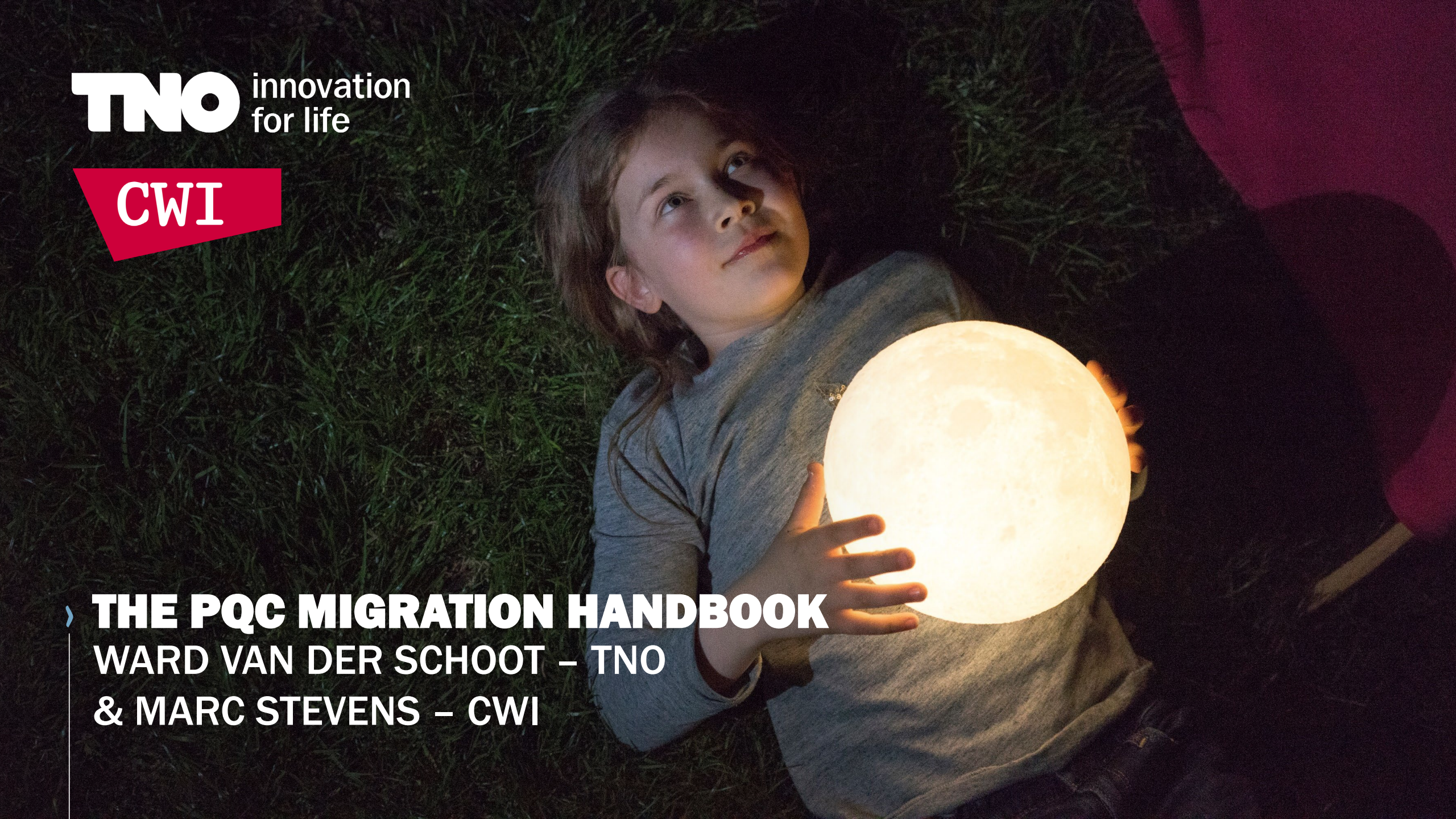

TNO innovation for life

CWI

THE PQC MIGRATION HANDBOOK

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& MARC STEVENS – CWI

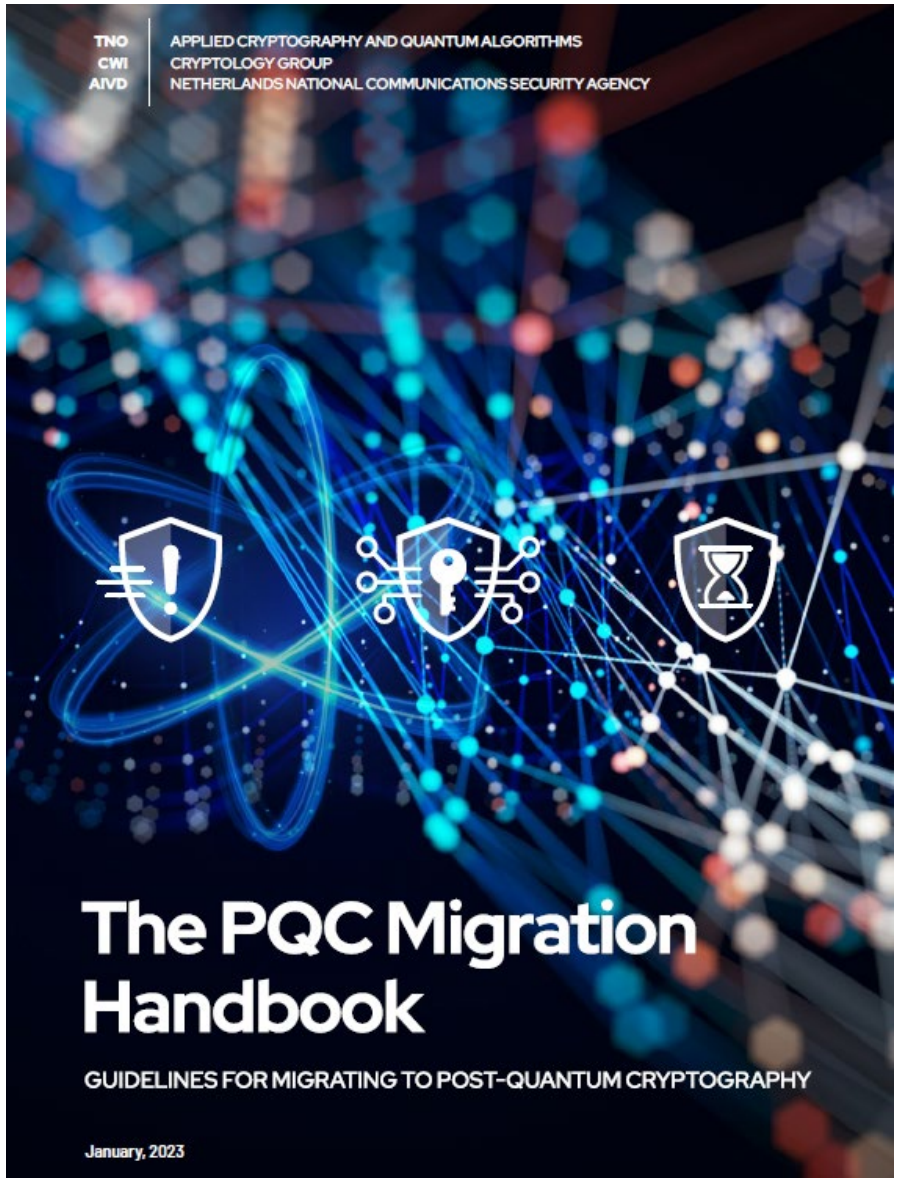
THE PQC MIGRATION HANDBOOK
GOAL & CONTRIBUTION

- Goal: pave the way for PQC migration in practice
  - Concrete, current and hands-on advice and action steps

- Strong points:
  - **Tailor -made** advice for each organisation
  - **Actionable:** checklists, decision trees and step-by-step guides
  - **Layered** approach. Describe full migration for:

    Management, policymakers, strategists, technical audience, etc.

