Karlsruhe Institute of Technology

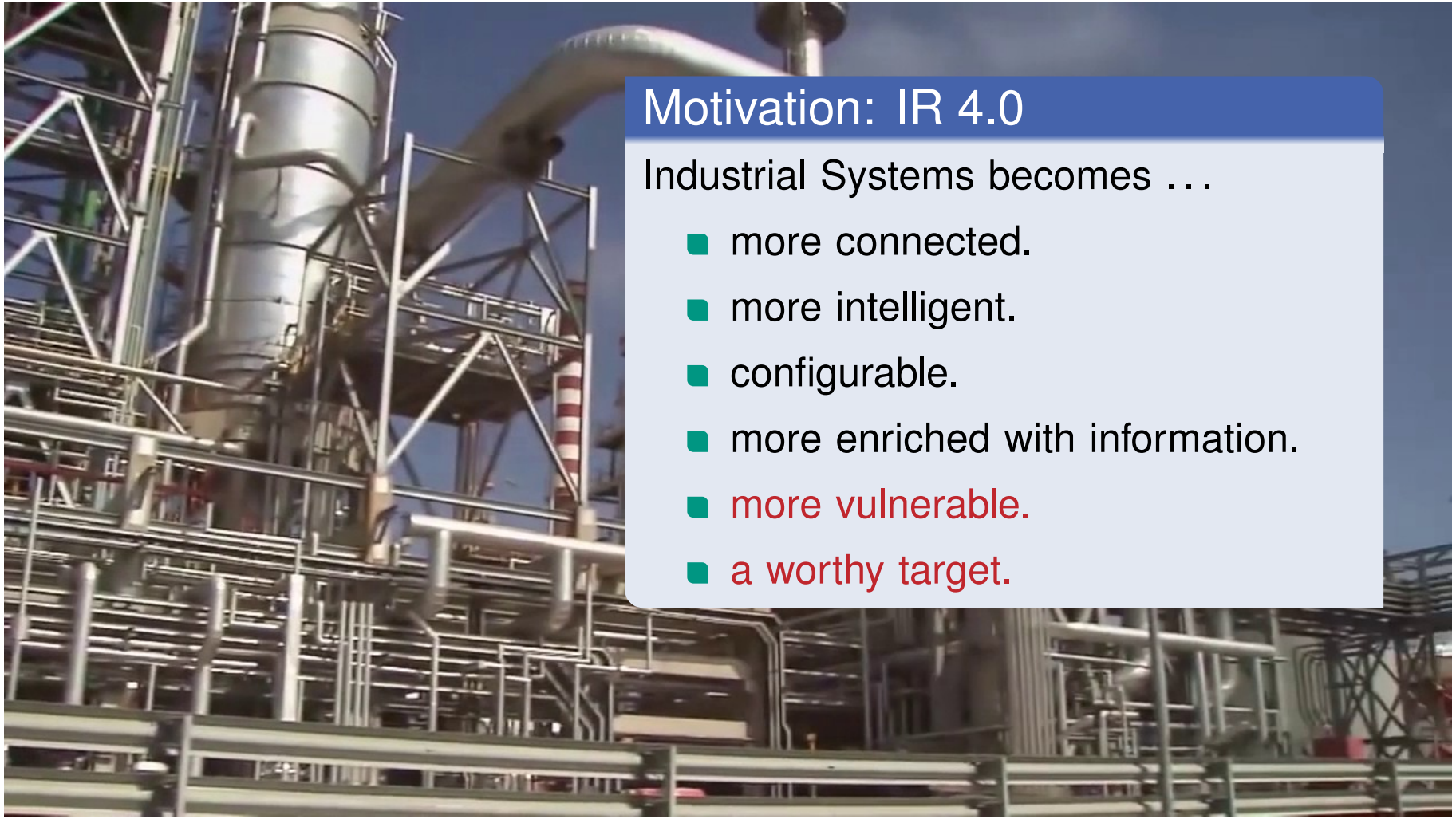
KASTEL Industry 4.0 Demonstrator

Provably Forgetting Information in PLC software

Alexander Weigl | 10. Oct. 2019

INSTITUTE FOR THEORETICAL INFORMATICS – APPLICATION-ORIENTED FORMAL VERIFICATION

Orientation & Story



Motivation: IR 4.0

Industrial Systems becomes ...

- more connected.
- more intelligent.
- configurable.
- more enriched with information.
- more vulnerable.
- a worthy target.

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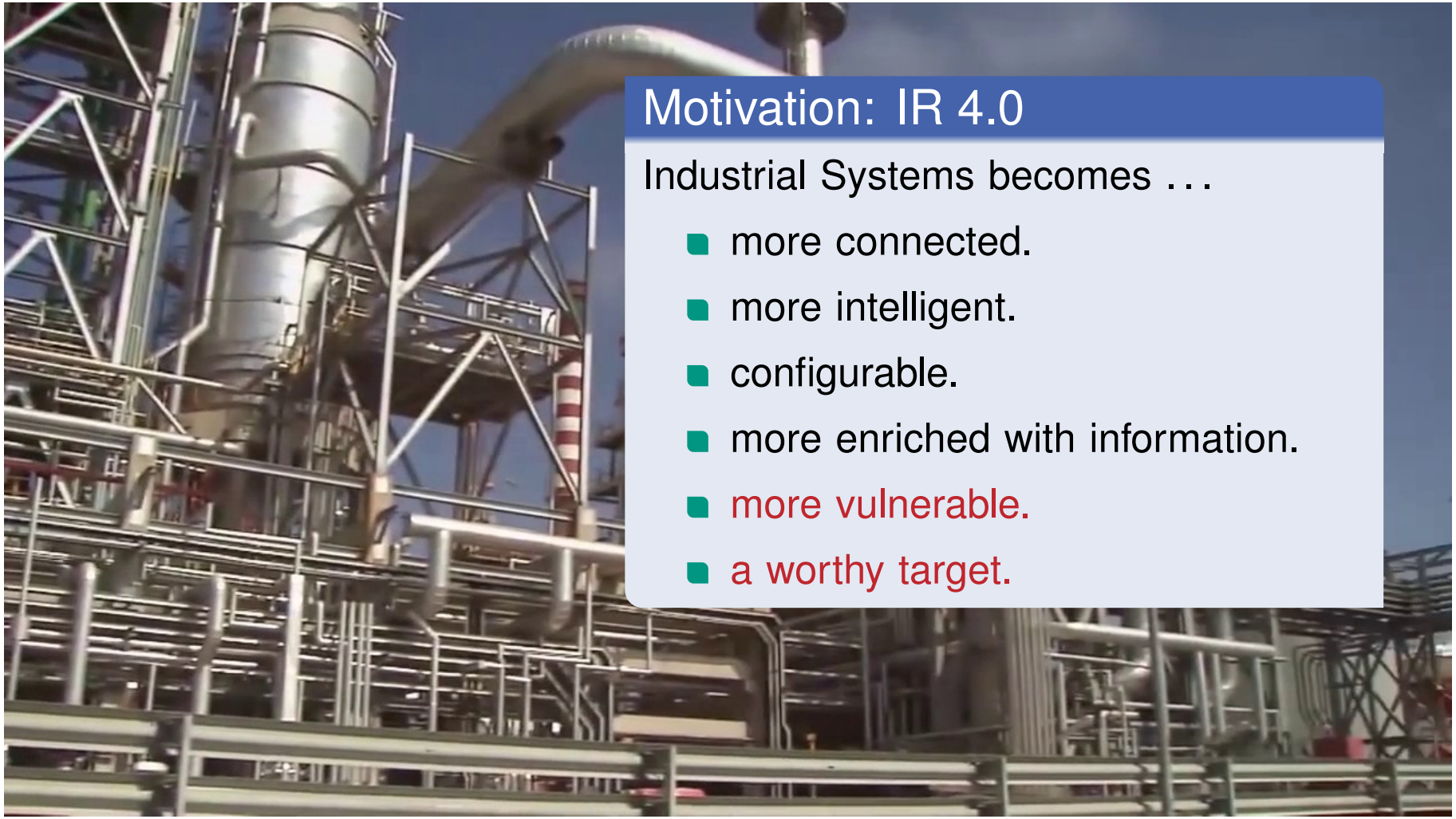

