Securing the Future: Quantum Computing Technology from Robust Hardware to Secured Applications

Java Card Forum Webinar Nov. 2025

Tackle the massive quantum computing challenge

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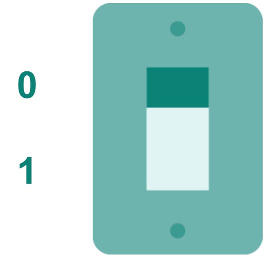
Quantum computers – far beyond just theory

- In January 2019, IBM presented the first commercially usable quantum computer i.e. outside of laboratory environments – the IBM Q System One

- Classical bits only know the state 1 or 0, a qubit can assume any superposition of the states "0" and "1"
  → This enables true parallelism in computing

- Quantum computers can solve special tasks in seconds while it would take conventional supercomputers many years to accomplish

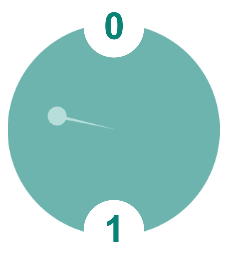
Classical bit



2 distinct states

switch on/off

Quantum bit



Superposition of 2 basic states

Point on the surface of a sphere

Current cybersecurity measures may soon be inadequate

Due to the specialized computing capabilities of quantum computers, some common cryptographic ciphers will be almost useless soon

- **Asymmetric encryption algorithms** used today (e.g. RSA or ECC) will no longer be considered appropriately secure anymore:
  - For instance, the security of RSA relies on the difficulty of factoring the product of two large prime numbers (prime factorization)
  - With adequate key length used, prime factorization would be impractical on a conventional computer, while a suitable quantum computer could solve it in minutes, making unauthorized extraction effortless
- **Symmetric encryption**, such as AES, is considered less threatened by quantum computers. However, for higher security levels it is recommended to use longer keys, such as AES-256