- Collection of state-of-the-art advice from NIST, ETSI, IETF, etc
  - Corporate insights from Deloitte, KPMG, KPN
  - Governmental insights from (Dutch) ministeries of defence, foreign affairs and health and infrastructure.



THE PQC MIGRATION HANDBOOK

THREE-STEP APPROACH BY ETSI

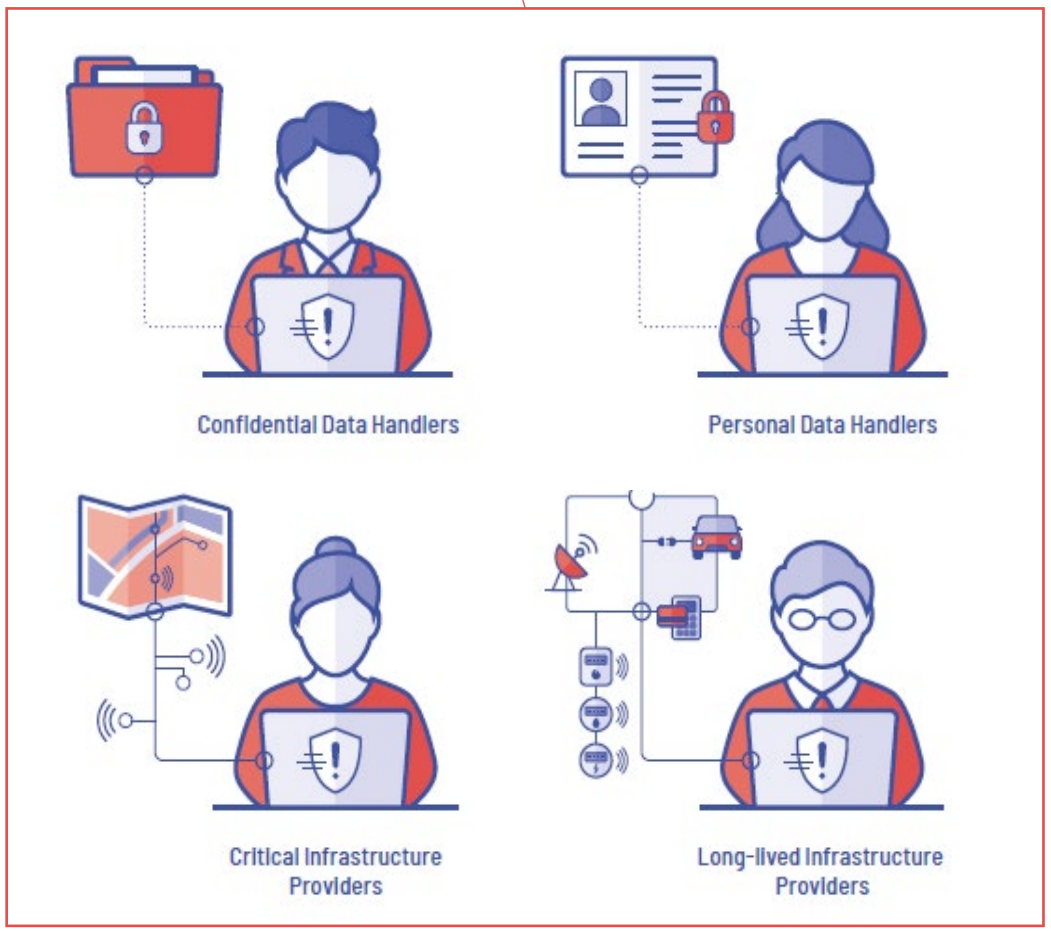
1. Diagnosis
   - Determine your stance towards PQC migration: PQC personas
   - PQC inventory
2. Planning
   - When? Determine your migration scenario
   - How? Business and technical planning
3. Execution
   - Choose migration per cryptographic asset
   - General strategies such as hybrid and pre-shared keys
   - Cryptographic agility