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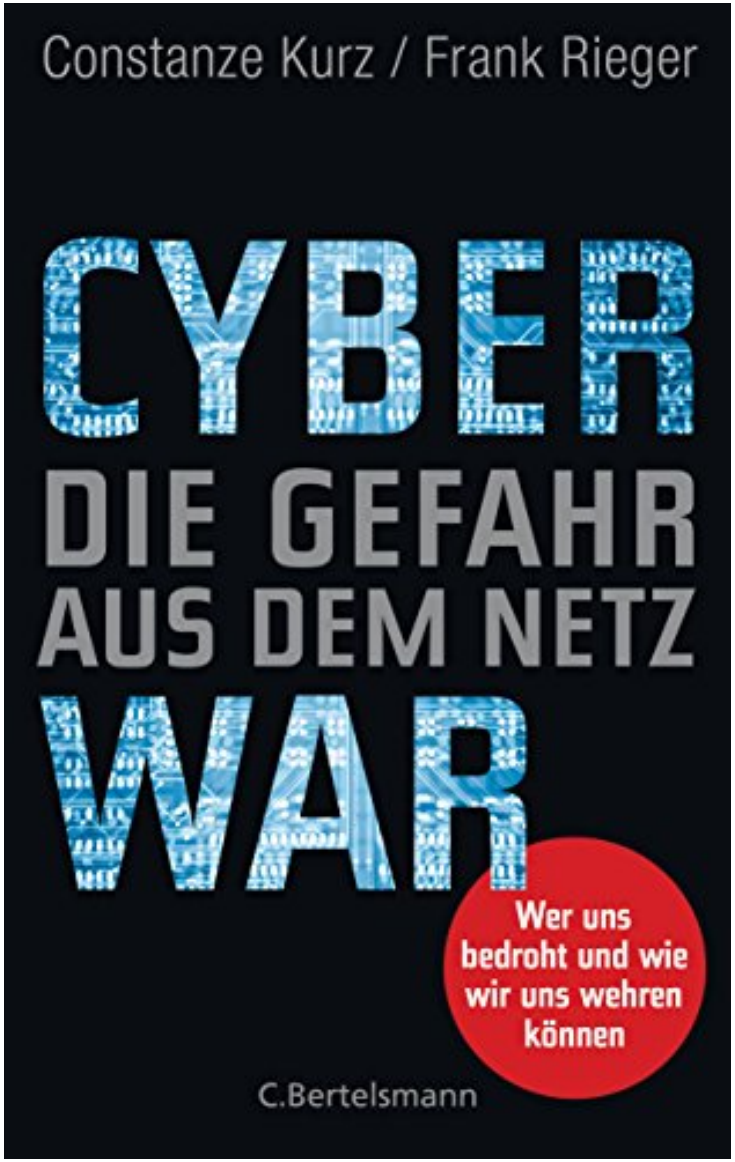

Constanze Kurz and Frank Rieger
Cyberwar – Die Gefahr aus dem Netz

also in *LNP272: Alles zerfragen*

Business Secrets are

confidential information of a company, and protected by **law**.
Protection requires efforts by the owning company to protect their data following the state of the art.

KASTEL

Demonstrator is part of KASTEL SVI (AP 4.6)

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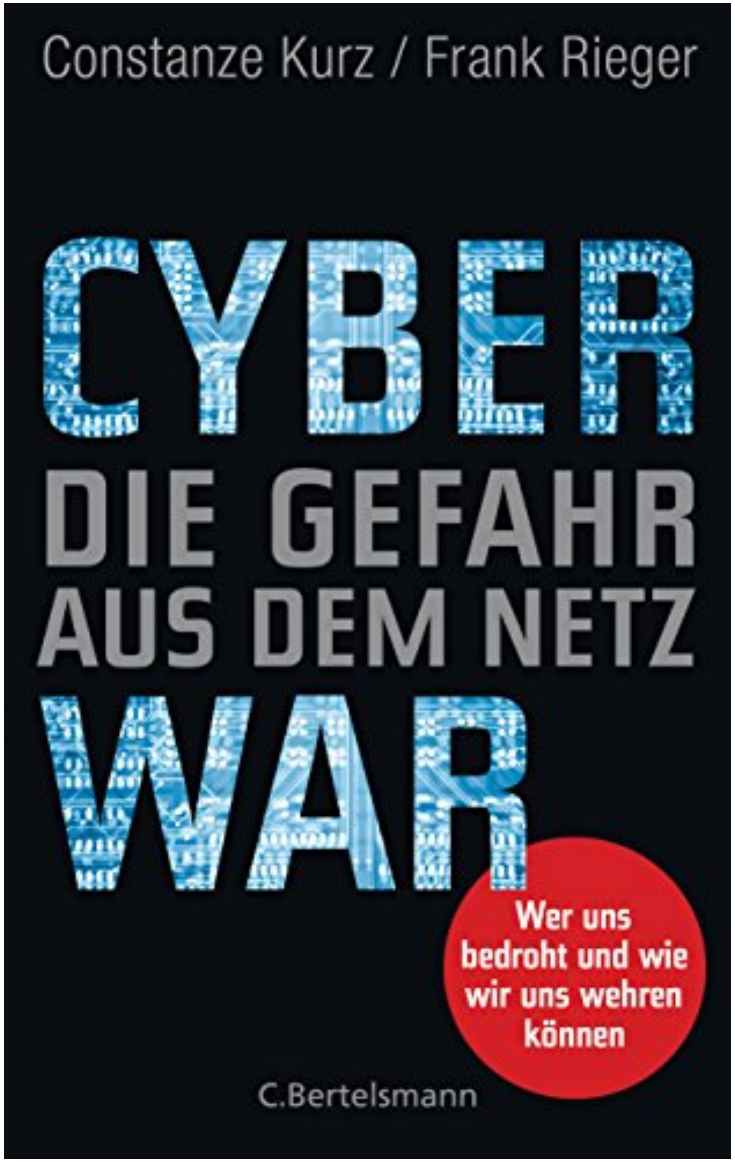

