The Impact of Quantum Technology on Cybersecurity

DAFITC

August 2023

Denis Mandich

- CTO and Co-founder of Qrypt.
- Founding member of the Quantum Economic Development Consortium (QED-C).
- Industry Advisory Board – Center for Quantum Technology.
- Founding member of the Mid-Atlantic Quantum Alliance (MQA).
- ANSI Accredited Standards Committee X9.
- ITU Telecommunications Standardization Sector (ITU-T).
- Forbes Technology Council.
- Former Quside board member.
- 20-year USIC veteran.
- Physicist.

Cryptography Basics

- Cryptography is the use of codes to secure communications over
an insecure medium.
- Must provide Secrecy and Authenticity even when the adversary controls the channel.
- Security proofs depend on the secrecy of a randomly generated key which may be shorter or longer than the message.

Brief History of Cryptography – “How we got here”

- Caesar cipher, Vernam, 1970s to today.
- Asymmetric/Symmetric.
- Information theoretic secure/computationally theoretic secure.
- Quantum-safe/quantum-secure difference.
- Suite A/Suite B/CNSA.
- No “*security through obscurity*” – we partner with the National Labs and publish everything.

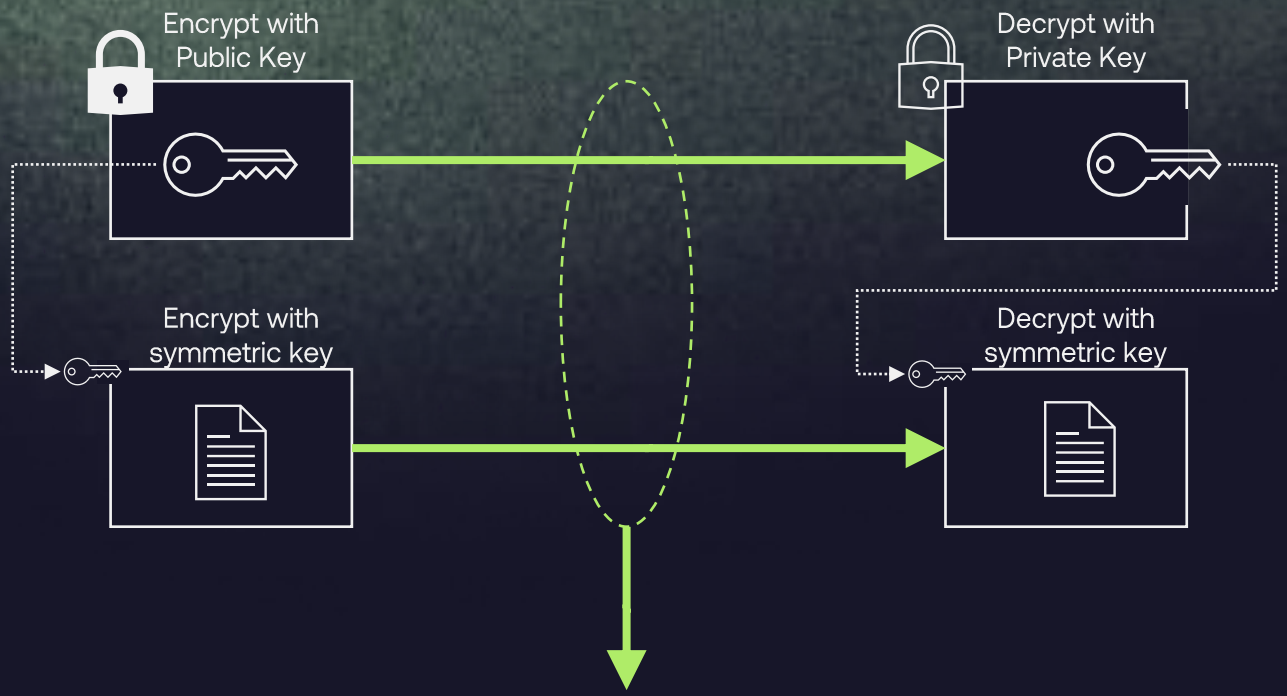
Suite A

Suite B

Public-Private key pairs are used to exchange symmetric keys to both encrypt and decrypt data:

1. Transmit keys

2. Transmit data



Quantum computers will be able to decrypt key transmission, which gives access to encrypted data.

Public Key Infrastructure, E2E

- The internet is fragile as are all apps for banking, privacy, health records, govt, etc.
- PKI was never completed and continues to grow in complexity and management challenges.
- Zoom, Yubikey examples; FedRamp, FIPs certifications.