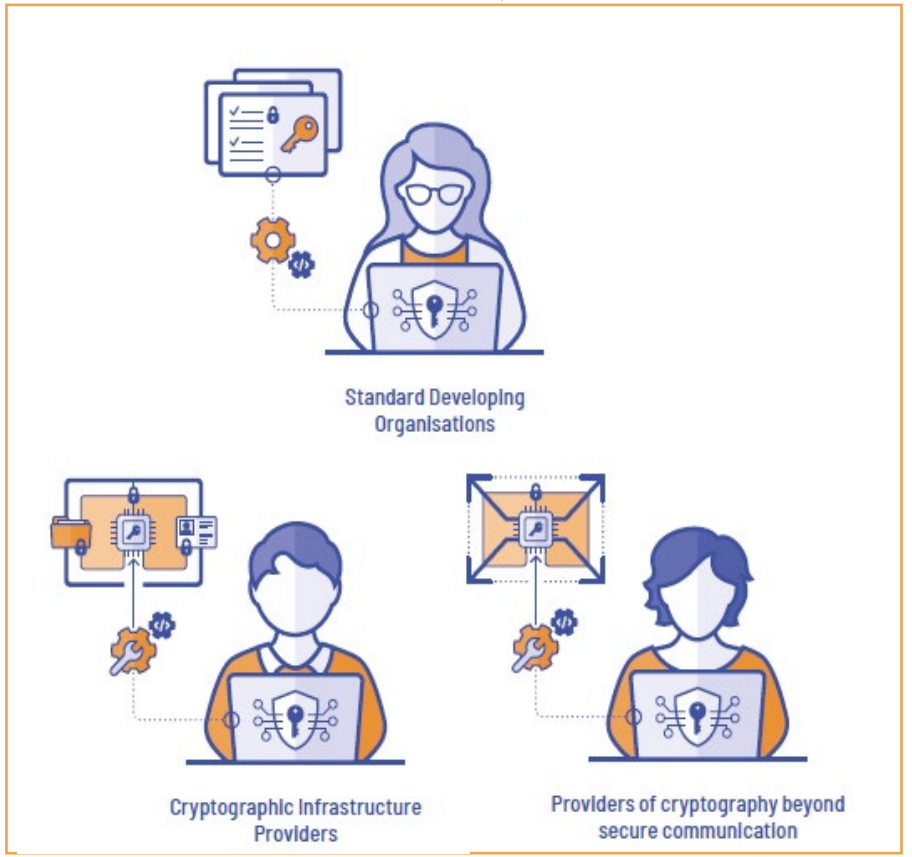
- Main contribution:
  - Collect advice and tailor it to each organisation with PQC personas

