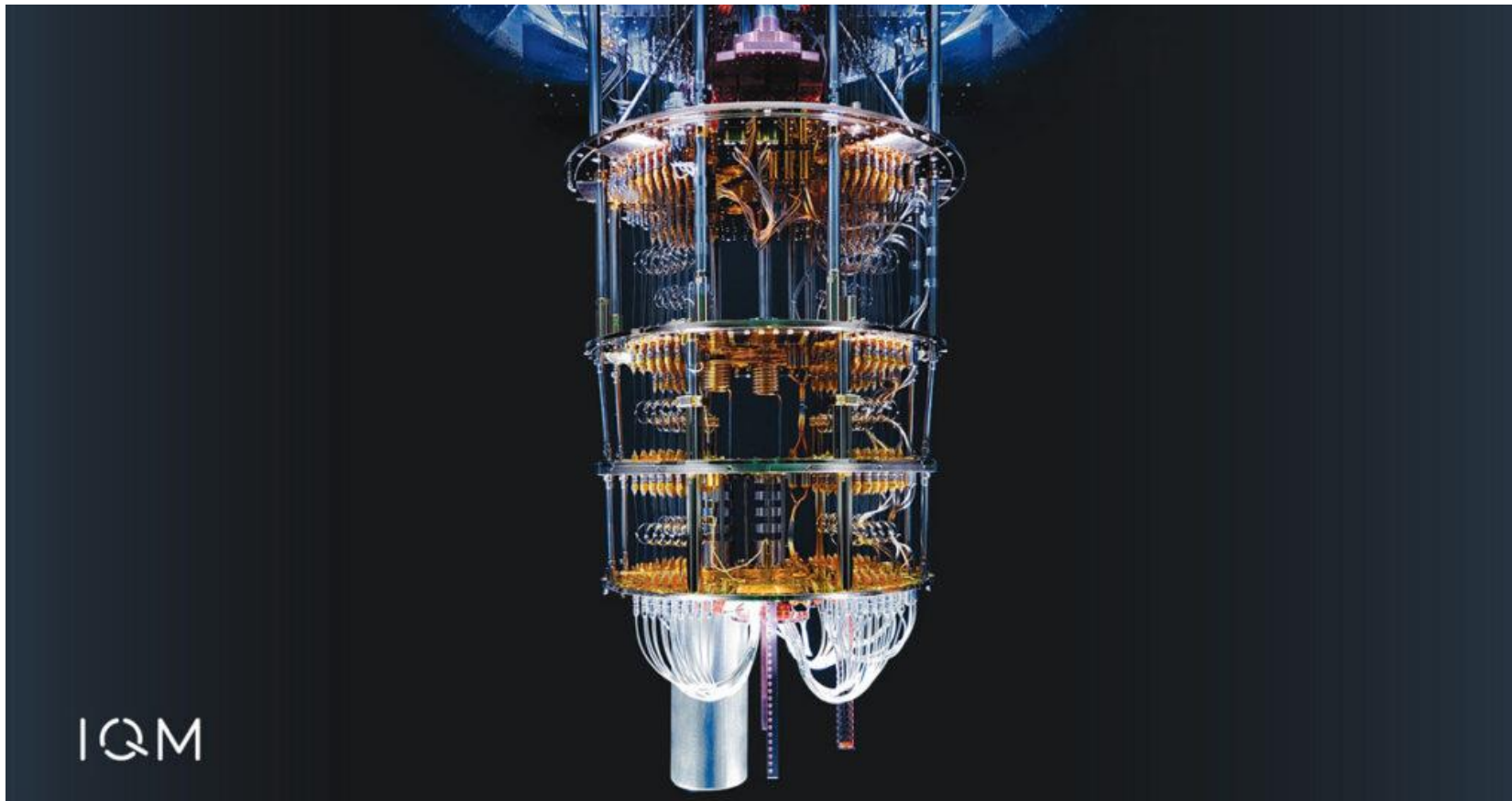


DeiC Q-Access Roadshow



Europe takes a quantum leap: LUMI-Q consortium signs contract to establish quantum computer in the Czech Republic

DeiC Q-Access Roadshow

Outline

- 1. Introduction to DeiC's Quantum Department**
- 2. Background on Quantum Computing**
 - a. Classical vs. Quantum
 - b. Algorithms
 - c. Applications
- 3. Landscape of Quantum Computing**
 - a. Hardware Implementations
 - b. Global Providers of Software and Cloud Access
 - c. Denmark's National Strategy and Initiatives
- 4. Overview of DeiC's Q-Access Initiative**
 - a. Two-mode Access Strategy
 - b. Consulting Service with Quantum Experts
- 5. Q-Access via Microsoft Azure**
 - a. Application and Evaluation Process
 - b. Step-by-step Demo
 - c. Provider Status Updates
- 6. Q & A with Q-Access Team and Microsoft**

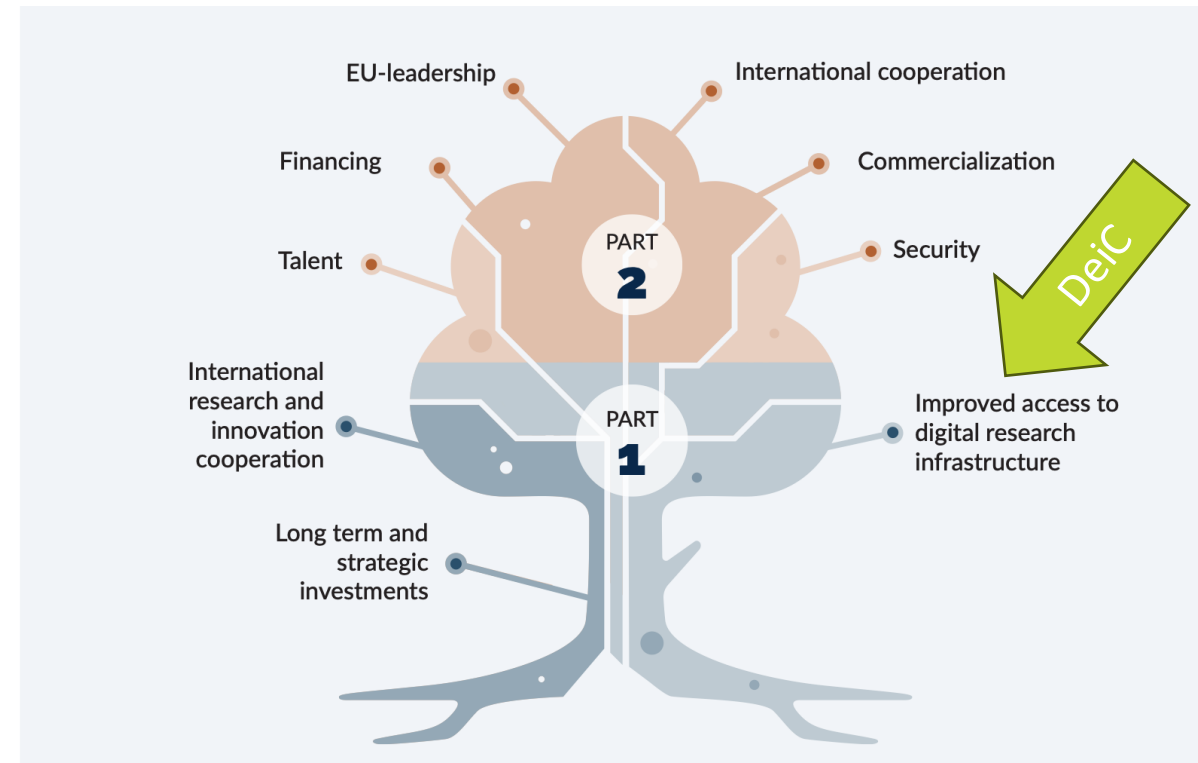
1. Introduction to DeiC's Quantum Department

