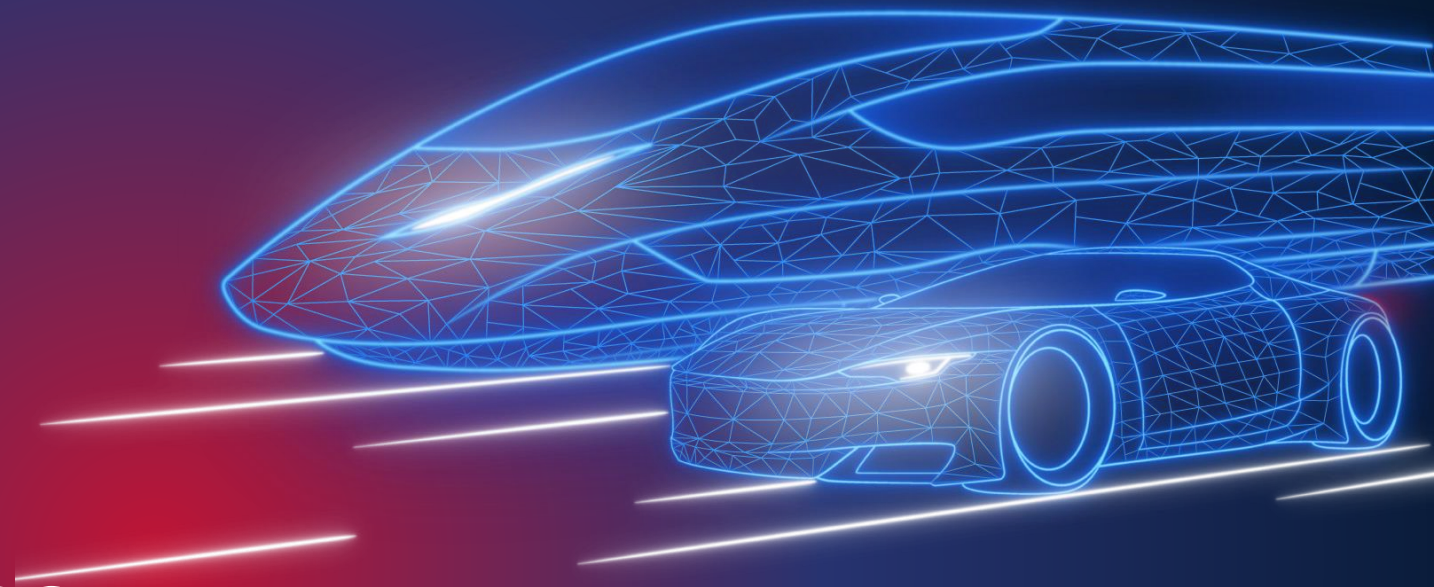

From ECU to VSOC: UDS Security Monitoring Strategies

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Emerging Security Information, Systems and Technologies

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CTO & Head of Cybersecurity

- 15+ years of cybersecurity experience in IT and OT systems
- Red and Blue Team specialist
- Building and operating SOCs for critical infrastructure
- Extensive experience in railway, automotive, and energy sectors
- Co-founder and Head of Cybersecurity at Yekta IT GmbH
- Research focus on OT security
- Master's degree in IT Security (Ruhr University Bochum)
- OSCP, OSWE, OSEP, CRTO Certifications

FINESSE – Research Project

FINESSE Project Objectives:

- Multi-modal security monitoring for road and rail vehicles with synergy effects identification
- Unified security architecture across all system layers
- On-board components for vehicle-specific attack detection and system-wide analysis
- Fleet-scale attack detection and backend analytics

https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/finesse

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Federal Ministry of Research, Technology and Space

Motivation

Modern Vehicles

- Increasing complexity
- Connectivity and wireless interfaces
- Vulnerable to cyberattacks