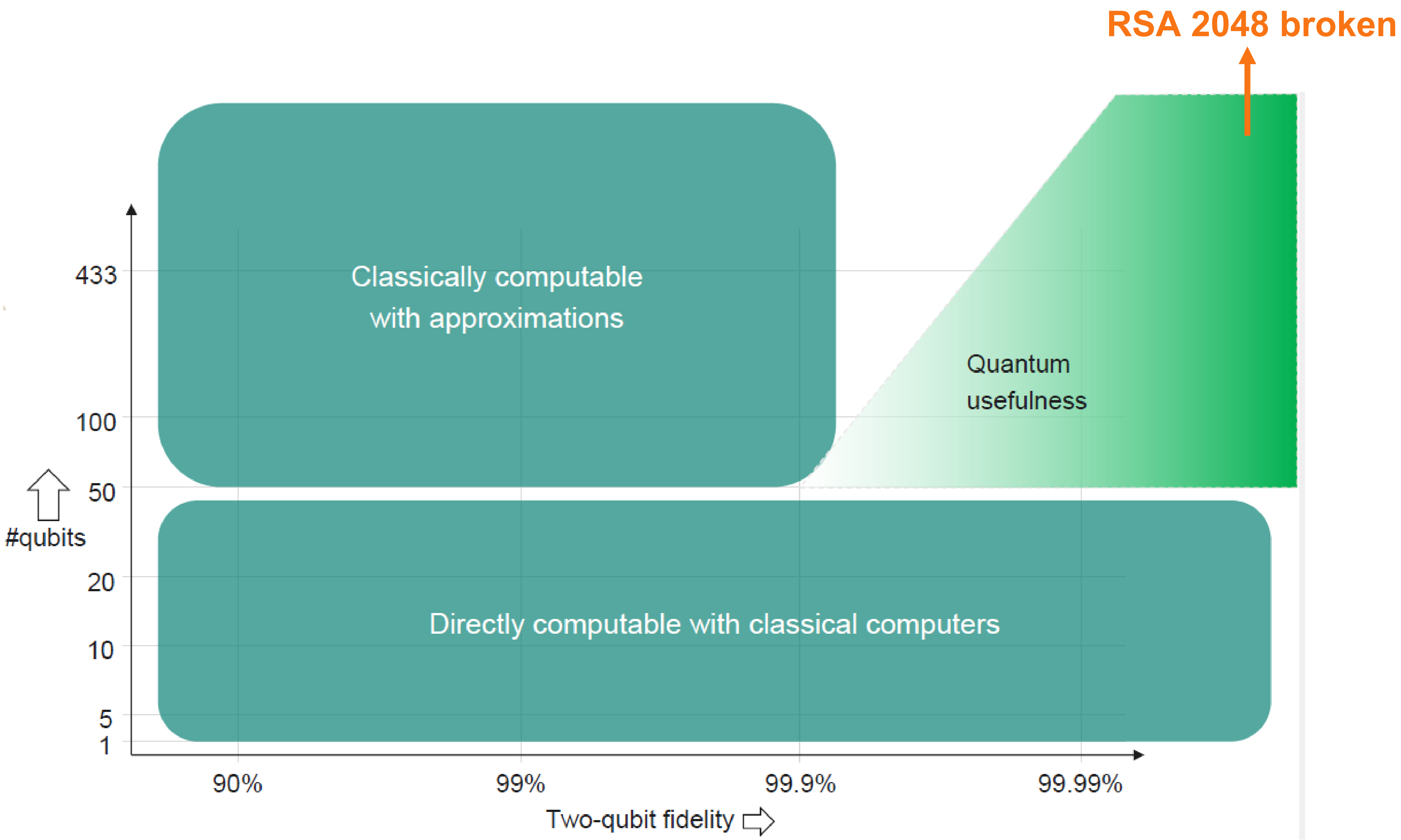
Example

Prime factorization of an RSA encryption with a key length of 2,048 bits

Conventional computer	Quantum computer
~ 100,000 years	**< 2 minutes**

Source: EY

Number of Qubits versus logical Qubits



source: Infineon (2025)

The technology is not yet ready. So, no reason to worry?

Quantum computers **currently** only achieve a performance of about **10 - 50 high-quality qubits**

This is only around 0.3 – 1.3% of the amount required to crack current cryptography (*RSA 2048*)

However

The first universal **quantum computers** capable of breaking main encryption methods used today could be ready as early as **2030 – 2035**

Source: German Federal Office for Information Security (BSI)

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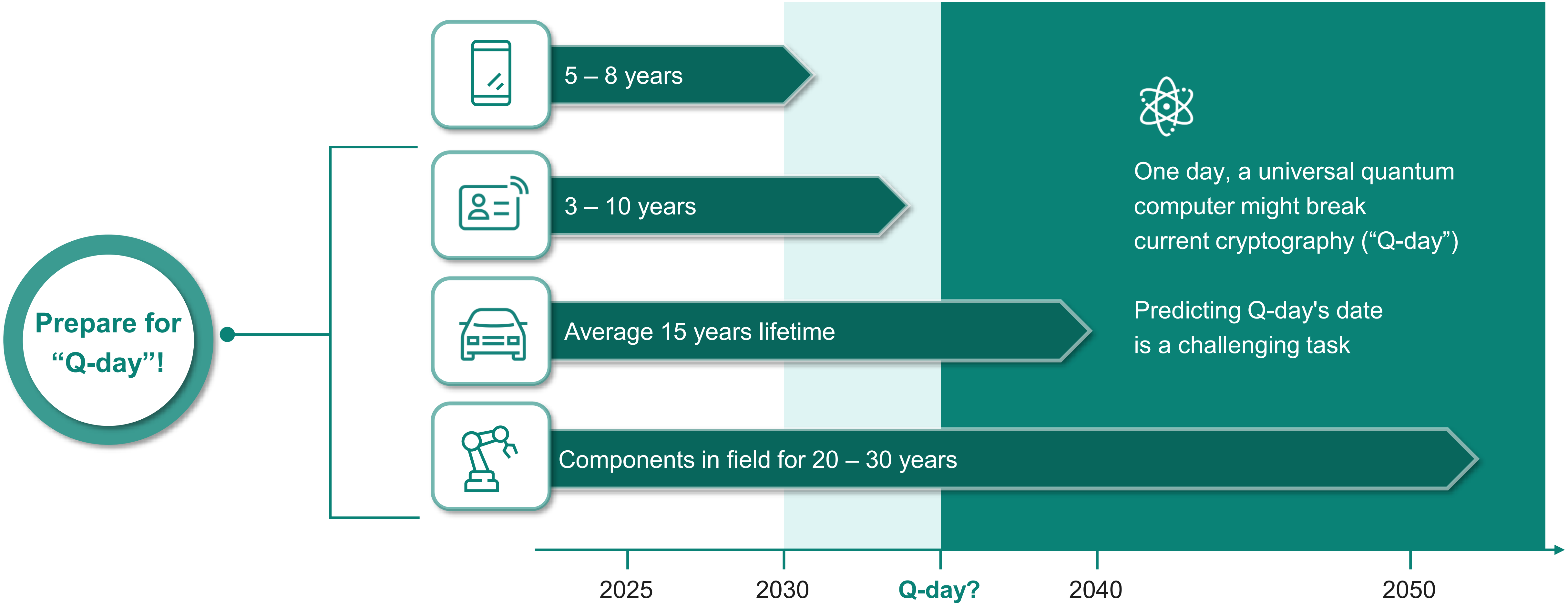
Thinking about tomorrow today

