Security Architecture and Formal Analysis of an Airplane Software Distribution System

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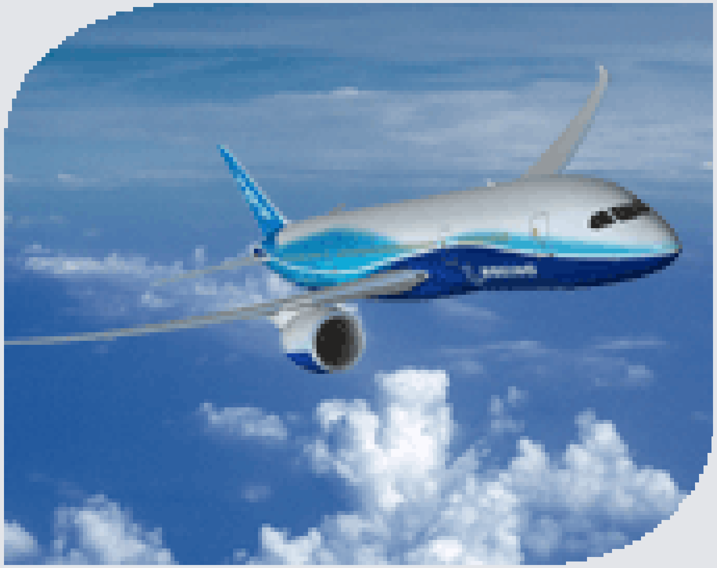

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Overview

- **A**irplane **A**sset **D**istribution **S**ystem
- Hybrid security assessment and architecture
- Formal crypto protocol model
- Validation with AVISPA Tool
- Conclusion

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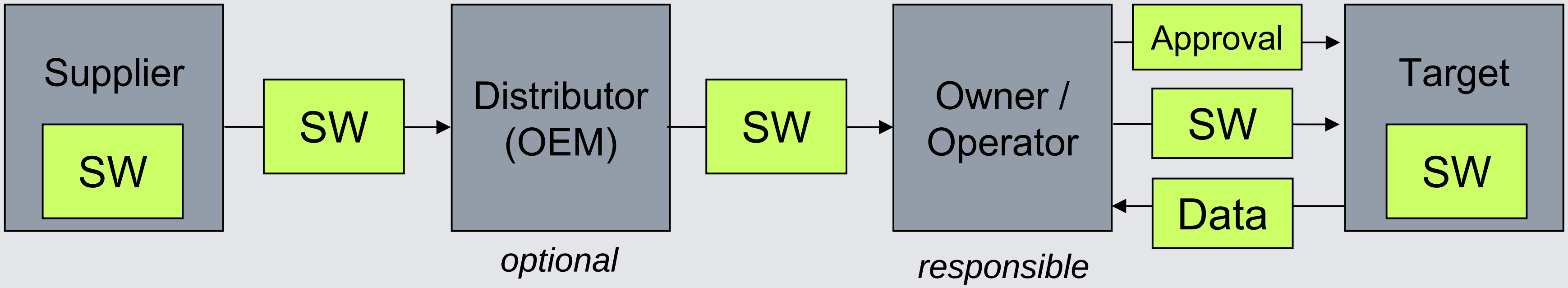
Airplane Asset Distribution System (AADS)

System providing secure distribution of software (aka. LSAP, parts, assets) and data from software supplier to aircraft in production or in service
→ **A**irplane **A**sset **D**istribution **S**ystem (AADS)



More general: IT system with networked devices in the field performing safety-critical and/or security-critical tasks.
Field devices require secure update of embedded software.

Transition from media-based (CD-ROMs etc.) to **networked transport** increases **security risks** due to transport over open, insecure networks