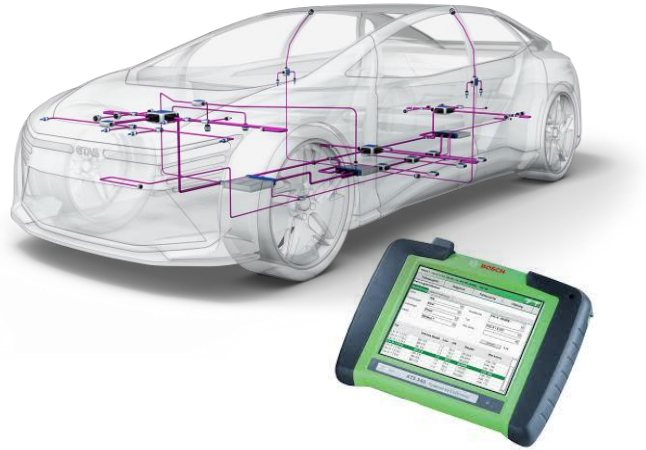
UN R155 Regulation

- Mandatory cybersecurity requirements
- Detection & response required
- Fleet security monitoring is a technical measure to satisfy certain regulation requirements

- Vehicle security monitoring for vehicle fleets has been established
- Still not well understood how to detect higher-level attack techniques from low-level security events
- We consider a widely used vehicle diagnostic protocol (UDS) as an example

Research Gap: Security monitoring for the UDS protocol has not been studied systematically before

Unified Diagnostic Services (UDS) Security



Unified Diagnostic Services (UDS) Protocol [ISO 14229]: **The Critical Entry Point**

- **Most widely used** automotive diagnostic protocol
- **Entry door** to Electronic Control Units (ECUs)
- Used during **all lifecycle phases**: development, testing, operation, maintenance
- **High level of control** over ECU functionality

- UDS security investigated in **isolated cases**
- Focus mainly on **Security Access Service**

- **Comprehensive taxonomy of attack techniques for UDS** [1]
- 53 UDS attack techniques along 9 tactics of known attack frameworks

Persistence (PS)
Resource Development (RD)
Lateral Movement
Privilege Escalation (PE)
Affect Vehicle Function (AF)
...

[1] A. Yekta, et al, “UDS attack taxonomy: Systematic classification of vehicle diagnostic threats,” CPS-Sec 2025, IEEE, 2025.

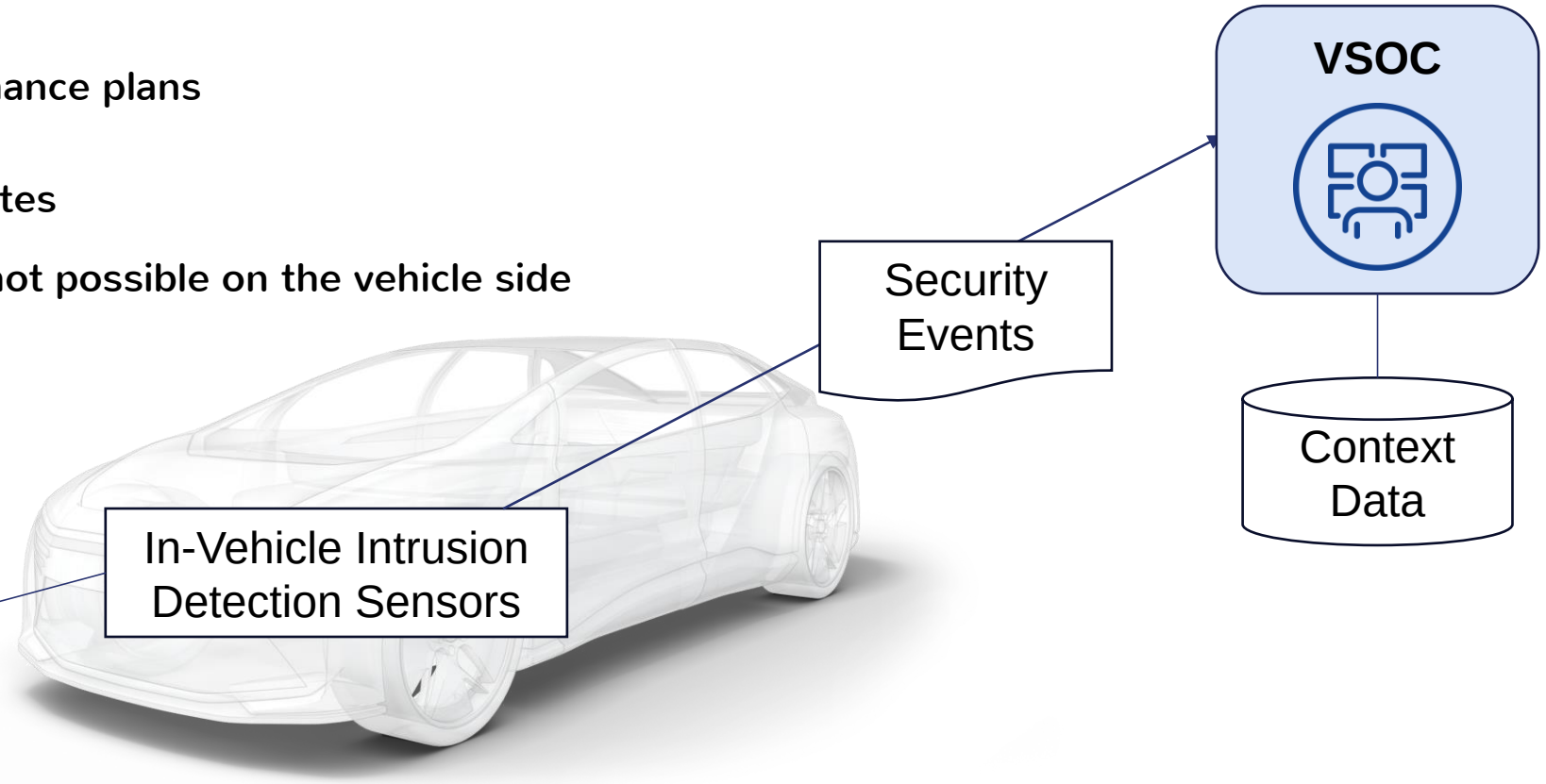
UDS Protocol Overview [ISO 14229]