The Objective of the Strategy for Quantum Technology - Part 1

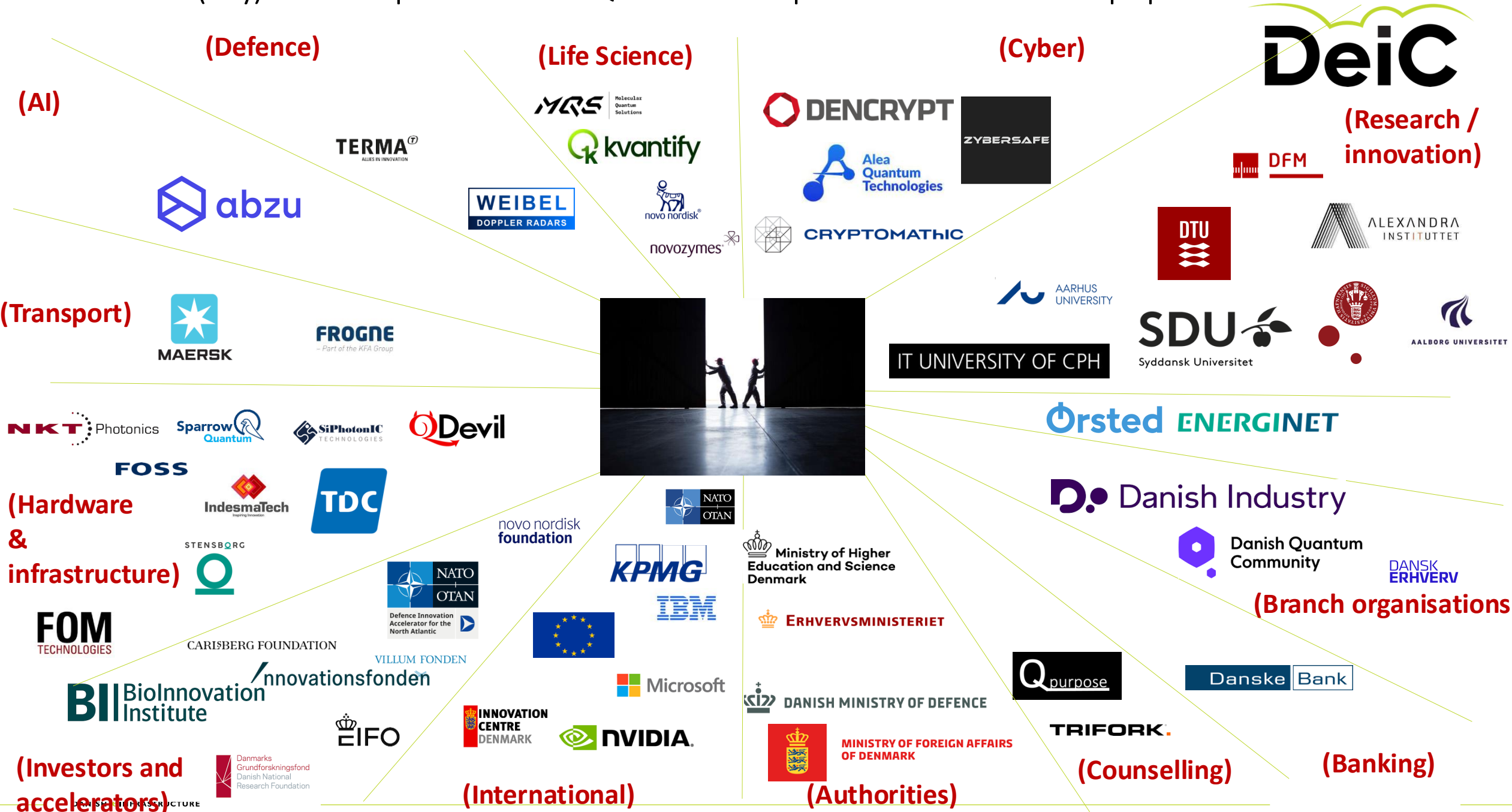
Denmark aims to have one of the world's leading quantum research environments and to have the ability to effectively translate research into new, usable technology.



Link between Part 1 and Part 2



A (very) small example of the Danish Quantum landscape. Which is in a form of "superposition"

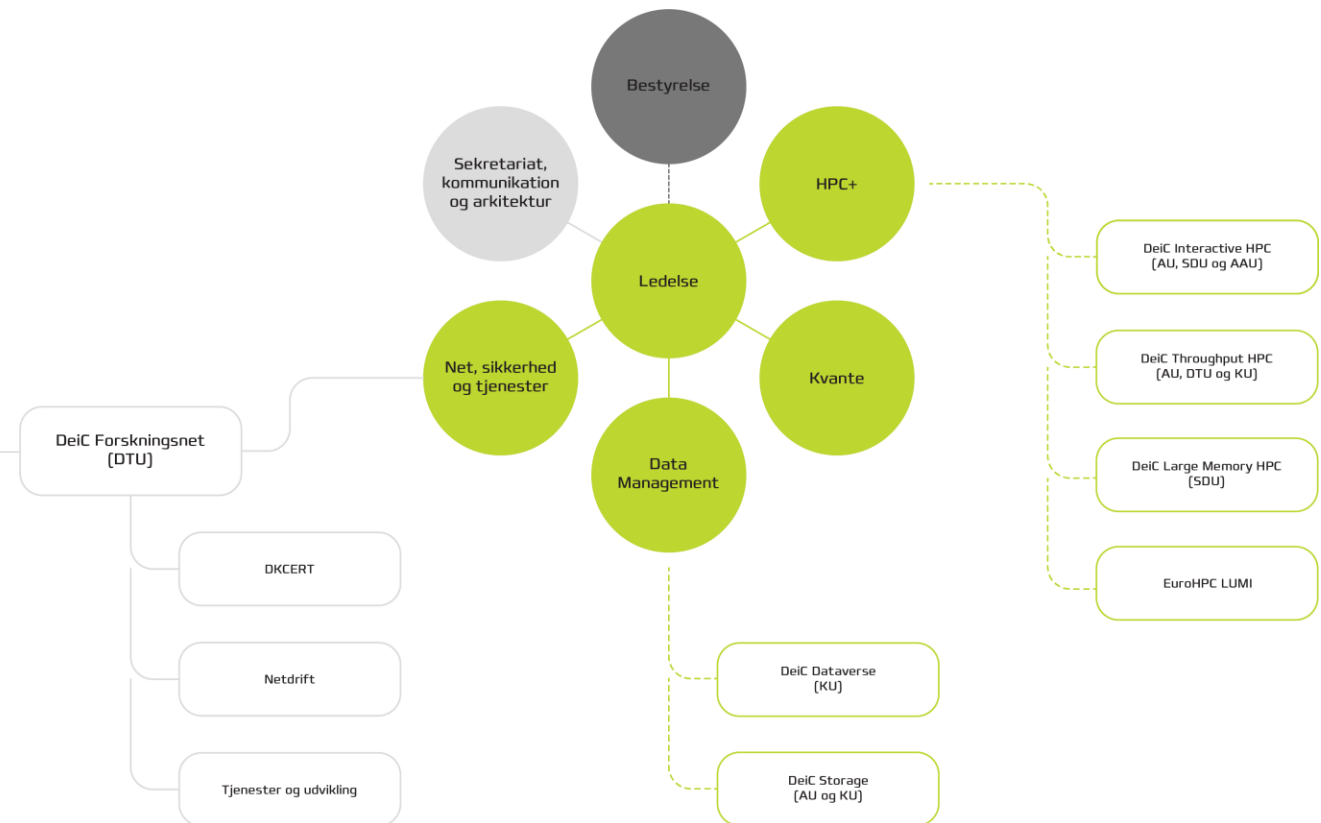


Overview of DeiC

The **Danish e-Infrastructure Consortium (DeiC)** develops and coordinates access to digital research infrastructure for Danish universities, enabling research and education at a high international level.



The research network is a high-speed network that connects Danish universities and research institutions.



DeiC's Quantum Department

DeiC's Quantum Department is the newest department in DeiC, established as part of the implementation of the Danish government's national quantum strategy.

Initiatives

Q-Competence

- Disseminate skills and increase understanding of the potential and risks of quantum technology.
- Financial support for developing quantum computing material and events.

Q-Algorithm

- DQA Academy to boost work in developing and testing quantum algorithms and the associated software stack.
- Scholarships for Ph.D. students and Postdocs.

Q-Access

- Calls for specialized access to quantum computers.
- Access via Microsoft Azure for testing.
- Consulting service with quantum experts.

Niels Bohr Quantum Summer School

Two-week summer school, for the next 4 years, for both Danish and international Ph.D. students to learn about quantum computing and attract talent to the quantum community in Denmark.

LUMI-Q

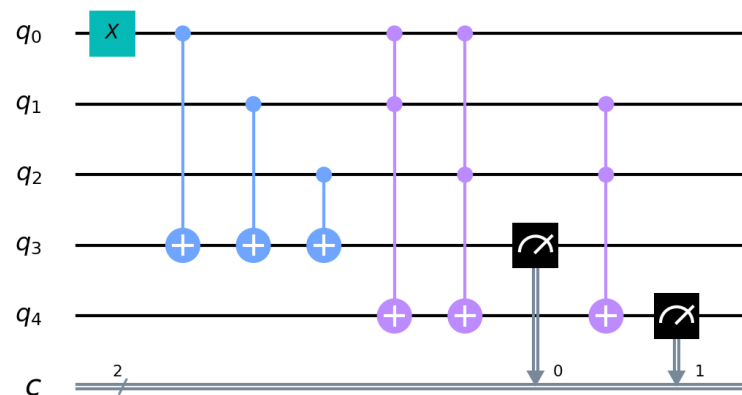
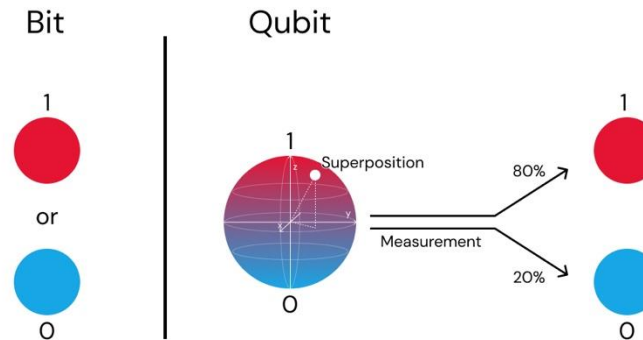
The LUMI-Q consortium has signed a contract to set up a quantum computer, purchased from IQM in Finland and deployed in the Czech Republic.