Harvest now – decrypt later: Attackers are already collecting and copying data today, to decrypt it tomorrow using quantum systems

Threat especially for sensitive data from governments and public institutions

Threat to products with long research and development cycles, such as in the automotive, aerospace and life sciences sectors

Assets with a long service life are particularly at risk



> Devices with over 10 years lifecycle must be prepared for the quantum computing age

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Post-quantum cryptography (PQC)

Use of algorithms that are not threatened by prime factorization or other mathematical problems with similar complexity (e.g. discrete logarithm)

Can be implemented on conventional hardware

The first standards developed through a process organized by the US NIST were published in August 2024

The quantum computer evolution does not wait. Deploy PQC-ready products today

The infrastructure challenge

- Any major change in larger infrastructures is complex and a long-term activity
- A full transition from today's cryptography to PQC will be gradual and typically require several years

Quantum computers evolution will not wait

- The threat of a quantum computer will not wait until all infrastructures are migrated and quantum-secured
- An expensive exchange of existing non-quantum secured products in the field needs to be avoided

The solution: Deploy today and update later

- PQC-ready hardware should be already deployed today (with sufficient computing power and memory configuration)
- The products (hardware and software included) need to be prepared for field-updates and crypto agility
- Once all standards and infrastructures are established, an easy and rapid transition to PQC can be performed

Field Update

Quickly and easily update embedded software (i.e. Operating systems) for already field-deployed products

Crypto agility

Quickly and easily exchange cryptographic functions without significant disruption

PQC-Standards

NIST Competition				
Scheme	**Purpose**	**Replacement for ***	**Status**	**Math behind**
ML-KEM (CRYSTALS-Kyber)	**Key Encapsulation/Key Exchange**	**(EC)DH, RSA**	**FIPS 203 (final)**	**Module-lattice-based (module learning with errors)**
ML-DSA (CRYSTALS-Dilithium)	**Digital Signature**	**(EC)DSA, RSA**	**FIPS 204 (final)**	**Module-lattice-based (module learning with errors)**
SLH-DSA (SPHINCS+)	Digital Signature	(EC)DSA, RSA	FIPS 205 (final)	Stateless-hash-based
FN-DSA (Falcon)	Digital Signature	(EC)DSA, RSA	FIPS 206 pending	FFT over NTRU-lattice-based
HQC Hamming Quasi-Cyclic (backup to ML-KEM)	*Key Encapsulation/Key Exchange, demands more commputing recources than ML-KEM*	*(EC)DH, RSA*	*Release planned in 2027*	*Error-correcting codes*

Stateful-Hash-based				
Scheme	**Purpose**	**Replacement for ***	**Status**	**Math behind**
XMSS	Digital Signature	(EC)DSA, RSA	NIST SP 800-208 (final)	Stateful-hash-based
LMS	Digital Signature	(EC)DSA, RSA		Stateful-hash-based

* Not a simple one-to-one / drop-in replacement for existing protocols !

Country Overview

		European Union			Great Britain	USA	
		European Commission	**Germany BSI**	**France**	**Great Britain**	**NIST**	**NSA**
Algorithms		Dec. 2030: migration of high-risk use cases Dec. 2035: migration of medium-risk use cases			Full transition by 2035	Conventional algorithms deprecated with 2030 and disallowed with 2035	Full transition by 31st Dec. 2030
KEM	FrodoKEM		✓	✓	×	×	×
	McEliece		✓	×	×	×	×
	ML-KEM		✓	✓	✓	✓	✓
Signatures	ML-DSA		✓	✓	✓	✓	✓
	SLH-DSA		✓	✓	✓	✓	✓
	FN-DSA		×	✓	×	✓	×
	LMS,XMSS		✓	✓	✓	✓	✓
Symmetric	AES		AES-128/192/256	AES 256	n.i.	AES-128/192/256	AES 256
Hash	SHA		SHA-256, SHA-384, SHA-512, SHA-512/256 and; SHA3-256, SHA3-384, SHA3-512	SHA-384, SHA2-512, SHA3-256, SHA3-384 and SHA3-512	n.i.	SHA 1 for non-dig. sig , SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256 SHA3-224, SHA3-256, SHA3-384, SHA3-512	SHA-384, SHA-512
Hybrid mode			✓	✓	Interim only for selected appl.	NIST leaves the decision to each specific application.	Generally, not required