- Communication standard between **diagnostic testers** and **ECUs**
- Request-response protocol with **Service IDs (SIDs)**
- Many services provide **powerful ECU control**

Service ID	Service Name	Purpose
0x10	DiagnosticSessionControl	Change diagnostic sessions
0x22	ReadDataByIdentifier	Read ECU data
0x27	SecurityAccess	Authentication & authorization
0x2E	WriteDataByIdentifier	Write ECU data
0x31	RoutineControl	Execute ECU routines
0x34/36	RequestDownload/TransferData	Software updates
...	...	...

VSOC: Vehicle Security Operations Center

- Collects security events from **entire vehicle fleet**
- Correlates with **context data**:
  - Vehicle records & maintenance plans
  - Threat intelligence feeds
  - Authorized firmware updates
- Enables **advanced detection** not possible on the vehicle side



- CAN IDS
- Ethernet IDS
- Host-Based IDS
- …

AUTOSAR Security Events

Industry Standard for Automotive Software

- Widely adopted **firmware specification**
- Native support for **Security Events (SEvs)**
- Standardized logging Formats

Example: AUTOSAR Security Event 103

SEV_UDS_SECURITY_ACCESS_FAILED

Triggered when SecurityAccess (0x27) authentication fails

Evaluation Focus: Assess how well current AUTOSAR standard supports UDS attack detection

Methodology

Methodology: Three-Layer Strategy

1. **Logging Strategies:** Define **which events** to log in vehicles
2. **Context Data Strategy:** Specify **which context information** to capture with logs
3. **Detection Strategies:** Develop rules to **identify attack scenarios** from logs

Logging Strategies

IR: Invalid Request: Log UDS requests that are invalid due to:

- Input validation failures (format, parameters, payload)
- Unexpected circumstances (e.g., vehicle driving, missing authorization)

FE: Function Execution: Log execution of **critical UDS services**

- Memory modifications
- Routine executions
- Authentication attempts

MFI: Message Flow Inconsistency: Log messages with routing anomalies:

- Unexpected source
- Modified during routing
- Unexpected sequence

Context Data Strategy

Basic Context

Service ID (SID)

Subfunction (SF)

Negative Response Code (NRC)

Timestamp

Service-Specific Context

Data Identifiers (DIDs)