2. Background on Quantum Computing

Background on Quantum Computing

Classical vs. Quantum Bits

- Classical bits are either 0 or 1, while quantum bits (qubits) have a probability of being either 0 or 1 when measured.
- Qubits allow for an entirely new way of computing.
- Physical qubits are two-state physical quantum systems (ranging from photons to ions) located within a quantum processing unit (QPU).



Quantum Circuit Model

- A model for computation in which a sequence of quantum gates and measurements are applied to a set of qubits.
- Typically, this defines a single execution of a shot on a QPU.
- Gates are unitary operation on one or more qubits. In particular, they are always reversible, as opposed to measurements, and their complexity grows exponentially in the number of qubits.

Quantum Algorithms

- Leveraging this new way of computing requires both high-fidelity hardware implementations of qubits and gates as well as new quantum algorithms.

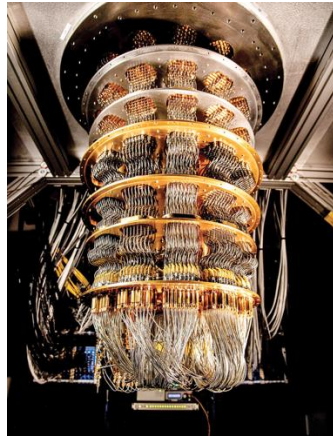
Algorithm	Problem	Quantum Complexity	Classical Complexity	Speedup
Shor's Algorithm	Factoring integers	$O(\text{poly}(N))$	$O(\exp N^{1/3} (\log N)^{2/3})$	Exponential
Grover's Algorithm	Unstructured search	$O(\sqrt{N})$	$O(N)$	Quadratic
HHL Algorithm	Solving certain linear systems $Ax = b$	$O(\text{poly}(\log N, 1/\epsilon))$	$O(\text{poly}(N, \log 1/\epsilon))$	Exponential
Hamiltonian Simulation	Simulating quantum systems (e.g. chemistry, materials)	$O(\text{poly}(\log M, t))$	$O(\text{poly}(M, t))$	Exponential

Applications

Domain	Example Use Cases	Algorithms
Cryptography	<ul style="list-style-type: none"> • Breaking RSA/ECC (factoring, discrete log) • Search for symmetric key attacks 	<ul style="list-style-type: none"> • Shor's Algorithm • Grover's Algorithm
Finance	<ul style="list-style-type: none"> • Portfolio optimization • Option pricing 	<ul style="list-style-type: none"> • QAOA, Variational Algorithms • Amplitude Estimation
Pharmaceuticals	<ul style="list-style-type: none"> • Drug discovery • Protein folding/structure optimization 	<ul style="list-style-type: none"> • Hamiltonian Simulation • Variational Quantum Eigensolver (VQE)
Machine Learning	<ul style="list-style-type: none"> • Classification and clustering • Generative models 	<ul style="list-style-type: none"> • QNNs and QGANs • HHL-based Linear Algebra
General Optimization	<ul style="list-style-type: none"> • Combinatorial optimization • Scheduling, resource allocation 	<ul style="list-style-type: none"> • QAOA, Variational Algorithms • Grover's Algorithm
General Linear Algebra	<ul style="list-style-type: none"> • Solving large linear systems • Matrix inversion 	<ul style="list-style-type: none"> • HHL Algorithm • Quantum Singular Value Transform

3. Landscape of Quantum Computing

Implementing a Quantum Computer



Leaders in Superconducting QC

IBM (US)

Google (US)

Amazon (US)

Rigetti (US)

SEEQC (US)

Qolab (US)

Bleximo (US)

D-Wave (CA)

Anyon (CA)

Nord Quantique (CA)

Oxford Quantum Circuits (GB)

QuantWare (NL)

Alice & Bob (FR)

IQM (FI)

Fujitsu (JP)

NEC (JP)

Origin Quantum (CN)

Huawei (CN)

Tencent (CN)

Leaders in Neutral Atom QC

QuEra (US)

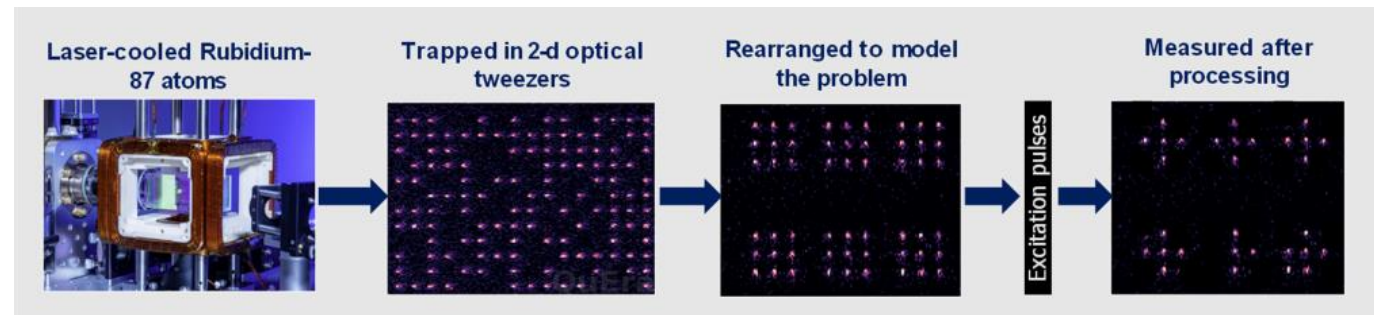
Pasqal (FR)

Inleqtion (US)

Atom Computing (US)

planqc (DE)

NanoQT (JP)



Implementing a Quantum Computer

Leaders in Trapped Ion QC

Quantinuum (US)

IonQ (US)

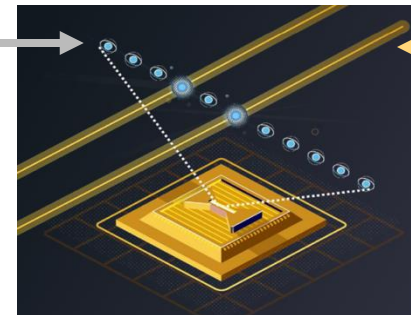
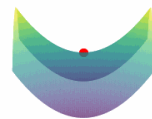
Universal Quantum (GB)

Oxford Ionics (GB)

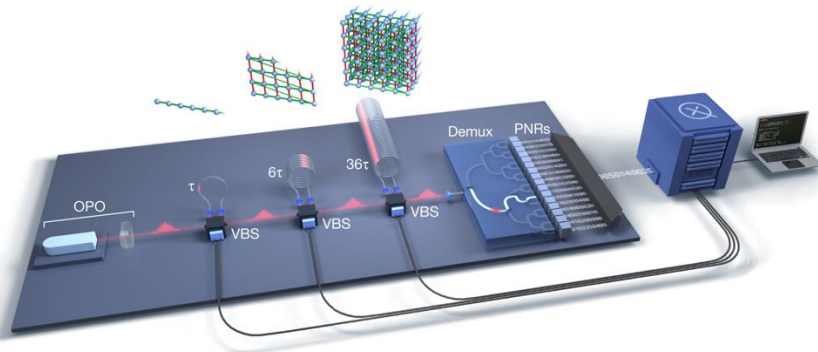
AQT (AT)

Qubitcore (JP)

Trapped Ion



Laser beams
creating
entangled state



Leaders in Photonic QC

Xanadu (CA)

PsiQuantum (US)

ORCA Computing (GB)

QuiX Quantum (NL)

Quantum Computing Inc. (US)

Quandela (FR)