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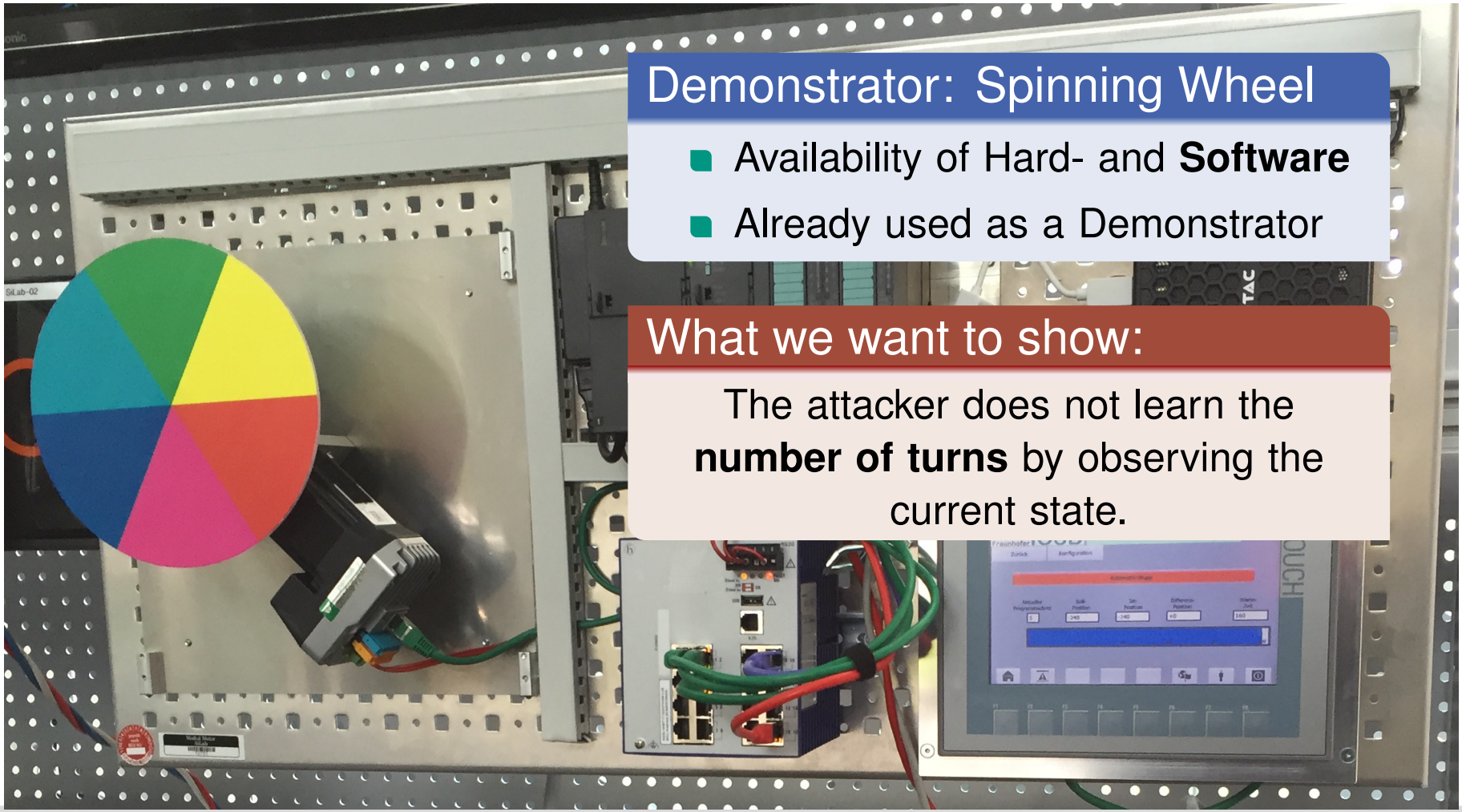
The KASTEL Demonstrator

What we demonstrate?

An approach to ensure that no Business Secrets are stored.



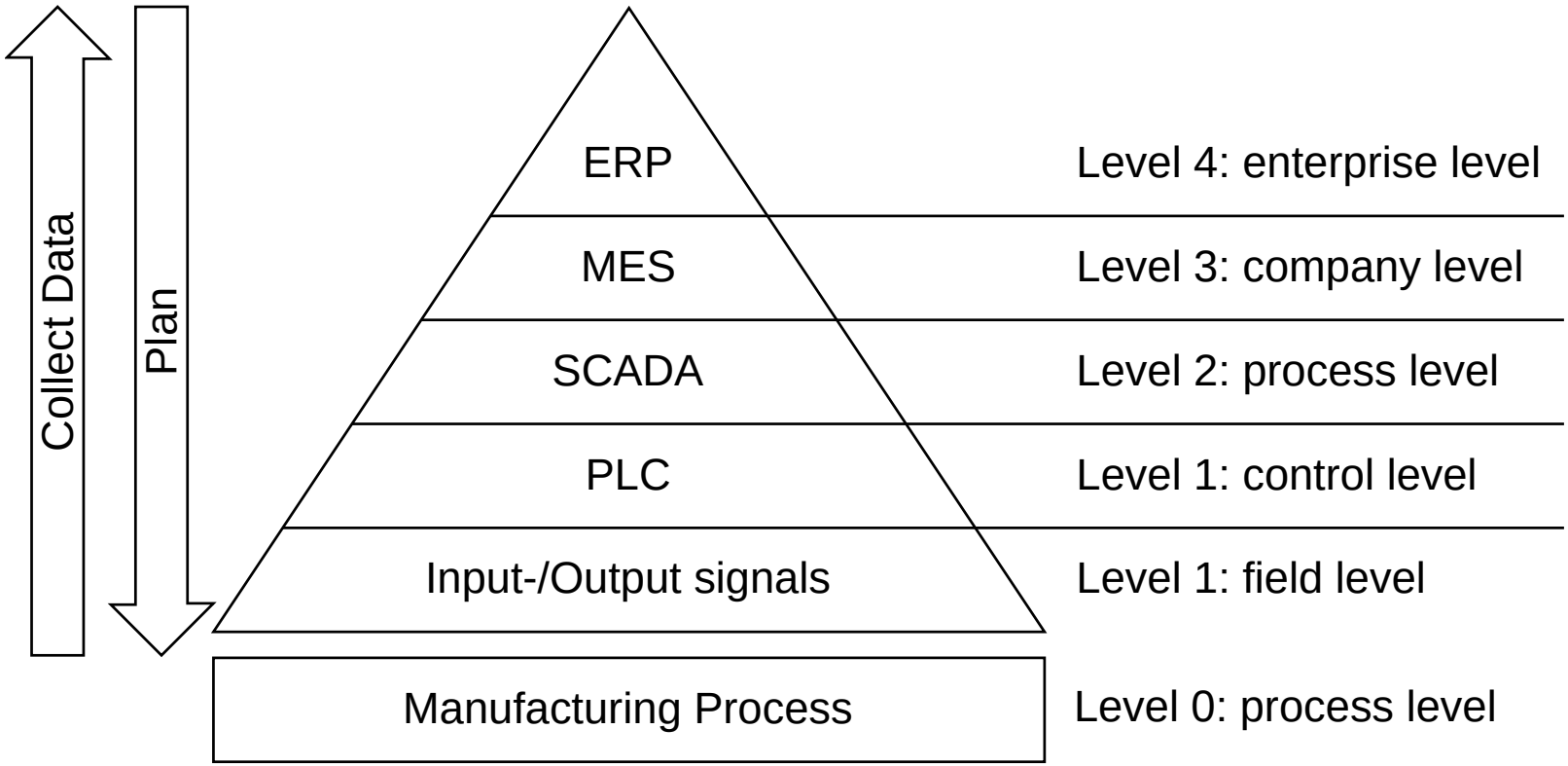
Demonstrator: Spinning Wheel

- Availability of Hard- and **Software**
- Already used as a Demonstrator

What we want to show:

The attacker does not learn the **number of turns** by observing the current state.