PQC PERSONAS

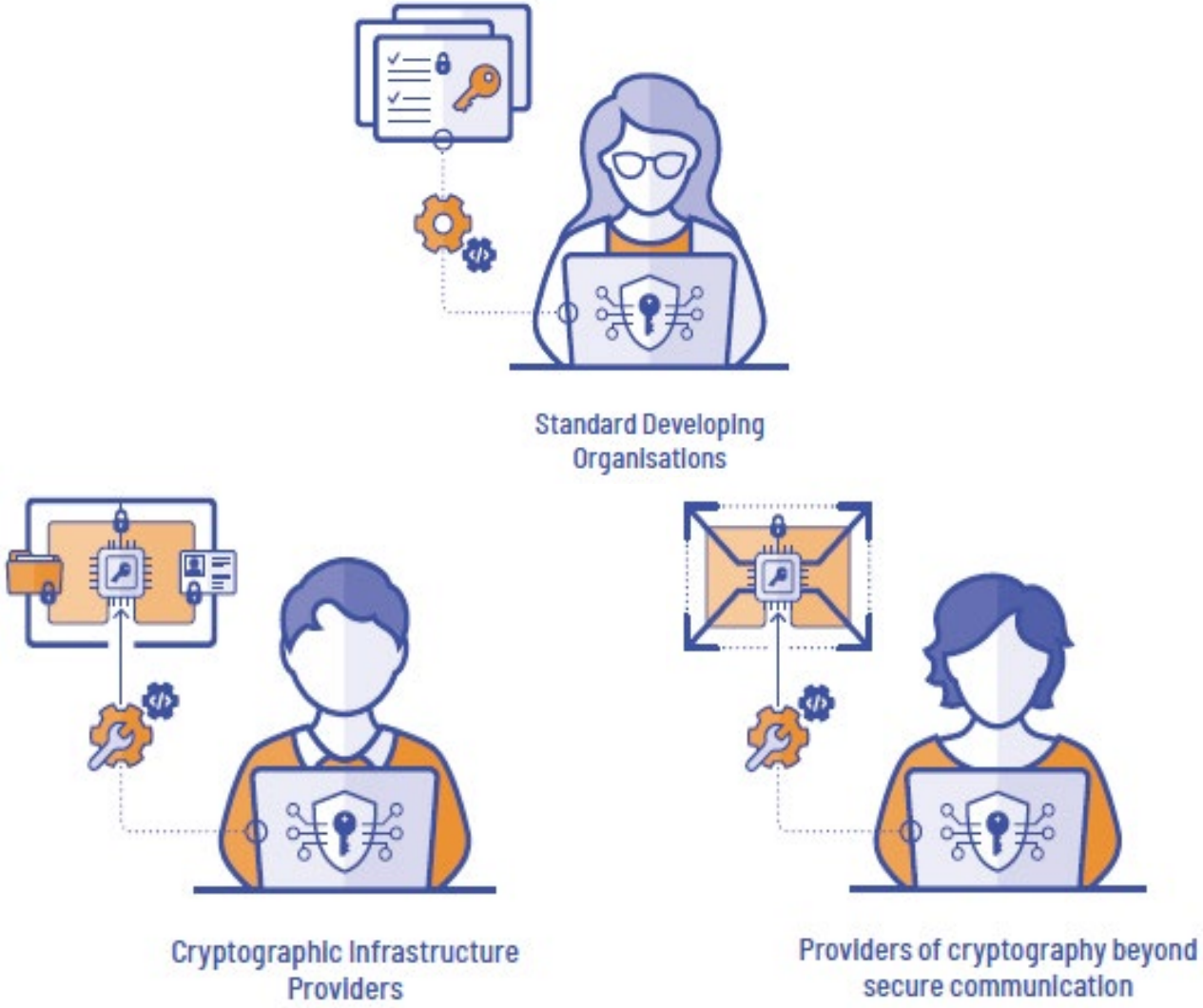
ALL PERSONAS

PQC PERSONAS
ALL PERSONAS



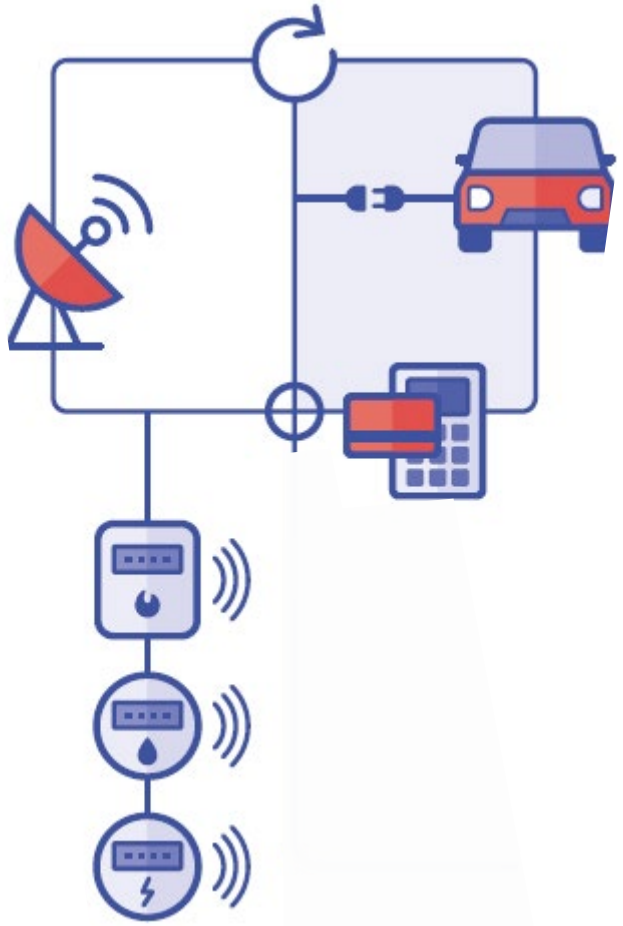


PQC PERSONAS
CRYPTO EXPERTS

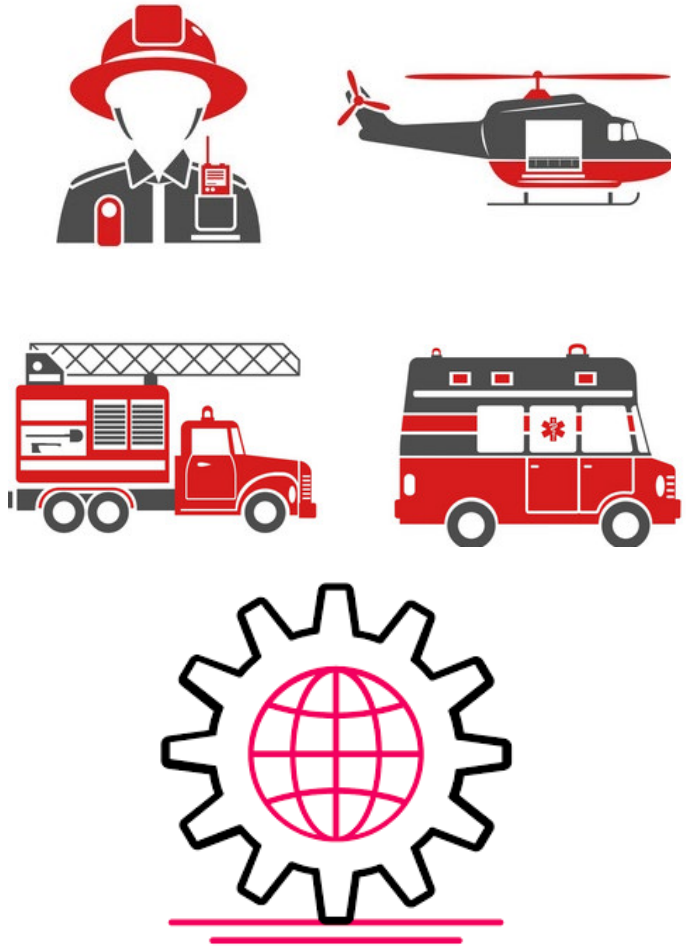


PQC PERSONAS
URGENT ADOPTERS

Store-now-decrypt-later attacks



Long-lived systems

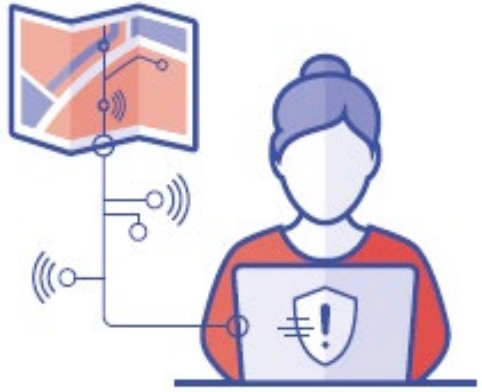


Vital infrastructure

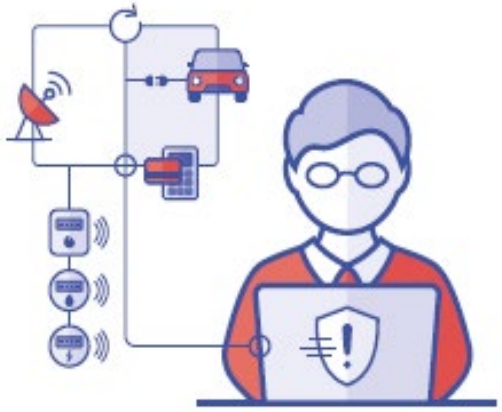
PQC PERSONAS
URGENT ADOPTERS

Confidential Data Handlers

Personal Data Handlers