NIST

Information Technology Laboratory

COMPUTER SECURITY RESOURCE CENTER

UPDATES 2022

Decision to Revise NIST SP 800-22 Rev. 1a

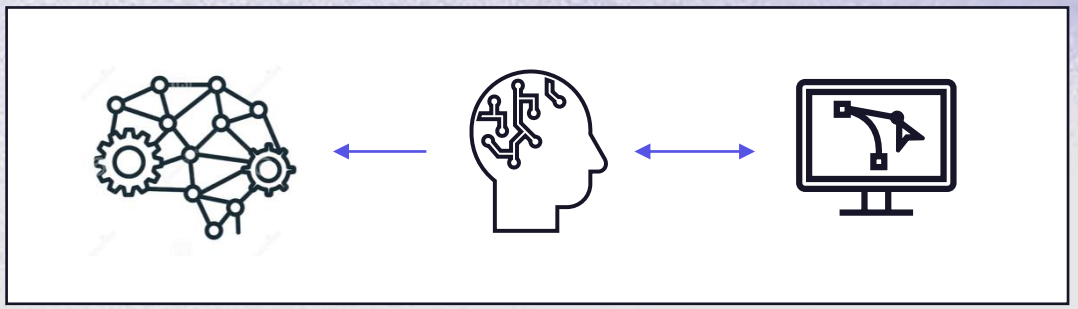
...rejecting its use for assessing cryptographic random number generators

Where is encryption used?

- Bank transactions, ATMs, https, e-commerce, PCI
- Cryptocurrency, digital wallets and assets
- Cloud infrastructure, virtual networks
- Ubiquitous always-on systems and sensor networks

Where are the greatest threats?

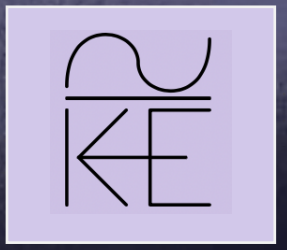
- Integrity of automated and interconnected systems.
- Trust in the financial industry and data exchanges.
- Security of deposits, trading strategies, M&A.
- Risk to operational AI and ML infrastructure.



Persistence of classical vulnerabilities

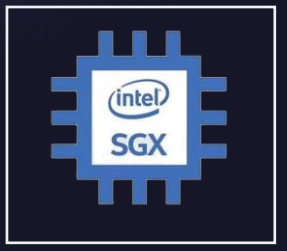
SIKE – NIST PQC Finalist

- Broken by a 2010 desktop computer with a Xeon processor.
- What if this wasn't discovered for 5-10 years after implementation?



Intel SGX enclaves – the encryption keys to the kingdom

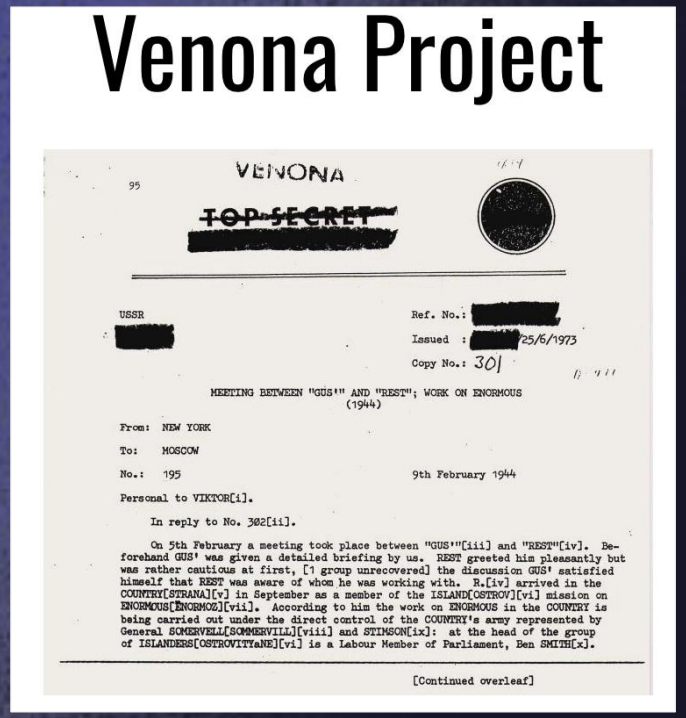
- Cornerstone of a trusted execution environment, even when the operating system is compromised.
- Multiple types of flaws discovered over four years, new CacheOut attack.



SHA-1, Dual_EC_DRBG, Heartbleed, Spectre, Meltdown, PacMan...

“Harvest now, decrypt later”

- Venona project, China today, low/no cost for storing, high potential benefit.
- Real world examples, Rosenbergs, IoT.
- Change in data theft priorities, targeting strongly encrypted data.



