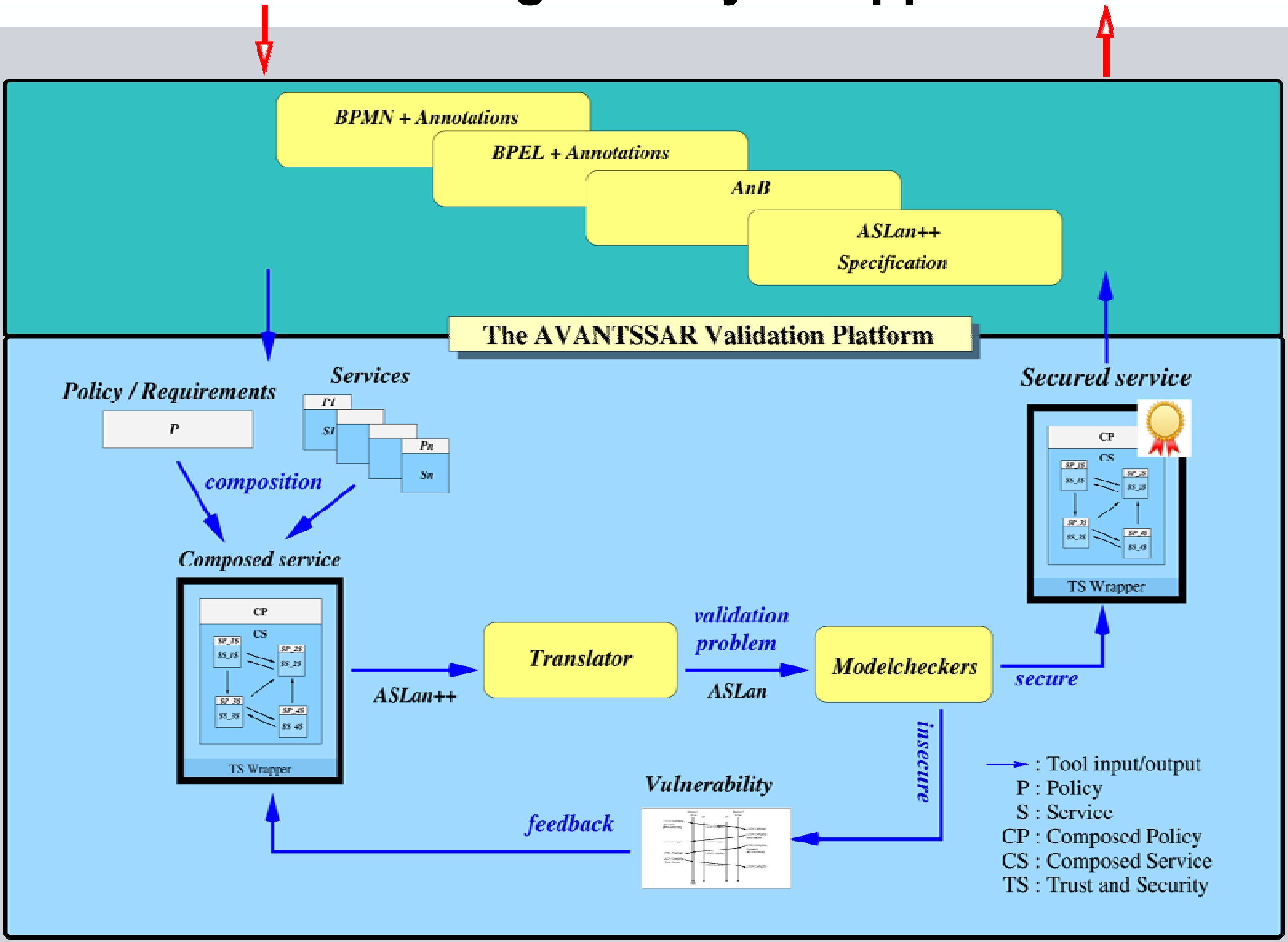
AVANTSSAR product: Platform for formal specification and automated validation of trust and security of SOAs

