MAFTIA Project Overview

presented by

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MAFTIA - Malicious and Accidental Fault Tolerance for Internet Applications

- The MAFTIA project will systematically investigate the ‘tolerance paradigm’ for constructing large-scale dependable distributed applications.
- Its major innovation is a comprehensive approach for tolerating both accidental faults and malicious attacks in such systems, including attacks by external hackers and by corrupt insiders.

Contribution to EC Policies

- Large network infrastructures, such as the Internet, are vital for citizens to benefit from the services provided by the Information Society.
- Development depends on how much the users will ‘trust’ the services offered to them.
- Critical to make such services dependable, and in particular resilient to malicious attacks perpetrated by external hackers or by corrupt insiders.

Added Value

- Project consistent with the ‘European Dependability Initiative’.
- Expertise gathered at International level in the fields of fault-tolerance, distributed computing, computer security, intrusion detection and cryptography.

Partners

- **QinetiQ, Malvern (UK)** - Sadie Creese
- **IBM, Zurich (CH)** - Andreas Wespi / Michael Waidner
- **LAAS-CNRS, Toulouse (F)** - Yves Deswarte / David Powell
- **Newcastle University (UK)** - Robert Stroud / Brian Randell
- **Universität des Saarlandes (D)** - Andre Adelsbach
- **Universidade de Lisboa (P)** - Paulo Veríssimo

- Project Coordinator - Newcastle

Industrial Advisory Board

- Representative of a wide range of industrial sectors with an interest in security and intrusion tolerance:
  - Jean-Claude Lebraud, Rockwell Collins
  - Derek Long, Cisa Ltd
  - Gritta Wolf, Credit Suisse Financial Services
  - Joachim Posegga, SAP
  - Andrew Izon, North Durham Healthcare NHS Trust
  - Gilles Trouessin, Ernst Young
  - Carlos Quintas, Altitude Software
  - Tom McCutcheon, DSTL
- Invited to all workshops, kept informed of progress, and asked to comment on future directions

Project Objectives

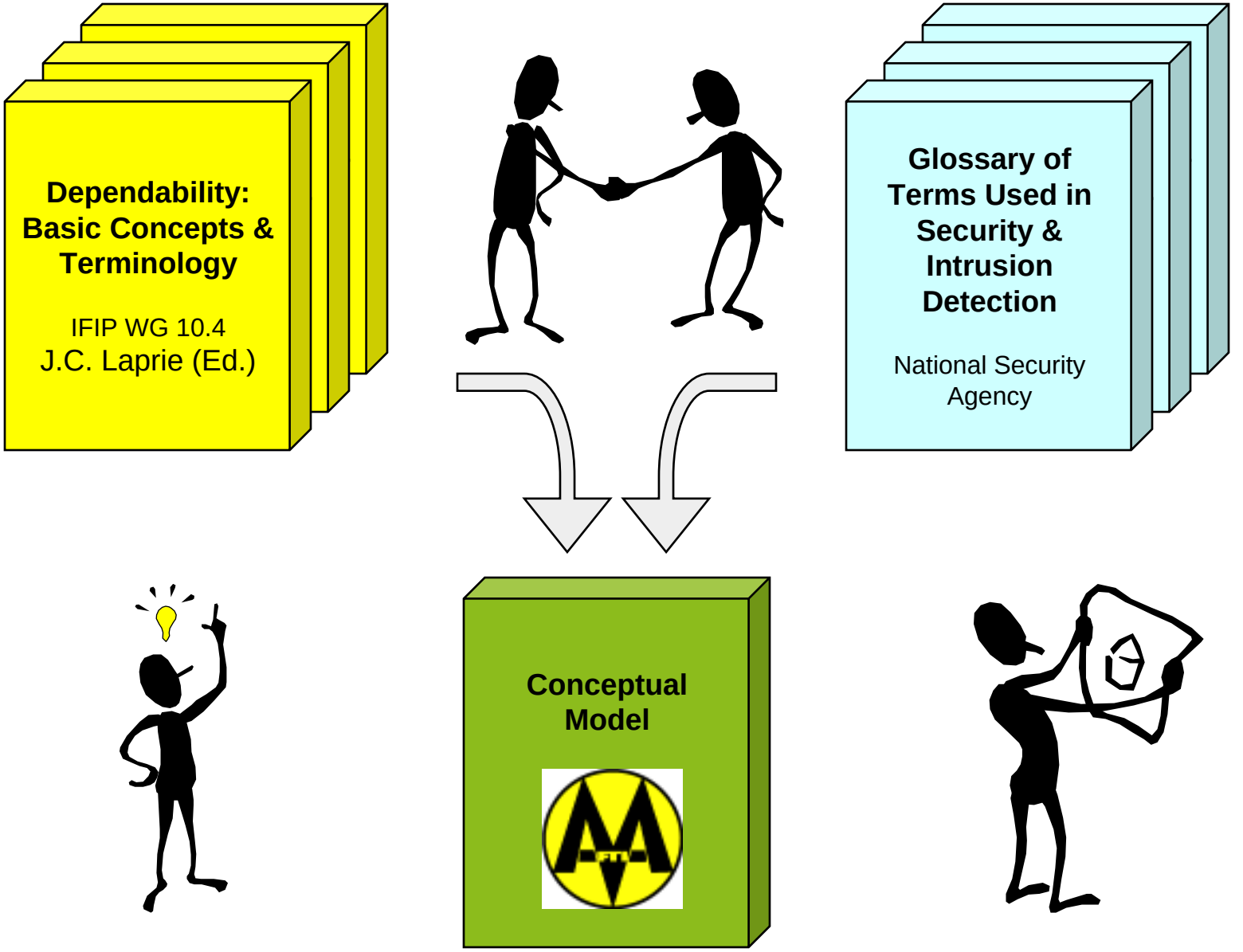
- The objective of MAFTIA is to investigate the ‘tolerance’ paradigm for security systematically
- Work is focused in three main areas:
  - the **architecture** of MAFTIA: providing a framework that ensures the dependability of distributed applications in the face of a wide class of faults and attacks,
  - the design of **mechanisms and protocols**: providing the required building blocks to implement large scale dependable applications,
  - the **formal assessment** of our work: rigorously defining the basic concepts developed by MAFTIA and verifying the results of the work on dependable middleware.