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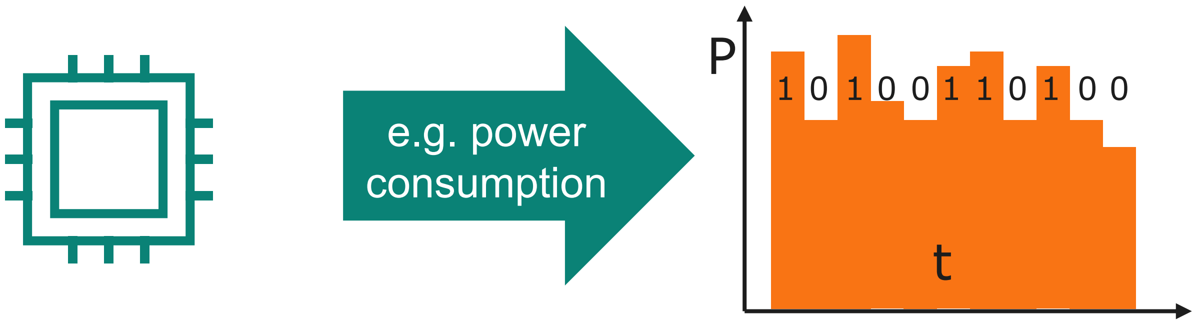
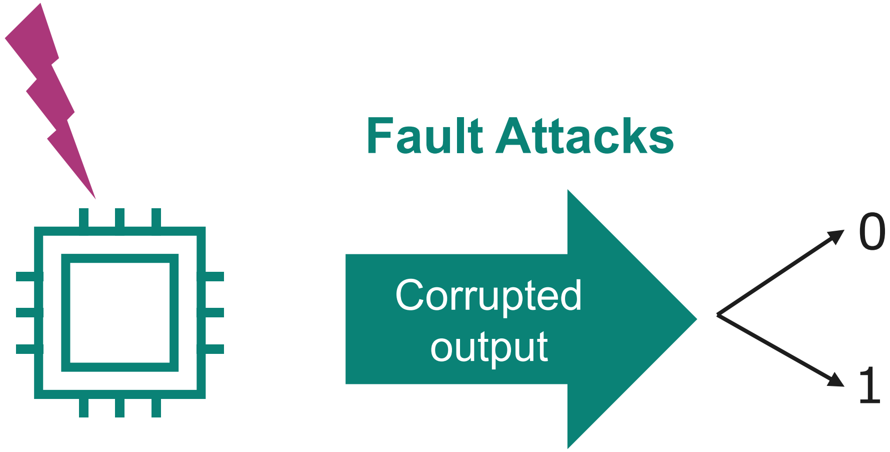
Attacks on classic vs. PQ cryptography

Side-Channel Attacks



Fault Attacks



Classic cryptography:

– More than 2 decades of research and **experience** in implementation security (attacks and countermeasures)

Post-Quantum cryptography:

– Fundamentally different algorithms can lead to fundamentally **different attack landscape**:
adapt tried and proven techniques, discover new methods

– **No real quantum computer attacks** in place yet → mathematical proof of protocols, hybrid implementation