- 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

AVANTSSAR modeling & analysis approach with ASLan++



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

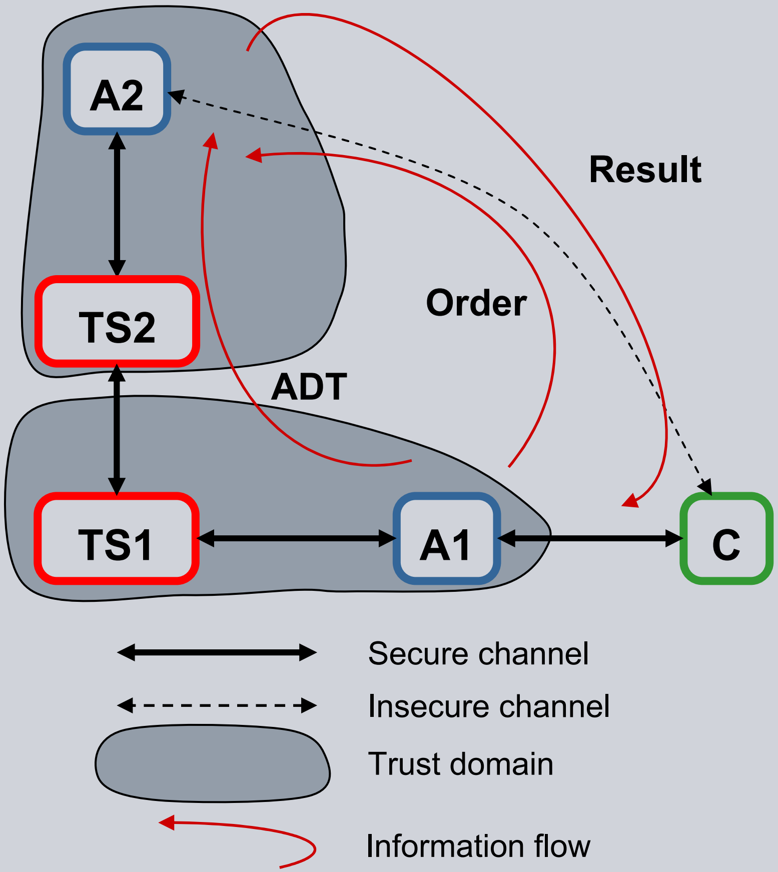
Each ***application* A** is in one domain,
each domain has exactly one active ***trust server* TS**

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

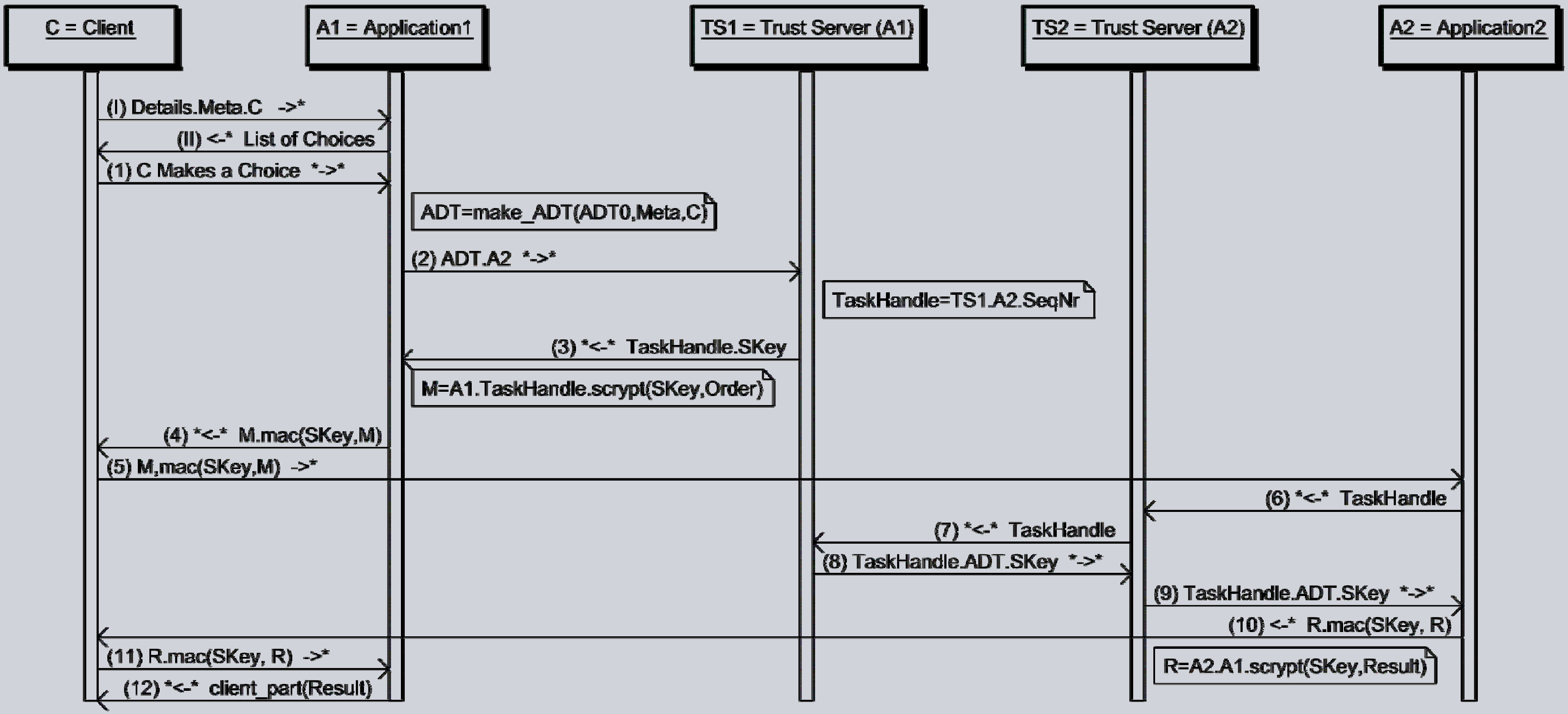
  to be delivered securely (integrity and confidentiality)
- **ADT** is mainly authorization *attributes* and *decisions*
  - sent via **TS1** and **TS2**, <u>who may weaken it</u>
  - must remain unaltered, apart from weakening by **TS**
  - must remain confidential among intended parties

