Introduction to IT Security

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What is IT Security?

- What is security about? – It‘s about bad things not happening.
- Where is the *difference to safety?* – It’s in the source of bad things.
- *Safety* protects against accidents due to technical failure or human mistakes.
- *Security* protects against evil due to **malicious human intentions**.
- Which is harder to achieve? – Security.
- Why? – Because people can be very creative and determined to search for and exploit vulnerabilities, while safety failures happen by chance.
- Is it simpler to attack or defend? – Attack.
- Why? – Only one weak point is needed to break in.
- What is *IT* security? – **Protection of data against unauthorized access.** *Not:*

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IT Security may impact safety – Example: Boeing 787

- **Situation**
  - Aircraft flight is controlled by avionics
  - Malfunction may lead to catastrophic accidents
  - Today's avionics is software controlled
  - Sabotage of software may cause malfunction
  - Avionics software can be updated via networks
  - Transmission of software might be attacked
  - *Classical IT security threatens flight safety!*

Measures

- *Boeing R&D* developed BEDS (Boeing Electronic Distribution of Software)
- *Siemens CT* assisted Boeing R&D in analyzing the security threats, designing proper countermeasures, and defining certification approach

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Threat Agents and Their Motivation

- How does one call people threatening IT security?
- Commonly they are called *hackers*.
- Security folks speak of *attackers*.
- Researchers tend to call them *adversaries*.

- What is the aim of attackers?
- *Script kiddies* typically want to have fun.
- *Criminals* typically want to steal money.
- *Insider attackers* typically want to take revenge.
- *Political activists* want to control decisions.
- *Terrorists* want to threaten society.
- *Spies* want to gain (technical/economic/organizational) knowledge.
- *Secret services* want to gain knowledge and influence at large scale.

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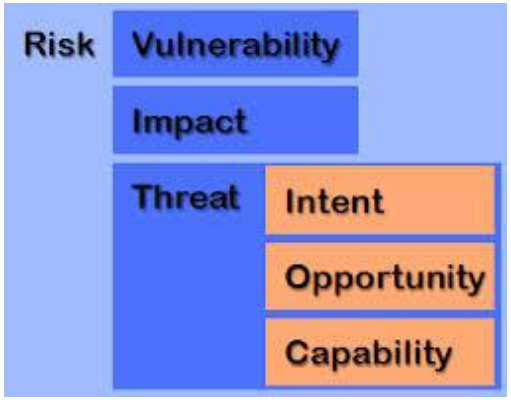
Vulnerabilities, Threats, Risk, and Aim of Security

- A vulnerability is a weakness (loophole) that could be used to do harm.
- An exploit is the use of a vulnerability for performing an attack.
- *An attack is* an activity exploiting vulnerabilities, typically to do harm.
- *Attack potential* is the strength of an attack (amount of ability, energy, motivation).
- *Impact* is the amount of harm to assets achieved via a successful attack.
- *Risk* is the amount of damage to be expected:

  Probability of successful attack × Impact



- Security aims at minimizing risk, by

  limiting potential impact, or better by

  minimizing vulnerabilities and/or opportunity,
  thus lowering the probability of successful attacks.
- **Residual risk is unavoidable – there is no 100% security!**

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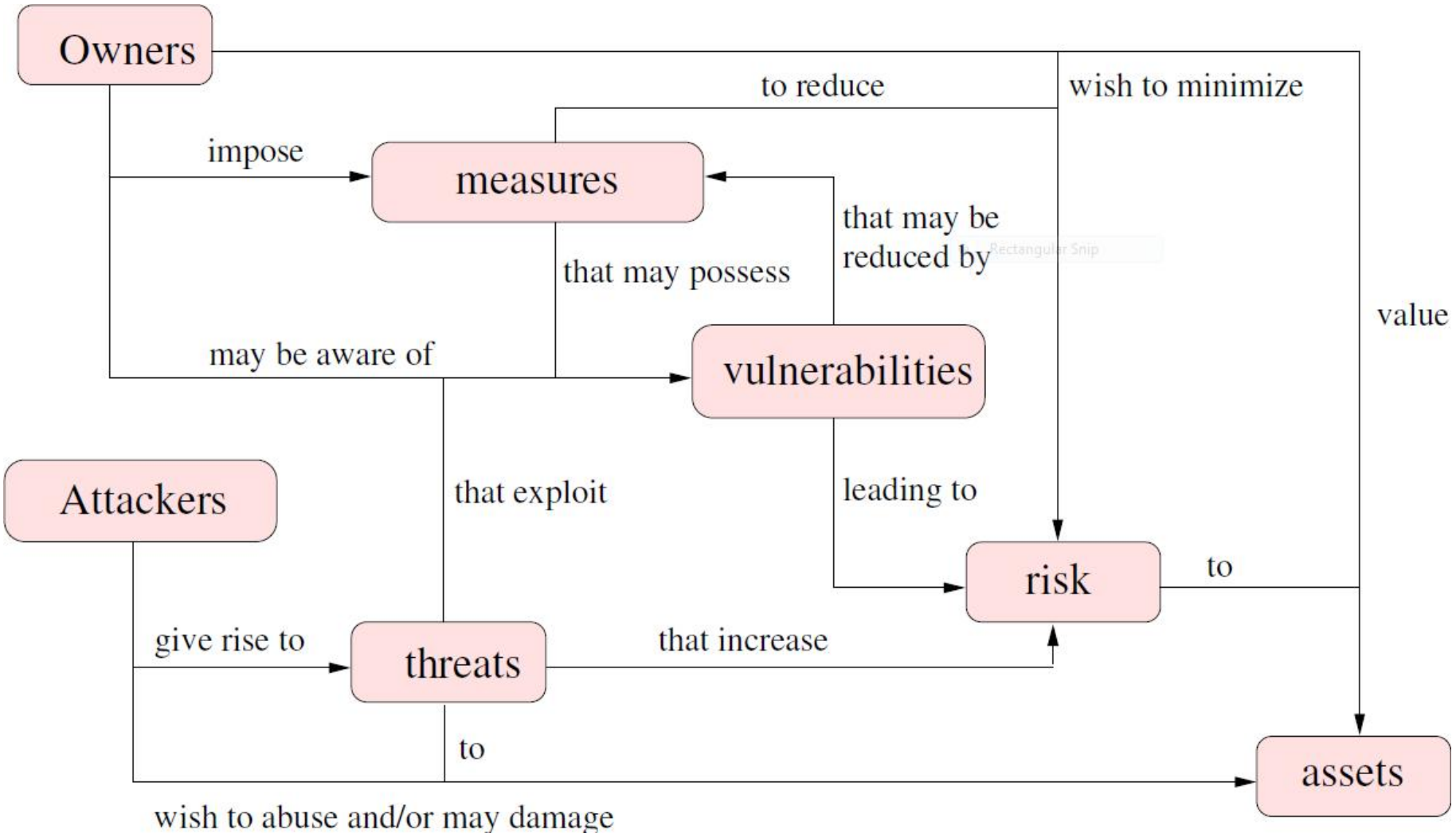
Assets protected by owners and threatened by attackers



