

18-819F: Introduction to Quantum Computing 47-779/47-785: Quantum Integer Programming & Quantum Machine Learning

Create AWS Braket, Dwave Leap, and IBM Qiskit accounts

Access USRA RIACS Resources

Join CMU Quantum Computing Group

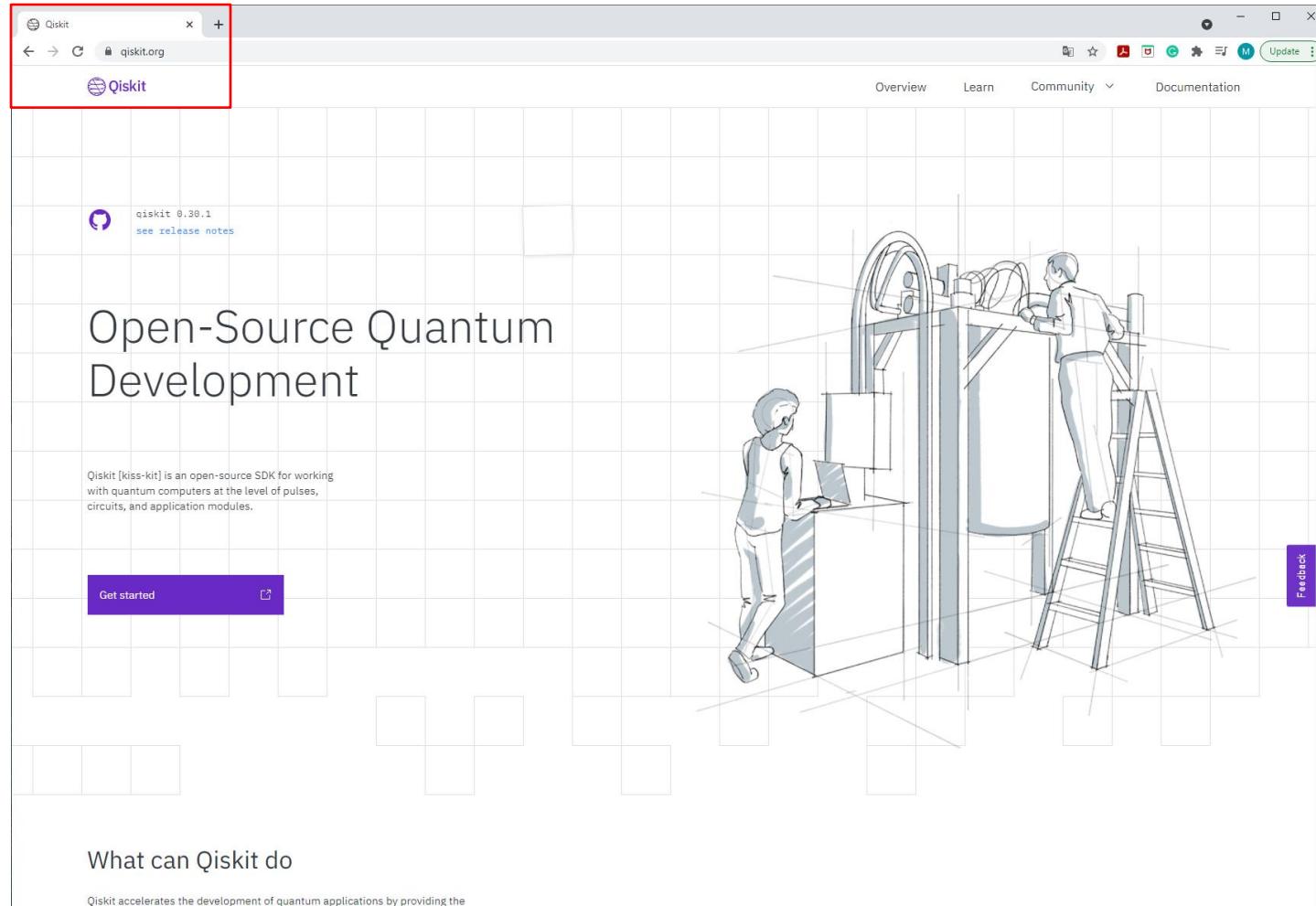
Lecture X

2021.10.12

Agenda

- Create IBM (Qiskit) account
- Create D-Wave (Leap) account
- Create AWS account
- Amazon Bracket
- Accessing USRA resources

Create IBM (Qiskit) account



1- Go to www.qiskit.org

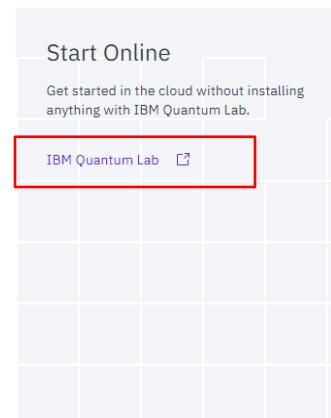
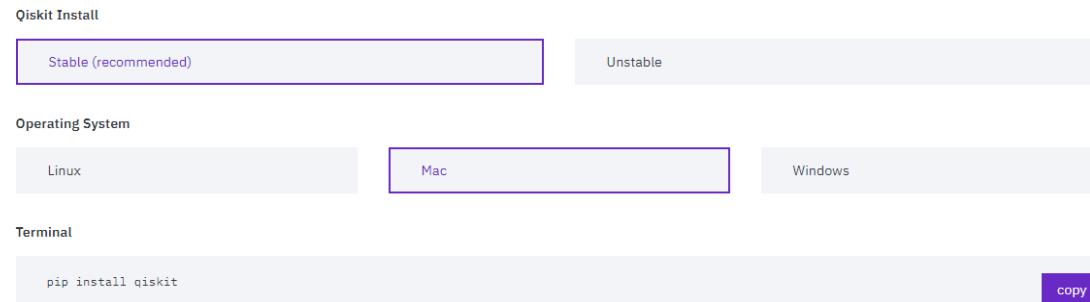
Create IBM (Qiskit) account

Quick Start

When you are looking to start Qiskit, you have two options. You can start Qiskit locally, which is much more secure and private, or you get started with Jupyter Notebooks hosted in IBM Quantum Lab.