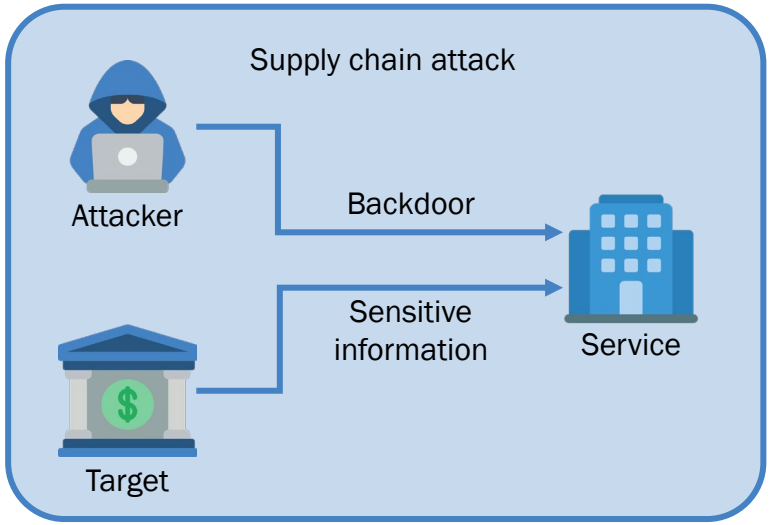
Critical Infrastructure Providers

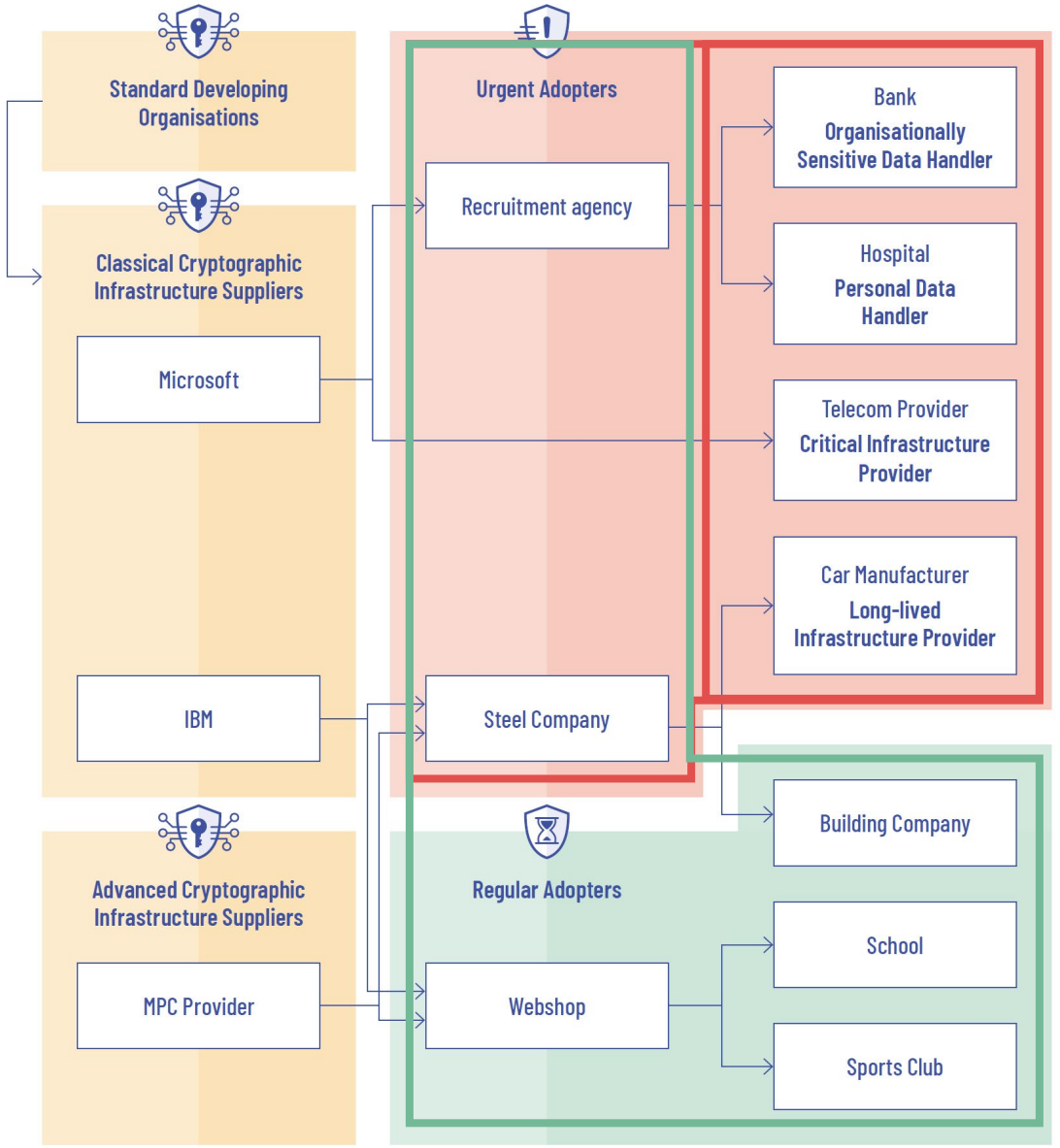


Long-lived Infrastructure Providers

PQC PERSONA'S
SUPPLY CHAIN

- Organisations are dependent on each other via collaboration and services
- This influences the migration in different ways:
  - Coordinated migration can be more efficient or even necessary
  - An organisation's persona can change due to supply chain risks





DIAGNOSIS
PQC INVENTORY

- Make a PQC inventory
  - Risk assessment