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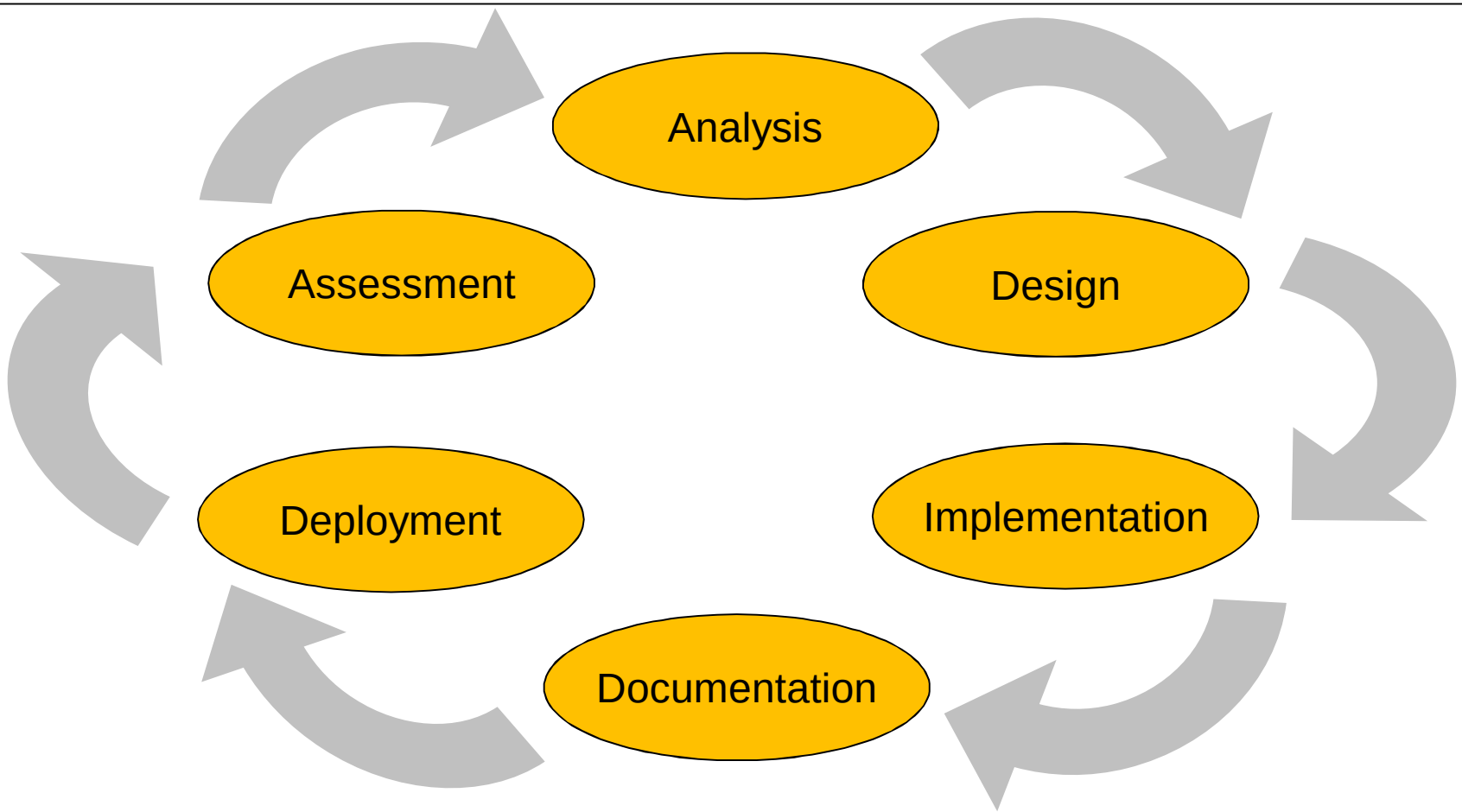
Process to assure holistic security



Any of these activities can be chosen as entry point.
In each of them, mistakes easily lead to an insecure system.