Venona Project

VENONA

95

~~TOP SECRET~~ [redacted]

USSR [redacted]

Ref. No.: [redacted]

Issued : [redacted]25/6/1973

Copy No.: 301

MEETING BETWEEN "GUS'" AND "REST"; WORK ON ENORMOUS
(1944)

From: NEW YORK

To: MOSCOW

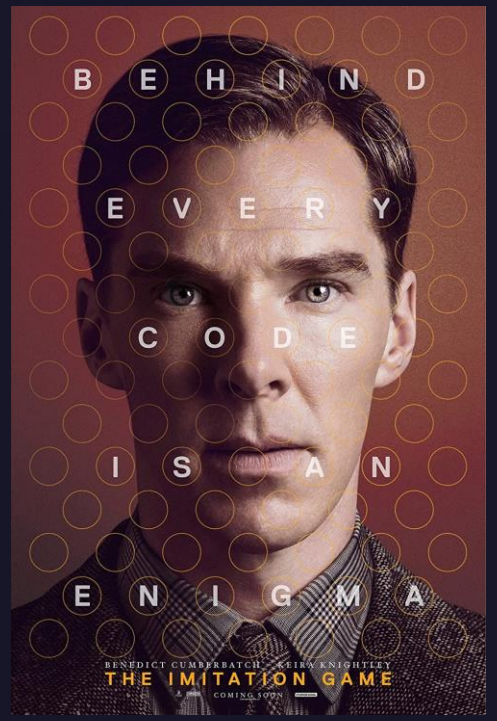
No.: 195 9th February 1944

Personal to VIKTOR[i].

In reply to No. 302[ii].

On 5th February a meeting took place between "GUS'"[iii] and "REST"[iv]. Beforehand GUS' was given a detailed briefing by us. REST greeted him pleasantly but was rather cautious at first, [1 group unrecovered] the discussion GUS' satisfied himself that REST was aware of whom he was working with. R.[iv] arrived in the COUNTRY[STRANA][v] in September as a member of the ISLAND[OSTROV][vi] mission on ENORMOUS[ENORMOZ][vii]. According to him the work on ENORMOUS in the COUNTRY is being carried out under the direct control of the COUNTRY's army represented by General SOMERVELL[SOMMERVILL][viii] and STIMSON[ix]: at the head of the group of ISLANDERS[OSTROVITYaNE][vi] is a Labour Member of Parliament, Ben SMITH[x].

[Continued overleaf]



The Washington Post

China harvests masses of data on Western targets, documents show

Dec 31, 2021

THE EPOCH TIMES

Massive Leak Shows Big Data Is Central to CCP's Ambitions, But It Does Not Protect Chinese Citizens

Jul 17

THE CONVERSATION

Concerns over TikTok feeding user data to Beijing are back – and there's good evidence to support them

Jul 5

TETRA Backdoors - critical infrastructure, police, military, intel

- Terrestrial Trunked Radio Standard – established by European Telecommunications Standards Institute (ETSI) in 1995
- Widely deployed in NATO and countries with most nuclear weapons ever made
- Weakened entropy to reduce encryption key strength from 80 bits of security to 32 bits
- *In the 1990s, DES (56 bits) and RSA-155 (512 bits) were already broken!*
- Five critical vulnerabilities in authentication, deanonymization, tracking and encryption key generation
- Enables vast bulk data access for *"harvest now, decrypt later"* methodology
-