Workpackages

- WP1 - Conceptual Model and Architecture
- WP2 - Dependable Middleware
- WP3 - Intrusion Detection
- WP4 - Dependable Trusted Third Parties
- WP5 - Distributed Authorization
- WP6 - Verification and Assessment

WP1 – Conceptual Model and Architecture

- A discussion of the relationship between security policies, goals, rules, and security failures
- An analysis of attacks, vulnerabilities and intrusions in terms of the basic dependability concepts of fault, error and failure
- A classification of ten security methods for dealing with attacks, vulnerabilities and intrusions
- The development of an integrated intrusion detection/tolerance framework for building intrusion tolerant systems
- The identification of various architectural strategies for building intrusion tolerant components based on different models of trust
- A fault tree analysis of MAFTIA's intrusion tolerance capabilities based on a simplified but realistic use case

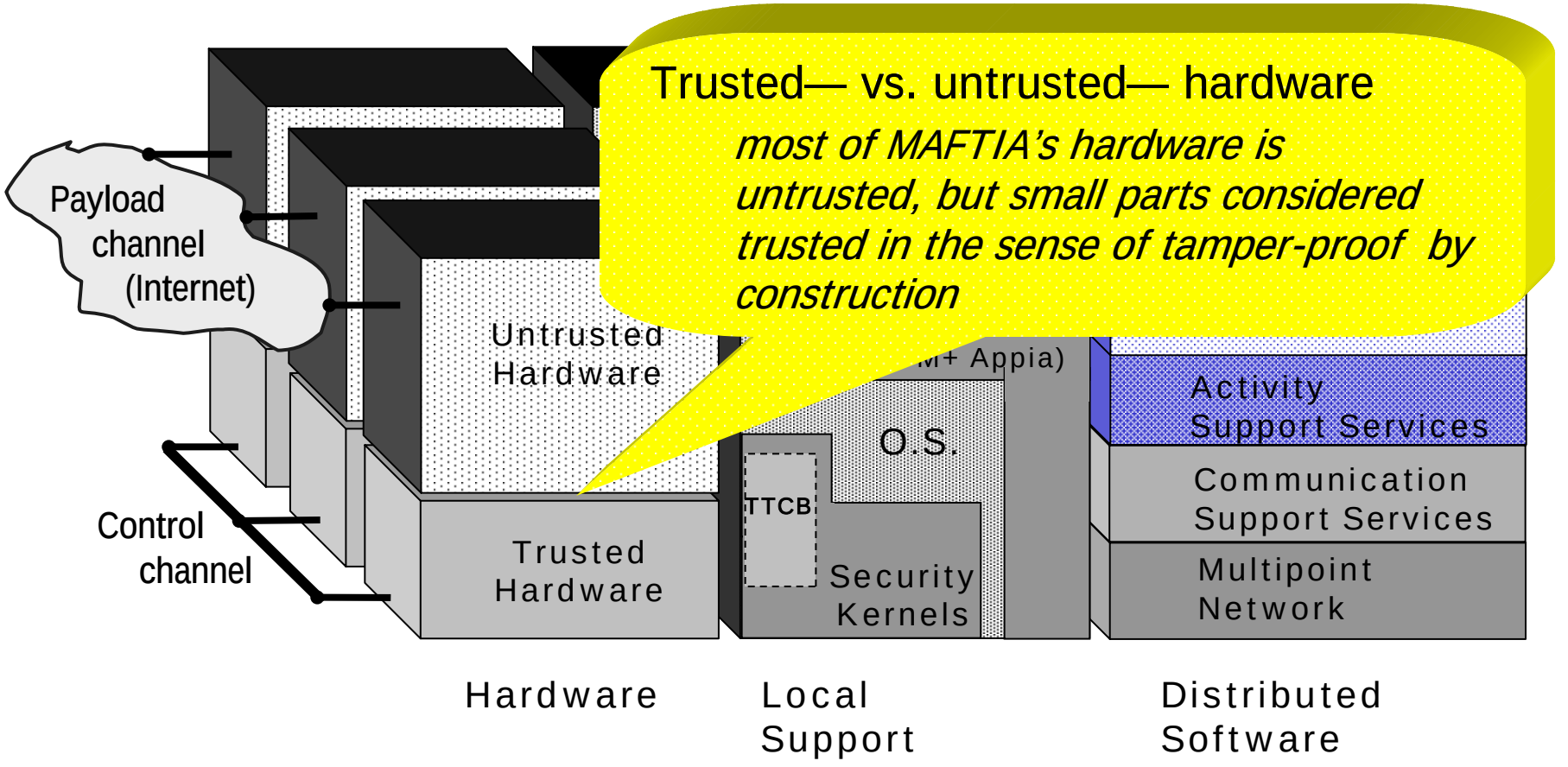

Dependability:
Basic Concepts &
Terminology
IFIP WG 10.4
J.C. Laprie (Ed.)
Glossary of
Terms Used in
Security &
Intrusion
Detection
National Security
Agency
Conceptual
Model

WP2 – Dependable Middleware

- Guiding principles:
  - Hybrid failure assumptions
  - Recursive use of fault tolerance and fault prevention
  - Components trusted to the extent of their trustworthiness
- Within this framework, a number of different approaches to the construction of dependable middleware have been explored:
  - Fail uncontrolled
  - Fail controlled with local trusted components
  - Fail controlled with distributed trusted components
- Specification, design and implementation of APIs and protocols for various aspects of the MAFTIA middleware, namely…
  - The Trusted Timely Computing Base (TTCB)
  - Secure group communication protocols (two versions)
  - An intrusion tolerant transactional support service built using these protocols