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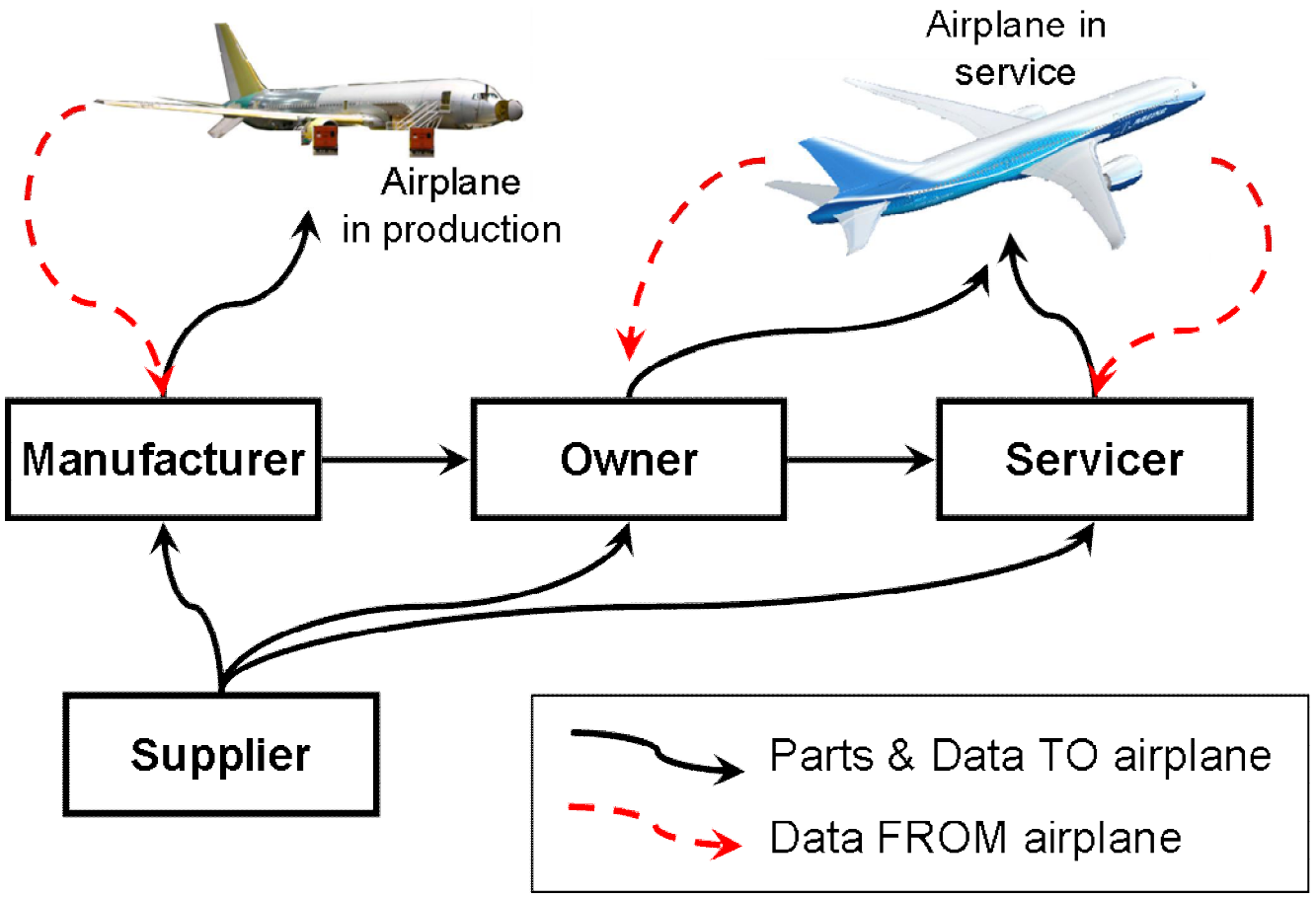
Analysis step 1: Know your system and its assets