Memory addresses & sizes

Routine IDs

Hashes over transferred data

Context Data: Examples

SID	Service	Context Data to Log
0x27	SecurityAccess	SID, Subfunction, NRC
0x2E	WriteDataByIdentifier	SID, DID, **hash over data**, NRC
0x31	RoutineControl	SID, Subfunction, RoutineID, NRC
0x34	RequestDownload	SID, memAddr, memSize, NRC
0x37	RequestTransferExit	SID, NRC, **hash over transferred data**

Detection Strategies

SLP: Suspicious Log Patterns

- Pattern matching with **threshold-based counting**
- Monitor for failed/rejected **UDS** operations
- Trigger alert when threshold exceeded

PTI: Product Threat Intelligence

- Use **threat intelligence feeds**
- CVE databases, forums, research papers
- Supplier vulnerability disclosures

CLC: Contextualized Log Checks

- Validate against **additional context information**
- Vehicle state & configuration
- Maintenance plans & service records
- Authorized firmware databases

Evaluation

AUTOSAR Logging Coverage

Question: ***How useful are current AUTOSAR standardized security events in UDS attack detection?***

Observations:

- AUTOSAR specifies Security Events for **13 out of 26 UDS services**.
- For UDS **attack technique taxomony with 53 attacks:**
  - **full logging support for 20 attacks**
  - **partial logging support for 10 attacks**

38-56%

Conclusions:

➔ AUTOSAR provides a good basis for UDS attack logging but it fails at providing complete coverage

➔ AUTOSAR does not support MFI (Message Flow Inconsistency) logging strategy

Example 1: **Brute-Force Security Access**

- **Attack:** Attacker tries to brute-force all possible "key" values for SA (0x27)
- **Detection:** Can be detected using
  - AUTOSAR Event 103:
  - SEV_UDS_SECURITY_ACCESS_FAILED

✓

Example 2: **Data Extraction**

- **Attack:** Attacker uses ReadDataByIdentifier (0x22) to extract confidential data (e.g., cryptographic keys)
- **Detection:** No AUTOSAR security event is available for 0x22

✗

Applicability of Detection Methods

Question: ***How well do the proposed detection strategies cover realistic attack scenarios?***

Reference: Comprehensive UDS Attack Taxonomy containing 53 attack techniques for UDS

Attack ID	Attack Name	SIDs	Logging Strategies	AUTOSAR Support	Detection Strategies
AT-RD-1	Firmware Reverse-Engineering	-	NA	No	PTI
AT-RD-2	Leak Secrets		NA	No	PTI
AT-PS-1	Download Custom Package	0x34, 0x36, 0x37	IR, FE	Only 0x34	SLP, CLC, PTI
AT-PE-1	Change to Privileged Session	0x10	FE, MFI	No	CLC
AT-PE-2	Valid Credentials	0x27, 0x29	FE	✓	CLC, PTI
AT-PE-3	Replay Attack SA	0x27	IR, FE, MFI	✓	SLP, CLC, PTI
AT-PE-4	Brute-Force SA	0x27	IR, FE	✓	SLP, CLC
AT-PE-5	Weak Auth29 configurations	0x29	IR, FE	✓	CLC
AT-DE-1	Block DTCs Generation	0x85	FE	✓	CLC
AT-DE-2	Remove Attack Traces in DTCs	0x14	FE	✓	CLC
AT-DE-3	Replay Download	0x34, 0x36, 0x37	FE	Only 0x34	CLC
					CLC, PTI
					CLC, PTI
				31	CLC
					SLP, CLC

Detection strategies
can be mapped to 52 attack techniques

Applicability of Detection Methods – Example 1

Brute-Force Security Access

Attack: Attacker tries to brute-force all possible "key" values for SA (0x27)