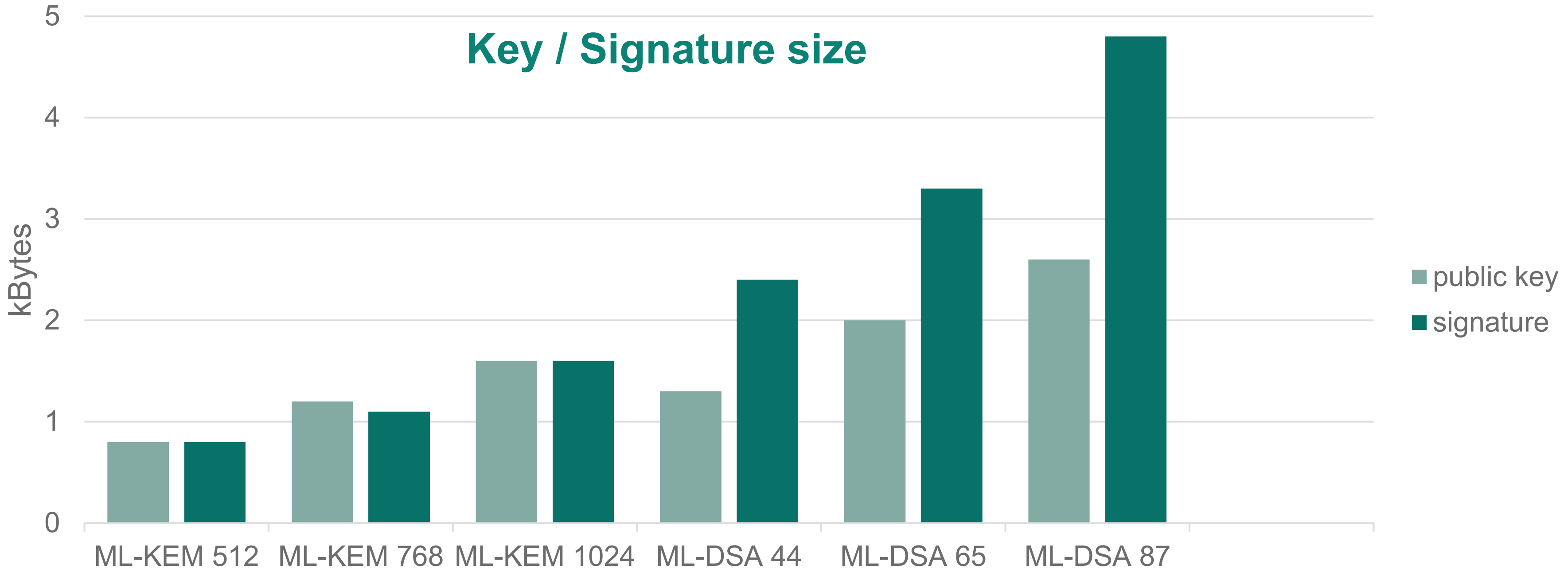
– Develop and analyze countermeasures:
adapt proven frameworks, optimize for peculiarities, develop **new countermeasures**

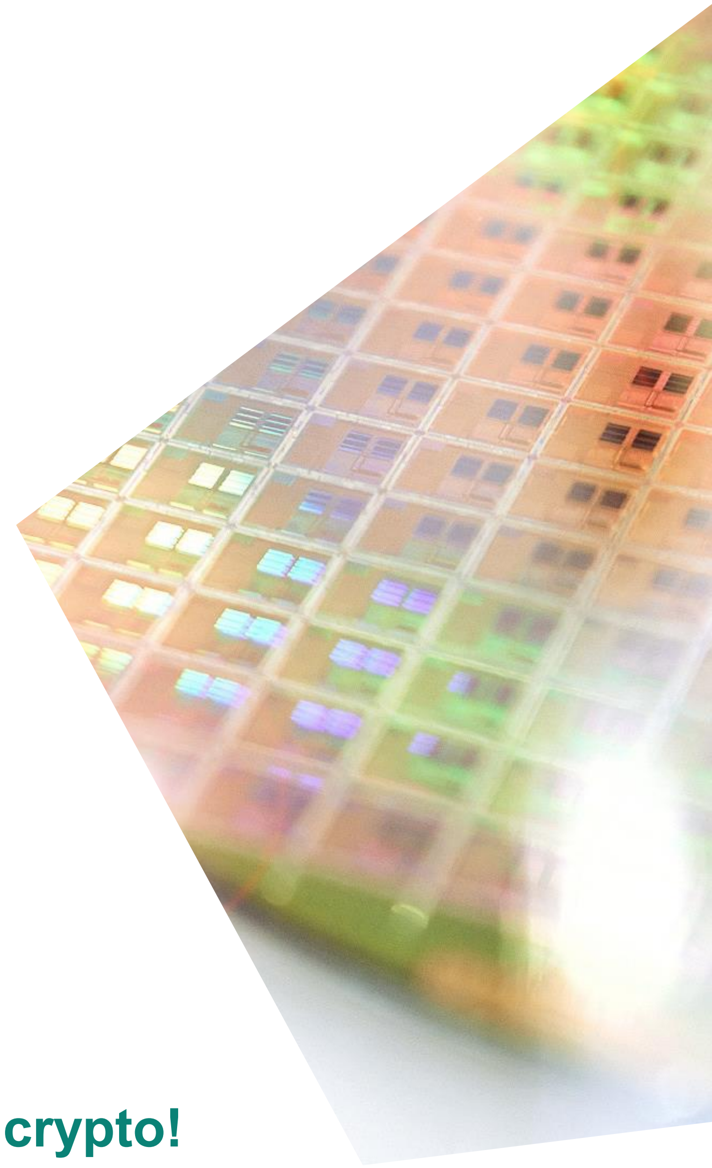
– Need to **anticipate** improvements in **attack techniques**

Highly active research area!

Running PQC on constrained devices

– **High data requirements** (memory and communication): public keys, ciphertexts, NVM, RAM





Encryption key sizes up to 80 times longer compared to conventional crypto!