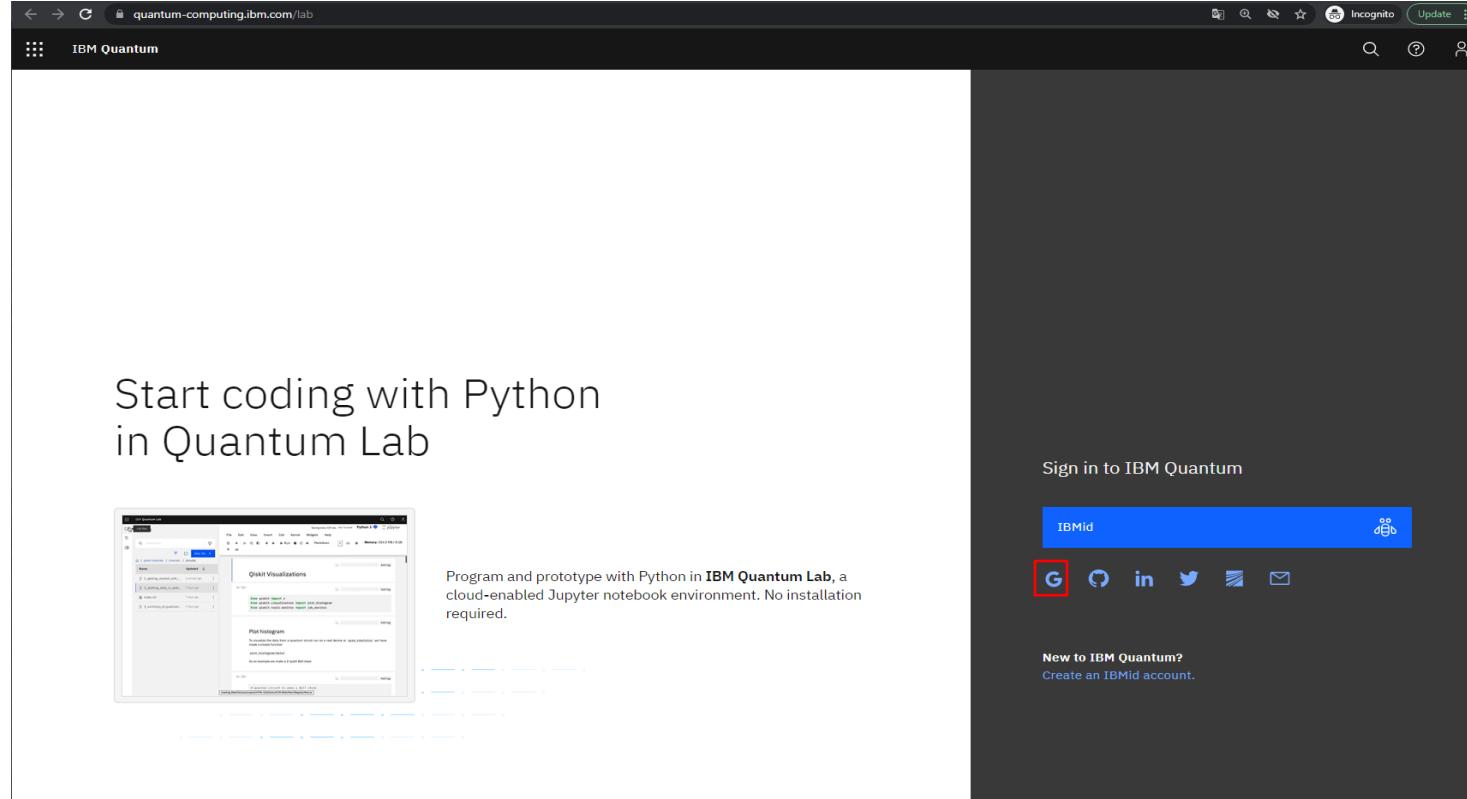
Start locally

To install Qiskit locally, you will need [Python 3.6+](#). Although it is not required, we recommend using a [virtual environment with Anaconda](#).



2- Scroll down to Start Online and click where it says “IBM Quantum Lab”.

Create IBM (Qiskit) account



3- If you want to log with your cmu account, click Google's symbol

Create IBM (Qiskit) account

G Acceder con Google

Acceder

Ir a [ibm.com](#)

Correo electrónico o teléfono

[¿Olvidaste el correo electrónico?](#)

Para continuar, Google compartirá tu nombre, dirección de correo electrónico, preferencia de idioma y foto de perfil con ibm.com. Antes de usar ibm.com, revisa su [política de privacidad y condiciones del servicio](#).

[Crear cuenta](#) [Siguiente](#)