Architecture Overview

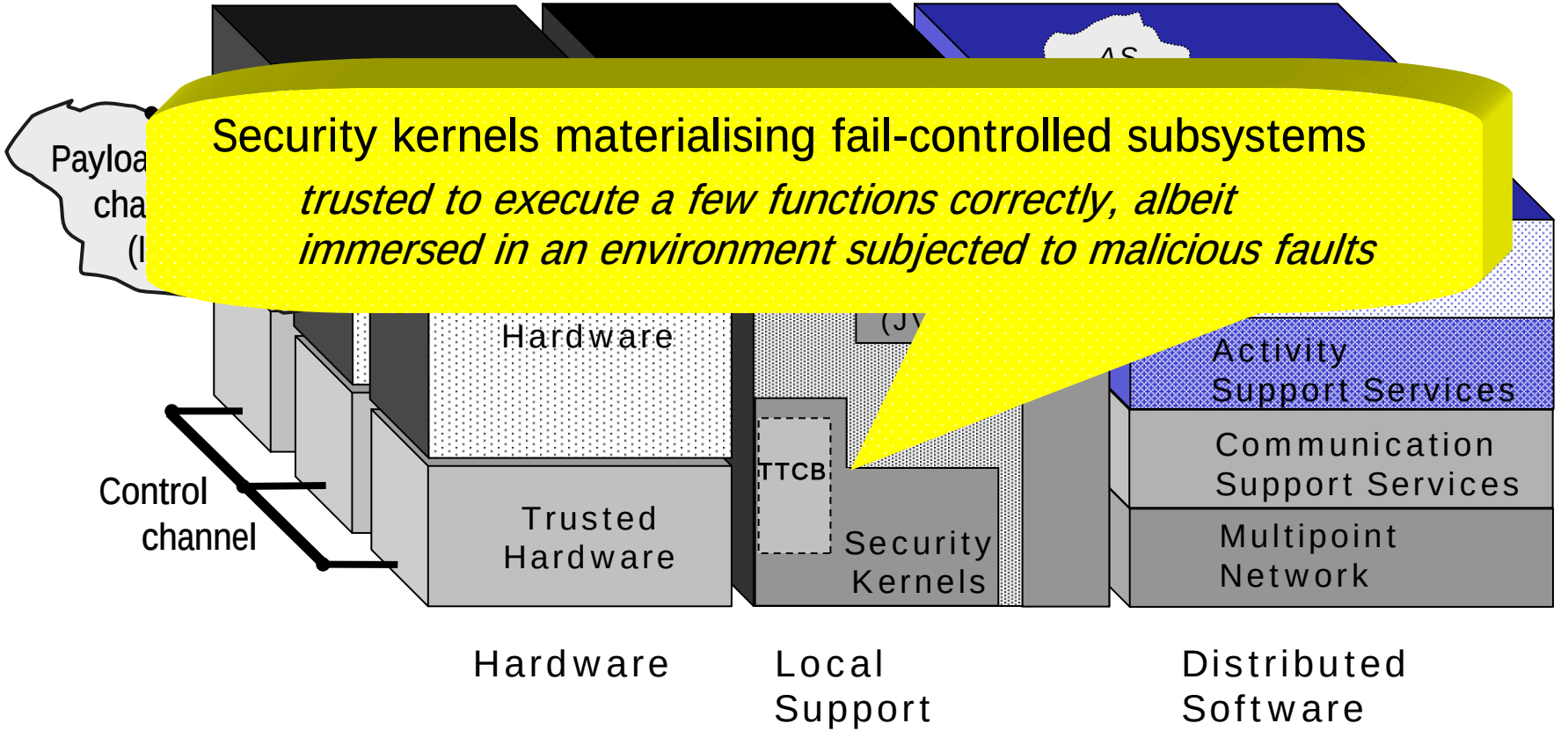
Host architecture



AS - Authorisation Service, IDS - Intrusion Detection Service, TTP - Trusted Third Party Service