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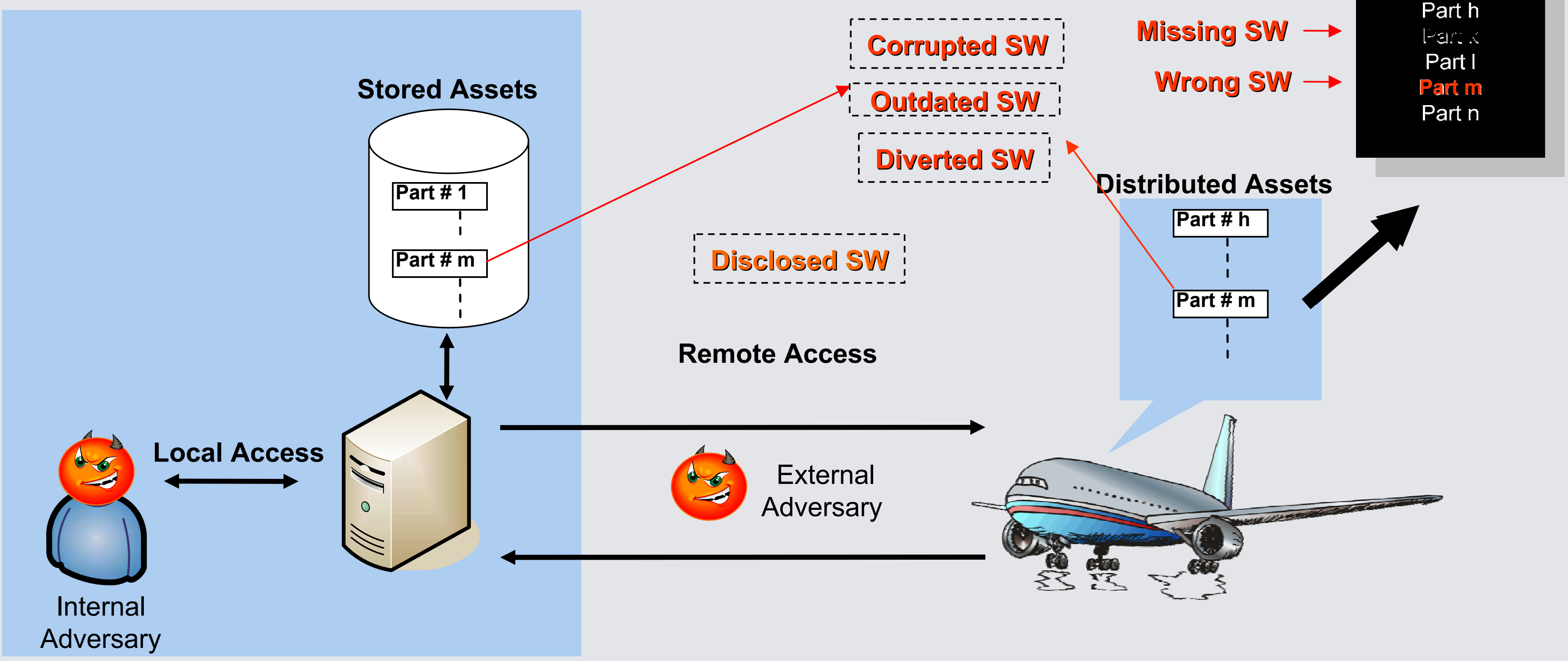
Security threats

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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Common Criteria (CC) for IT security evaluation

Common Criteria

product-oriented methodology

for **IT security assessment**

ISO/IEC standard 15408

Current version: 3.1 of end-2006

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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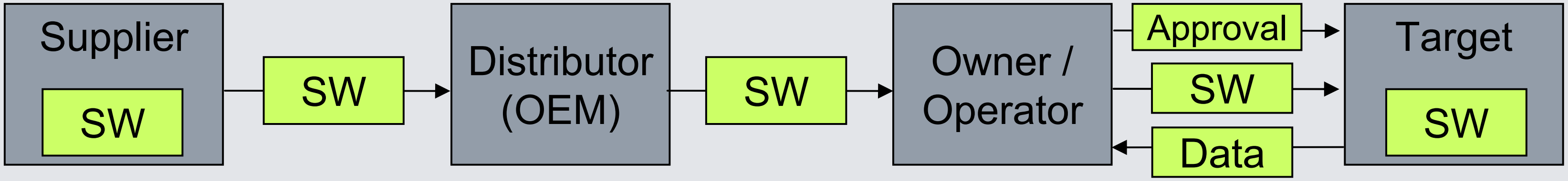
Hybrid security assessment

- AADS usually are complex distributed systems with many components



- Highest CC evaluation assurance levels (EAL 6-7) require formal analysis

General problems:

- Complete formal analysis too costly
- CC offer only limited support ("CAP") for modular system evaluation

Pragmantic approach:

- Define **confined security kernel** with generic component: ASV
- **Asset Signer Verifier (ASV)** handles digital signatures at each node
- Evaluate ASV according to Common Criteria EAL4 (non-formal)
- Analyze the interaction of ASVs in a formal way (→ crypto protocol)

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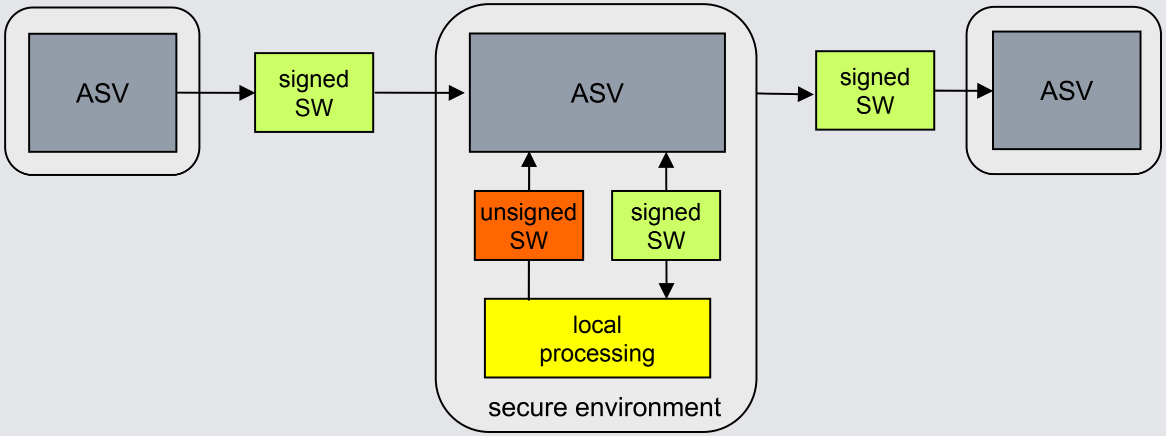
Asset Signer Verifier (ASV)