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

Example 2: Message Sequence Chart of PTD



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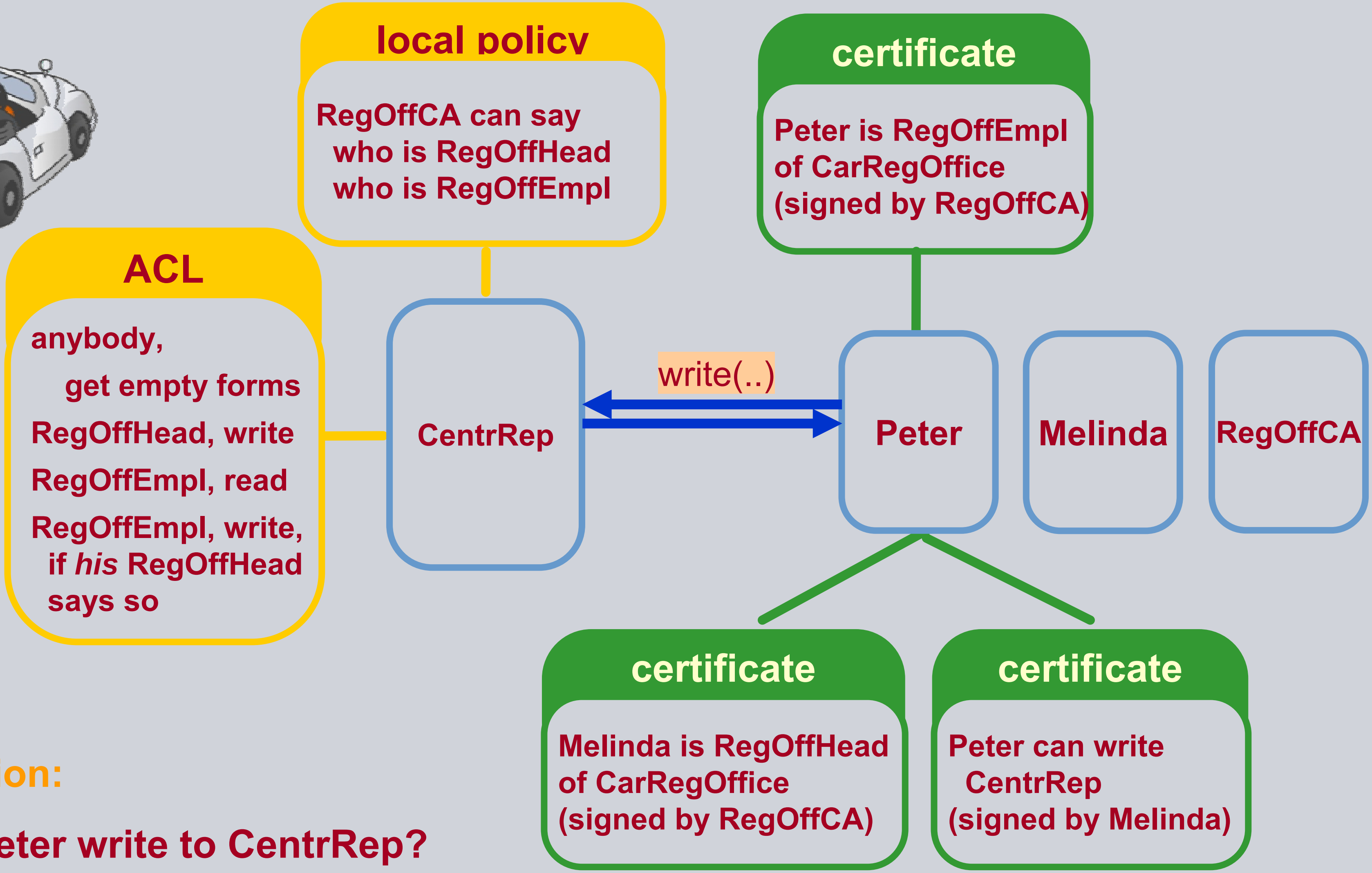
Example 2: ASLan++ model of PTD Application A2

```
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?

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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]
http://en.wikipedia.org/wiki/Needham-Schroeder_protocol

Simplified version without key server, assuming that A and B already know the public key of their peers:

$$
\begin{aligned}
A &\longrightarrow B: \{Na.A\}_{pk(B)} \\
B &\longrightarrow A: \{Na.Nb\}_{pk(A)} \\
A &\longrightarrow B: \{Nb\}_{pk(B)}
\end{aligned}
$$

Goal: strong mutual authentication

Example: ASLan++ model 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); } }
  } …
}
```

Example: ASLan++ model 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 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 party, e.g. Chuck, who in fact is an intruder.

In the second session, Bob thinks that he was contacted by Alice but actually talks to the intruder.

Therefore, also his nonce Nb gets leaked to the intruder.