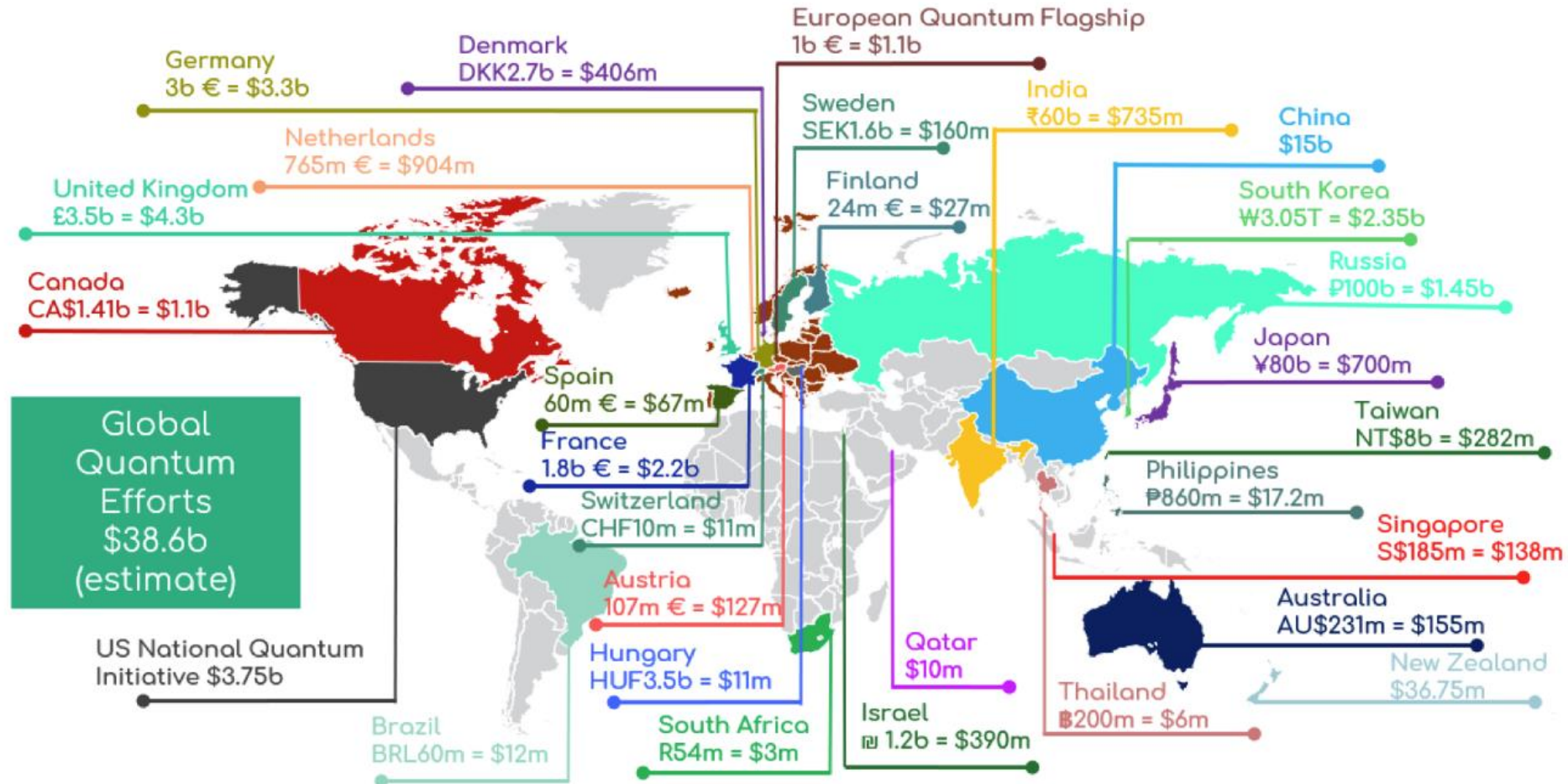
OptQC (JP)

TuringQ (CN)

eleQtron (DE)

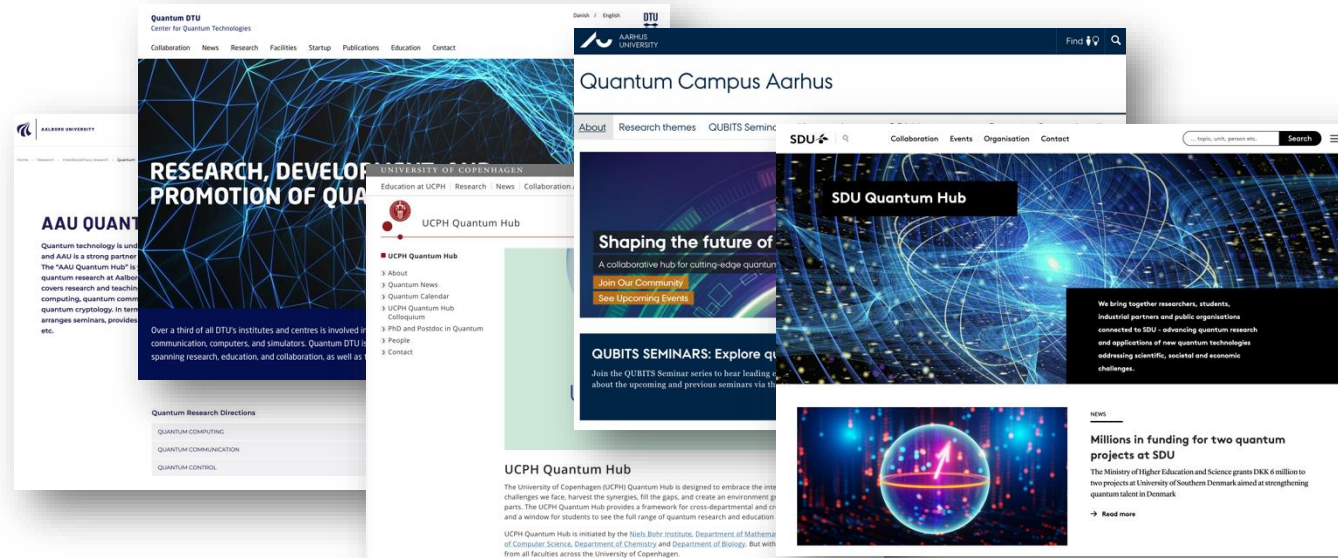
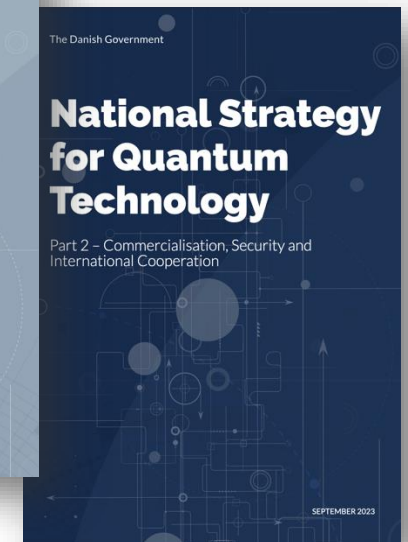
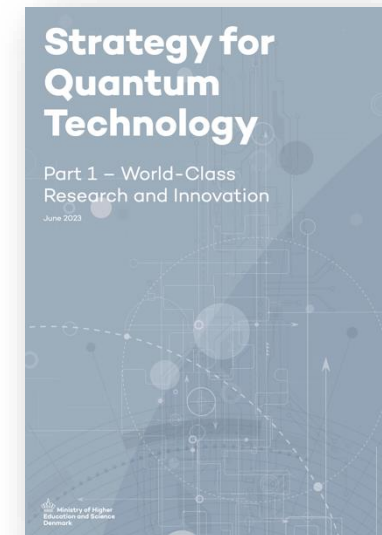
NQCG (NO)

Global Landscape of Quantum Computing



Denmark's National Quantum Strategy

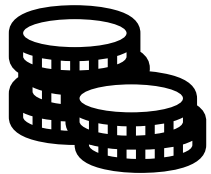
- The Danish government has committed to invest 1.000.000.000 DKK into quantum research and innovation from 2023 to 2027.
- **Quantum Hubs** have been established at 5 of the Danish research universities: KU, DTU, SDU, AU, AAU



4. Overview of DeiC's Q-Access Initiative

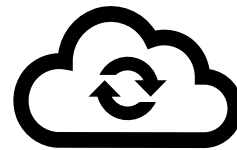
- a. Two-mode Access Strategy
- b. Consulting Service with Quantum Experts

Two-Mode quantum access



Yearly budget –2027: 12 million DKK

- Est. 1 million kr for Mode 1
- Est. 11 million kr for Mode 2



Mode 1: Microsoft Azure Quantum - cloud computing platform

- **Simple online request** form with quick response
- Access to quantum simulator and hardware from IonQ, Quantinuum and Rigetti
- Access **worth of up to 25.000 kr.** (can be requested multiple times)

Roadshow purpose



Mode 2: Selected quantum computers for specialized research needs

- Evaluation by international scientific committee
- Two annual calls for research project proposals
- Apply for access worth of up to est. 7 milion Kr

Q-Access consulting service



- Fill out the form below to consult with experts in quantum computing from DeiC

○ <https://deic-backoffice.atlassian.net/servicedesk/customer/portal/3/group/4/create/34>

DeiC Backoffice Help / Quantum Back Office

Quantum Back Office

Welcome! You can raise a request for Quantum Back Office using the options provided.

What can we help you with?



Consult with Experts In Quantum Computing

Fill out the form below to consult with experts in quantum computing from DeiC.

Required fields are marked with an asterisk *

Raise this request on behalf of *

Muyang Liu (muyang.liu@deic.dk)

Summary *

Consult with Experts in Quantum Computing

DeiC provides comprehensive support to researchers across Denmark, enabling them to harness the power of quantum computing for their projects. Fill out the form below to consult with experts in quantum computing from DeiC, who can understand your computational needs and provide support for leveraging quantum computing systems relevant to reaching your research goals.

Required fields are marked with an asterisk *

Background

1. What is your research field, your specific area, and your current project?*

Short written response *

Normal text | B I ... | A | | | | | | | | | |

2. Where does your research fall on the scale from experimental to theoretical?*

Single choice *

Select...

3. How familiar are you with quantum computing?*

Single choice *

Select...

4. How familiar are you with programming?*

Single choice *

Select...

5. If applicable, how are you currently using quantum computing or programming in your project?

Short written response

Normal text | B I ... | A | | | | | | | | | |

Message

1. Select a topic*

Multiple choice *

Select...

2. If you selected other, please describe your topic.

Short written response

3. Describe your questions and goals for the consultation.*

Label *

Normal text | B I ... | A | | | | | | | | | |

4. Add any relevant attachments.

Add attachment that you think will help solve the issue.