Each node in AADS runs an ASV instance, used for:

- Introducing unsigned software into the AADS, by digitally signing and optionally encrypting it
- Verifying the signature on software received from other ASVs, checking integrity, authenticity and authorization of the sender
- Approving software by adding an authorized signature
- Delivering software out of the AADS after successfully verifying it



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Formal modeling: Alice-Bob notation

```
SUP - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP}_KDIS -> DIS
DIS - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
            .{h(Asset).OP }_inv(KDIS).CertDIS}_KOP  -> OP
OP  - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
            .{h(Asset).OP }_inv(KDIS).CertDIS
            .{h(Asset).TD }_inv(KOP ).CertOP }_KTD  -> TD
```

`A - M -> B`	message M sent from A to B
`Asset`	a software item including its identity
`h(M)`	the hash value (i.e. crypto checksum) of content M
`M.N`	the concatenated contents of M and N
`{M}_inv(K)`	content M digitally signed with private key K
`{M}_K`	content M encrypted with public key K

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Formal modeling: AADS node structure

```
SUP  - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP}_KDIS -> DIS
DIS  - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
             .{h(Asset).OP }_inv(KDIS).CertDIS}_KOP   -> OP
OP   - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
             .{h(Asset).OP }_inv(KDIS).CertDIS
             .{h(Asset).TD }_inv(KOP ).CertOP }_KTD   -> TD
```

SUP: software supplier with private key **inv(KSUP)**

DIS: software distributor with private key **inv(KDIS)**

OP : target operator with private key **inv(KOP)**

TD : target device with private key **inv(KTD)**

Signatures comprise hash value of asset and identity of intended receiver

Signatures are applied in parallel (rather than nested or discarded)

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Formal modeling: approvals and certificates

```
SUP - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP}_KDIS -> DIS
DIS - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
            .{h(Asset).OP }_inv(KDIS).CertDIS}_KOP  -> OP
OP  - {Asset.{h(Asset).DIS}_inv(KSUP).CertSUP
            .{h(Asset).OP }_inv(KDIS).CertDIS
            .{h(Asset).TD }_inv(KOP ).CertOP }_KTD  -> TD
```

- Certificate of a node relates its identity with its public key, e.g. certificate of supplier `SUP`: **`CertSUP`** `= {SUP.KSUP}_inv(KCA)`
- Certificate authority (CA) with private key `inv(KCA)`
- Certificates are self-signed or signed by CA
- Locally stored sets of public keys of trusted ASVs and CAs
- Approval information partially modelled: **`operator`** specifies **`target`**

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Formal validation: goals

Show asset authenticity, integrity and confidentiality*:*

- assets accepted by target have indeed been sent by the supplier
- assets accepted by target have not been modified during transport
- assets remain secret among the ASV instances
- asset authenticity and integrity also hop-by-hop

Correct destination covered*:*

- Name of the intended receiver in signed part, checked by target.
  Signature of the operator acts as installation approval statement.

Correct version partially covered:

- Integrity of version info, *checks delegated* to ASV local environment.

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Formal validation: remarks

Modelling:

- Alice-Bob notation not detailed and precise enough
- Use the specification language of the AVISPA Tool: HLPSL
- Asset Signer Verifier (ASV) as parameterized role, multiple instances
- AADS as communication protocol linking different ASV instances
- Multiple protocol sessions describing individual SW transports

Checking:

- At the level of detail of the model, **all goals are met**
- Modelcheckers at their complexity limits, due to
  - parallel signatures, only the latest one being checked
  - multiple instances of central nodes (e.g. manufacturer)
  - …?

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Conclusion

- Challenges for AADS development
  - complex, heterogeneous, distributed system
  - security is critical for both flight safety and airline business
- Experience with AADS evaluation
  - Common Criteria most widely accepted methodology available
  - Problem of compositional security evaluation not solved
  - Use formal analysis where cost/benefit ratio is best
  - Highly precise design and documentation: assumptions, requirements
  - Shape system architecture to support security evaluation
- Future steps
  - Trust management aspects including Public Key Infrastructure (PKI)
  - Configuration management with installation instructions and reports

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