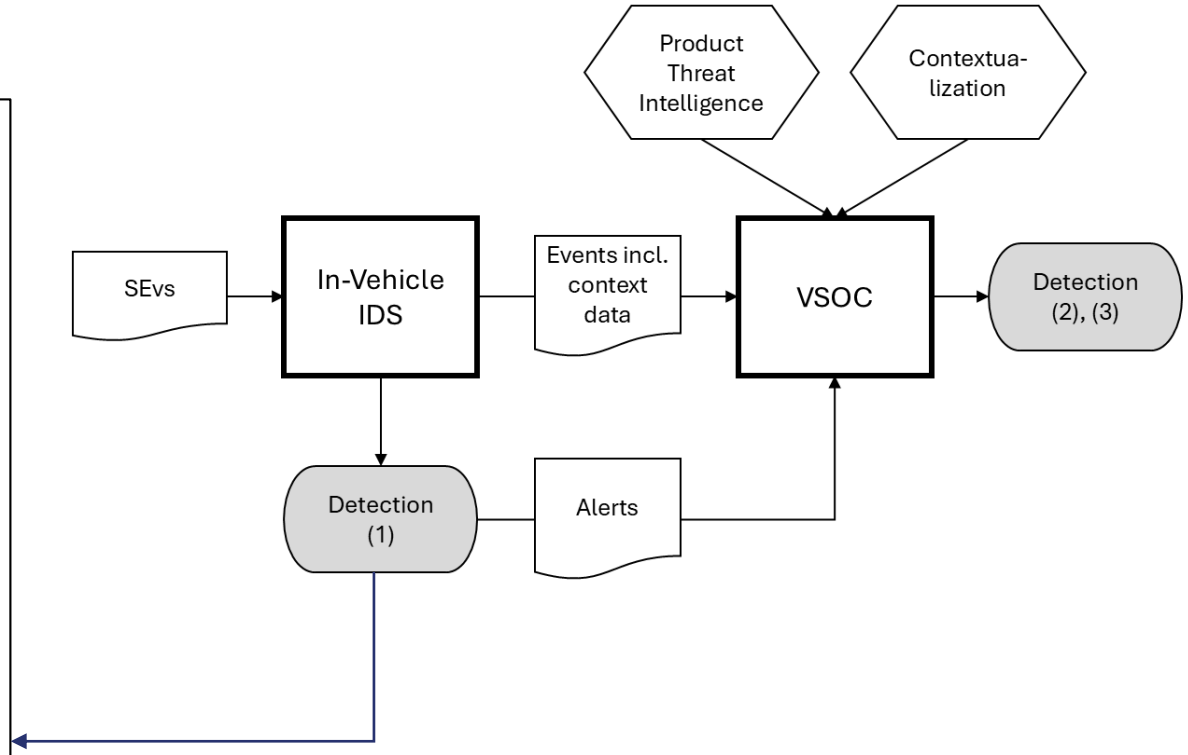
Detection Approach

Logging: IR strategy

- Use AUTOSAR Event 103: SEV_UDS_SECURITY_ACCESS_FAILED

Detection: SLP strategy

- Count failed 0x27 attempts within time window
- Alert when threshold exceeded



Applicability of Detection Methods – Example 2

Data Extraction

Attack: Attacker uses ReadDataByIdentifier (0x22) to extract confidential data (e.g., cryptographic keys)