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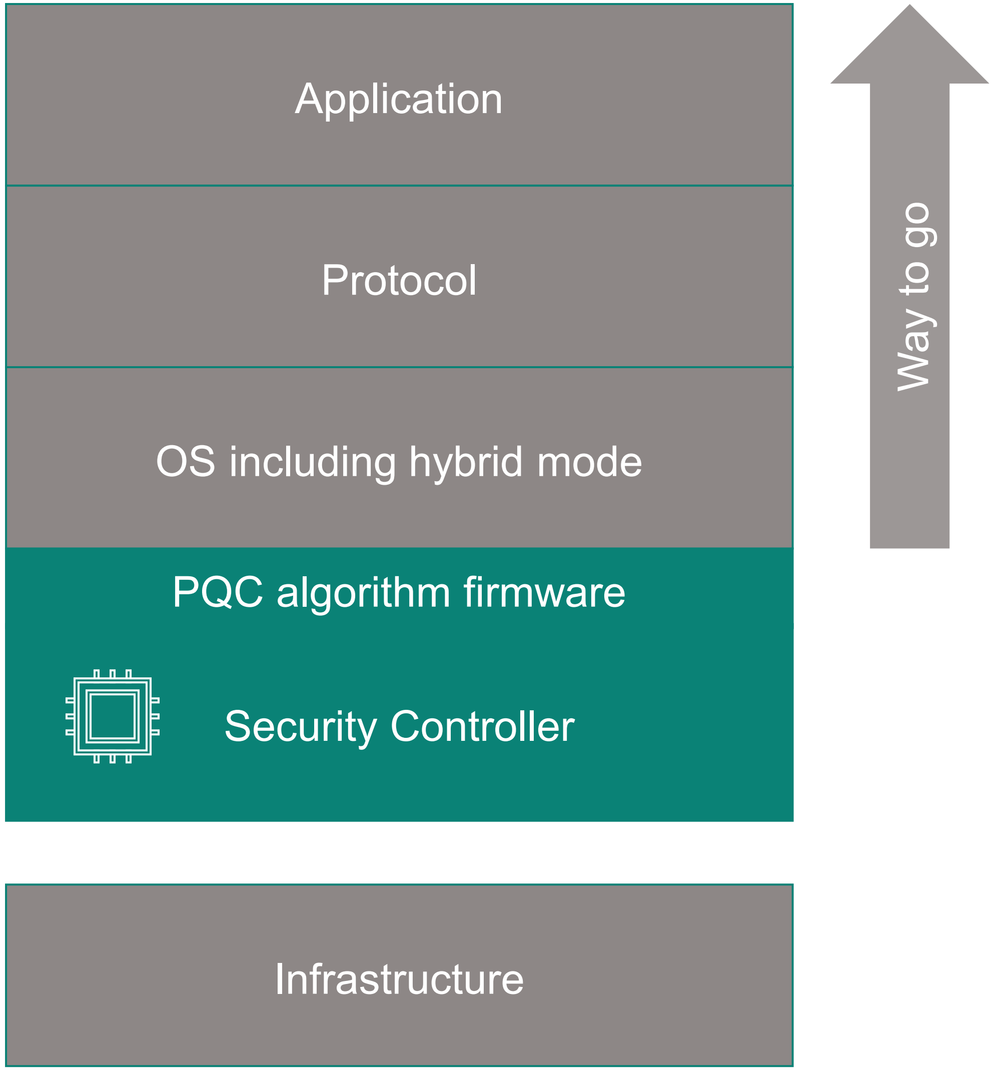
From Algorithm to Application



- **Application** dependent protocols (multiple standardization organizations are working on **PQC migration**).
- **Protocol** includes crypto, challenge: **mathematical proof** (Protocols **cannot be PQC attacked** – currently no experimental proof possible)
- OS needs to support crypto **hybrid mode** for higher security
- PQC algorithms with **long key sizes**
- Security controller with **PQC coprocessor**, large NVM **memory** and **crypto agility** and large RAM **for long key sizes**
- **Infrastructure migration** (personalization, PKI,…).

Java Card and PQC

JAVA CARD
Forum

Status

- Currently ML-KEM and ML-DSA APIs including keys are in definition.
- Example: Signature generation and verification based on existing JC API.

Challenges

- Big keys and signature buffers for efficient usage.