System & Attacker Model



Attacker's Environment

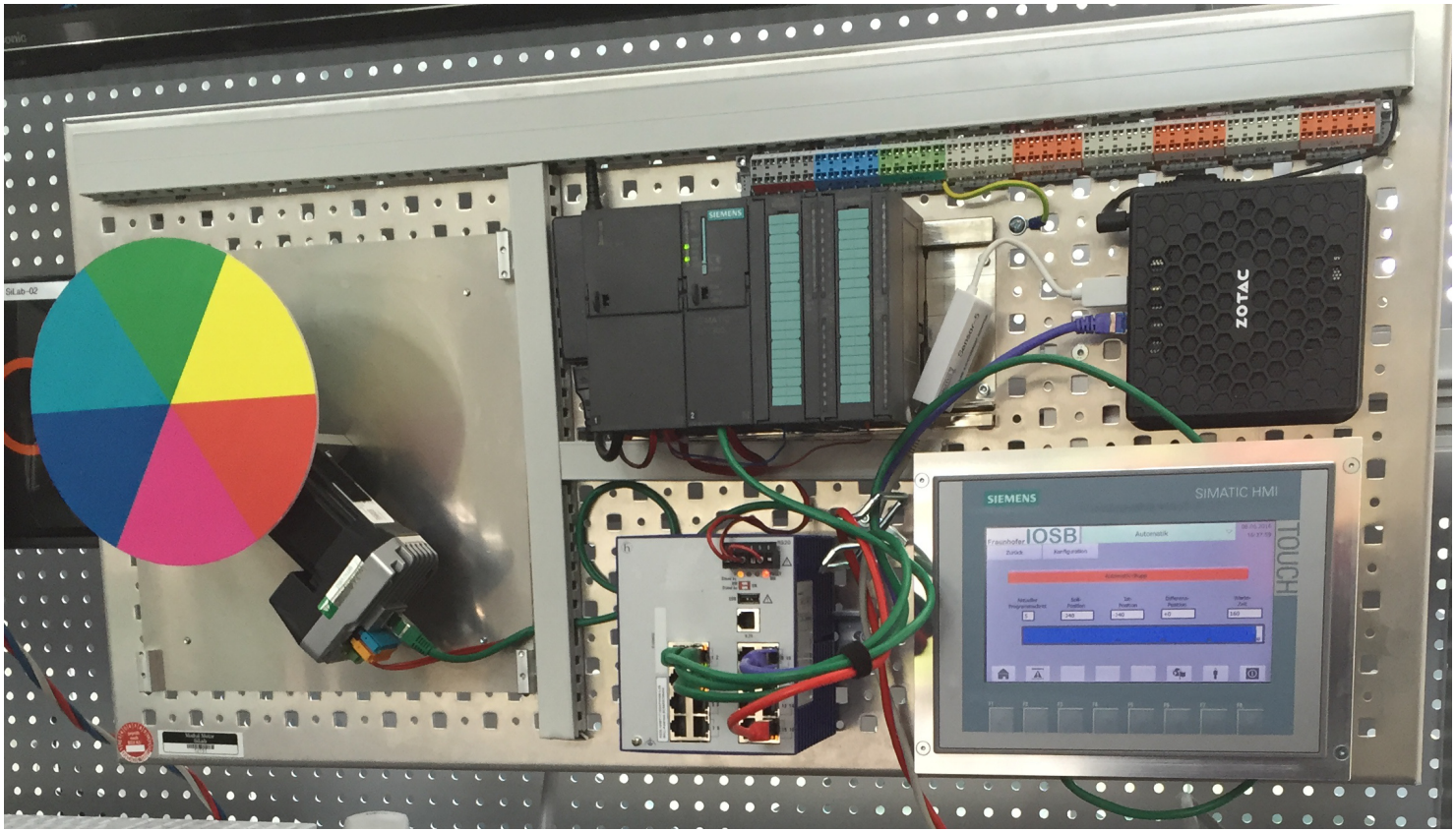
- Focus on the PLC system
- Attacker can observe only one system state

Overview

1. The Software
   - Functionality
   - Software Architecture
   - Preparation for Verification
2. The Verification
   - Information Flow
   - Forgetting Information
   - Results
   - Discussion: Validity
3. Closing Remarks
   - Quantification
   - Conclusion

The Software

Operator view



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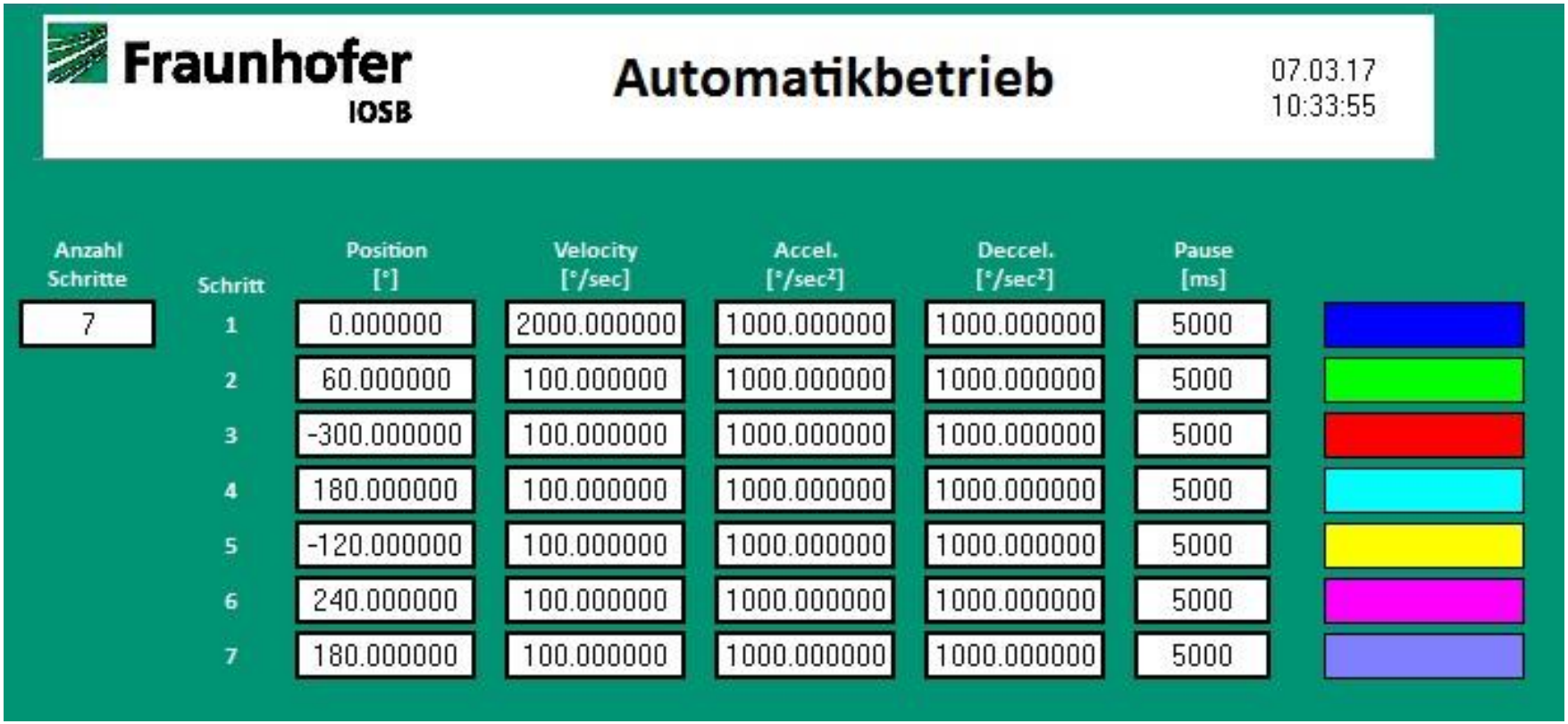
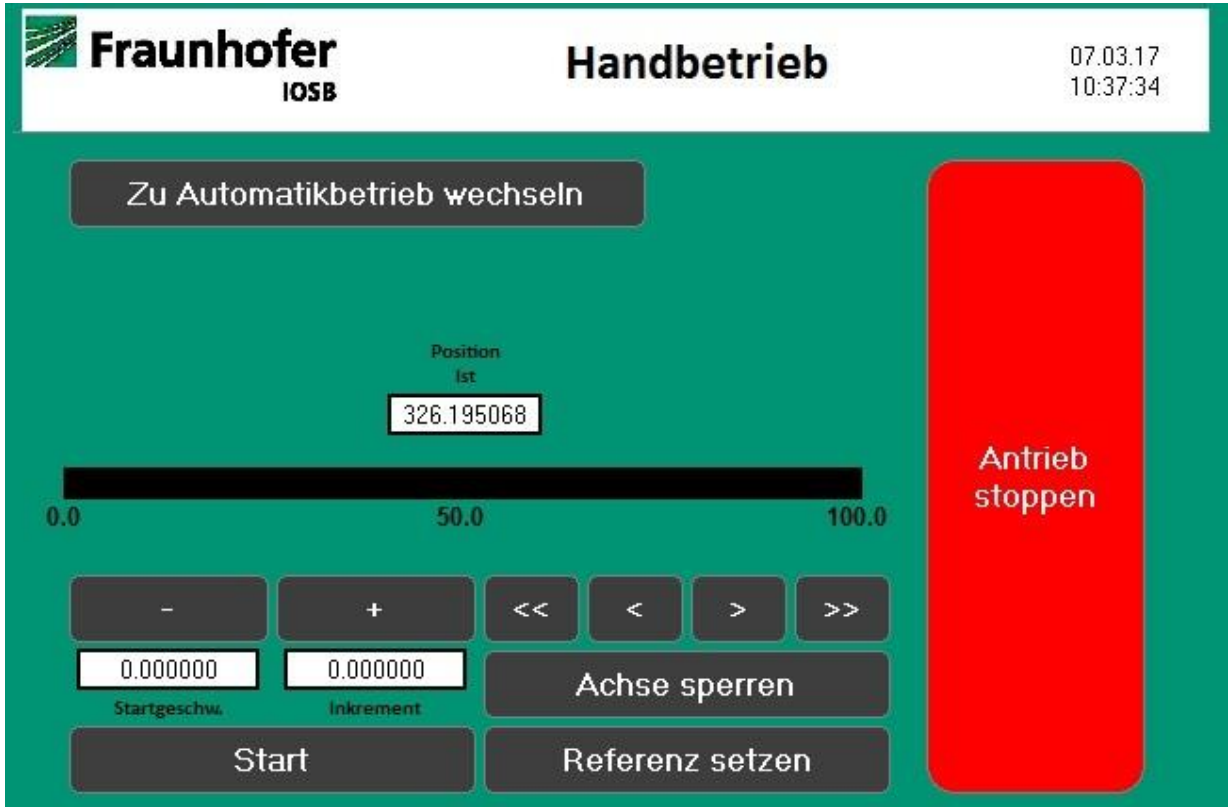