  - Inventory of cryptographic systems
  - Inventory of data
  - Inventory of cryptographic dependencies

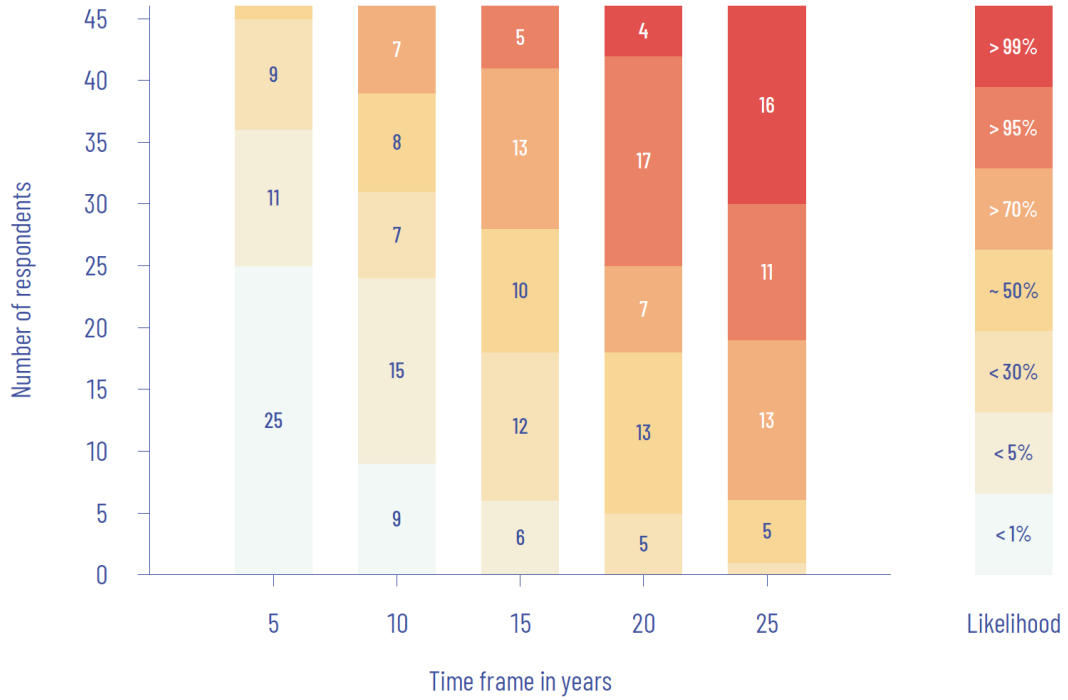
- Depending on ones persona, inventory has different focus
  - Data personas should have a thorough data inventory
  - Infrastructure personas should have a thorough systems inventory

- Each organisation is advised to prepare this already
  - Migration is a timely process
  - Increase readiness for future migration steps

PLANNING
WHEN TO MIGRATE?