Architecture Overview

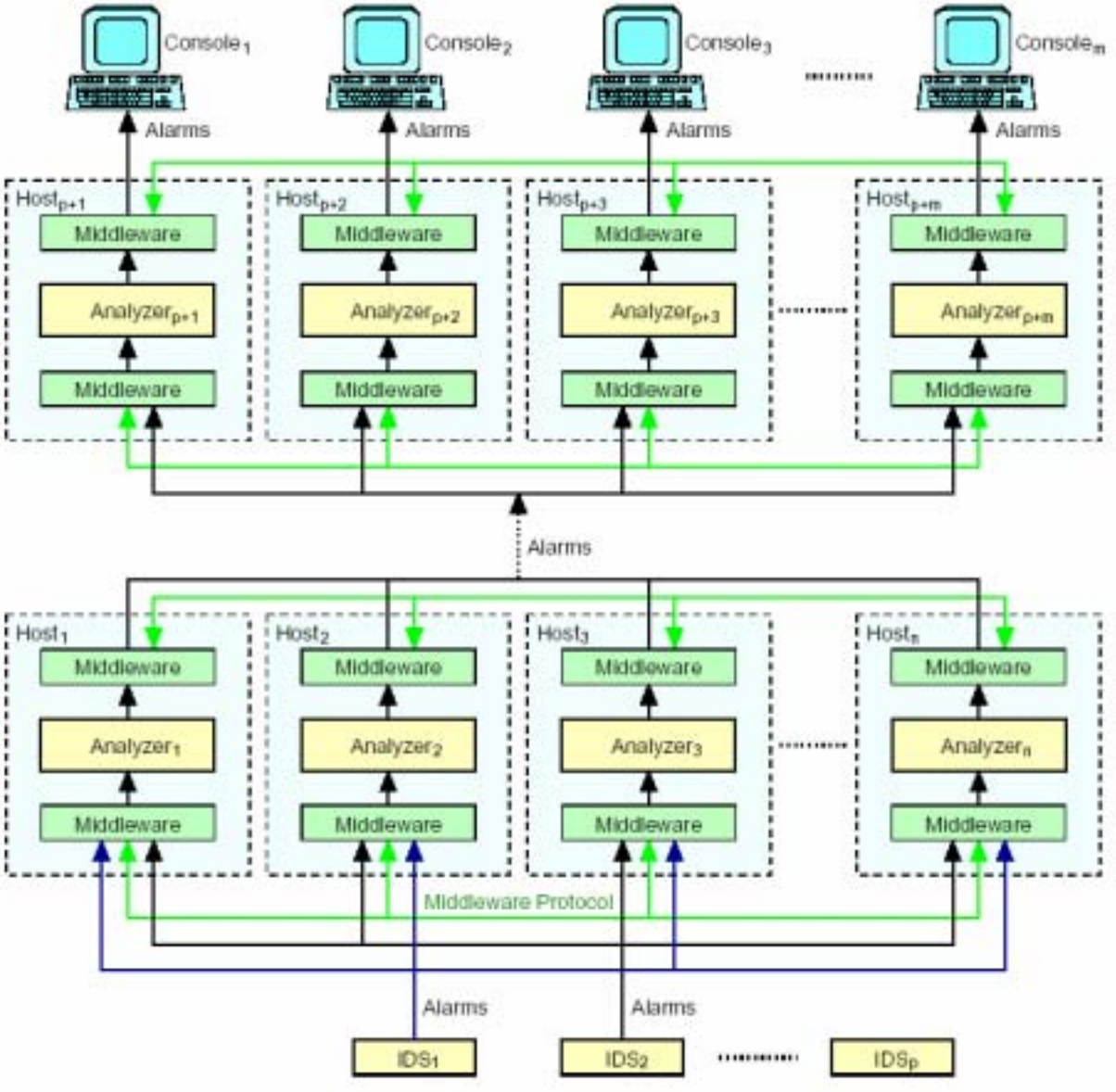
Host architecture



AS - Authorisation Service, IDS - Intrusion Detection Service, TTP - Trusted Third Party Service

WP3 – Intrusion Detection

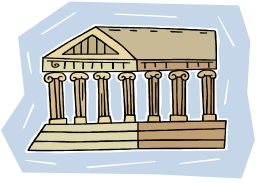
- The development of a taxonomy and framework for analyzing the strengths and weaknesses of existing Intrusion Detection Systems (IDSs)
- The development of a novel algorithm for clustering together ID alerts with similar root causes
- Techniques for reducing the rate of false positives and false negatives
- A testbed for evaluating IDSs
- The specification of an architecture for a large scale intrusion tolerant distributed IDS
- Development of a prototype intrusion tolerant IDS using the MAFTIA middleware


Console1
Console2
Console3
Consolem
Alarms
Alarms
Alarms
Alarms
Hostp+1
Hostp+2
Hostp+3
Hostp+m
Middleware
Middleware
Middleware
Middleware
Analyzerp+1
Analyzerp+2
Analyzerp+3
Analyzerp+m
Middleware
Middleware
Middleware
Middleware
Alarms
Host1
Host2
Host3
Hostn
Middleware
Middleware
Middleware
Middleware
Analyzer1
Analyzer2
Analyzer3
Analyzern
Middleware
Middleware
Middleware
Middleware
Middleware Protocol
Alarms
Alarms
IDS1
IDS2
IDSp