Web Login

AndrewID 

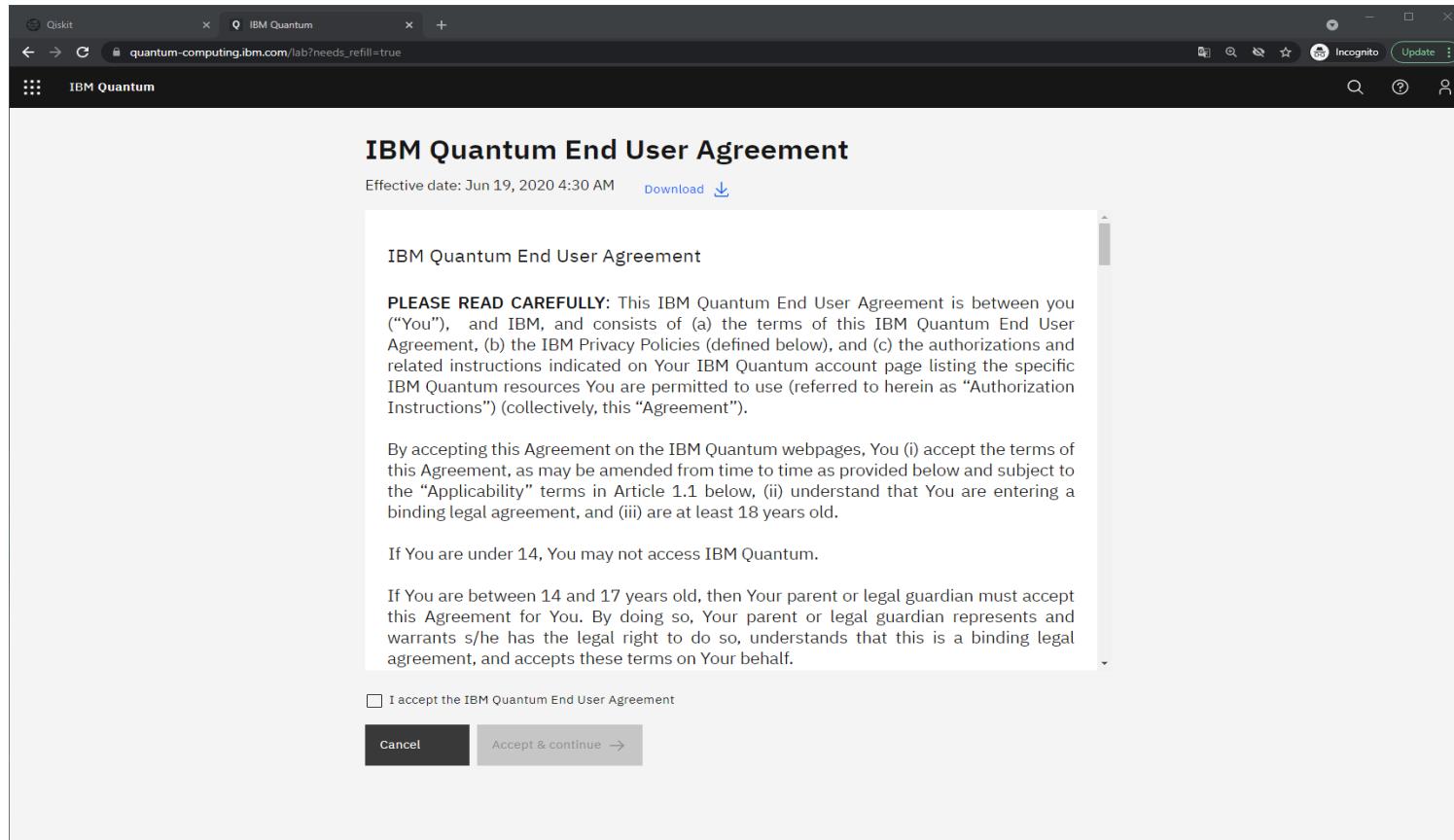
Password

Warning: The URL for this page should begin with <https://login.cmu.edu>. If it does not, do not fill in any information, and report this site to it-help@cmu.edu.

[About](#) | [Change Password](#) | [Forgot Password?](#)

4- Log with your credentials

Create IBM (Qiskit) account



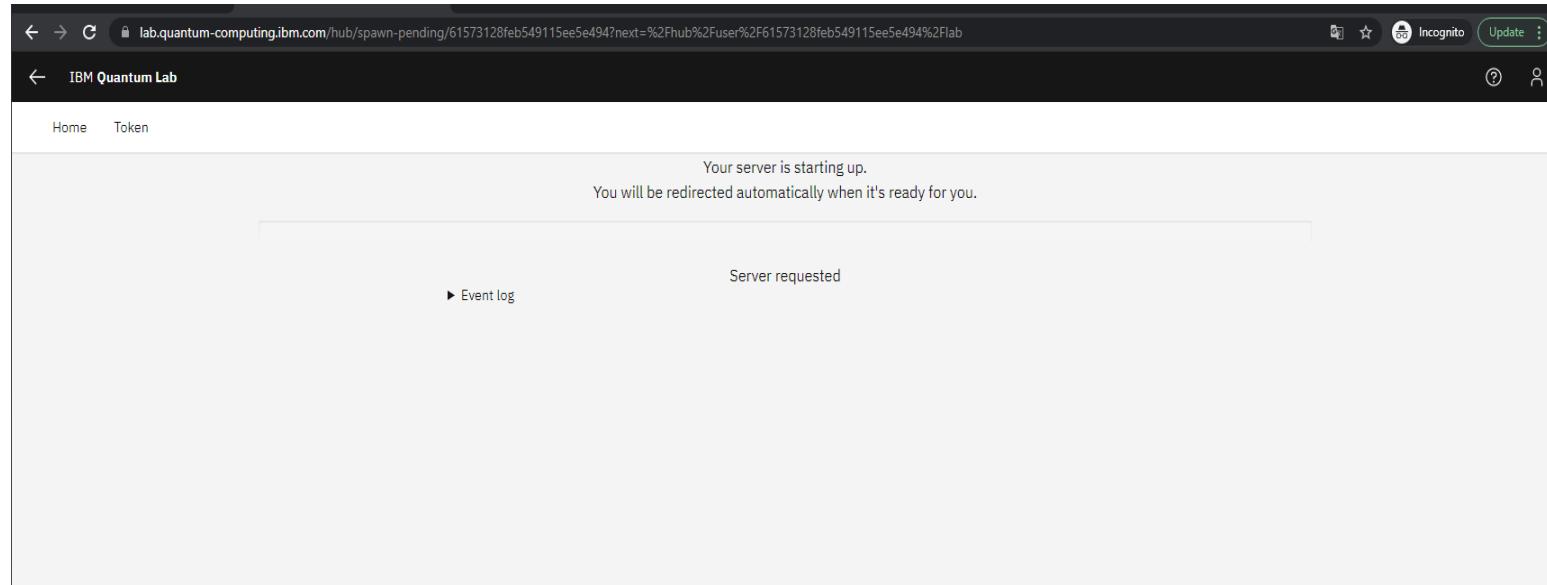
5- Read the End User Agreement

Create IBM (Qiskit) account

The screenshot shows a web browser window for 'quantum-computing.ibm.com/lab?needs_refill=true'. The title bar says 'IBM Quantum'. The main content area is titled 'Last step! Before you get started,' followed by 'Tell us a little more about yourself'. It contains several input fields: 'First name *' (empty), 'Last name *' (empty), 'Your institution *' (containing 'Carnegie Mellon University' which is highlighted with a blue border), 'What is your familiarity with quantum?' (dropdown menu showing 'Select an option'), 'What would you like to use IBM Quantum for?' (text area empty), and a section 'Stay up to date with the latest news and updates by receiving:' with four checkboxes: 'Product updates and announcements', 'IBM Quantum newsletter', 'Tips about using our tools', and 'Requests for feedback to help improve our tools'. At the bottom are 'Cancel' and 'Continue' buttons.