- Migration equation: $X + Y < Z$:
  - Z: Time until old public-key crypto can be broken by a sufficiently large quantum computer
  - X: Time that information/systems need to stay protected
  - Y: Migration time

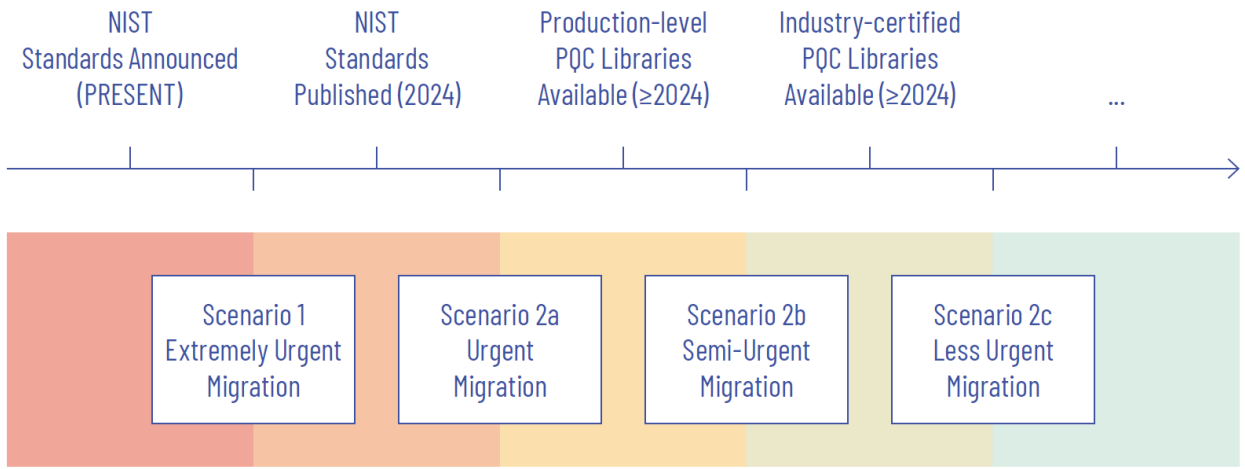
- Estimate Z on expert information and own risk appetite



- Urgent adopters:
  - Store-now-decrypt-later: larger X due to loss of control over encrypted information
  - Long-lived systems: larger X due to difficulty of migrating hardware/systems
  - Vital infrastructure: smaller Z

PLANNING
WHEN TO MIGRATE?

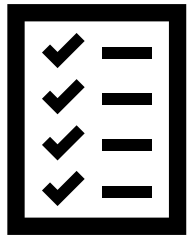
- Migration to be planned under 4 possible scenarios:

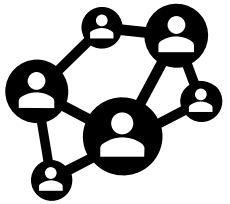


- Migration equation: $X + W_i + Y_i < Z$:
  - Z: Time until old public-key crypto can be broken by a sufficiently large quantum computer
  - X: Time that information/systems need to stay protected
  - W_i: Waiting time until scenario i
  - Y_i: Migration time under scenario i

PLANNING
ORGANISATIONAL PLANNING

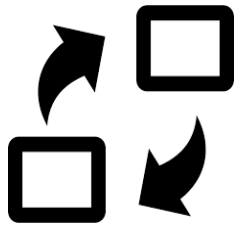
- Establish migration team
  - Migration manager with knowledge and access of overall organisation
  - 5-10 other people depending on size of organisation
- First steps migration team
  - Diagnosis
  - Prioritize assets to be migrated
  - Draw up migration plans
- Sufficient budget should be allocated for necessary migration steps
  - Financial & facilities resources
  - Time: Expect several years for the migration
- Interoperability: consider planning migration with community of similar and/or connected organisations

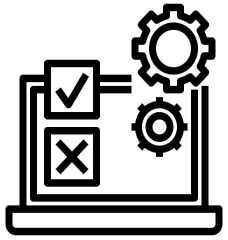




PLANNING
TECHNICAL PLANNING

- Identify *dependency of assets*
  - Decide order of migration
  - Maintain interoperability through 2 stages: PQC opportunistic ⇒ PQC mandated
- For each asset decide to either: *Replace*, *Redesign*, *Retire* (or something else)
- *Replace* or *Redesign*: choose which PQC depending on asset & usecase
- *Replace hardware* where needed
  - Acquisition, availability and deployment time should be taken into account
- In some cases *isolation of data/systems* is needed for protection
  - Especially against immediate store-now-decrypt-later protection
  - Temporary during switch-over to PQC
  - When timely migration is too costly
- *Test*, *test*, *test*

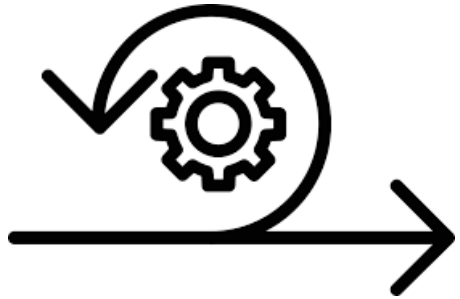




EXECUTION
GENERAL STRATEGIES

Cryptographic agility

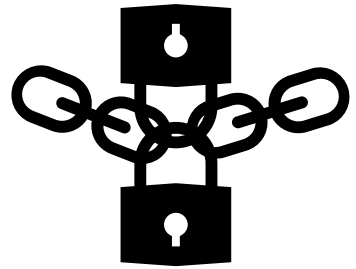
- Implement cryptography such that changes to cryptography can be made
  - Without significant changes to the systems
  - Without exposure to significant risk
- Why?
  - Need to change algorithms now, but future changes possible:
  - PQC is relatively young: better schemes, parameter tweaks, implementation bugs
  - Modernize cryptography, streamlined reporting, reduce risk of cryptographic failure
- Requires structuring people, processes and technology
  - Abstract cryptographic functionality from application code
  - Enforce crypto agility for new or updated systems
  - Integrate crypto agility in CI/CD systems