Detection Approach

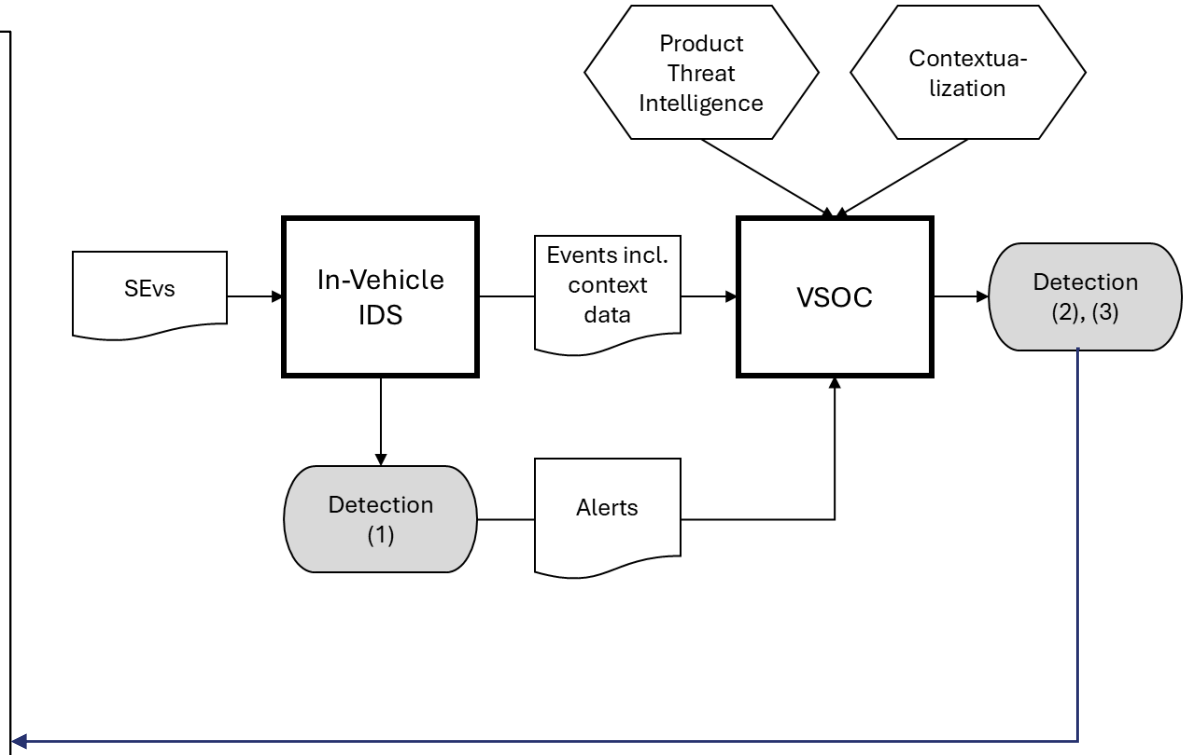
Problem: No AUTOSAR security events for 0x22

Logging: IR + FE strategies

- Log all accesses to **sensitive DIDs**
- Context: DID + NRC (for failed attempts)

Detection: CLC strategy in VSOC

- Filter: Only critical DIDs (e.g., crypto material)
- Validate against authorized access patterns



Applicability of Detection Methods – Example 3

Download Custom Package

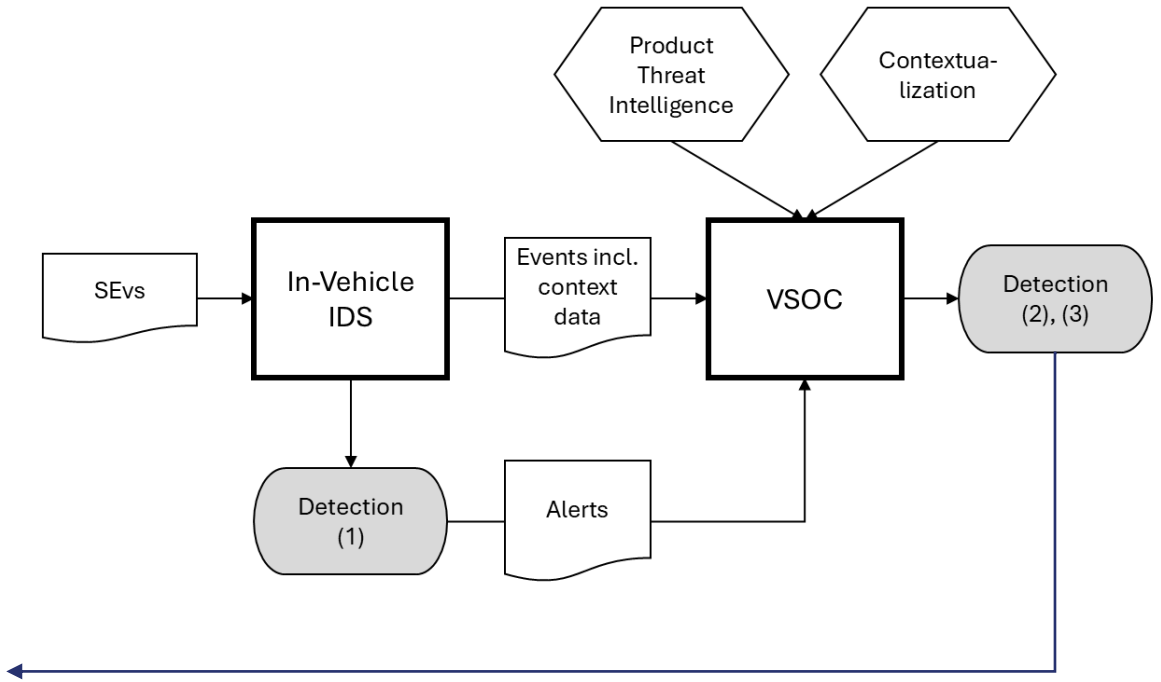
Attack: Attacker downloads malicious firmware using RequestDownload (0x34), TransferData (0x36), RequestTransferExit (0x37)