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



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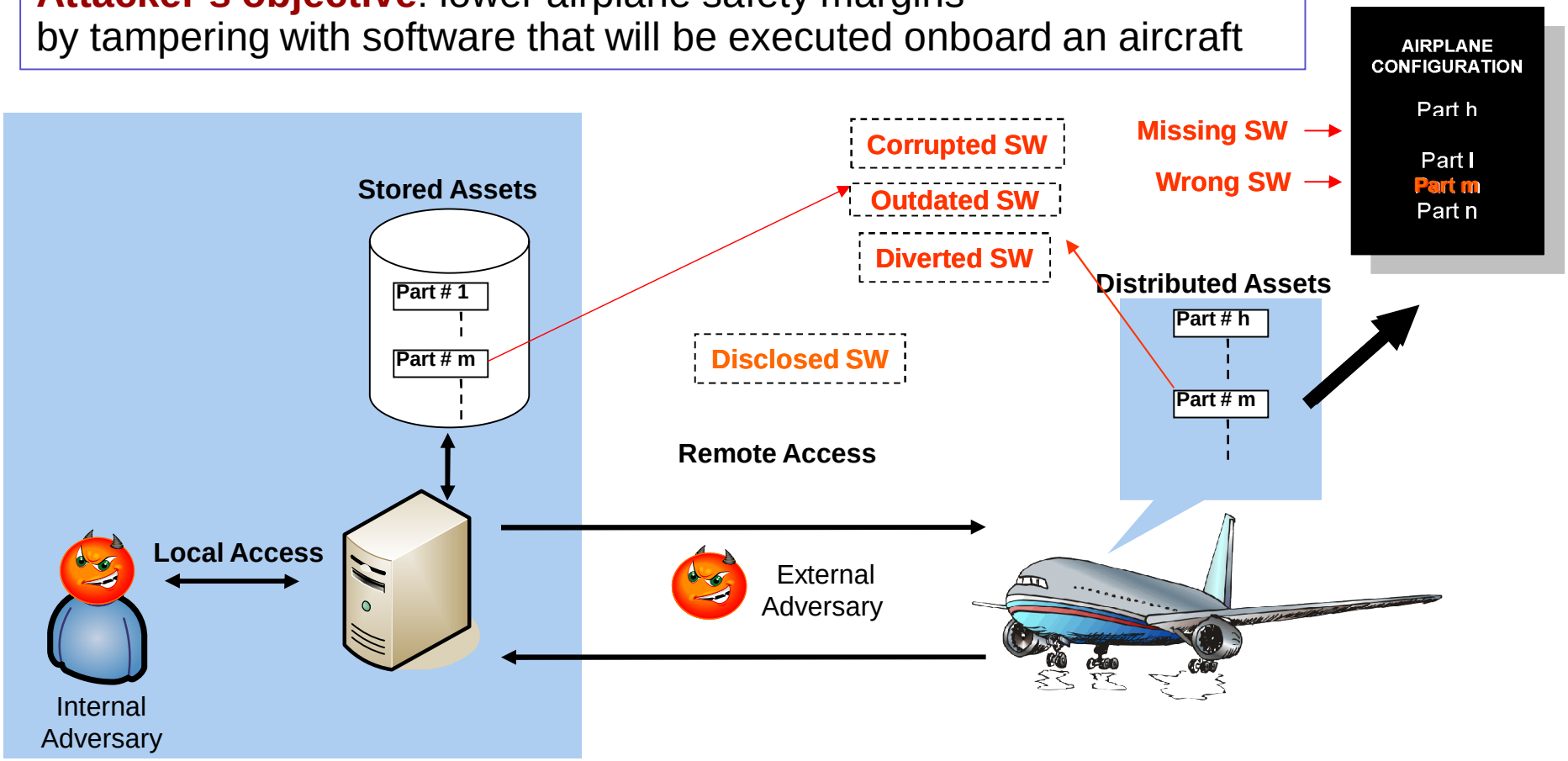
Analysis Step 2: Know your enemy and the threats to your assets

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



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

Security Goals

IT security aims at protecting data assets against threats. Classical goals:

C **Confidentiality**: Information must be disclosed to certain parties only

Example: personal information to be kept secret

I **Integrity & Authenticity**: Information must be changed by certain parties only; fake or manipulation must be detectable

Example: Signed contract must not be alterable

A **Availability**: Access by legitimate parties to asset must not be blocked

Example: Web server should remain usable.

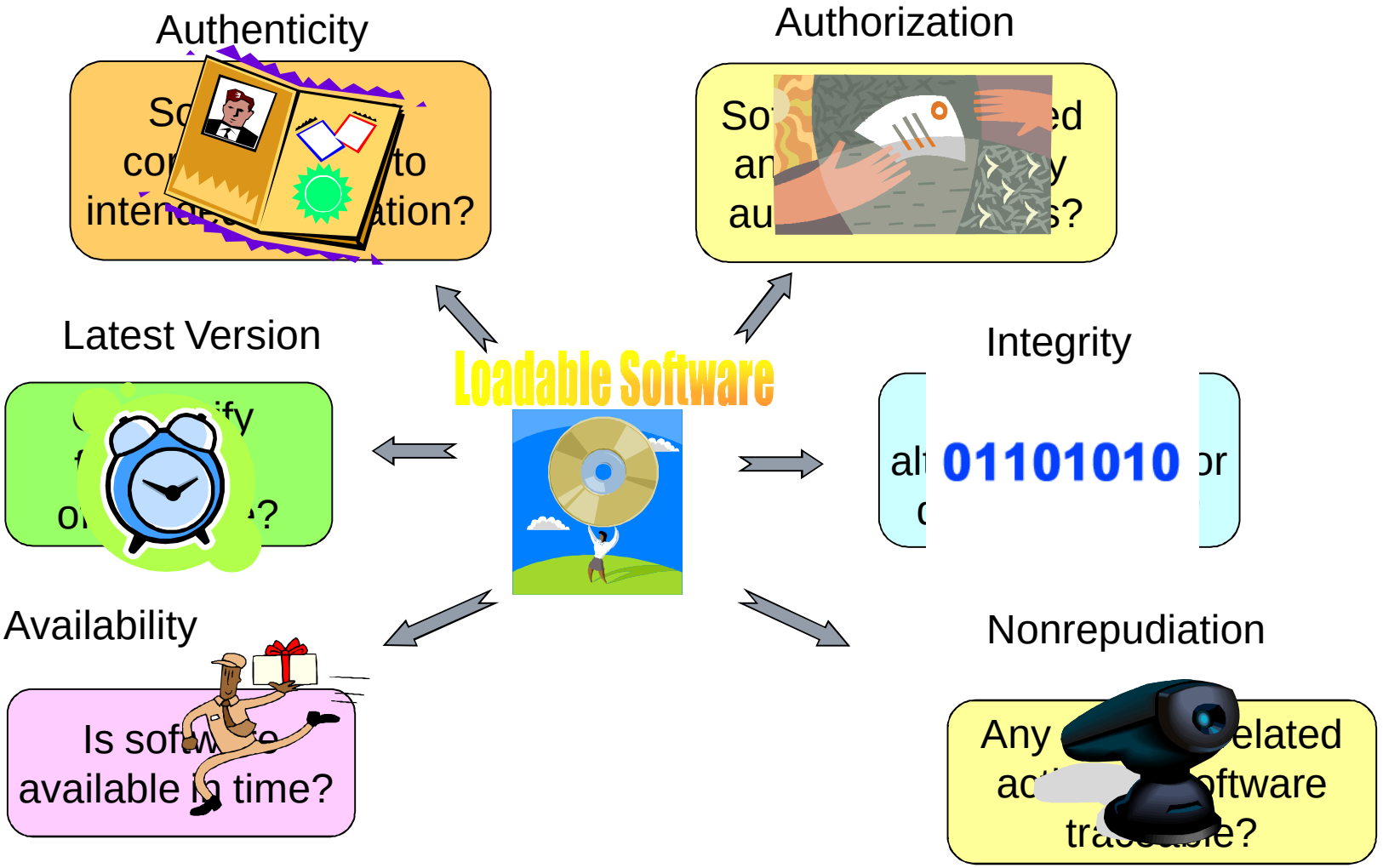
Further ones exist, e.g.:

Authorization: Only privileged parties must be able to perform action.

Non-Repudiation: Parties must not be able to deny certain actions.

Example: Buyer is accountable for accepted deal.

Design Step 1: Define security objectives



Security Policies and Mechanisms

A **security policy** describes in sufficient detail who is allowed to do what.

Everything not allowed is considered an attack and must be prevented.

How to protect against illicit access?

Direct/simple approach: Use a gatekeeper to **enforce the policy**.

Example: File access control by operating systems

Problem: The power/domain of the gatekeeper doing access control is limited.

Example: The operating system cannot protect while not running.

Advanced approach: Use cryptography such that access requires knowledge.

Example 1: Encrypt a secret with a key known only to the group allowed to know the secret.

Example 2: Digitally sign a document such that nobody else can fake the signature but everybody can verify it.

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Symmetric Cryptography

Any number of parties (e.g., A and B) share a key K.

A encrypts secret X with K, sends it, B can decrypt it: $A \rightarrow B: \{X\}_K$

Two problems: How to distribute the shared key without revealing it?

Idea: Use other channel protected in different way.
A better solution will follow.

How to make sure that K cannot be guessed/tried out?

Use sufficiently long key and good random number generator.

Algorithms: DES – outdated, key length 56 bits

AES – current, key length 128 or 256 bits

Hashing

Can one use symmetric encryption also for integrity protection for data Y?

Yes, use a checksum h() of K and Y, and add it: A → B: Y.h(K.Y)

Two caveats: Make sure that h is not invertible,
i.e., one cannot deduce X from knowing h(X).

Make sure that h is pre-image resistant, i.e.,
different X and X' should lead to different h(X) and h(X').

C**ryptographically strong checksums** are called **hashes**.

Algorithms: MD5 – outdated, result length 128 bits

SHA – current, result lengths 128 or 256 bits

General problem with symmetric integrity protection (aka HMAC)?
Everyone knowing K can produce h(K.Y) – this is not good as a signature.

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Asymmetric Cryptography

Each party A has a pair of a private key priv(A) and public key pk(A).

The public key can be known to everyone, while
the private key must not be shared with anyone.

If A sends secret X encrypted with pk(B),
only B can decrypt it using his corresponding private key: $A \rightarrow B: \{X\}_{pk(B)}$

This partly solves the key distribution problem: A can freely access pk(B).

Yet one problem remains: the authenticity of pk(B).

Asymmetric cryptography allows for real **digital signatures**:

If A sends Y with its hash encrypted with priv(A), written $A \rightarrow B: \{Y\}_{priv(A)}$
everyone can verify it using pk(A), but nobody can fake it!

Algorithms: RSA – key length 1024 or 2048 or 4096 bits

ECC – key length 80 or 112 or 160 bits has same strength

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Digital Certificates and PKI

Signatures can be used also for solving the authenticity the public key of B:

A third party C signs a **certificate** with name B and pk(B): $\{B.pk(B)\}_{priv(C)}$

Such a trusted third party is called a **Certificate Authority (CA).**

For sending secrets to B or verifying a signature of B, use pk(B), where its authenticity is verified using B's certificate.

To verify in turn B's certificate, pk(C) must be trusted or itself be verified using a certificate for C, issued by another CA, until reaching a trusted root CA.

Typically, certificates have a validity period and possibly further attributes.