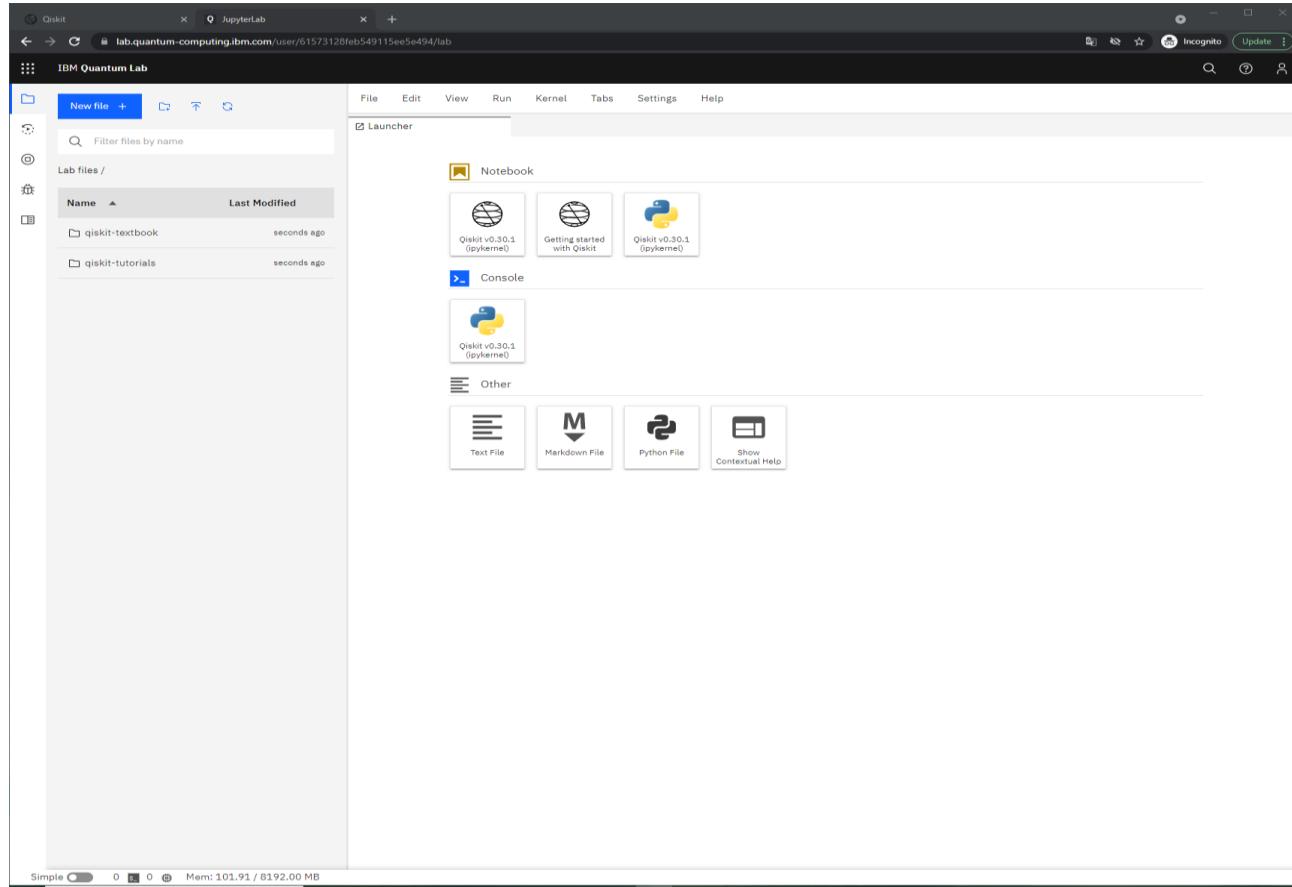
6- Complete the last step

Create IBM (Qiskit) account



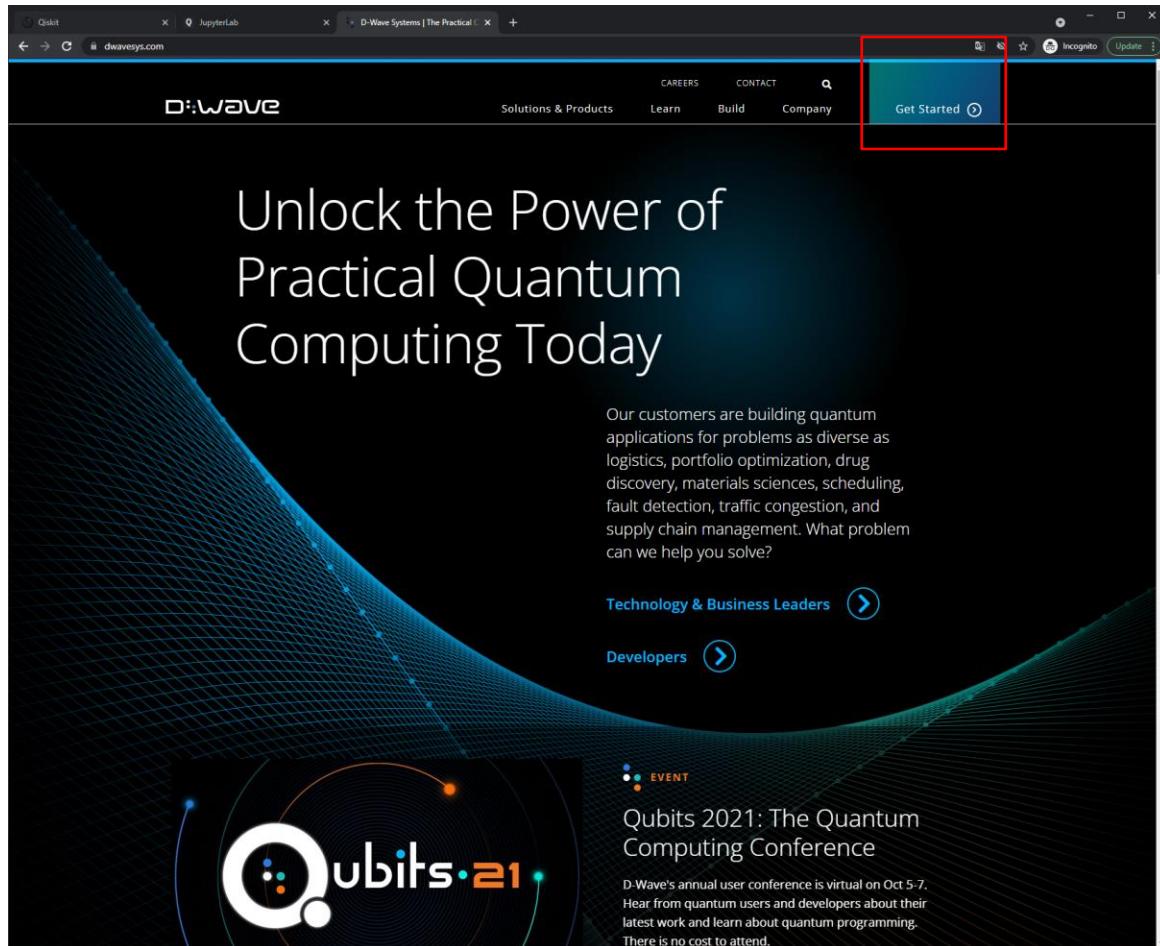
7- Wait while the server is starting up

Create IBM (Qiskit) account