Drop files to attach or [browse](#)

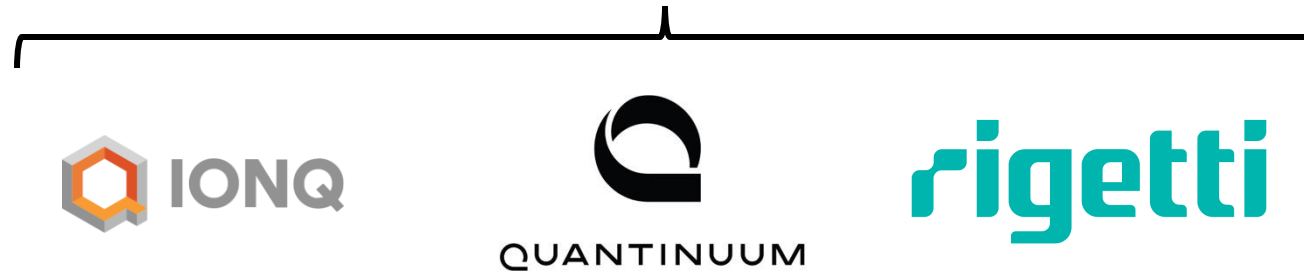
5. Q-Access via Microsoft Azure

- a. Application and Evaluation Process
- b. Step-by-step Demo
- c. Provider Status Updates

Q-Access via Azure

- Access to Azure for testing worth up to **25.000 DKK** can be applied for by filling out a simple form at: <https://deic-backoffice.atlassian.net/servicedesk/customer/portal/3/group/4/create/35>

 Microsoft Azure



- Evaluation process – within a week

Application form

- Fill a simple online form as below (+ accept the term of service) !

[DeiC Backoffice Help](#) / [Quantum Back Office](#)

Quantum Back Office

Welcome! You can raise a request for Quantum Back Office using the options provided.

What can we help you with?



Request Access to Microsoft Azure Quantum

Using the below form, you can apply for a quota to use Microsoft Azure Quantum.

Required fields are marked with an asterisk *

Raise this request on behalf of *

 Muyang Liu (muyang.liu@deic.dk)

Summary *

DeiC provides access to the [Microsoft Azure Quantum cloud service](#) to Danish academia, industry, and the public sector (see the [FAQ](#) for more information on eligibility). This access is intended to allow users to explore and test a variety of quantum platforms. Users requiring more significant access to a specific platform can apply for such access from one of the DeiC Q-Access calls.

Through Microsoft Azure Quantum, users have access to a diverse portfolio of quantum simulators and quantum computers from Quantinuum, IonQ, Quantum Circuits Inc., Rigetti, and Pasqal. Because this access is intended for testing, we strongly encourage users to start with testing the various free simulators (from [Microsoft](#) and their [backend providers](#)) before moving on to actual hardware tests.

Using the below form, you can apply for a quota to use Microsoft Azure Quantum (see [Azure Quantum pricing](#) for more information). The standard initial resource quota is 10.000 DKK in Azure Quantum Credits. However, it is possible to apply for up to 25.000 DKK. Moreover, it is possible to apply for more credits multiple times once your quota has been used up.

Allocated resources can be used up until 30/06/2025, at which point unused resources will be returned to the pool, and a new usage period will begin. Users will be asked to fill out a short report on their usage, which will be required for future allocations of resources.

Background

Full Name *

What area are you in? *

Select...

Describe the project that the access will be used for and who will be using it. *

If you are in academia and applying for access for a project involving a Postdoc, PhD or Master's student who will be using the access, please provide their details. If you are in industry or the public sector, please describe how the project is new and different from current activities.

Normal text ...

Access Usage

Describe your intended use for the access. *

Normal text ...

Have you applied for Microsoft Azure Quantum access from DeiC in the past? *

- Yes
 No

Required Resources

Does the standard initial resource quota of 10.000 DKK suffice for your needs? *

- Yes
 No

Customized user group in DeiC plan

Why split the user groups

- a) It can take up to 24 hours for Microsoft to update a resource group's real cost, rendering it ineffective for limiting user spending based on usage.
- b) Currently, Azure does not offer adequate controls to limit user spending.

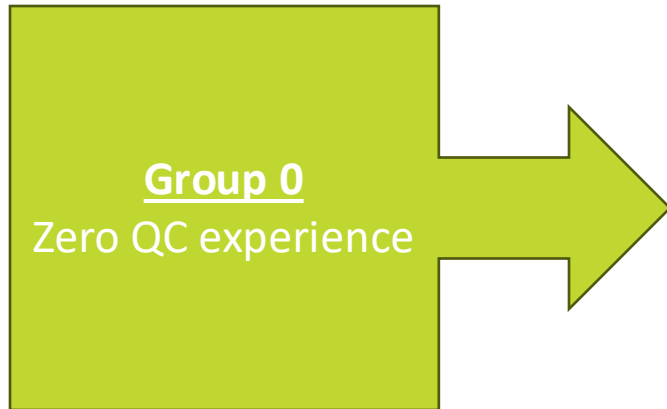
Intermediate solution

- a) Users will be split into two(three) groups, each with different levels of access to Azure (see next slide).
- b) The separation of multiple groups is especially important for mitigating risk.
- c) Most of the development and testing should take place on simulators due to high cost of QPU.

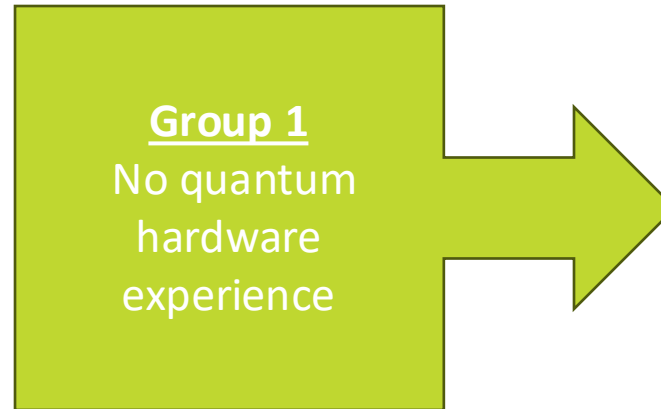
DeiC's Support

- a) Actively developing a set of supporting materials.
- b) Share regular updates on the status of Azure's quantum providers .

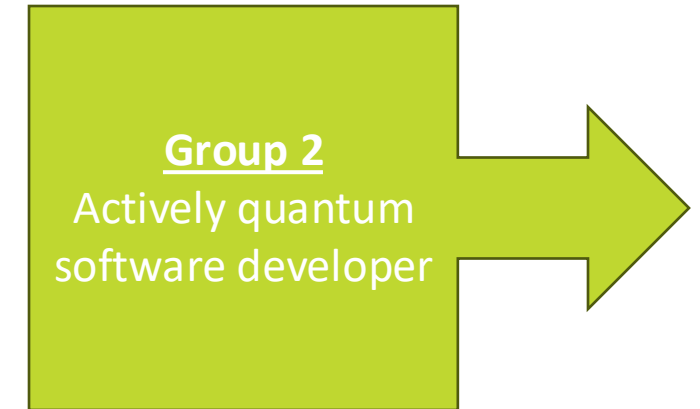
Customized user group in DeiC plan



- Recommend to use a free browser interface simulator <https://quantum.microsoft.com/en-us/tools/quantum-coding>
- Can get access to quantum simulators from Microsoft and Quantinuum



- Indirectly access to allocated QPU resources on Azure
- Submit requests to DeiC via an online form
- DeiC performs submitted jobs



- Direct access to allocated QPU resources on Azure
- Responsible to cover the cost if significantly exceeding allocation

How to submit a job for users in Group 1

Fill out an online form with the following information

- a) User's name and e-mail address
- b) Script to be executed on Azure + A Brief description
- c) Confirmation that the script fits the standards outlined below
 - The file has been successfully tested on a simulator (along with the values of the parameters used)
 - The output from the simulator
 - Specific QPU to be used for the job
 - Parameters of the script to be used for the job
 - Cost estimate for resources necessary to complete the job (e.g, unit of HQC on Quantinuum system)

After submitting the form, a DeiC quantum expert will

- a) Follow up and resolve any questions, execute the job on a QPU
- b) Return the output of the job to the user
- c) The job output follows Azure's format; users must handle their own post-processing