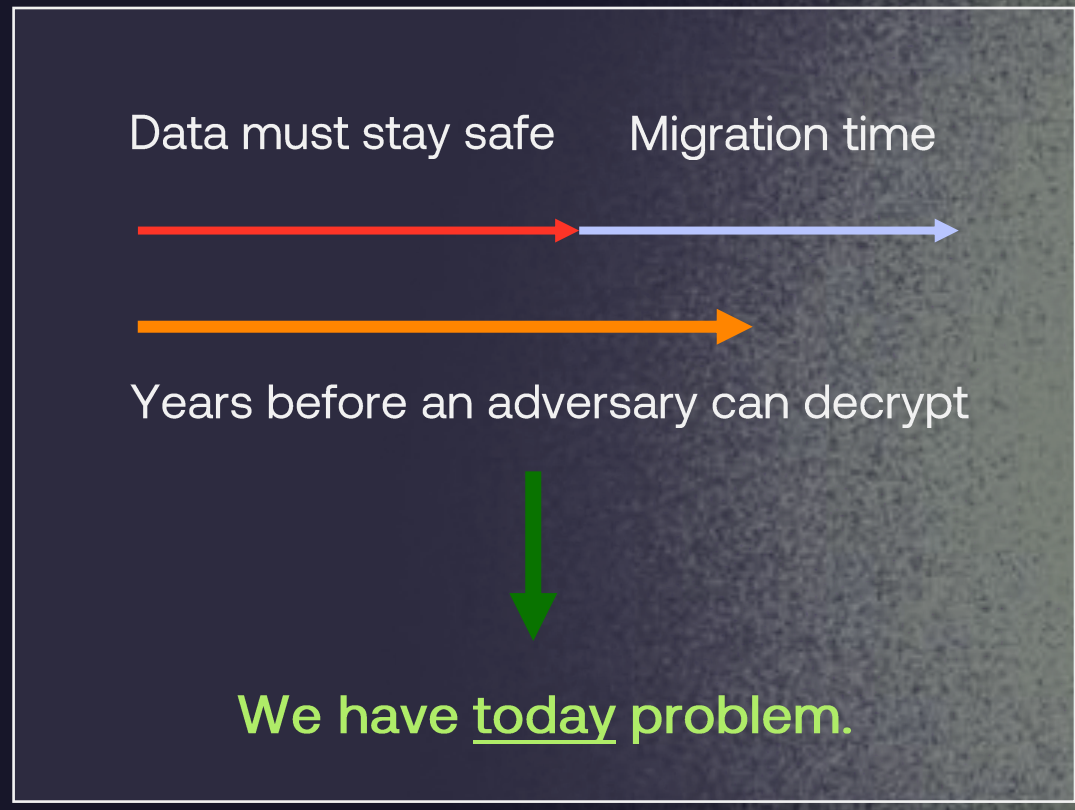
Multiple Access Vectors

- CVE-2022-24401 - The Air Interface Encryption (AIE) keystream generator relies on publicly broadcast and unauthenticated network time, enabling **decryption oracle attacks.**
- CVE-2022-24403 - The cryptographic scheme used to obfuscate radio identities has a weak design that allows attackers to **deanonymize** and **track** users.
- CVE-2022-24400 - Flawed authentication allows attackers to set the **Derived Cypher Key (DCK) to 0**
- CVE-2022-24402 - Reduces the original key size making them trivial to **brute-force** on basic laptops in minutes.
- CVE-2022-24404 - Lack of AIE ciphertext authentication allows for **malleability attacks.**

When quantum is here, it will be too late. Your data is ready for decryption.

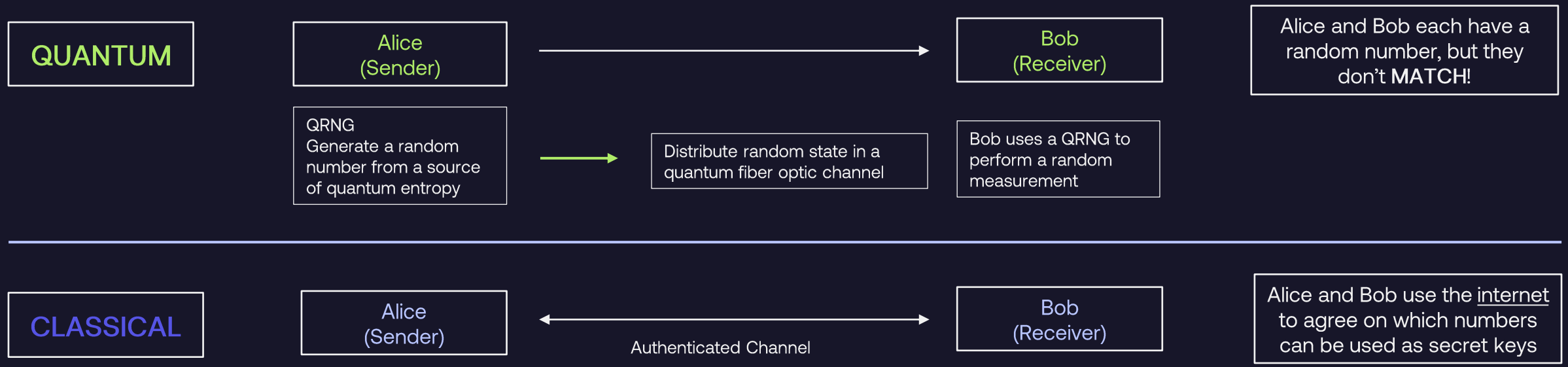
- **Harvest Now, Decrypt Later** means adversaries are storing your encrypted data *today*.

- **Waiting for NIST PQC algorithms isn't enough.**
- All of today's stolen data can be decrypted when Y2Q hits.
- If/when future PQC algorithms fail, that data will also be vulnerable.



What makes cryptography quantum?

- Keys must be generated from a source of quantum entropy, not electronic noise.
- Identical quantum keys must reach multiple endpoints to be useful.
- SneakerNet, DI-QKD, BB84, E91 – all rely on inescapable classical assumptions.
- NSA affirmed rejection of QKD:



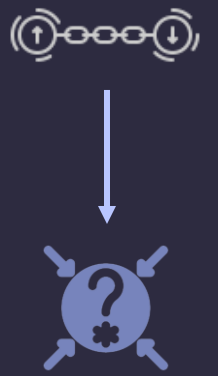
**Still uses classical information so what was gained by sacrificing redundancy?*

The core issues with QKD and variants:

- Trusted node network until we have reliable and scalable quantum repeaters and quantum memory.
- Expensive physics appliances at the endpoints – still need to get keys to clients (iPhones, laptops, etc.)
- Centralized point of attack and failure for denial-of-service, accidents (shovels and backhoes!)
- Requires authenticated classical channels so what's the point? Just use PQC instead?
- NSA repeatedly stated their position: **"It's a HARD NO!"**

The "must-haves" in quantum cryptography to make it commercially viable and deployable:

- QRNGs to make random numbers/states [SOLVED]
- Redundancy and decentralization – must be resilient, no single point of failure
- Leverage existing massive global communications infrastructure (not physical security)
- Accessible by any classical device endpoint, *not just datacenter-datacenter*



What is the best solution?