Logging: FE + IR strategies

- Log download operations (0x34, 0x36, 0x37)
- Context: **Firmware hash** on completion (0x37)

Detection: By detection strategy CLC

- **Detection strategy CLC: Correlate firmware hashes with those of authorized firmware databases**
- Detection strategy PTI: Look for published exploit patterns to install firmware
- Detection strategy SLP: Detect failed software update attempts in the operation



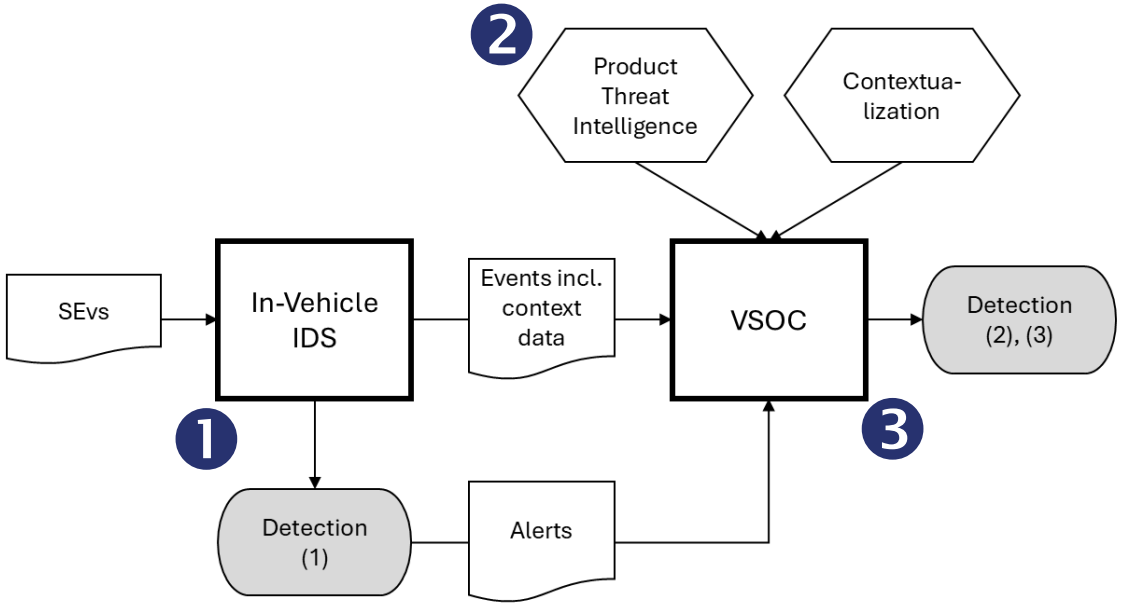
used additionally to raise reliability

Applicability of Detection Methods – Key Take-Aways

1. **Vehicle-side detection** can only cover a subset of UDS attack techniques.

2. **Product Threat Intelligence** is needed as part of a VSOC infrastructure

3. A **combination of detection strategies** as well as **backend processing in a VSOC** are needed for a maximum coverage and reliable detection of UDS attack techniques.



Conclusion

Contributions & Future Work

- ☑ Overview on detection strategies for attack techniques misusing the UDS protocol.
- ☑ Example for developing security monitoring strategies for an automotive communication protocol.
- ☑ VSOC detection scenarios: End-to-end monitoring strategies to detect the occurrence of higher-level attack techniques based on low-level security events.
- ☑ Guidance for vehicle-side logging and backend-side log processing in a VSOC.