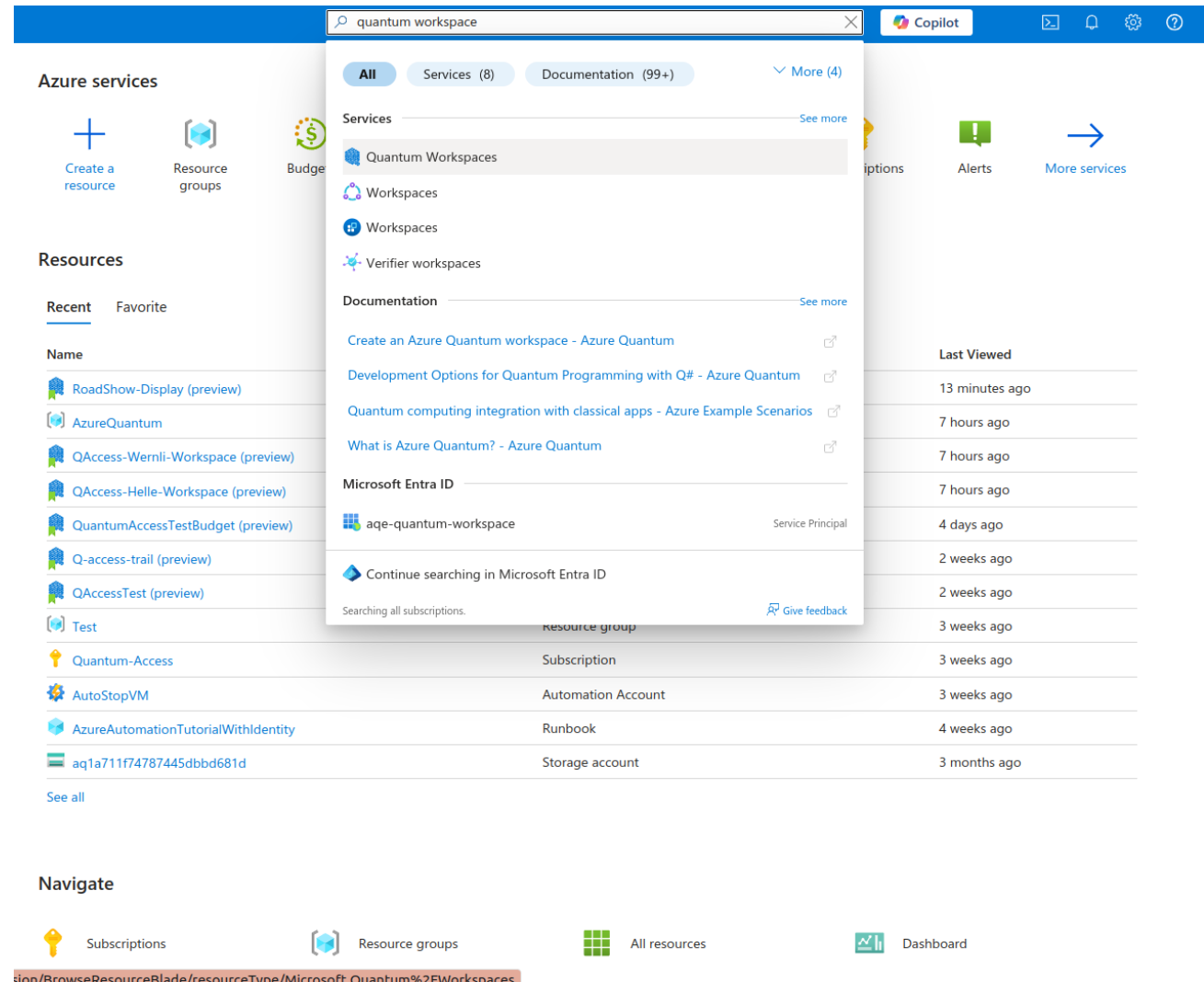
Step-by-step Demo of Using Azure – Group 2 Users

1) Log in to Azure

- Go to <https://portal.azure.com>
- Use the credentials associated with your organization or Microsoft account

2) Navigate to your Quantum Workspace

- Use the search bar at the top to find “Quantum Workspaces.”
- You must be in the DTU directory to access resources allocated from DeiC’s Q-Access initiative.

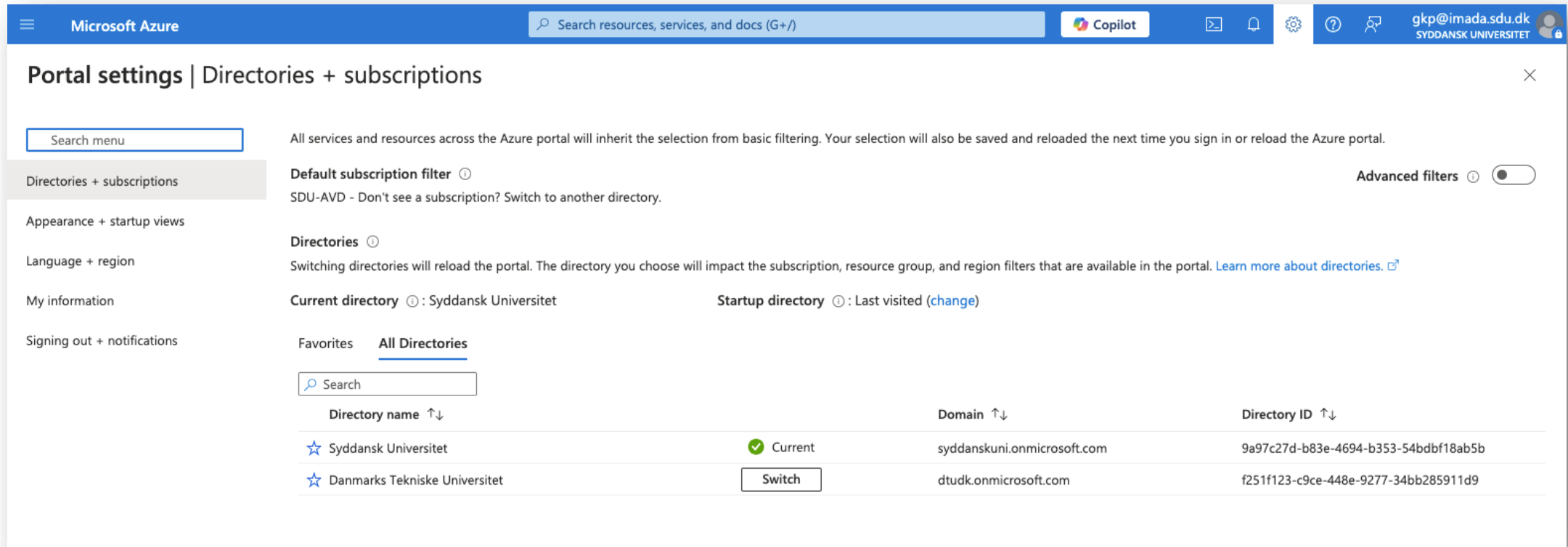


The screenshot shows the Azure portal search results for 'quantum workspace'. The search bar at the top contains the text 'quantum workspace'. Below the search bar, there are tabs for 'All', 'Services (8)', and 'Documentation (99+)'. The search results are categorized into 'Services', 'Resources', and 'Documentation'. Under 'Services', 'Quantum Workspaces' is highlighted. Under 'Resources', a table lists various resources with columns for 'Name', 'Subscription', and 'Last Viewed'. The 'Documentation' section lists several articles related to Azure Quantum workspaces. At the bottom, there is a 'Navigate' section with icons for Subscriptions, Resource groups, All resources, and Dashboard.

Name	Subscription	Last Viewed
RoadShow-Display (preview)		
AzureQuantum		
QAccess-Wernli-Workspace (preview)		
QAccess-Helle-Workspace (preview)		
QuantumAccessTestBudget (preview)		
Q-access-trail (preview)		
QAccessTest (preview)		
Test		
Quantum-Access	Subscription	3 weeks ago
AutoStopVM	Automation Account	3 weeks ago
AzureAutomationTutorialWithIdentity	Runbook	4 weeks ago
aq1a711f74787445dbbd681d	Storage account	3 months ago

Accessing Allocated Resources for Users in Group 2

Note: You must be in the DTU directory to access resources allocated from DeiC's Q-Access initiative.



The screenshot shows the 'Microsoft Azure' portal settings page for 'Directories + subscriptions'. The user is logged in as 'gkp@imada.sdu.dk SYDDANSK UNIVERSITET'. The page title is 'Portal settings | Directories + subscriptions'. A search bar is present at the top with the text 'Search resources, services, and docs (G+/)'. The left sidebar contains navigation options: 'Directories + subscriptions', 'Appearance + startup views', 'Language + region', 'My information', and 'Signing out + notifications'. The main content area shows the 'Default subscription filter' set to 'SDU-AVD - Don't see a subscription? Switch to another directory.' and 'Advanced filters' turned off. Under the 'Directories' section, the 'Current directory' is 'Syddansk Universitet' and the 'Startup directory' is 'Last visited (change)'. There are two tabs: 'Favorites' and 'All Directories'. A search bar is provided for the directory list. Below is a table of directories:

Directory name ↑↓	Domain ↑↓	Directory ID ↑↓
☆ Syddansk Universitet	syddanskuni.onmicrosoft.com	9a97c27d-b83e-4694-b353-54bdf18ab5b
☆ Danmarks Tekniske Universitet	dtudk.onmicrosoft.com	f251f123-c9ce-448e-9277-34bb285911d9

The 'Syddansk Universitet' row has a green checkmark and the word 'Current' next to it. The 'Danmarks Tekniske Universitet' row has a 'Switch' button next to it.

The Quantum Workspace Overview

Workspace Essentials:

- **Displays general workspace info:**

Subscription ID, status, resource group, region.