- Pre-shared key, OTPs, quantum keys, send data in the clear with no risk.
- Random number generator stations during the cold war.
- Embassies communication over adversarial controlled comms.

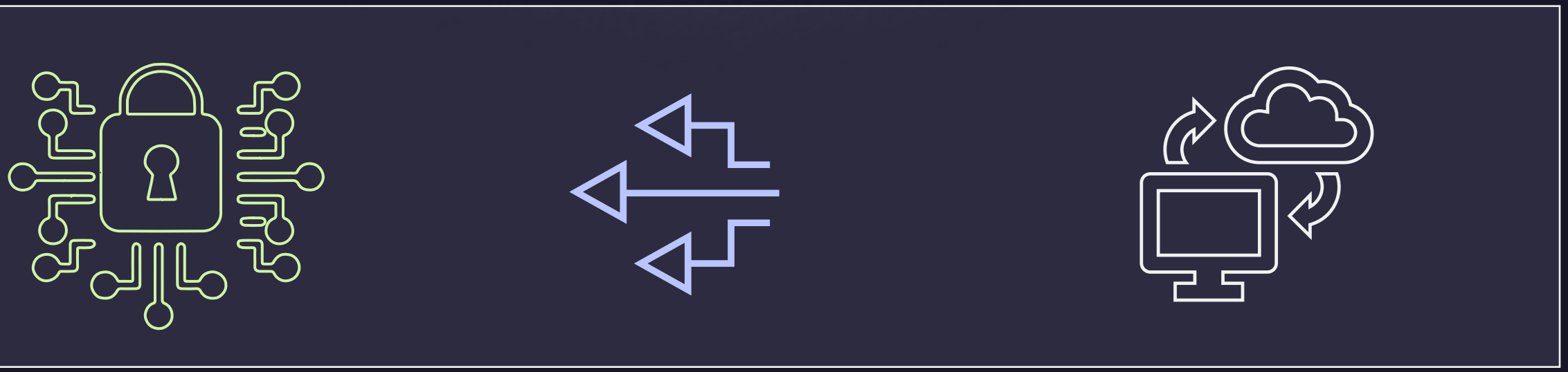
The spooky world of the 'numbers stations'

By Olivia Sorrel-Dejerine
BBC News Magazine

16 April 2014

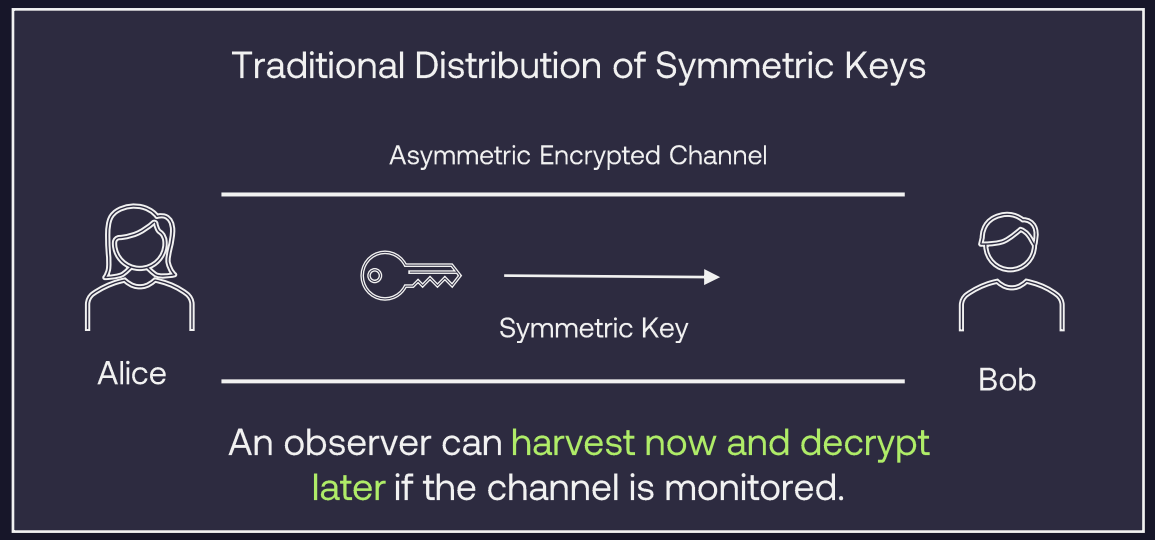
What if we didn’t distribute keys?