Automatic Mode

- PLC drives to *user-defined* segments sequentially
- A segment consists of position, velocity, accel-/decelaration, break time
- Sequence can be repeatedly executed

Operator view

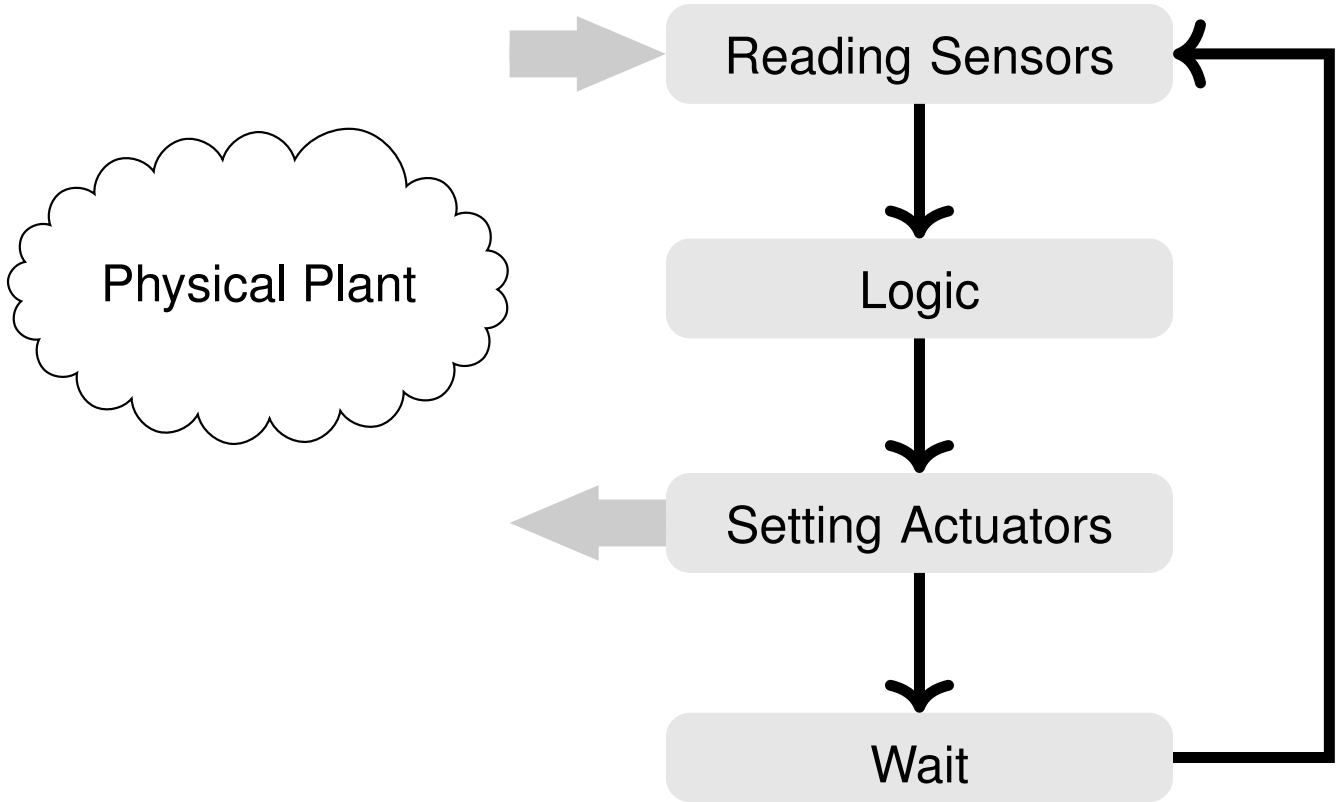


Manual Mode

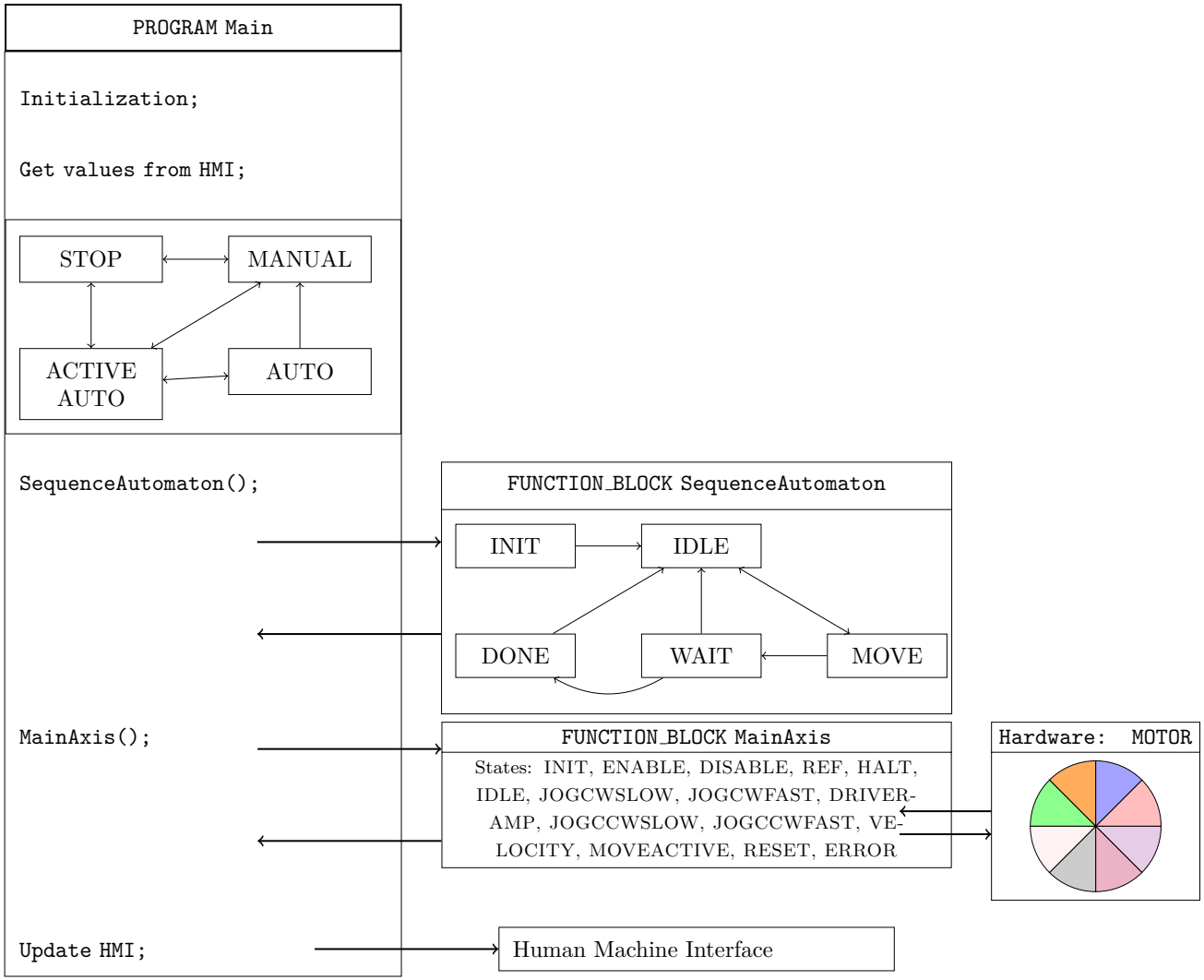
- Operator can manually control velocity, and
- set the reference position