- **Contains key inputs to job initiative:**

resource_id, location

The screenshot shows the Azure Quantum Workspace Overview page for 'RoadShow-Display'. The page includes a navigation sidebar on the left with categories like Overview, Activity log, Access control (IAM), Tags, Diagnose and solve problems, Operations (Notebooks, Job management, Providers, Credits and Quotas, Access Keys), Monitoring (Alerts), Automation (CLI / PS, Tasks), and Help (Resource health, Support + Troubleshooting). The main content area features a warning banner about Azure Quantum Credits, an 'Essentials' section with details for Resource group (AzureQuantum), Status (Succeeded), Location (North Europe), Subscription (Quantum-Access), and Subscription ID (3e99863b-52af-420e-b240-6ac1c67fb462). Below this is a 'Getting started' section with three options: Online Jupyter notebooks, VS Code (Web), and Local development, each with a brief description and a 'Get started' button.

```
from azure.quantum import Workspace
from azure.quantum.qiskit import AzureQuantumProvider
```

```
workspace = Workspace(
    resource_id = "/subscriptions/3e99863b-52af-420e-b240-6ac1c67fb462/resourceGroups/AzureQuantum/providers/Microsoft.Quantum/Workspaces/RoadShow-Display",
    location = "northeurope")
```

```
provider = AzureQuantumProvider(workspace)
```

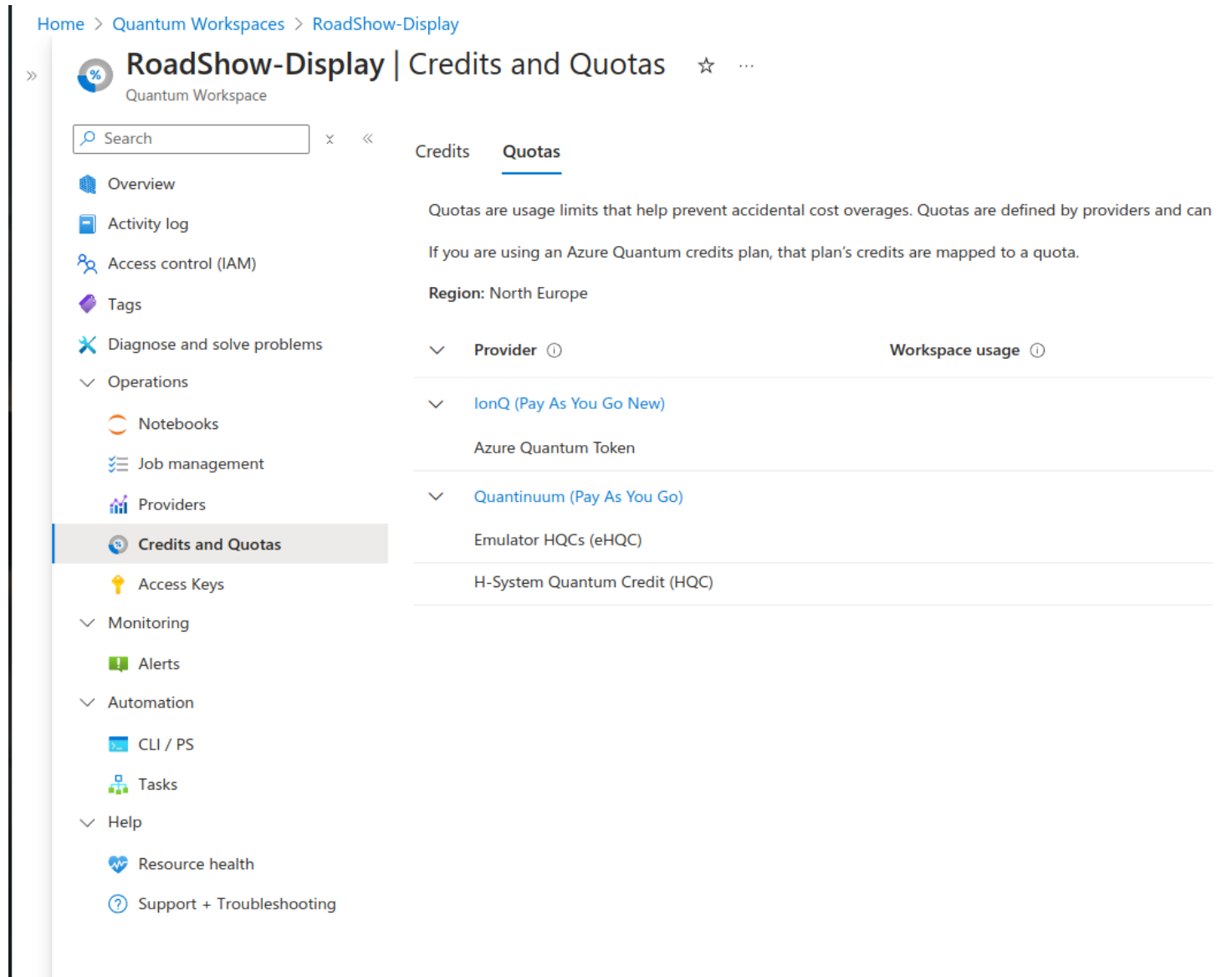
The Providers Tab

1. List of Allocated Providers

- Status of providers (see next slides).
- Management of providers (done by DeiC).

2. Credits & Quotas

- Shows the whole DeiC's plan usage (**not your personal allocation**), because quota allocation happens at the subscription level.



Home > Quantum Workspaces > RoadShow-Display

RoadShow-Display | Credits and Quotas ☆ ...
Quantum Workspace

Search

Overview
Activity log
Access control (IAM)
Tags
Diagnose and solve problems
Operations
Notebooks
Job management
Providers
Credits and Quotas
Access Keys
Monitoring
Alerts
Automation
CLI / PS
Tasks
Help
Resource health
Support + Troubleshooting

Credits **Quotas**

Quotas are usage limits that help prevent accidental cost overages. Quotas are defined by providers and can be used to restrict the amount of resources that can be used in a workspace. If you are using an Azure Quantum credits plan, that plan's credits are mapped to a quota.

Region: North Europe

Provider ⓘ	Workspace usage ⓘ
IonQ (Pay As You Go New)	Azure Quantum Token
Quantinuum (Pay As You Go)	Emulator HQCs (eHQC)
	H-System Quantum Credit (HQC)

Azure Provider Status Updates

- DeiC’s quantum department will give **monthly updates** on the status of Azure’s quantum providers, as well as communicate with Microsoft and the providers to ensure full transparency on QPU availability.

Azure Status Update: February 2025

IonQ

Aria-1 and Aria-2 are unavailable due to “planned and unplanned maintenance” and are expected to be down until February 13 and March 28 respectively, but the IonQ simulator is still available.

Quantinuum

H1-1, the syntax checker, and emulator are all available. Note that reported average queue times are unreliable due to Quantinuum’s uptime schedule of 1:00 – 10:00 am UTC+1 for running jobs.

Rigetti




Ankaa-9q-3, Ankaa-3, and the simulator are all available. However, Ankaa-3 will not show up as a target unless you are running the latest version of the Azure Quantum Python library (<https://pypi.org/project/azure-quantum/2.3.0/>).

Pasqal

Pasqal is still in private preview and is not currently available through DeiC’s provided access.