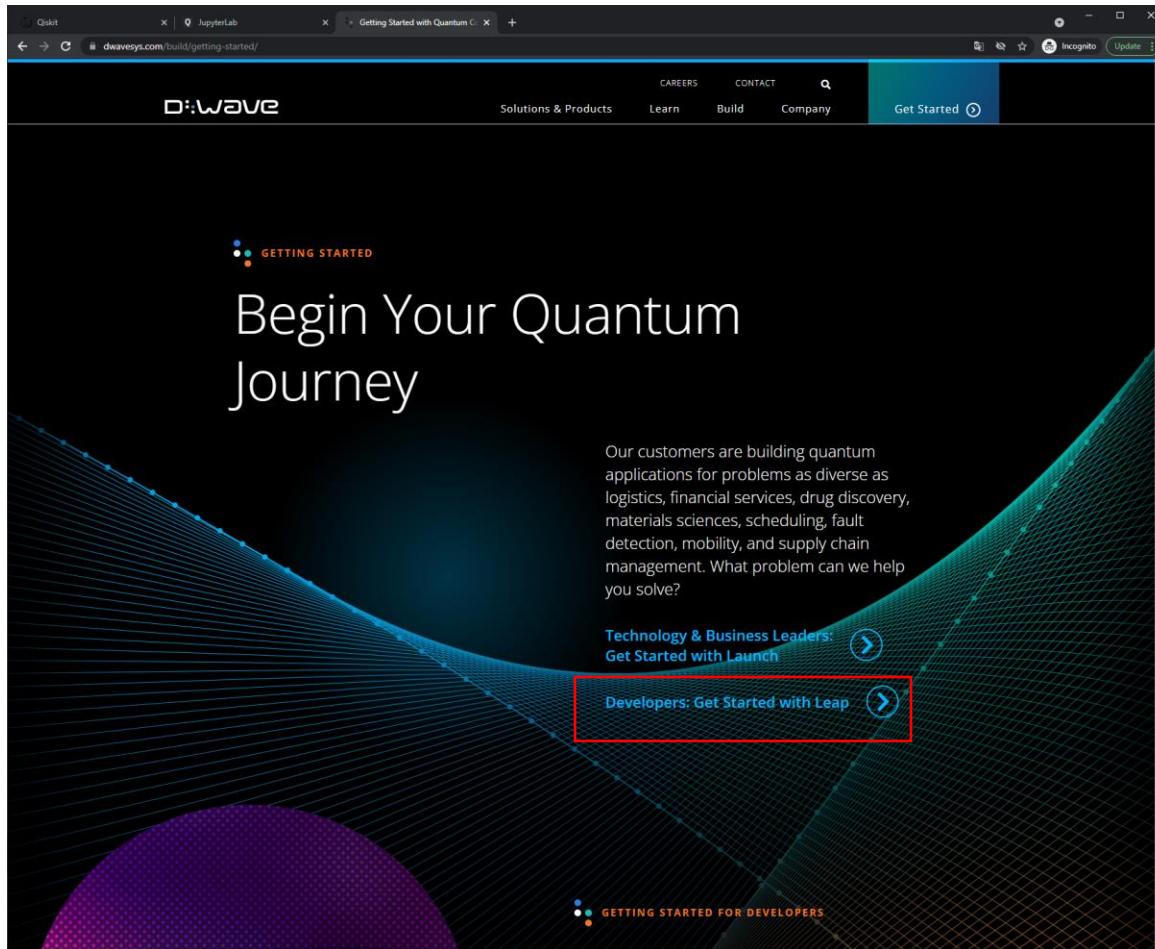
8- Your account should be created successfully!

Create D-WAVE (Leap) account



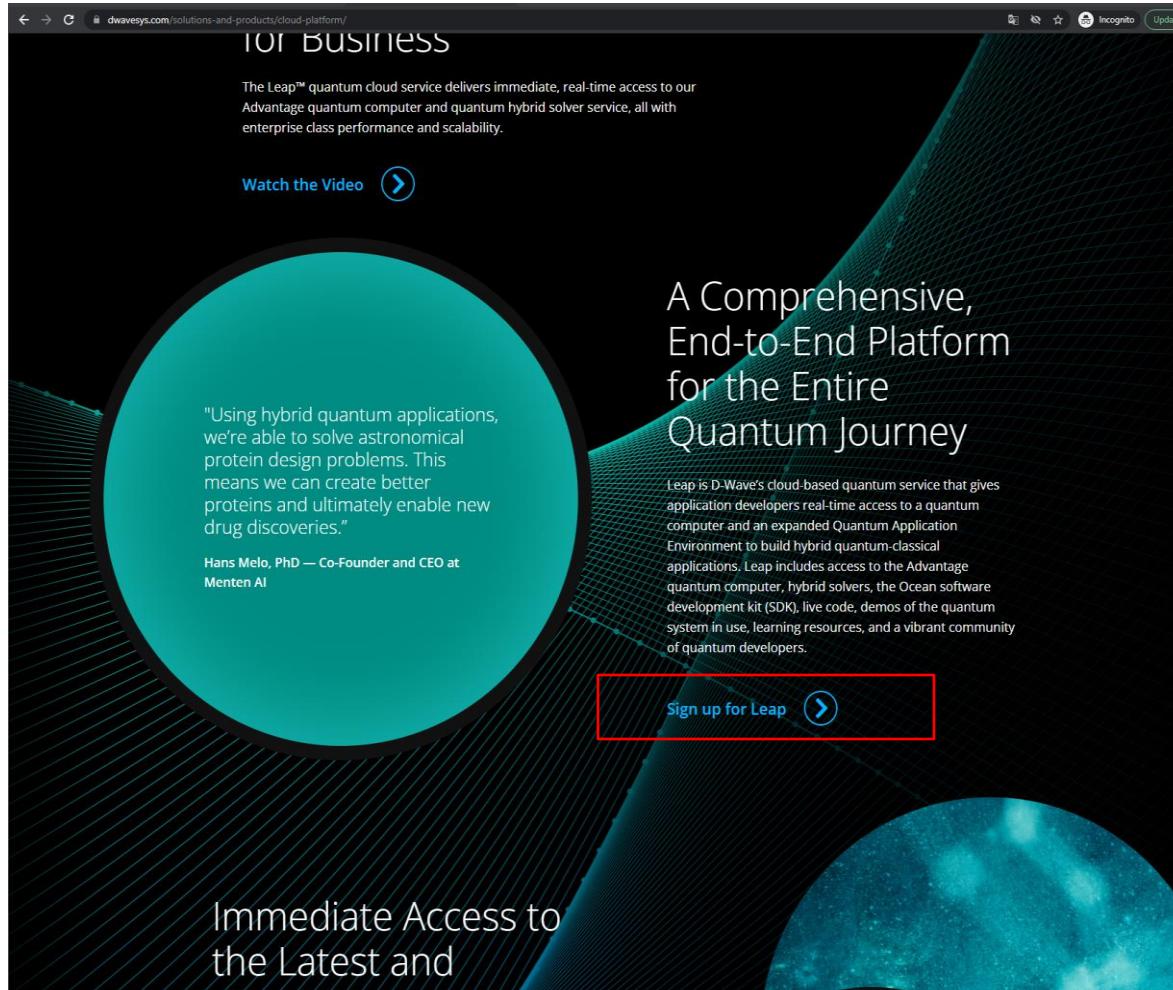
- 1- Go to dwavesys.com
- 2- Click on “Get Started”