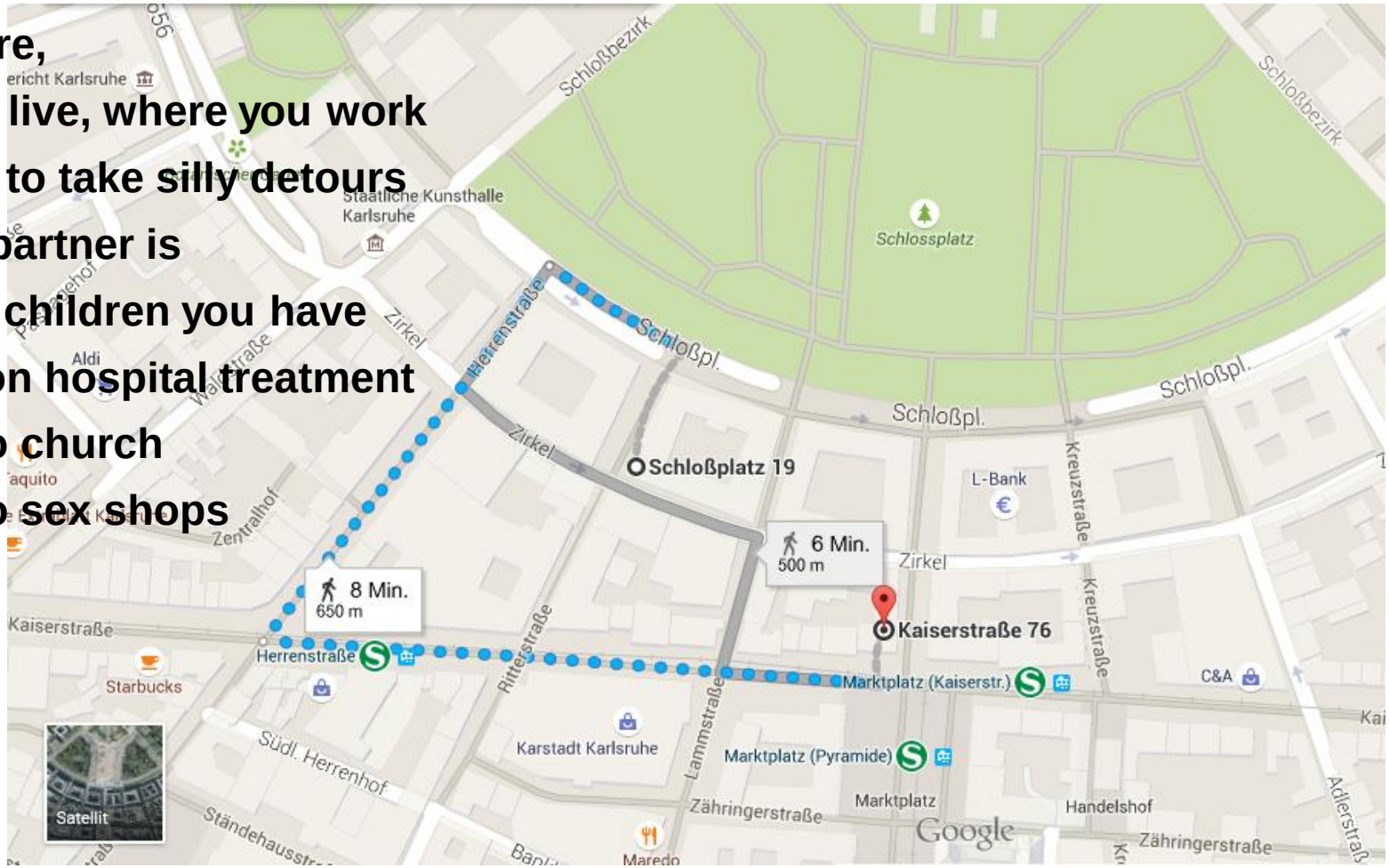
Standards: X.509 – defines format of large variety of attributes

Certificates need to be regularly updated and might be revoked, this their status is non-trivial to check.

The set of services handling all this is called **Public-Key Infrastructure (PKI)**.

Privacy is Tricky. Example: Location Data, e.g., From Smartphone

- If I have your location data over some time, I can tell:
- **Who you are,**
- **Where you live, where you work**
- **If you tend to take silly detours**
- **Who your partner is**
- **How many children you have**
- **If you are on hospital treatment**
- **If you go to church**
- **If you to go sex shops**