Timeline

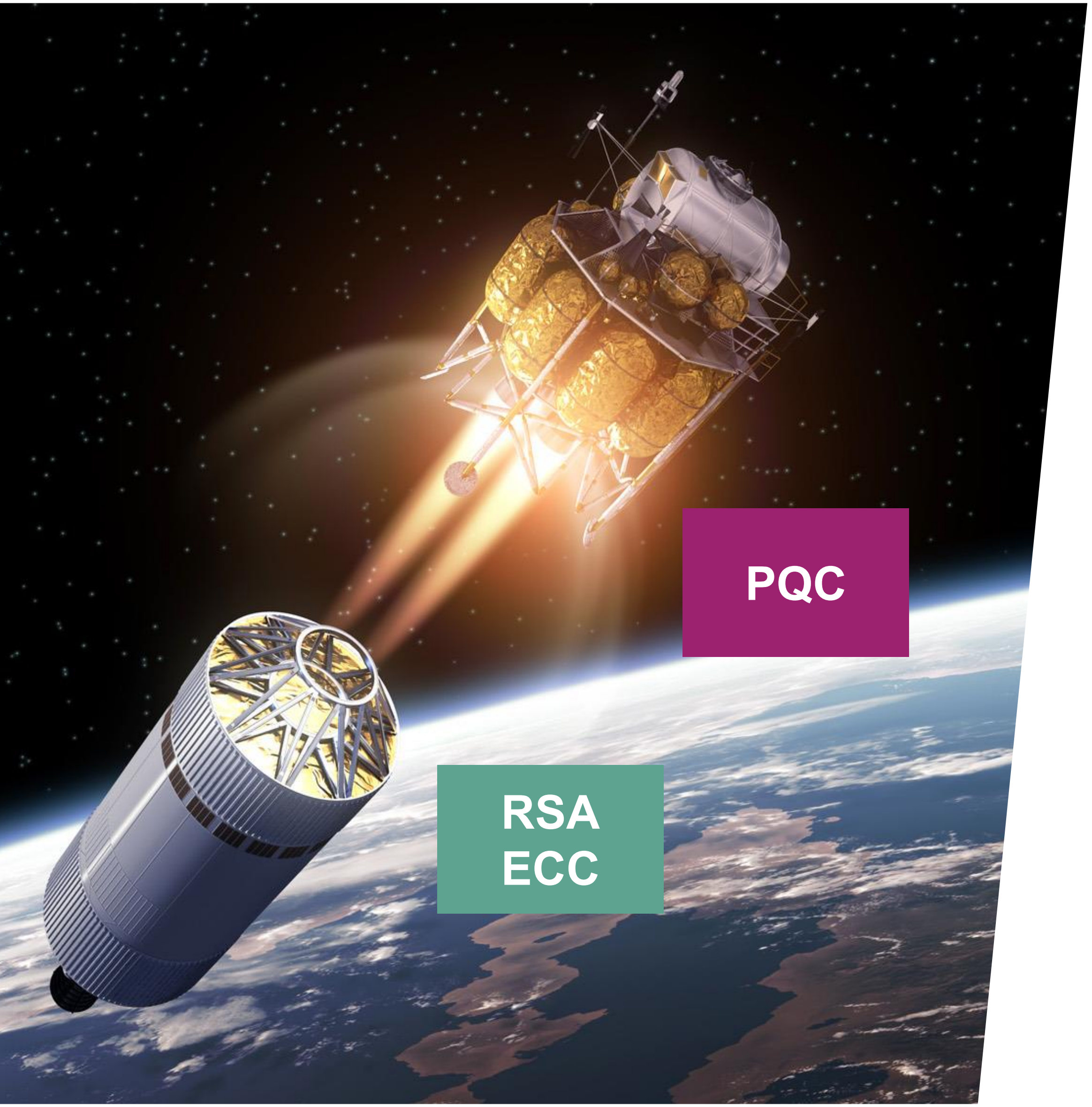
- Not defined yet

Status of Application Standards

Application	Urgency of*) migration	Standards	Status of PQC migration
Automotive security	High	V2X, CCC, vendor proprietary	Complex ecosystem, many players, CCC has low progress.
Brand Protection	High	Customer specific	High request of PQC for brand protection.
Subscriber Identity Modules (SIM)	High	GSMA, ETSI, GP, 3GPP	PQC is part of GSMA standard Used for Remote SIM Provisioning (RSP) use case.
Platform integrity (TPM)	High	TCG	Draft standard available.
Electronic passport	High	ICAO 9303	Integrity proof of attributes using PQC. Draft standard available
Logical and physical access (PIV)	High	FIPS	NIST will develop/update application-specific guidance throughout the transition.
Logical access (FIDO)	Medium	Fido alliance	PQC algorithms selected by study group (ML-DSA, ML-KEM) – standardization start expected soon.
Medical	Low	FDA	No request about PQC now.
Payment cards and connected wearables	Low	EMVCo	Migration planned by EMVCo approx.in 2038.
Physical access	Low	Aliro	PQC not mentioned in standard up to now.
Smart Home – Matter	Low	Matter v1.5	New version 1.5 will include PQC with device attestation certificate.