Create D-WAVE (Leap) account



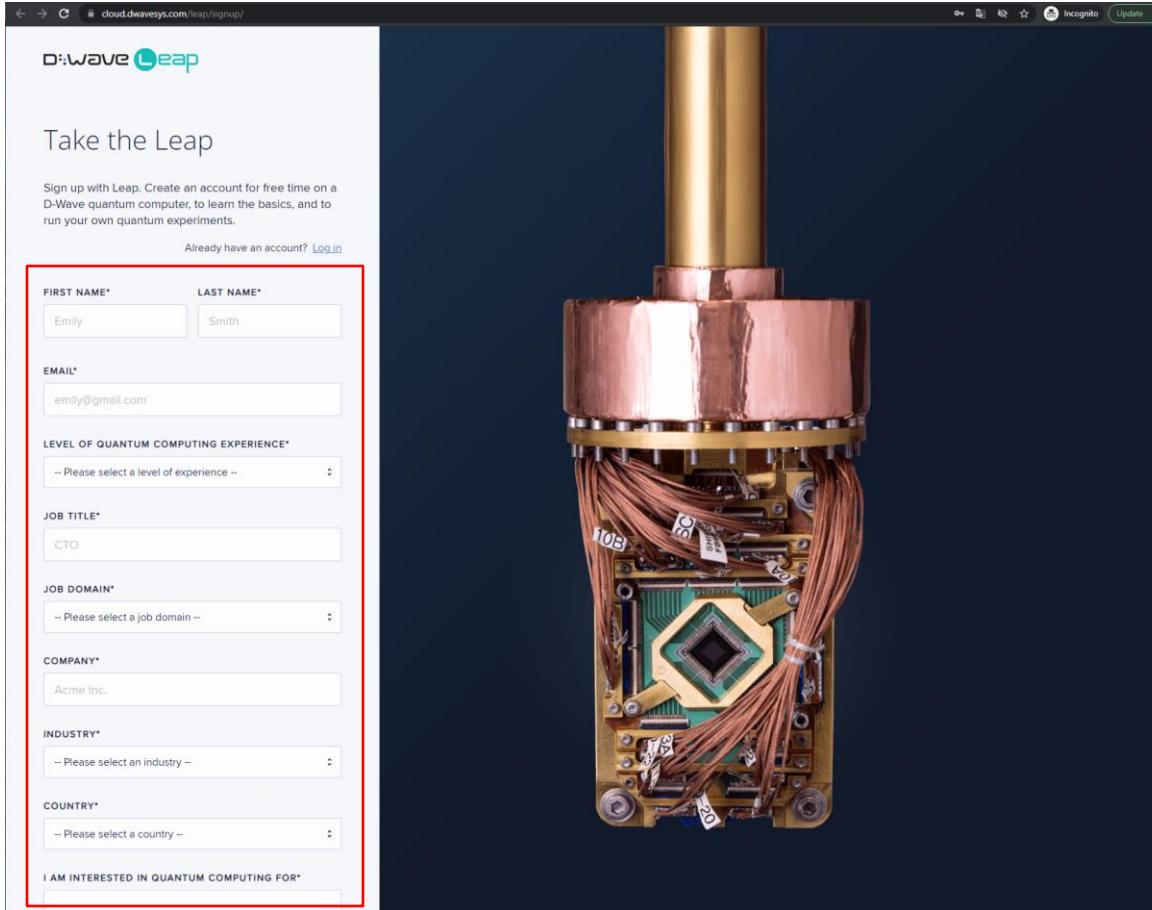
3- Click on “Developers Get Started with Leap”

Create D-WAVE (Leap) account



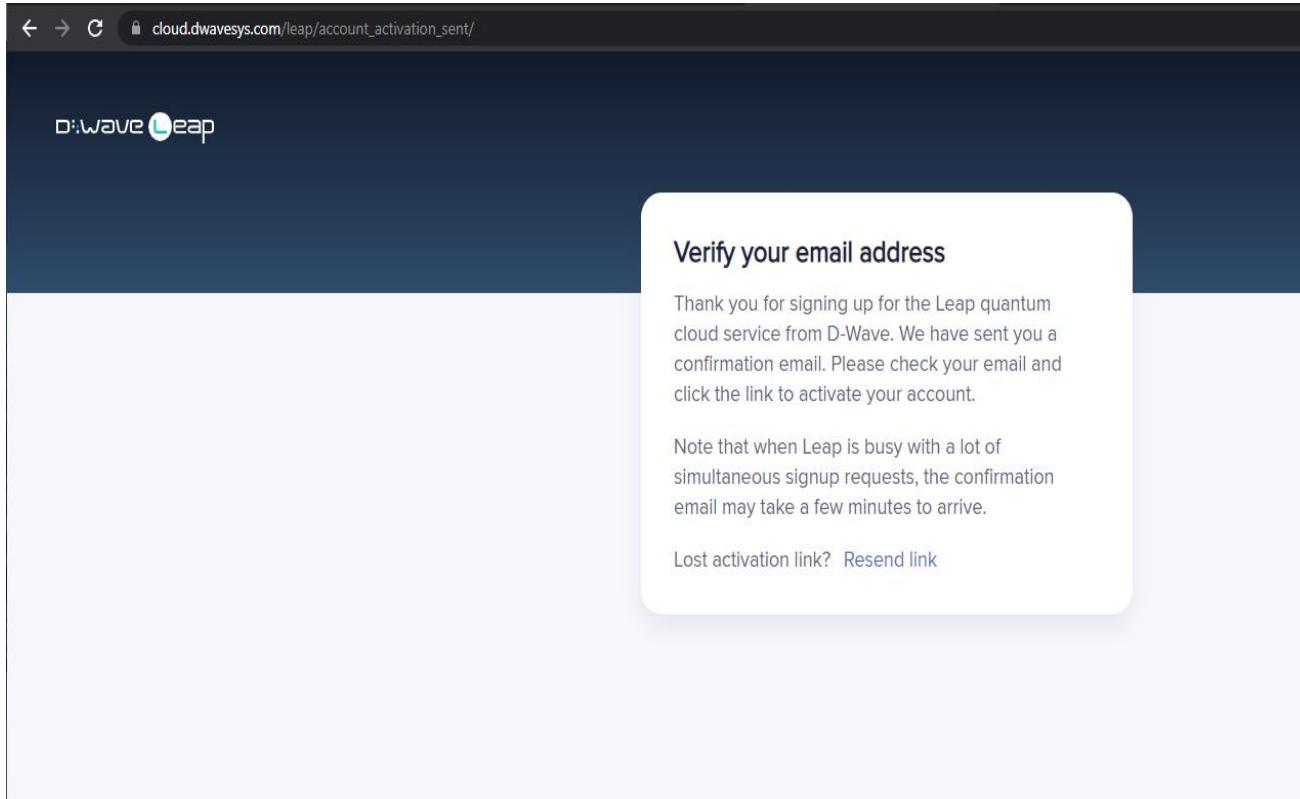
- 4- Scroll down
- 5- Click on “Sign up for Leap”

Create D-WAVE (Leap) account



6- Follow the steps

Create D-WAVE (Leap) account



7- Verify your email address

Create D-WAVE (Leap) account

Welcome to Leap - Account Activation External Inbox x

 notifications@dwavesys.com
to me ▾

Hi

Welcome to Leap, the only real-time Quantum Application Environment.

At login, you'll find access to demos about quantum computing, the Ocean quantum programming SDK, interactive coding examples, a growing quantum community and, most importantly, free time on an actual D-Wave quantum computer.