WP4 – Dependable Trusted Third Parties

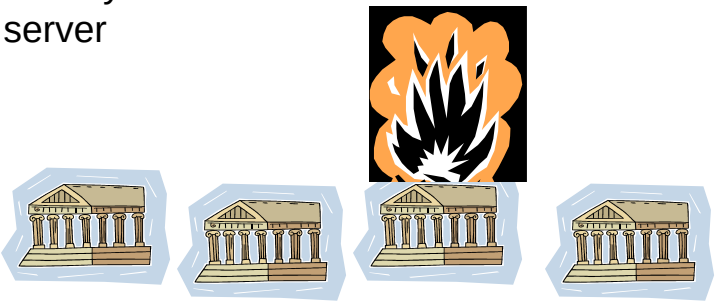
- A blueprint for building generic trusted third-party services using state-machine replication
- The full specification of a distributed certification authority (CA) and a trusted party for optimistic fair exchange, developed according to this blueprint
- A prototype implementation of the distributed CA using the protocol suite developed in WP2

Secure replication of trusted service



Domain name server
Certification authority
Electronic notary
Directory server
…

Single point of failure
(hackers, insiders)



Replicate critical system components:
t<n/3 intrusions or crashes can be tolerated.

Theoretical limits:
- $t < n/3$ malicious servers
- arbitrary delays

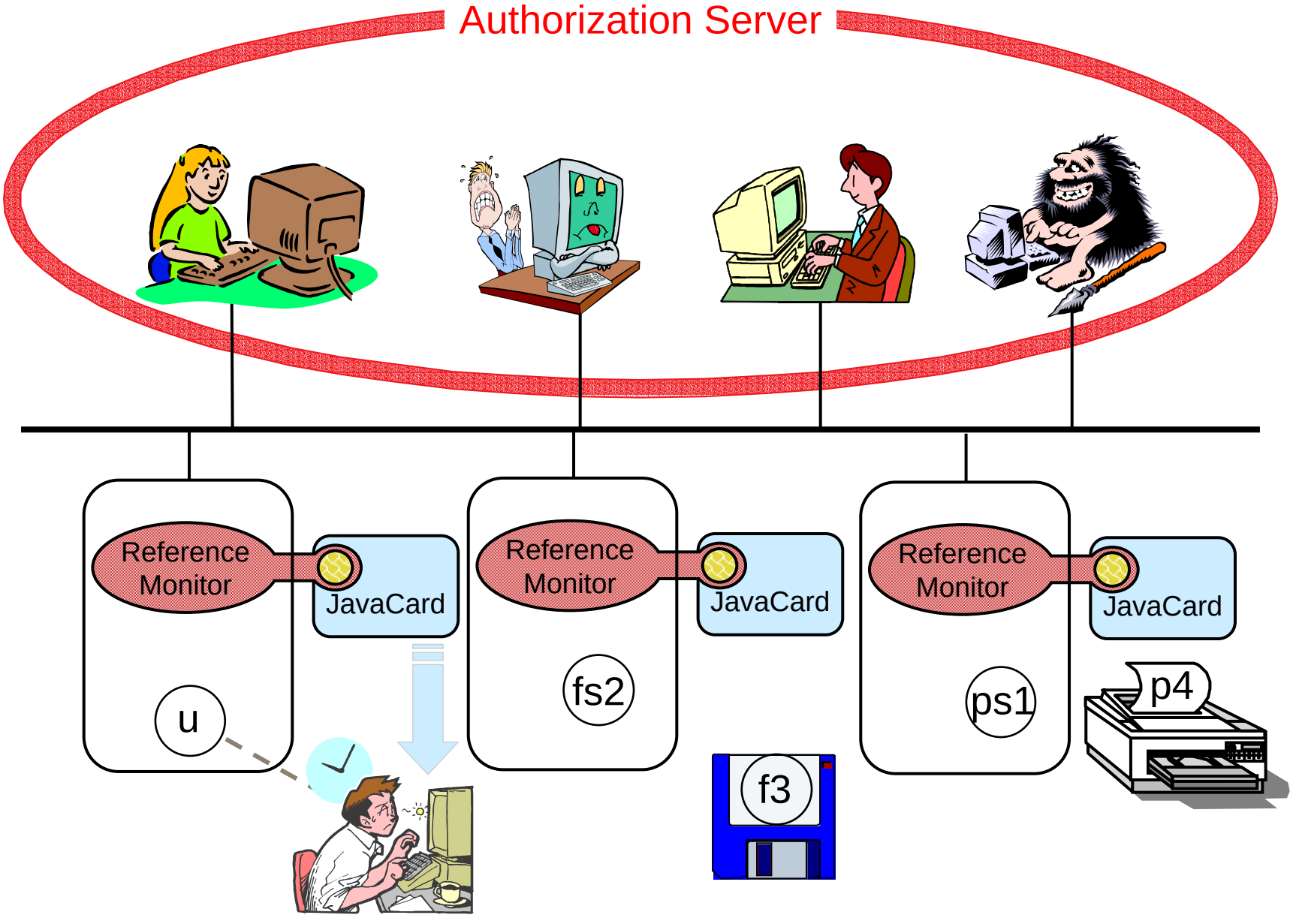
Folklore:
- No practical solution can reach these limits!