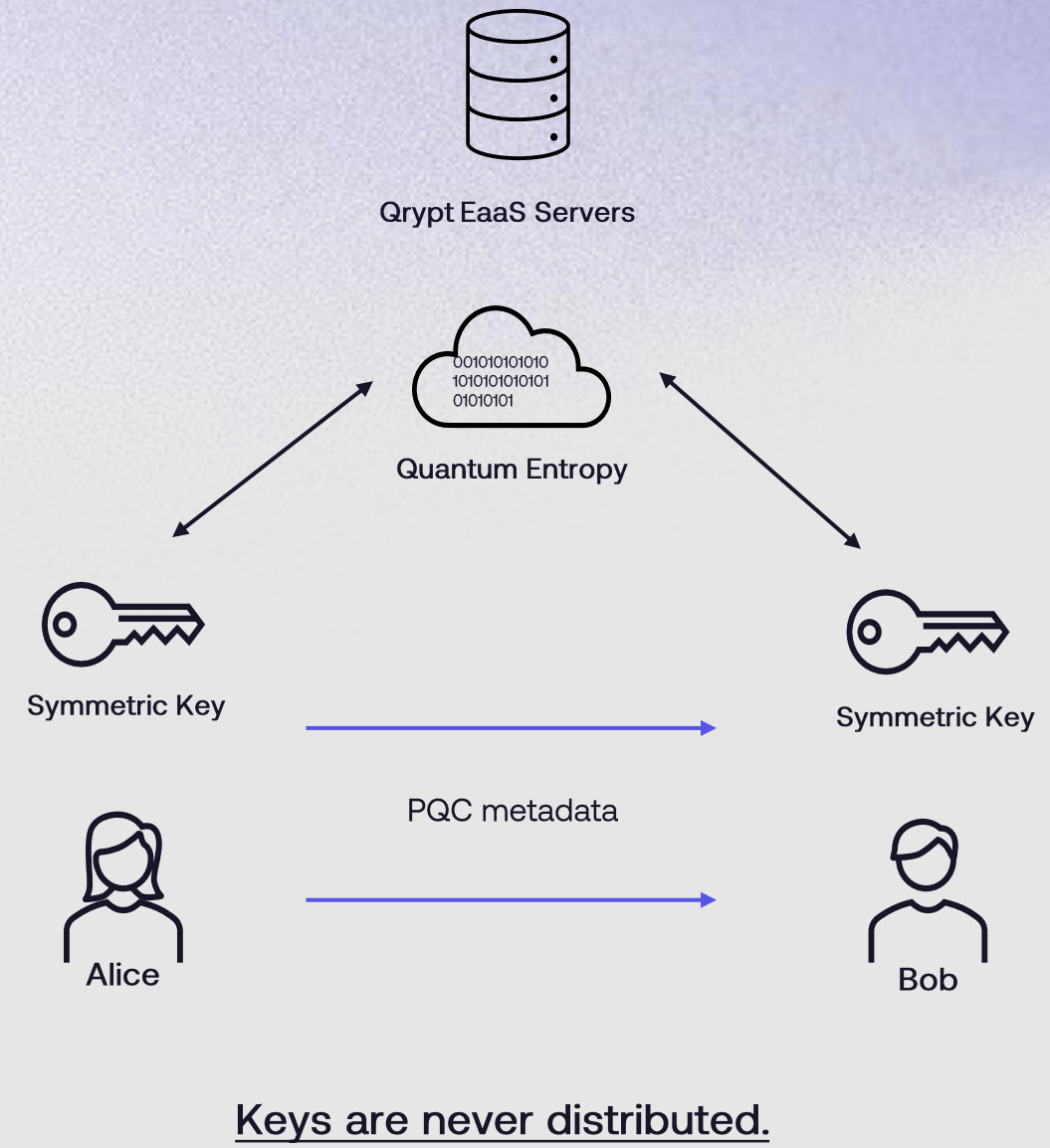
- Simultaneously generate them at the endpoints.
- HNDL issue is eliminated.
- Cryptographic channel, not the same as the data channel – decoupling.
- Cloud enabled, simplified implementation on modern cloud infrastructure.