Azure Provider Status Updates – March 4, 2025

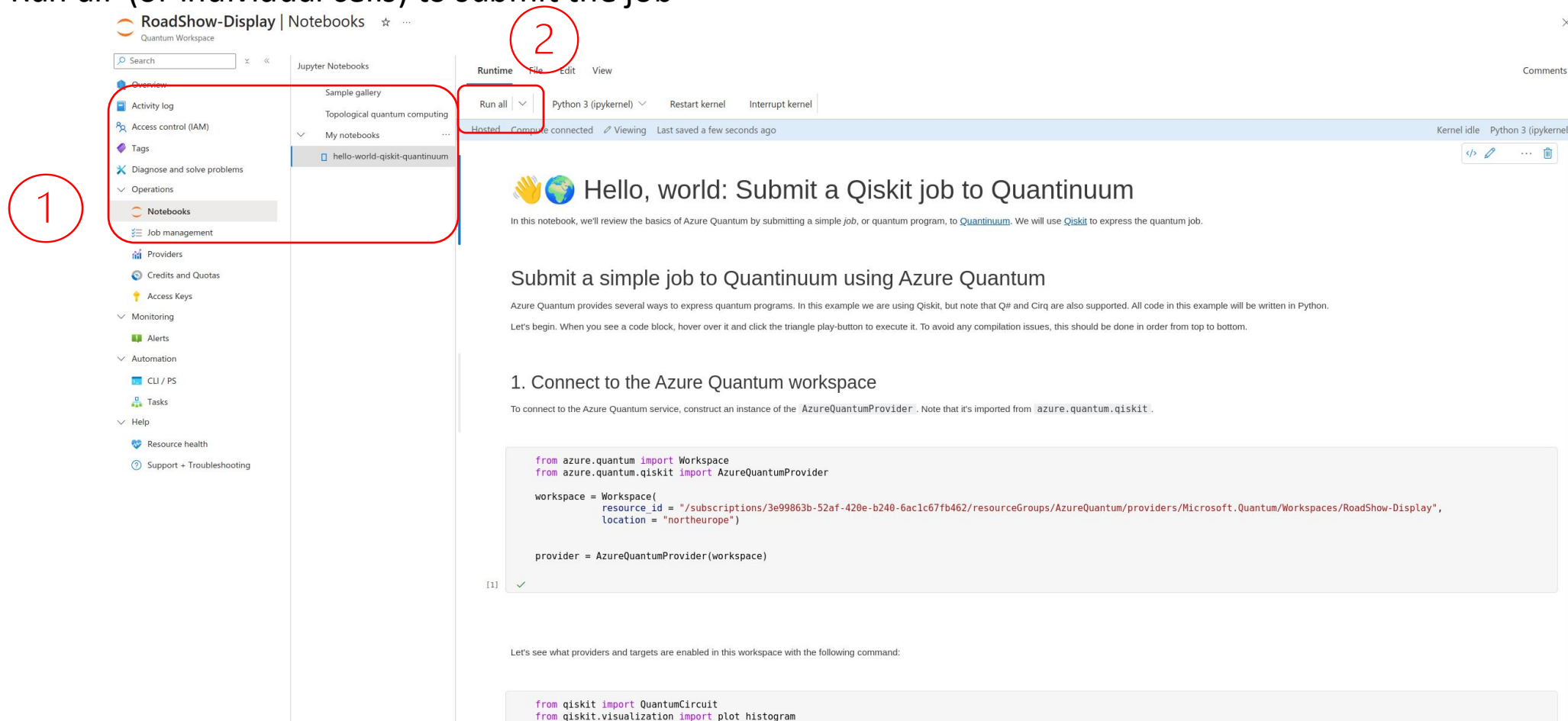


▼	 IonQ IonQ	Quantum Computing	Pay As You Go New	✓	Available	
	ionq.qpu.aria-1				Available	3m
	ionq.qpu.aria-2				Unavailable	N/A ⓘ
	ionq.simulator				Available	<1m
▼	 Quantinuum Quantinuum	Quantum Computing	Pay As You Go	✓	Available	
	quantinuum.qpu.h1-1				Available	13h 2m
	quantinuum.sim.h1-1sc				Available	<1m
	quantinuum.sim.h1-1e				Available	1h 23m
▼	 Rigetti Quantum Rigetti Computing	Quantum Computing	Pay As You Go	✓	Available	
	rigetti.sim.qvm				Degraded	<1m
	rigetti.qpu.ankaa-3				Available	<1m

Submitting Job – online Jupyter notebook

In the left-hand panel of the workspace, click on **“Operations”**

- 1) Click 'Notebook' on the scroll down menu
 - a. Provide necessary parameters of the script to be used for the job
- 2) Click 'Run all' (or individual cells) to submit the job



The screenshot shows the Azure Quantum workspace interface. On the left, the 'Operations' menu is highlighted with a red circle and the number '1'. The 'Notebooks' option is selected, and the 'hello-world-qiskit-quantinum' notebook is open. The 'Run all' button is highlighted with a red circle and the number '2'. The notebook content includes a title 'Hello, world: Submit a Qiskit job to Quantinuum', an introduction, and a code block for connecting to the Azure Quantum workspace. The code block is executed, and the output shows a green checkmark and the text '[1] ✓'. Below the code block, there is a command to check the providers and targets enabled in the workspace.

```
from azure.quantum import Workspace
from azure.quantum.qiskit import AzureQuantumProvider

workspace = Workspace(
    resource_id = "/subscriptions/3e99863b-52af-420e-b240-6ac1c67fb462/resourceGroups/AzureQuantum/providers/Microsoft.Quantum/Workspaces/RoadShow-Display",
    location = "northeurope")

provider = AzureQuantumProvider(workspace)
```

```
[1] ✓
```

Let's see what providers and targets are enabled in this workspace with the following command:

```
from qiskit import QuantumCircuit
from qiskit.visualization import plot_histogram
```


Viewing Job Results



- 1) Select Your Job in the “Job management” list.
- 2) Download Button: Allows you to **export** results locally as JSON format

The screenshot displays the Quantum Workspace interface. On the left, a navigation sidebar is visible with 'Job management' highlighted and circled in red with the number '1'. The main area shows a table of jobs with columns for Name, Id, Type, and Target. The table contains one row: 'Single qubit random' with Id 'a9ba6910-f2a2-11ef-9ae1-...' and Type 'Quantum Computing'. On the right, the job details panel is shown, with 'Download job output' circled in red with the number '2'. The job details include Name 'Single qubit random', State 'Succeeded', Id 'a9ba6910-f2a2-11ef-9ae1-00155daa1ae1', Provider 'quantinuum', Target 'quantinuum.sim.h1-1sc', and Cost estimate 'kr0'. The input parameters are shown as a JSON object: {"count":100,"shots":100,"items":[{"entryPoint":"Single qubit r...}

Name	Id	Type	Target
Single qubit random	a9ba6910-f2a2-11ef-9ae1-...	Quantum Computing	quant...
Single qubit random	839478ca-f2a2-11ef-9ae1-...	Quantum Computing	quant...
Single qubit random	508ac5ec-f2a2-11ef-9ae1-...	Quantum Computing	quant...
Single qubit random	3e9e1092-f2a1-11ef-9ae1-...	Quantum Computing	quant...

Quantum Workspace

Cancel job Refresh

Essentials

Name: Single qubit random, State: Succeeded

Id: a9ba6910-f2a2-11ef-9ae1-00155daa1ae1, Execution time: 00:00:01

Provider: quantinuum, Submission time: 2/24/2025, 12:29:51 PM

Target: quantinuum.sim.h1-1sc, Completion time: 2/24/2025, 12:29:55 PM

Cost estimate: kr0, Input parameters: {"count":100,"shots":100,"items":[{"entryPoint":"Single qubit r...

Input/Output Cost Estimation

Download job input

Download job output

Download job output

View all files

Pricing plans for Azure Quantum providers



- **Price Model 1 - usage unit** counted by an explicit formula depends on number of operations and shots



$$HQC = 5 + C(N_{1q} + 10N_{2q} + 5N_m)/5000 \quad \bullet \quad 1 \text{ HQC} = \$ 12.5 \text{ (15)}$$

- N_{1q} is the number of single-qubit operations in a circuit.
- N_{2q} is the number of native two-qubit operations in a circuit. Native gate is equivalent to CNOT up to several single-qubit gates.
- N_m is the number of state preparation and measurement (SPAM) operations in a circuit including initial implicit state preparation and any intermediate and final measurements and state resets.
- C is the shot count.



$$AQT = m + 0.000220 \cdot (N_{1q} \cdot C) + 0.000975 \cdot (N_{2q} \cdot C)$$

For IonQ:

- \$ 0.000220 / 1-qubit-gate shot
- \$ 0.000975 / 2-qubit-gate shot

m is the minimum price per program execution

- \$ 97.50 if error mitigation is on
- \$ 12.4166 if error mitigation is off

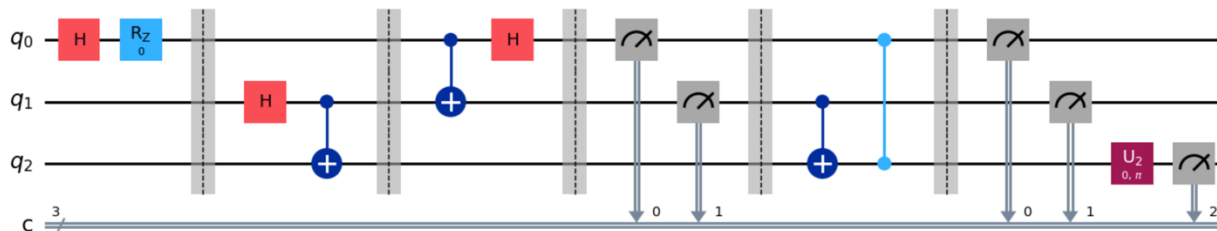
- **Price Model 2 - charges for job execution time** on their quantum processors



- USD 0.013 per 10-millisecond increment of job execution time

Example: Quantum Teleportation

- Designing circuits
- Estimating cost
- Submitting jobs
- Interpreting results



```

from qiskit import QuantumCircuit

def initialize_state(theta):
    qc = QuantumCircuit(1, name='initialize_state')
    qc.h(0)
    qc.rz(theta, 0)
    return qc

def create_Bell_pair():
    qc = QuantumCircuit(2, name='create_Bell_pair')
    qc.h(0)
    qc.cx(0,1)
    return qc

def entangle_with_Bell_pair():
    qc = QuantumCircuit(2, name='entangle_with_Bell_pair')
    qc.cx(0,1)
    qc.h(0)
    return qc

def measure_and_communicate_classically():
    qc = QuantumCircuit(2, 2, name='measure_and_communicate_classically')
    qc.measure([0,1], [0,1])
    return qc

def quantum_teleportation():
    qc = QuantumCircuit(3, name='quantum_teleportation')
    qc.cx(1,2)
    qc.cz(0,2)
    return qc

```

Azure Local Development using VS Code

See our DeiC quantum consultant's screen.

DeiC Q-Access Roadshow

Resources

- Q-Access Website: <https://deic.dk/da/q-access>
- IBM Quantum Learn: <https://learning.quantum.ibm.com/>
- Qiskit Documentation: <https://docs.quantum.ibm.com/>
- Microsoft Azure Documentation: <https://learn.microsoft.com/en-us/azure/quantum/>
- Quantinuum TKET Documentation: <https://docs.quantinuum.com/tket/>
- Xanadu's Strawberry Fields: <https://strawberryfields.ai/>
- Tensorflow Quantum Machine Learning: <https://www.tensorflow.org/quantum>

DeiC Q-Access Roadshow

Thank you all for listening!

Stick around for a Q&A session and hands-on support
with the Q-Access Team and Microsoft.