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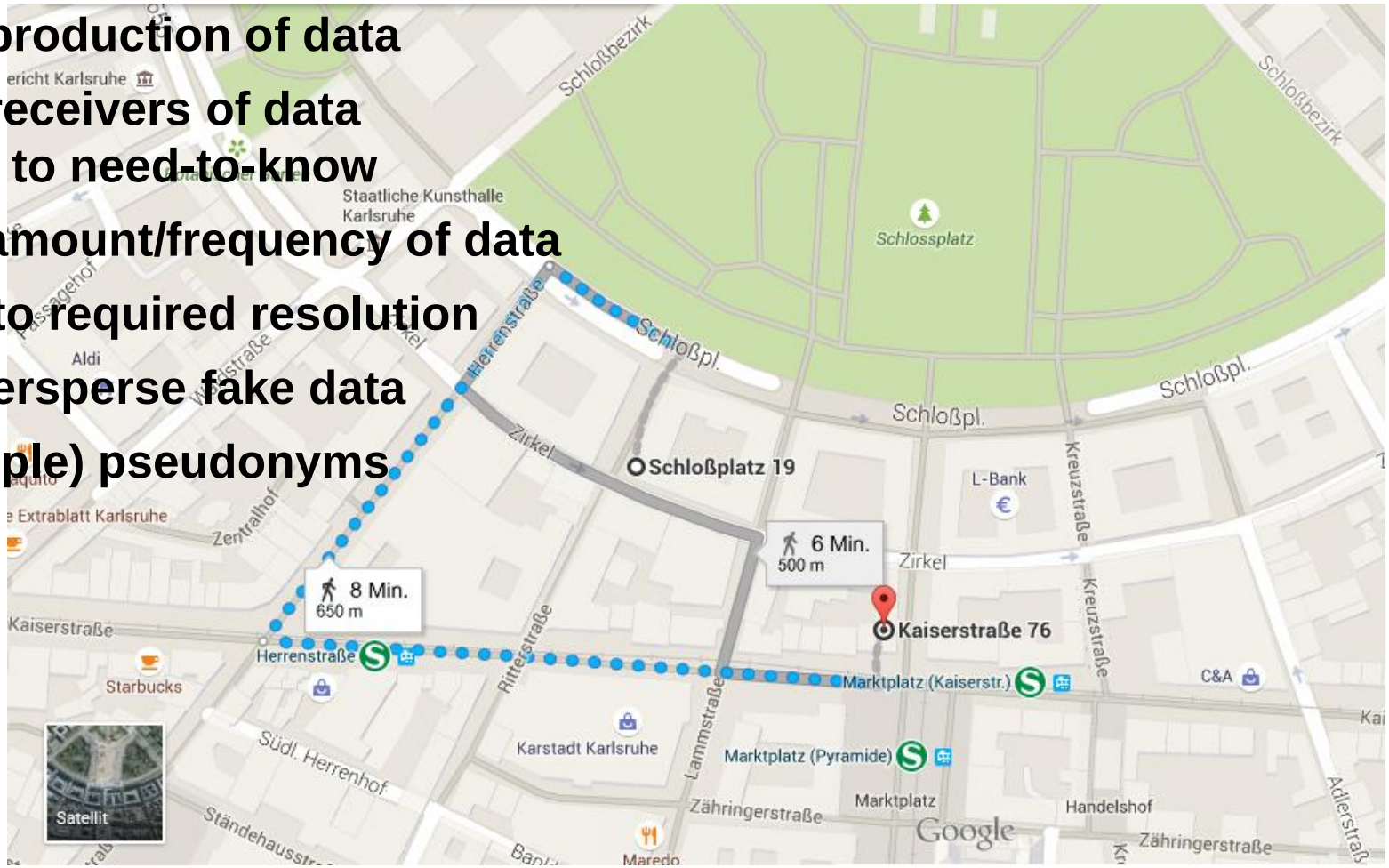
How to support privacy

- Principle of data sparingness:
  Only give as much data as needed, to as little parties as possible.
- **Minimize production of data**
- **Minimize receivers of data according to need-to-know**
- **Limit the amount/frequency of data**
- **Blur data to required resolution**
- **Maybe intersperse fake data**
- **Use (multiple) pseudonyms**



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Frequent Security Mistakes

What if a **programming error** anywhere in SW leads to a severe vulerability?

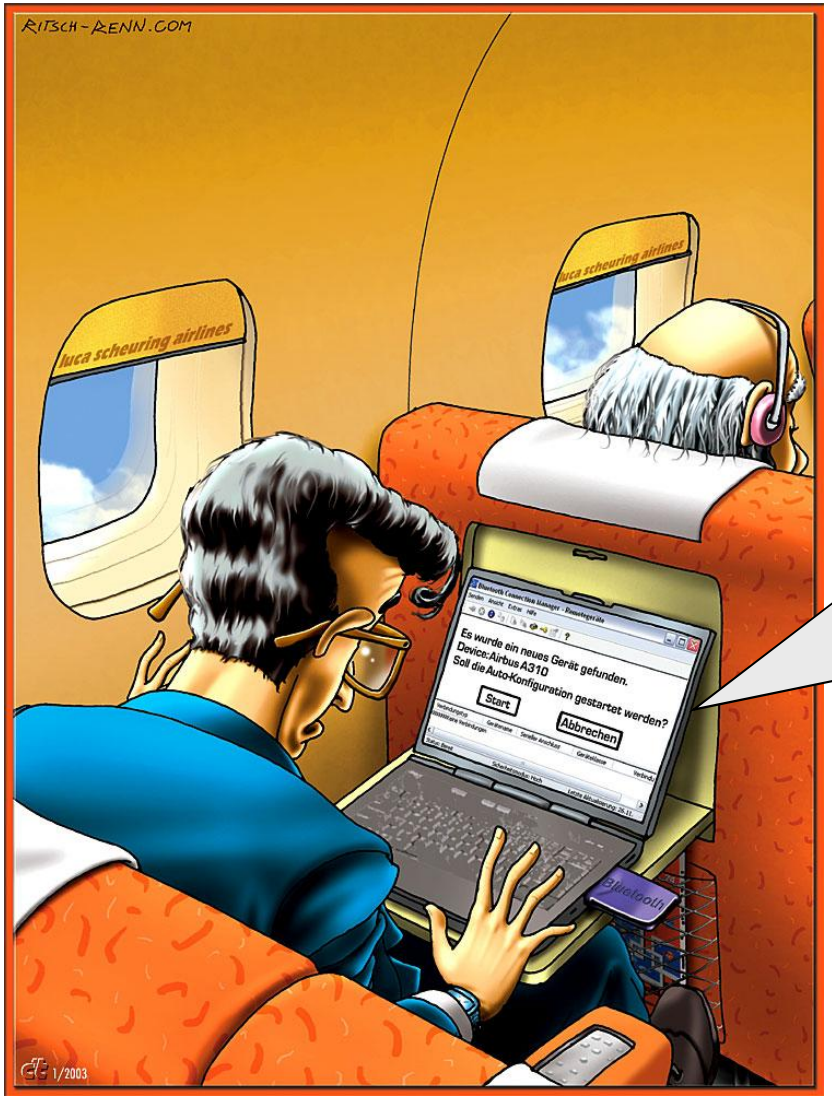
- Many such examples exist: buffer overflows, missing input validation, …

Why employ the best programmers if you **forgot an important requirement**?