EXECUTION
GENERAL STRATEGIES

Hybrid solutions

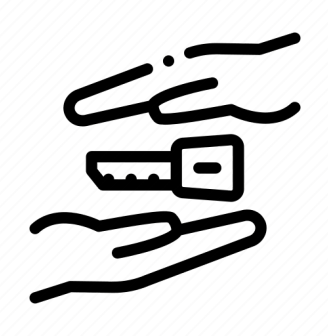
- Use PQC together with existing cryptographic standards
- Hydrid-AND: ‘Strongest link’ security
  - Attacker needs to break both algorithms
  - PQC protects against quantum attacks, while existing secure implementations are very mature
- Especially recommended for organisations that migrate under the early scenarios (1, 2a, 2b)
- Be careful for Hybrid-OR: ‘Weakest link’ security
  - Advertised hybrid solutions might use hybrid-OR instead of hybrid-AND
  - Opportunistic use of PQC for *backwards compatibility*
  - Introduces risk of *downgrade attacks*: security can be degraded to weakest option



EXECUTION
GENERAL STRATEGIES

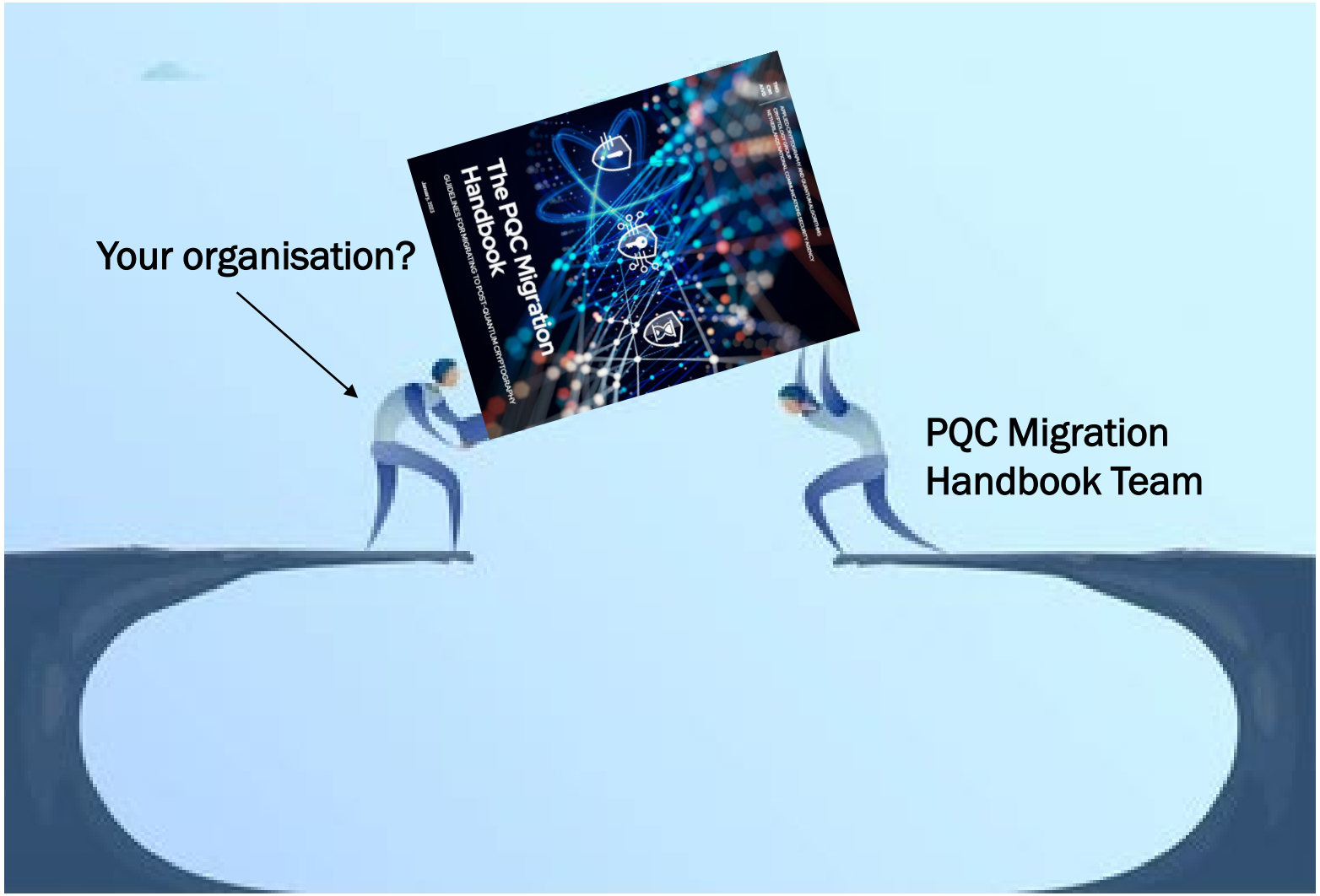
Pre-Shared Keys (PSKs)

- Use symmetric cryptography with PSKs
  - Replaces asymmetric cryptography entirely
- Pre-shared keys need to be established in physical way (courier, …)
  - Cumbersome process and scales badly
- Mostly applicable to very stringent cases:
  - Systems are fully controlled and trusted by organisation
  - There is a practical way of sharing secret keys
  - Adding or removing nodes happens rarely



THE PQC MIGRATION HANDBOOK

BRIDGING GAPS



THANK YOU
QUESTIONS?

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