Reactive Software

- Executed every n ms
- Feedback loop
- For verification, we focus on **Logic** component



Software Architecture



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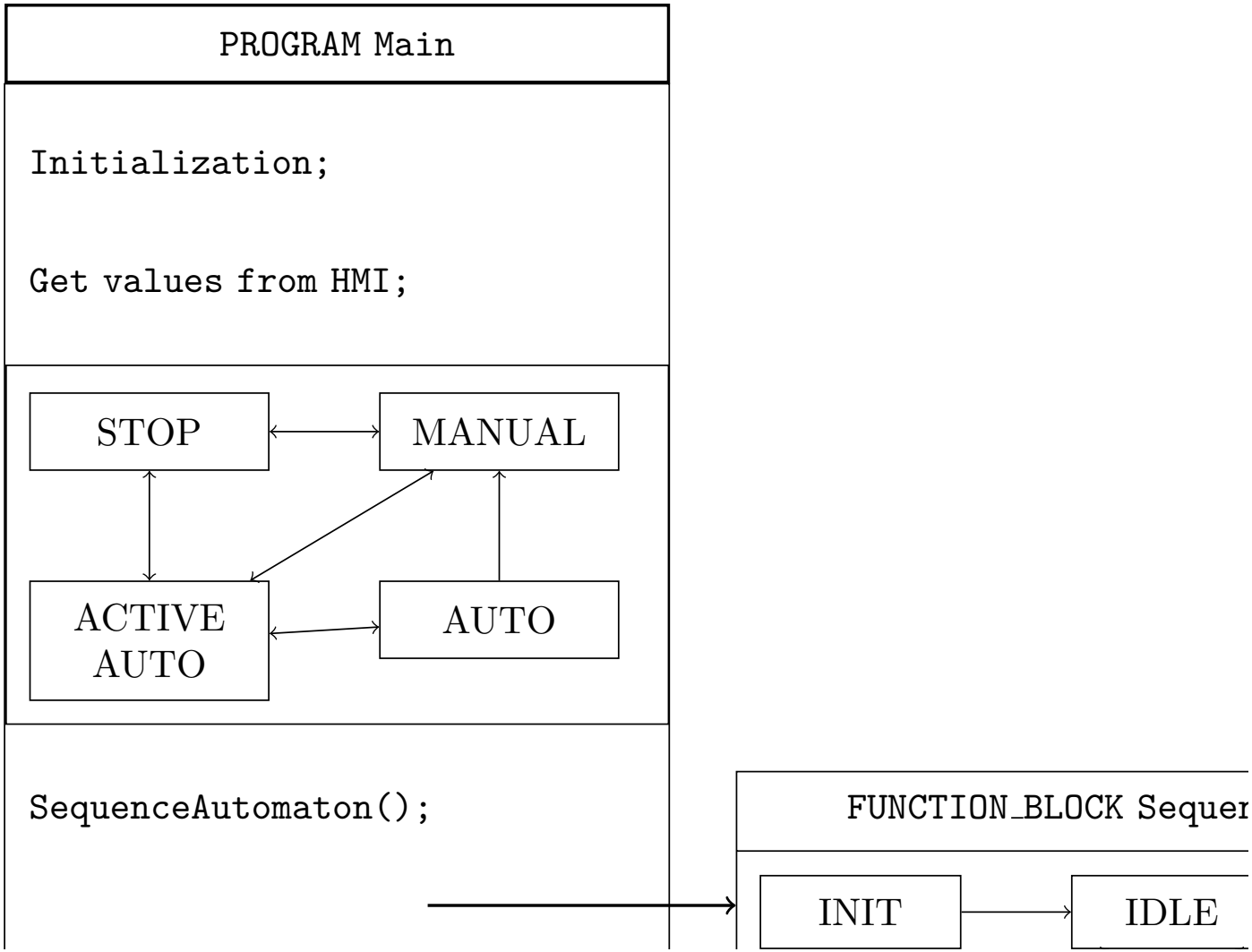

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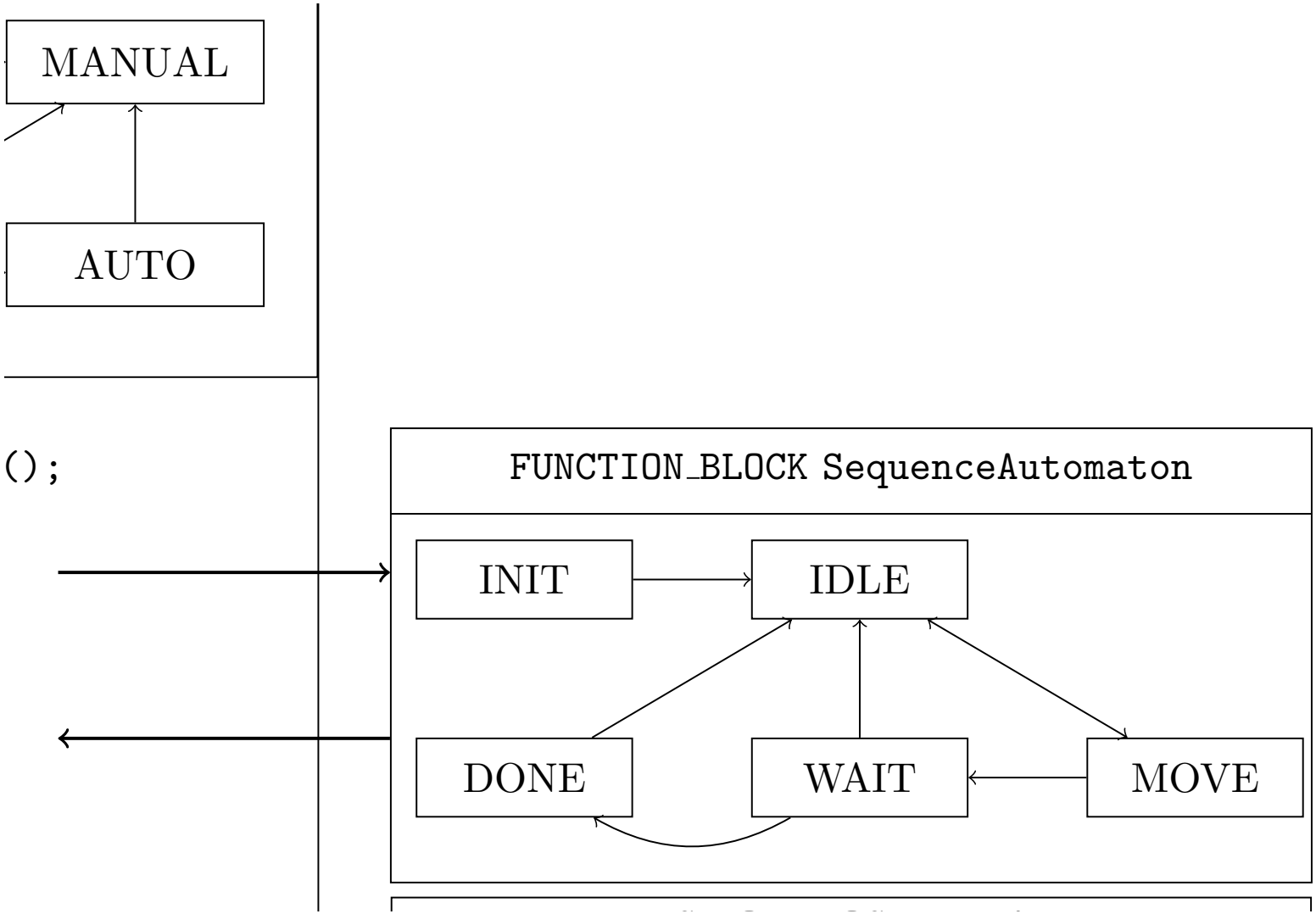