The best part, you'll get the jump on a new paradigm in quantum development. And who knows... maybe even design the first quantum killer app.

We're thrilled you're here.

Click below to confirm your registration and get started.

<https://cloud.dwavesys.com/leap/activate/Njk4NTQ/5ui-79c654686ce3c527e92c/>

This one-time link expires after three days.

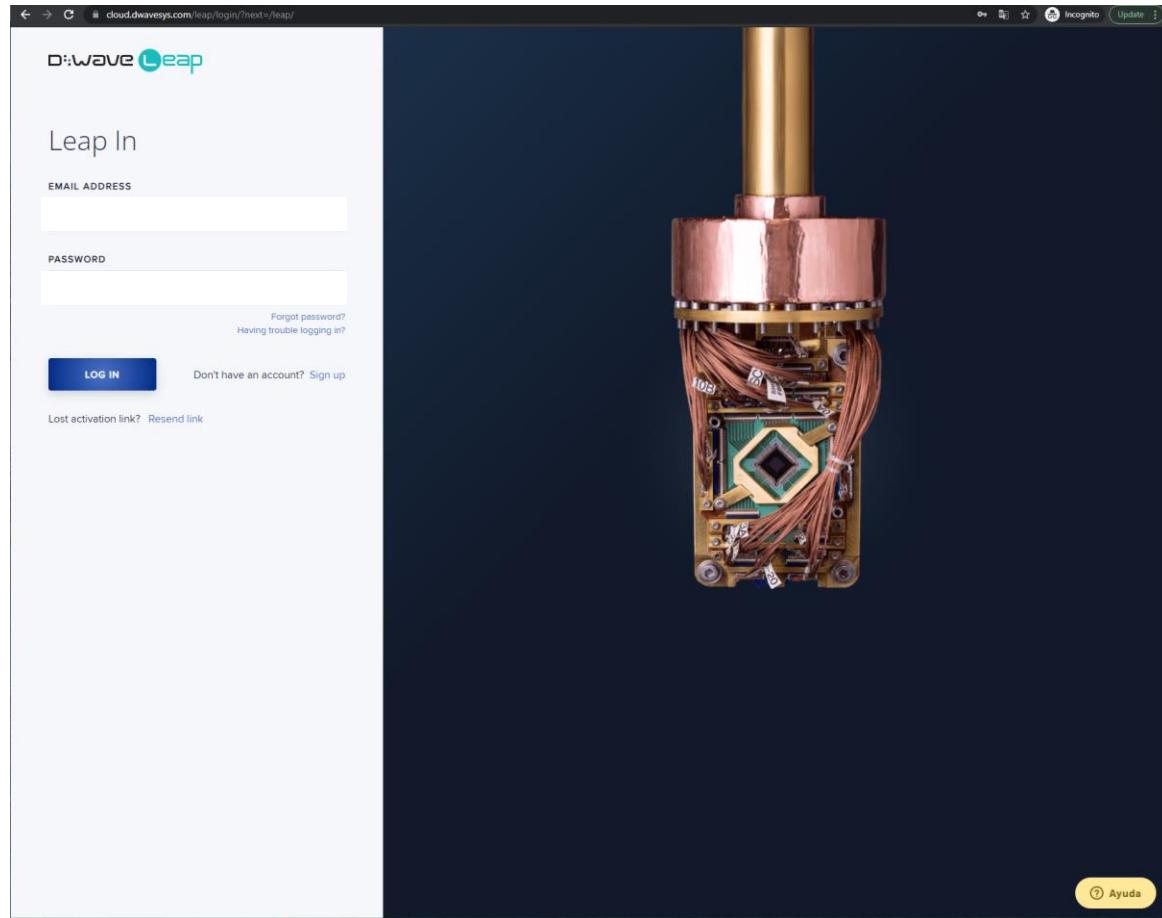
- - -

This is an unmonitored mailbox and unfortunately, this email is an automated notification unable to receive replies.

If you have a question or concern, please contact us directly at support@dwavesys.com.