What is any security mechanism worth if it can be **circumvented**?

- For instance, critical web server data may be accessible without login.

What Should Not Happen ;-)



A new device was found.

Device: Airbus A 310.

Shall auto-configuration be started?

start **cancel**

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Why employ the best programmers if you **forgot an important requirement**?

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- For instance, critical web server data may be accessible without login.

What does a decent security mechanism help if is **wrongly implemented**?

- Suppose the signature function uses the same test key on all systems.

Why use a strongest crypto algorithm if **secret keys can be leaked**?

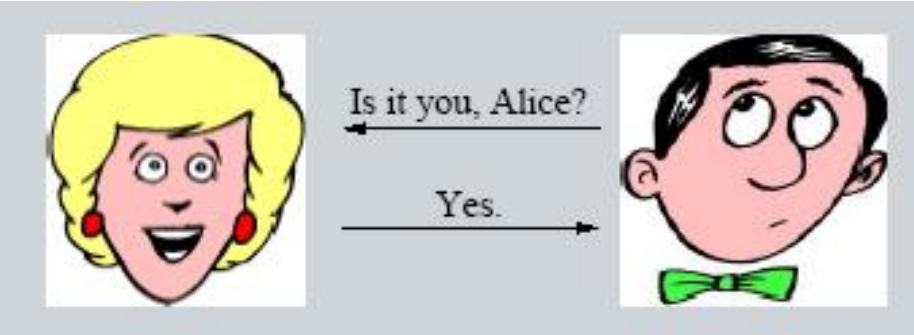
- E.g, due to differential power analysis (DPA)

What if your security mechanism has a **design flaw**?

- See Needham-Schroder Protocol example

Needham-Schroeder Public Key Protocol

- [Needham & Schroeder 1978]
- http://en.wikipedia.org/wiki/Needham-Schroeder_protocol
- Goal: strong mutual authentication



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

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

- Suffers from Man-In-The-Middle attack!

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Lowe's attack on NSPK

- [Lowe 1995] Man-in-the-middle attack by dishonest peer of A
- Requires two interleaved sessions, each with one honest party.
- In the first session, Alice talks with some party, e.g. Chuck, who in fact is an adversary, also called intruder.

1.1	A	- $\{Na.A\}_{pk(C)}$ ->		C
2.1			C(A) - $\{Na.A\}_{pk(B)}$ ->	B
2.2			C(A) <- $\{Na.Nb\}_{pk(A)}$ -	B
1.2	A <- $\{Na.Nb\}_{pk(A)}$ -			C
1.3	A	- $\{Nb\}_{pk(C)}$ --->		C
2.3			C(A) - $\{Nb\}_{pk(B)}$ -->	B

- In the second session, Bob thinks that he was contacted by Alice but actually talks to A via the intruder.
- Therefore, anything echoed by A, like Nb, gets leaked to the intruder.
- The protocol can be fixed by adding B's name to the 2nd message: $\{Na.Nb.B\}_{pk(A)}$

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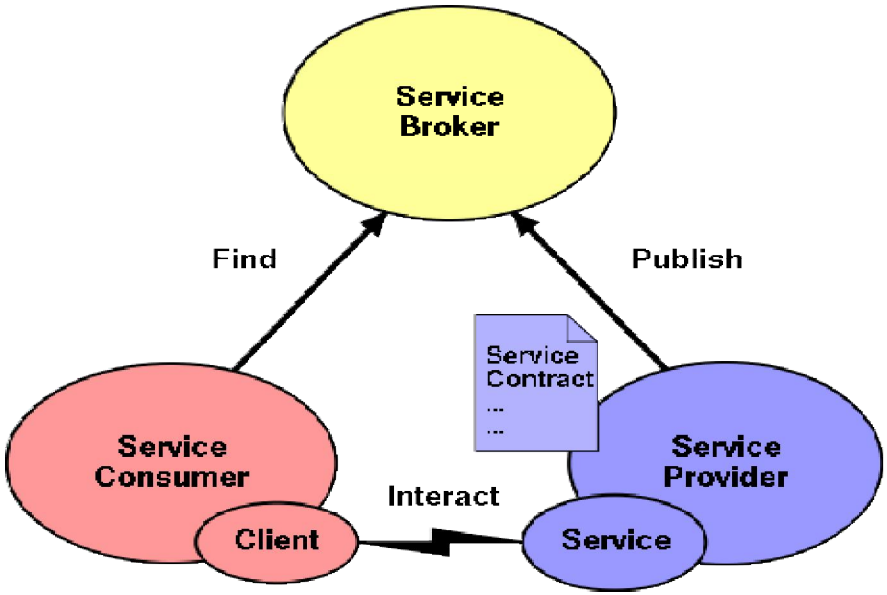
Model-checking SOA security — research project AVANTSSAR[1]



[1] **A**utomated **Va**lidatio**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

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How Not To Do Security ;-)