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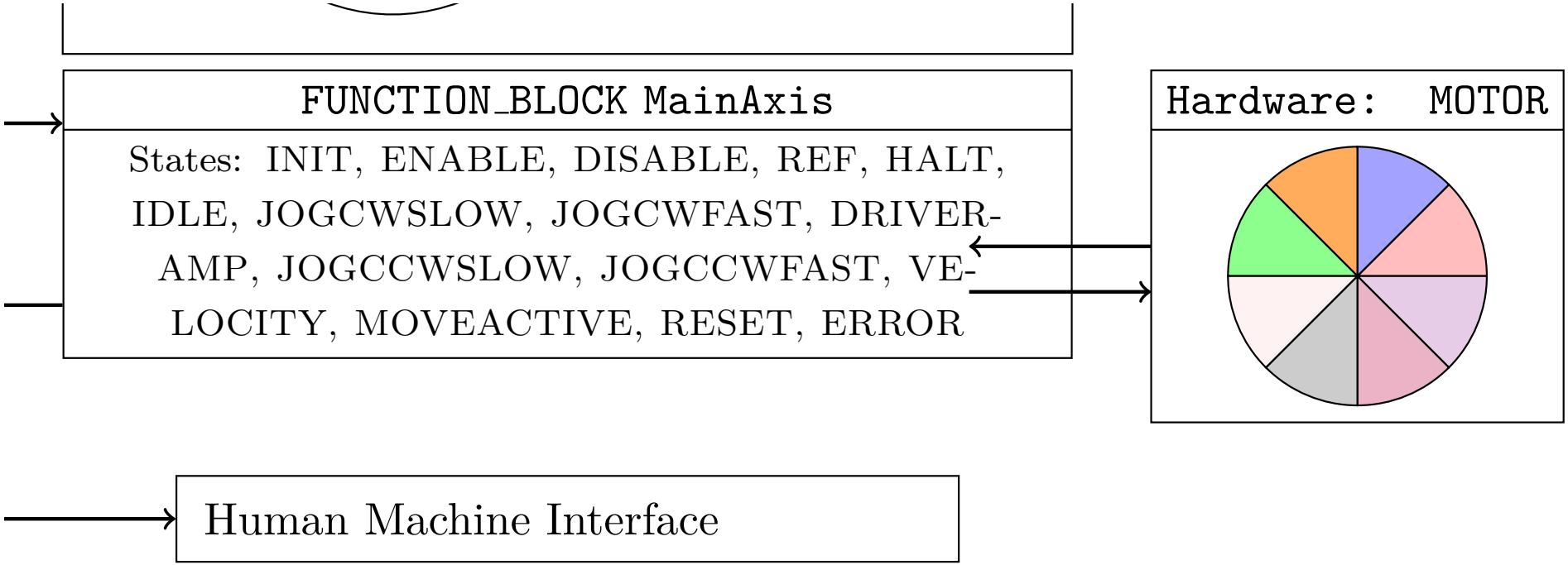

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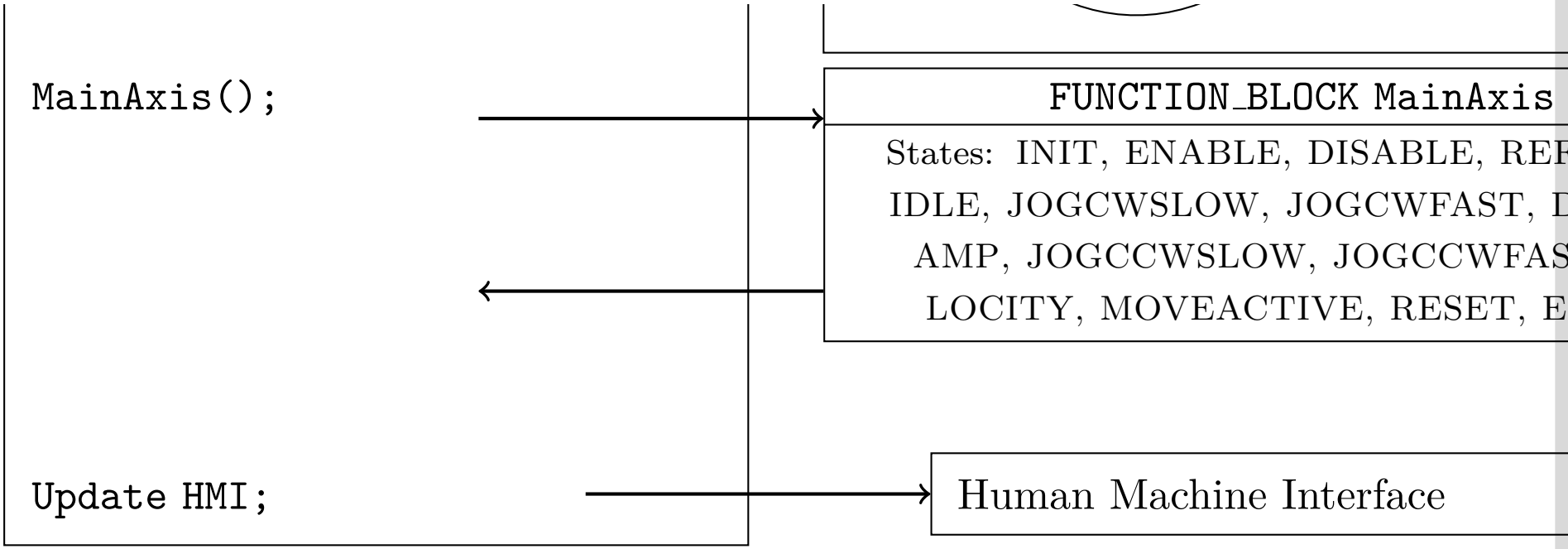

Preparation for Verification

Software not directly usable

- focus on `MainAxis`
- demote floating-point to integers
- reduce state, remove assignment to HMI variables

Are these abstractions valid?