Malicious corruption ≠ crash failure!
Might include delaying messages arbitrarily!

MAFTIA
Achieves these limits, efficiently and provably secure

WP5 – Distributed authorization

- Design and implementation of an intrusion tolerant distributed authorization service
- Each MAFTIA host (user workstation or server) has a local reference monitor, partially implemented on a JavaCard
- A distributed, intrusion-tolerant authorization server uses replication together with a threshold signature scheme to grant capabilities
- Java Cards are assumed sufficiently tamper-proof by design
- However, the overall security of the system does not depend on trusting individual hosts, so the effects of any corruption are limited
- A prototype implementation has been built, using the protocols provided by the MAFTIA middleware


Authorization Server
Reference Monitor
JavaCard
Reference Monitor
JavaCard
Reference Monitor
JavaCard
u
fs2
ps1
p4
f3

WP6 – Verification and Assessment

- Goals
  - Develop a rigorous model of selected malicious- and accidental-fault tolerance concepts
  - Formalize some properties and protocols in the language CSP and verify them with a model checker
  - Investigate how cryptography can be integrated into such formalizations in a faithful way
- Results
  - A cryptographic model for formalizing basic concepts of MAFTIA systems using a simulatability definition
  - The formalisation and verification of selected components of the MAFTIA middleware, including the TTCB
  - A composition theorem, which supports modular proofs that bridge the gap between these two models

Cryptography vs Formal Methods

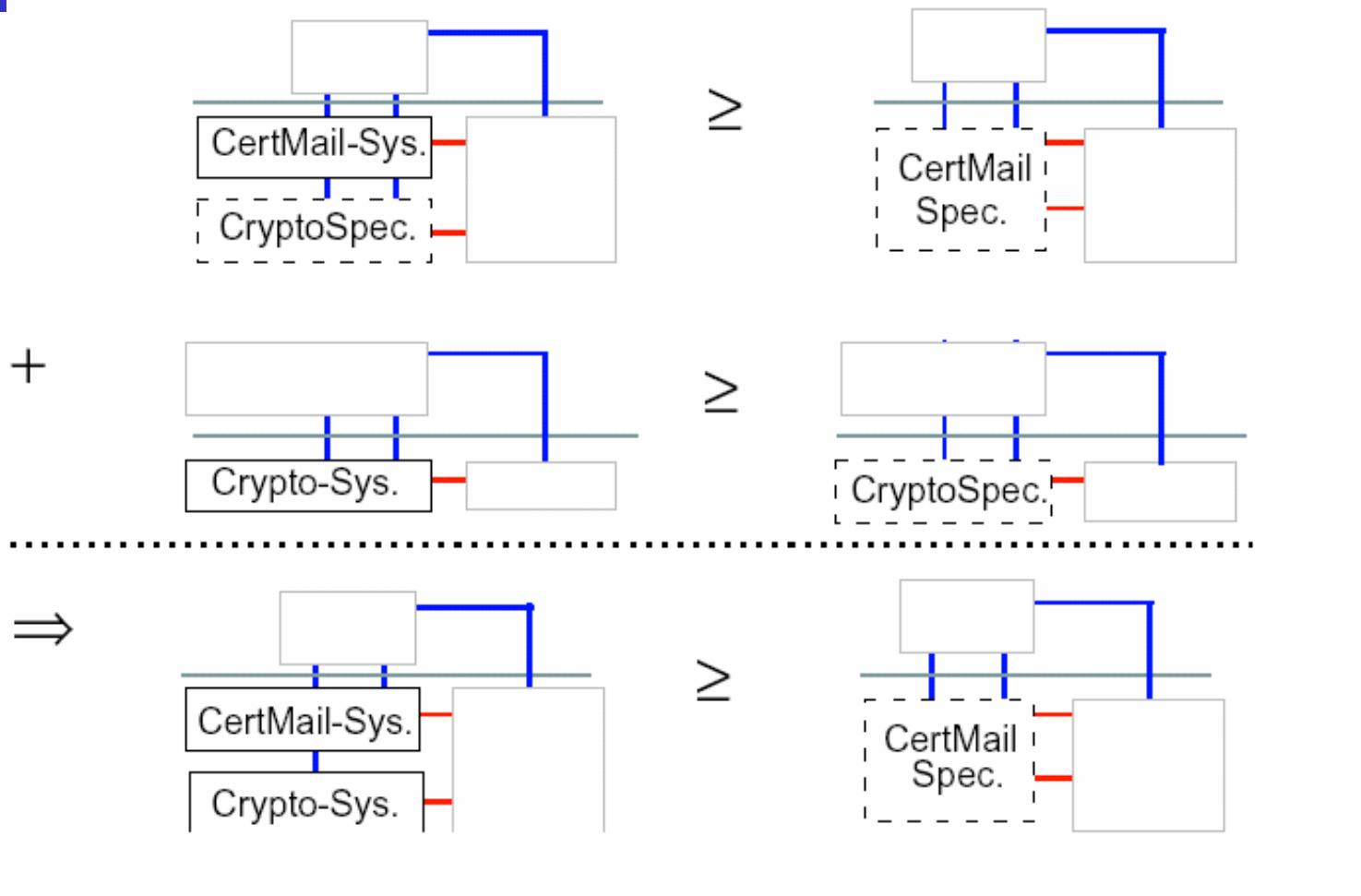
Cryptography:

- ✓ Precise definitions and proofs
- ✘ Each definition long and error-prone
- ✘ Proofs long and error-prone
- ✘ No tool support

Formal methods:

- ✓ Well-defined protocol languages (e.g., CSP)
- ✓ Tool-support (e.g., FDR)
- ✘ No cryptographic semantics
- ✘ Need to abstract from reality

Composition theorem



Links between work packages

- On concepts and models
  - WP1, WP2, WP3, WP6
- On architecture
  - WP1, WP2, WP3, WP4, WP5
- On middleware
  - WP2, WP4
- On distributed services
  - WP2, WP3, WP4, WP5
- On formal validation and assessment
  - WP2, WP4, WP6

Year 3 Deliverables

- Reports
  - D9 - Complete specification of APIs and protocols for the MAFTIA middleware
  - D10 - Design of an intrusion tolerant IDS
  - D21 - Conceptual model and architecture of MAFTIA
  - D22 - Final report on verification and assessment
  - D99 - Architectural analysis of MAFTIA's intrusion tolerance capabilities
- Demonstrations
  - D11 - Running prototype of MAFTIA middleware
  - D12 - Demonstration of dependable TTPs
  - D13 - Demonstration of an intrusion tolerant IDS
  - D14 - Demonstration of distributed authorization

Key deliverables by workpackage

- D21 Conceptual Model and Architecture of MAFTIA (WP1)
- D9 Complete Specification of APIs and Protocols for the MAFTIA Middleware (WP2)
- D3 Taxonomy of IDSs and Attacks (WP3)
- D10 Design of an Intrusion Tolerant IDS (WP3)
- D26 Specification of Dependable Third Party Services (WP4)
- D5 Full Design of Dependable Third Party Services (WP4)
- D27 Specification of Authorisation Services (WP5)
- D6 Design of the Local Authorisation Checker (WP5)
- D4 Formal Model of Basic Concepts (WP6)
- D22 Final report on Verification and Assessment (WP6)

Publications and Dissemination

- Publications at major conferences, including:
  - DSN, Oakland, Crypto, RAID, SRDS, EDCC, CCS, e-Smart, …
- Participation in workshops:
  - EU/US Dependability Initiative
  - Pan-dependability workshop
  - Road mapping and consensus building, planning for FP6
  - IFIP WG 10.4
  - DARPA, Survivability, …
- Links with other projects
  - DSoS, Matisse, …
  - DIRC
  - Cabernet