Outlook:

- ☐ Experimental evaluation with real vehicles
- ☐ Monitoring scenarios for other automotive use cases (beyond UDS)

Thank you

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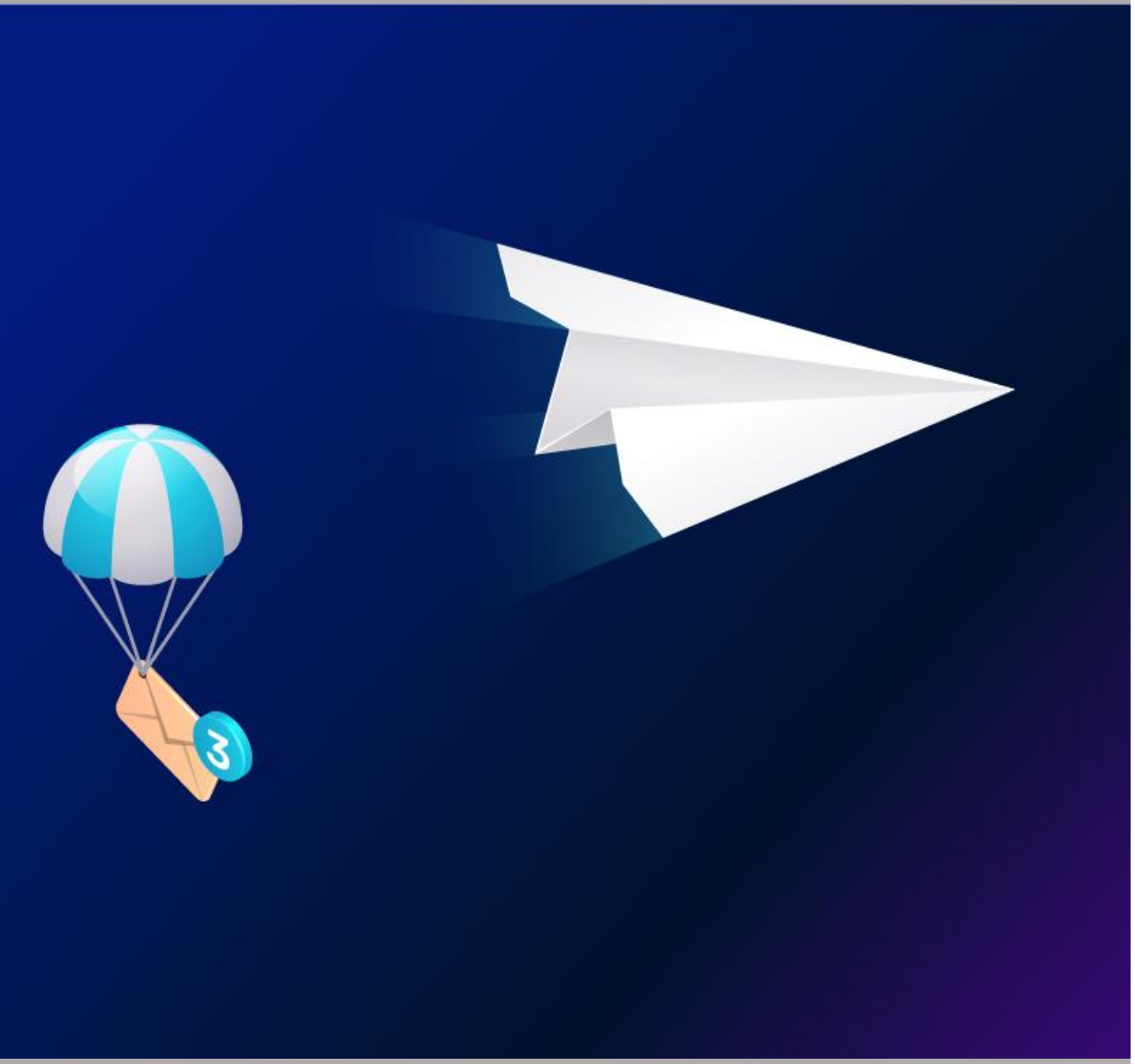

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