A quantum solution

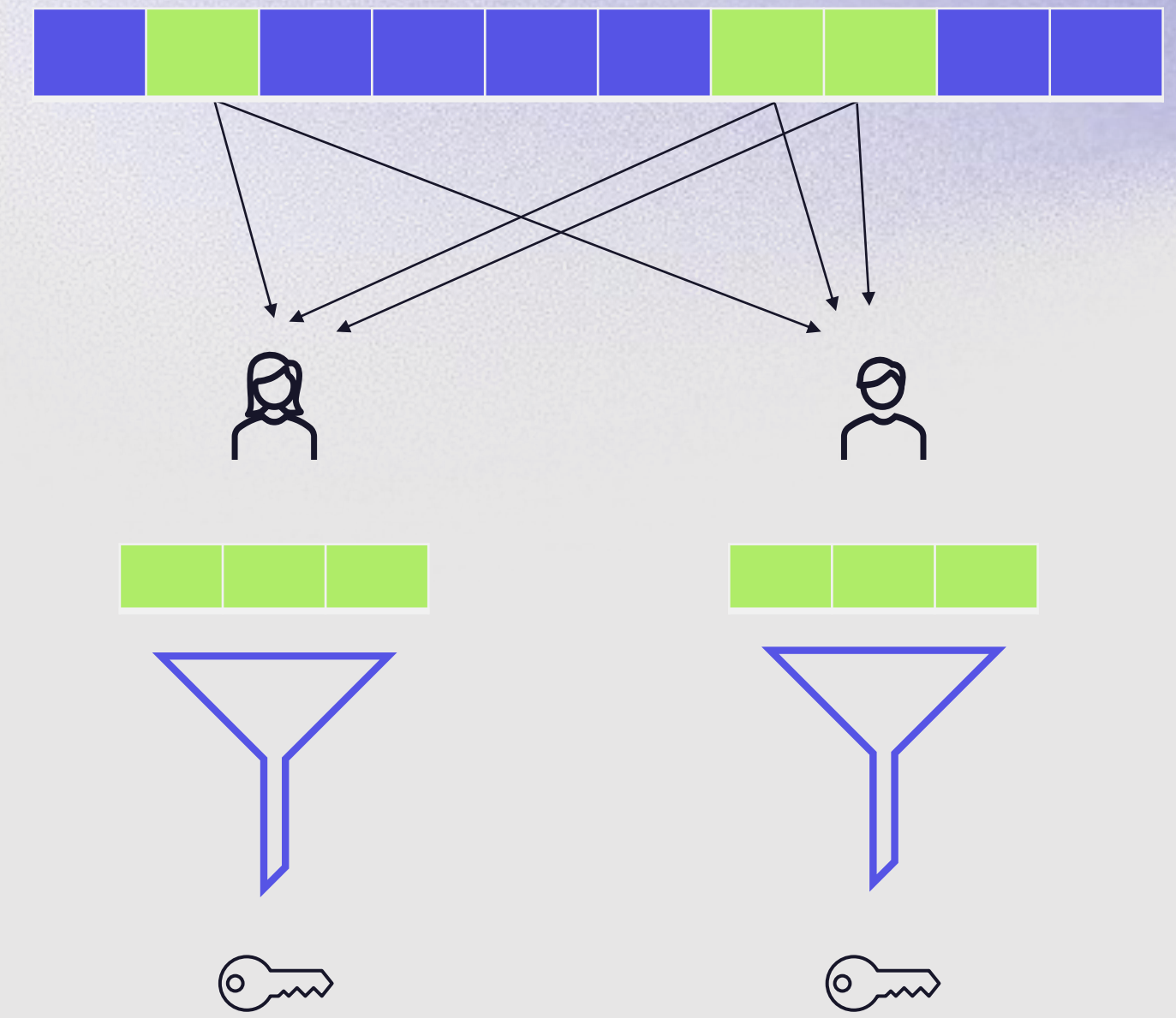
- Introduce cryptographic extractors, metadata and sample implementation.
- The cloud nor the app should be capable of recovering the keys.
- PQC is not used to exchange keys.
- Benefits/cost.