Verification Pipeline

PLC Program to be Verified

- 421 LoC in Structured Text
- 32 states variables, 52 input variables
- 566 bits large (270 bits input, 296 bits state)

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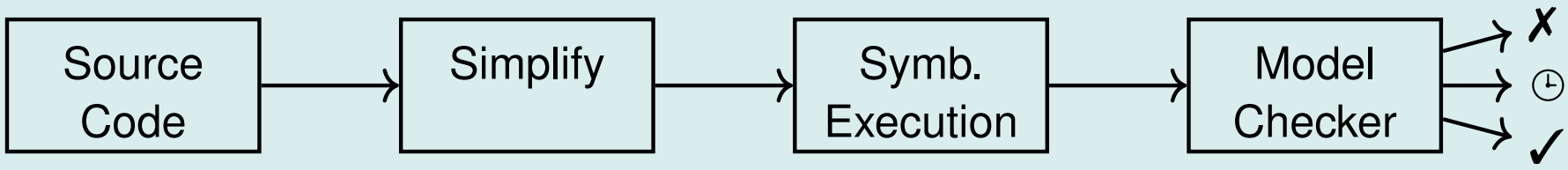

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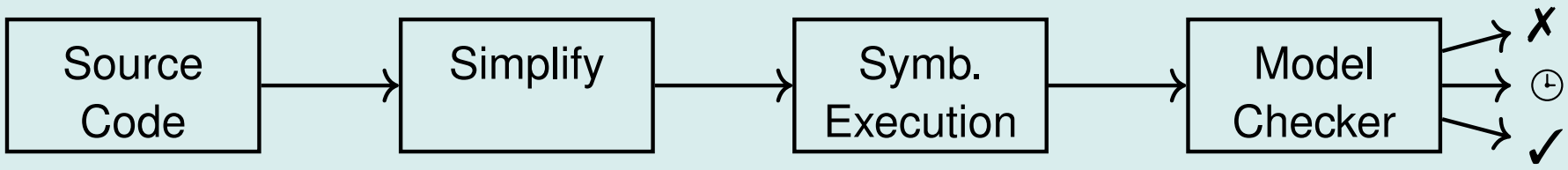

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The Verification

Information Flow

What we want to show:

The attacker does not learn the **number of turns** since the start of the PLC by observing the current state.

The attacker does not learn the number of turns by observing **one state** σ_{t_0}:

$$\#Turns(t_0) := \left\lfloor \frac{1}{360} \int_0^{t_0} v(t)\, dt \right\rfloor$$

$$\text{Prob}(\#Turns) = \text{Prob}(\#Turns \mid \sigma_{t_0})$$

$v(t)$ – Angular Speed ($\frac{deg}{s}$)

Classical Information Flow

- Property: No influence of $v(t)$ on the state.
- . . . Non-interference is too strong: Velocity is stored internally!
- . . . of course sensors values have influence
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Forgetting Information

Idea

- Relaxing the information flow
- Allowing the system to react to current sensor values

. . . but forget old information

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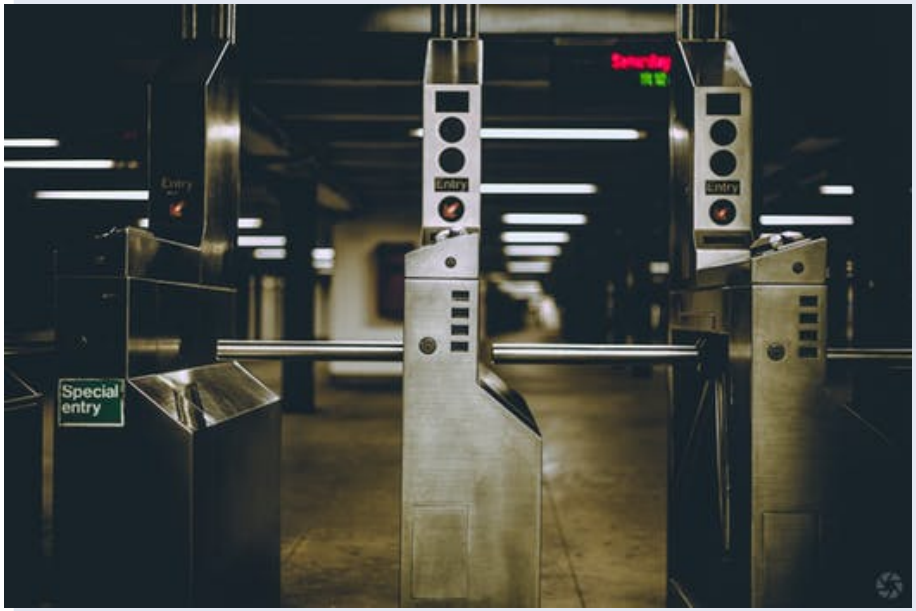
Example: Baffle Gate



- Granting access based on permission
- But does not store amount of passed

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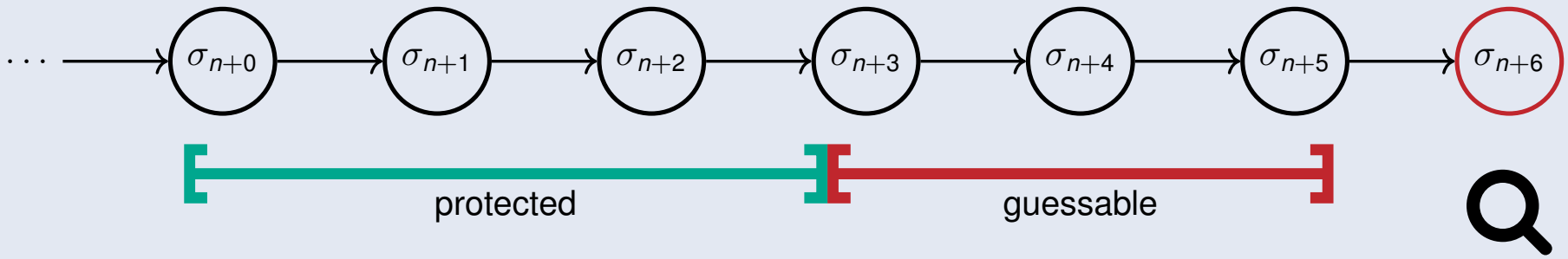
Privacy-preservation by forgetting

System is allowed to store secret data of m last steps.



Forgetting Information in Relational Test Tables

#	ASSUME			ASSERT	⏲
	S	I_L	I_H	S	
0	$=$	$=$	—	—	1
1	—	$=$	—	—	—
2	—	$=$	$=$	—	k
3	—	$=$	$=$	$=$	ω

We distinguish between

- state variables ($|S| = 32$)
- uncritical sensor variables ($|I_L| = 51$), and
- protected sensor variable ($|I_H| = 1$, angular velocity).

Syntax

- "—" expresses "DON'T CARE"
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For all possible two runs of the systems, starting in

- **arbitrary, but equal, states** and equal uncritical input I_L,
- then **injecting different secrets**,
- after **waiting** k **cycles**
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Results

The system does not adhere to information forgetting.
for $k = 2, 5, 7, 10$

Analysation of the counterexample

- *last* velocity is stored internally
- but not *last* velocity is not overwritten forcibly

If we do not consider the internal stored velocity, the system forgets the information.

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Why PLC level?

Protection on . . .

- PLC level is hard
- upper pyramid level easier and known

but also attacks on the sensor/actuator level happened

Single observable state

If an attacker sees a sequence of states, then

- the information of the sequence leak
- information that are k cycles past are still secret

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- HMI also reads the velocity from global state
- An attacker can get the complete user-defined program sequence

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- Demoting floating point to integer is critical
  ... justification in each individual case
- Symb. Execution and other simplification are uncritical

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- Starting in arbitrary equal states is an over-abstraction
- Spurious counterexample possible

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Closing Remarks

Quantification

In view of KASTEL continuation:

Information Forgetting is a Quantification of Security

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A system that . . .

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In the view of *risk assessment*

A system, that forgets faster, decreases the costs when a data breach occurs.

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Conclusion

Take away

- We can prove that systems forget information
- Forgetting information is a *quantitative* privacy property
  It does **not prevent attacks**, but the **loot is reduced**.
- Technical Report appears soon
- Verification software available:
  `https://github.com/verifaps/verifaps-lib`