*) Current subjective perspective of Infineon

Transition to PQC



- **RSA** and **ECC** are used almost everywhere
- No simple drop-in replacement into existing **protocols**
- **Standardization** still ongoing
- **Ship today** and **update** cryptography **later → Crypto agility**
- Flexible HW **accelerators** for different schemes

Firmware update mechanisms and **hybrid usage** of classical and PQ crypto for a **smooth and secure transition** to the post-quantum world !

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Leading the way in post-quantum security

Infineon has been working with customers, partners and the academic community on all facets of PQC for years

- **As early as 2017**, Infineon implemented a post-quantum key exchange method based on the "New Hope" algorithm on a commercially available chip for contactless smart cards

- **Since 2018**, Infineon has been actively involved in several funding projects and has published numerous pioneering papers

- **In 2022**, Infineon released a quantum-resistant firmware upgrade path for OPTIGA™ TPM

- Infineon actively contributed to the development of the **SPHINCS+** stateless hash-based signature scheme, which has recently been **standardized by NIST as SLH-DSA**

- **December 2024, World's first Common Criteria Certification** for post-quantum cryptography (ML-KEM) on a security controller

Infineon is ready: Worlds first CC certificate for PQC (ML-KEM)

Bundesamt für Sicherheit in der Informationstechnik

Deutsches IT-Sicherheitszertifikat
erteilt vom Bundesamt für Sicherheit in der Informationstechnik

BSI-DSZ-CC-1249-2024 (*)

Smartcard Controller

IFX_CCI_000068h, IFX_CCI_000080h design step G12 with firmware version 80.505.04.1, optional PQ Crypto Suite v5.00.012, optional HSL v04.05.0040, optional UMSLC v02.01.0040 and user guidance documents

SOGIS Recognition Agreement

from	Infineon Technologies AG
PP Conformance:	Security IC Platform Protection Profile with Augmentation Packages Version 1.0, 13 January 2014, BSI-CC-PP-0084-2014
Functionality:	PP conformant plus product specific extensions Common Criteria Part 2 extended
Assurance:	Common Criteria Part 3 conformant EAL 6 augmented by ALC_FLR.1
valid until:	16 December 2029

Common Criteria

The IT Product identified in this certificate has been evaluated at an approved evaluation facility using the Common Methodology for IT Security Evaluation (CEM), Version 3.1 extended by Scheme Interpretations, by advice of the Certification Body for components beyond EAL 5 and CC Supporting Documents as listed in the Certification Report for conformance to the Common Criteria for IT Security Evaluation (CC), Version 3.1. CC and CEM are also published as ISO/IEC 15408 and ISO/IEC 18045.

(*) This certificate applies only to the specific version and release of the product in its evaluated configuration and in conjunction with the complete Certification Report and Notification. For details on the validity see Certification Report part A chapter 5.

The evaluation has been conducted in accordance with the provisions of the certification scheme of the German Federal Office for Information Security (BSI) and the conclusions of the evaluation facility in the evaluation technical report are consistent with the evidence adduced.

This certificate is not an endorsement of the IT Product by the Federal Office for Information Security or any other organisation that recognises or gives effect to this certificate, and no warranty of the IT Product by the Federal Office for Information Security or any other organisation that recognises or gives effect to this certificate, is either expressed or implied.

Common Criteria Recognition Arrangement recognition for components up to EAL 2 and ALC_FLR only

Bonn, 17 December 2024
For the Federal Office for Information Security

DAkkS Deutsche Akkreditierungsstelle D-ZE-19615-01-00

Sandro Amendola L.S.
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Certification in December 2024

- **World's first CC-certificate for ML-KEM** on a security controller
- **Common press release** with German Federal Office for Information Security (BSI)

> The BSI consistently supports and demands the switch to post-quantum cryptography in order to make files and applications secure in the long term. **The availability of quantum-safe IT products, which can also be found in numerous everyday applications, is therefore a real milestone!**
>
> *Claudia Plattner, President of the BSI*

Infineon – your trusted advisor for the PQC landscape

First market player to offer hardware with dedicated PQC coprocessor

Infineon TEGRION™ product family of next gen security controllers with Integrity Guard 32 for long-lasting security and superior fault protection

Partnering with customers, partners, and the academic community to prepare for a post-quantum future

Global team of experts and researchers dedicated to the PQC field

We can help you to bridge the gap between quantum theory and practical application

Achieve future-proof security in the era of quantum computing now!

Infineon