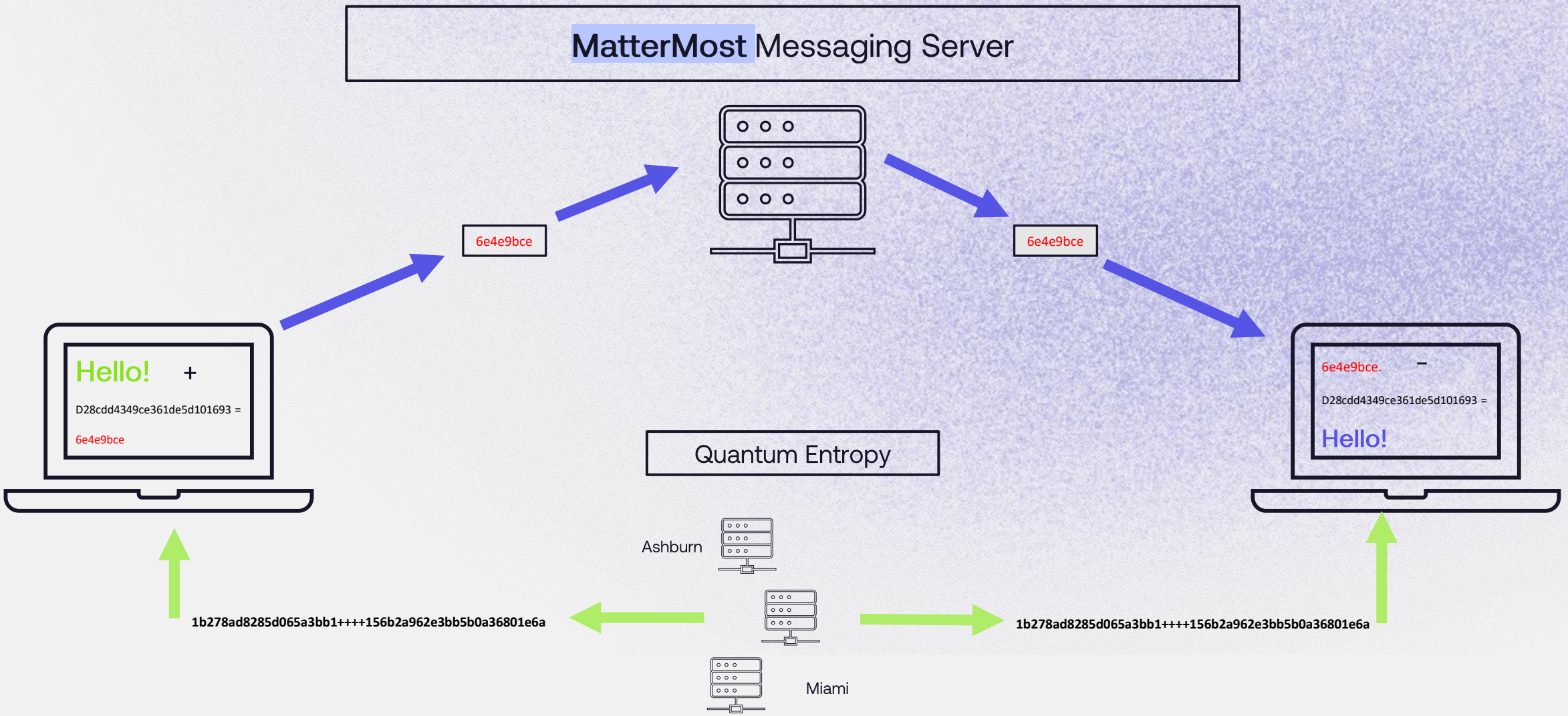


Sample then Extract

- Stateless and locally computable.
- Preserve quantum entropy.
- Force the attacker to compromise decoupled systems, but get nothing.
- Compatible with PQC, but provides additional protections in a crypto-agile world even when new algorithms are compromised.



Quantum security for any application – **MatterMost**



No free lunches

- If an attacker is on the endpoint/client, no encryption can help.
- Compatible with PQC, but provides additional protections in a “crypto-agile” world.
- Trust no one or leave vulnerabilities.
- *USG key escrow and backdoors never work.*

NIST process for PQC algorithm standardization

- Remaining candidates, problem with signatures.
- Assume another transition is coming, SIKE has fallen, potential weakness found in Kyber.
- MFA analogy and trajectory.

Public Key/KEMs	Digital Signatures
Finalists for standardization	
Kyber	Dilithium
~~SIKE~~	Falcon
	SPHINCS+
4th round in reserve	
BIKE	*????? Nothing yet!!!*
HQC	
McEliece	

USG Directives, government is leading the way

- NSMs, EOs, HR, Senate bipartisan support.
- Message is clear: industries doing govt business must implement PQC.
- National Security implications and changes to data governance.

Executive Order 14073 National Quantum Initiative Advisory Committee (4 May 2022)
Enhancing the National Quantum Initiative Advisory Committee

NSM-10 NATIONAL SECURITY MEMORANDUM (4 May 2022)
National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems | The White House

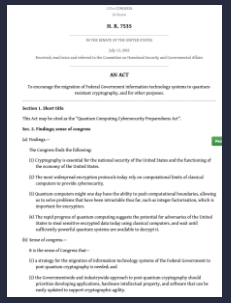
NSM-8 NATIONAL SECURITY MEMORANDUM (19 January 2022)
Memorandum on Improving the Cybersecurity of National Security, Department of Defense, and Intelligence Community Systems

HR 7535 Quantum Computing Cybersecurity Preparedness Act (18 April 2022)
Text - H.R.7535 - 117th Congress (2021-2022): Quantum Computing Cybersecurity Preparedness Act | Congress.gov | Library of Congress

Executive Order 14028 (12 May 2021) Improving the Nation's Cybersecurity
Executive Order on Improving the Nation's Cybersecurity | The White House
Executive Order 14028: Improving the Nation's Cybersecurity | GSA

National Quantum Initiative (NQI) (21 December 2018)
About the National Quantum Initiative - National Quantum Initiative

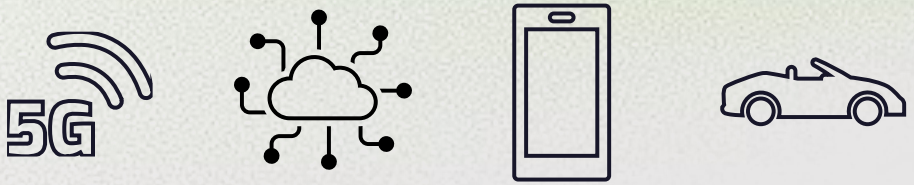
National Cybersecurity Strategy Implementation Plan (July 2023)
White House NCSIP - Strategic Objective 4 prepare for a Post Quantum future



Qrypt

This will be a long process, decades of insecurity

- PQC is not a permanent fix, especially for long lived devices (SCADA, vehicles).
- QKD is unsuitable for the vast majority of applications.
- Always on internet, 5G, IoT, all have new requirements.
- Design considerations and project planning.



“If all of mathematics disappeared, physics would be set back by exactly one week.”– Richard Feynman

Thank you!

denis@qrypt.com