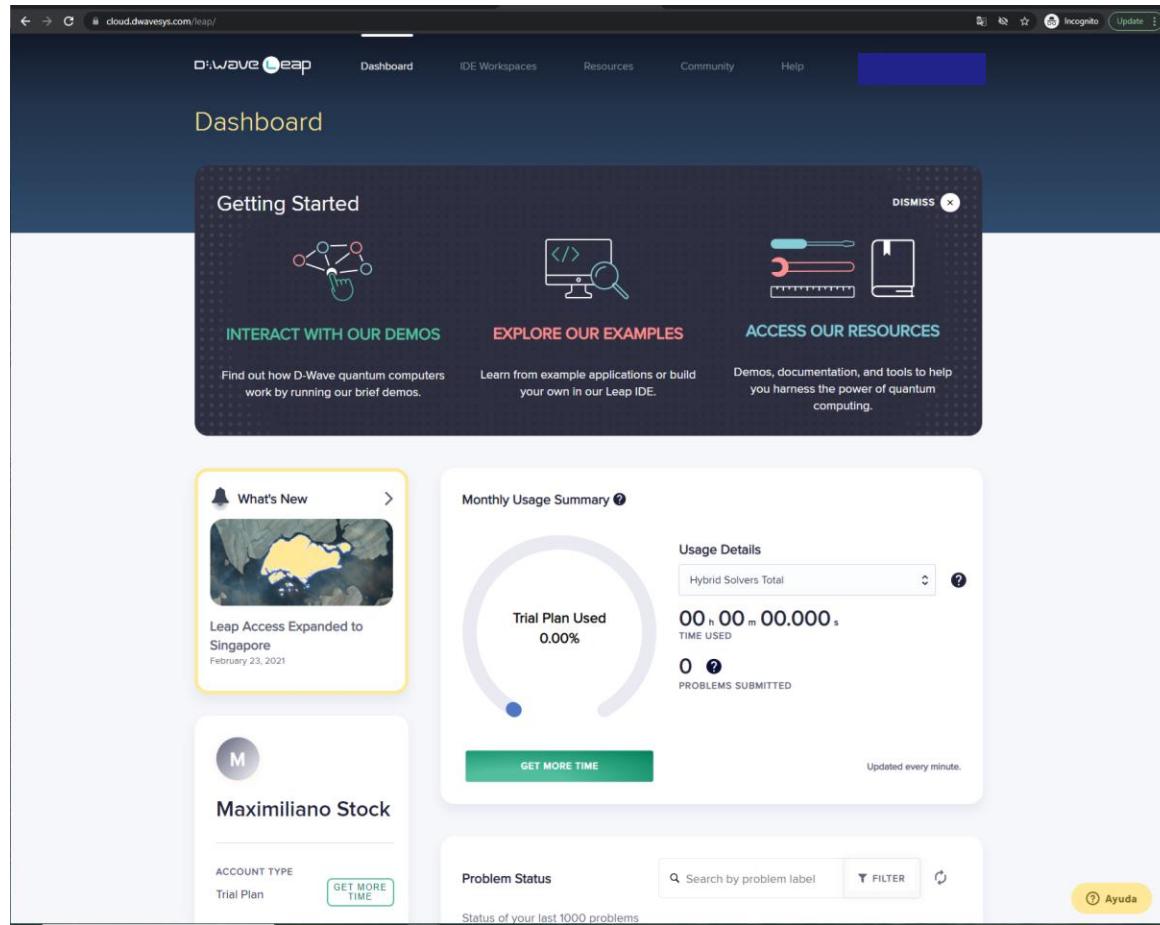
8- Confirm your registration

Create D-WAVE (Leap) account



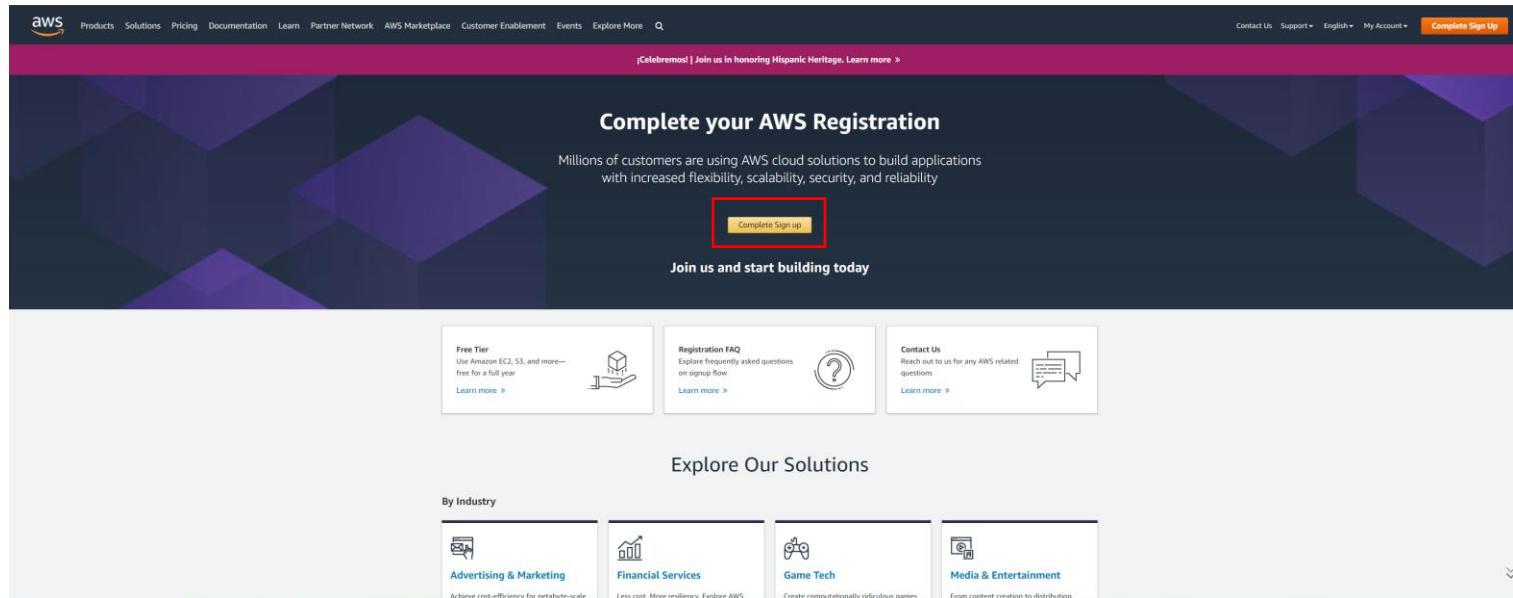
9- Log in

Create D-WAVE (Leap) account



10- Enjoy!

Create AWS account



- 1- Go to <https://aws.amazon.com/>
- 2- Click “Complete sign up”

Create AWS account



Sign in

Root user

Account owner that performs tasks requiring unrestricted access. [Learn more](#)

IAM user

User within an account that performs daily tasks. [Learn more](#)

Root user email address

username@example.com

Next

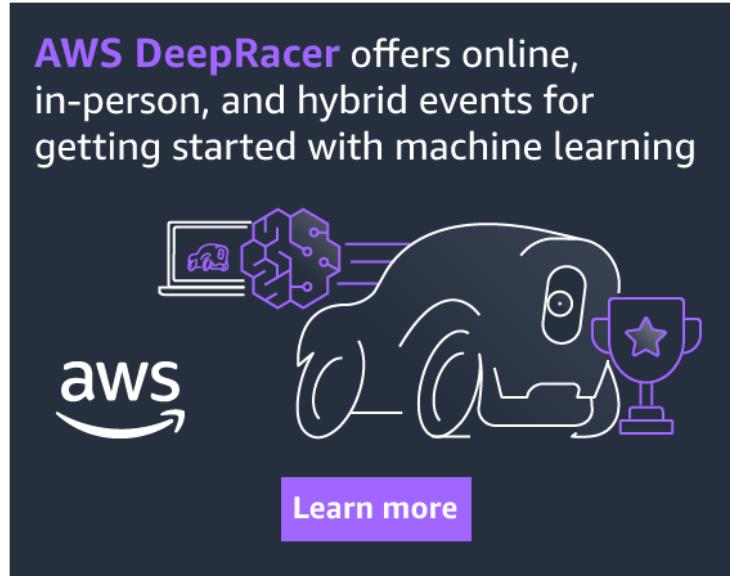
By continuing, you agree to the [AWS Customer Agreement](#) or other agreement for AWS services, and the [Privacy Notice](#). This site uses essential cookies. See our [Cookie Notice](#) for more information.

New to AWS?

[Create a new AWS account](#)

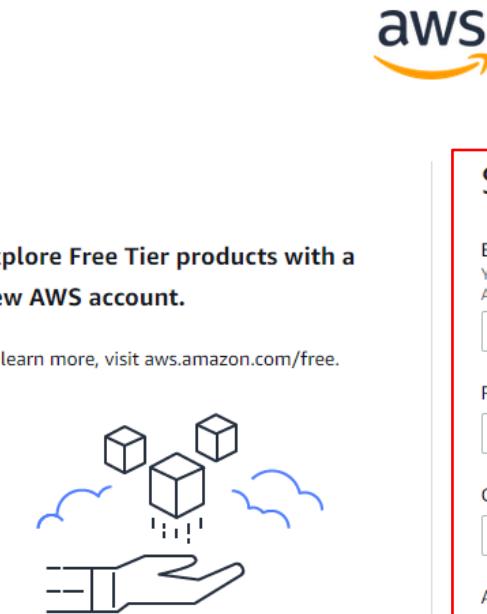
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English ▾



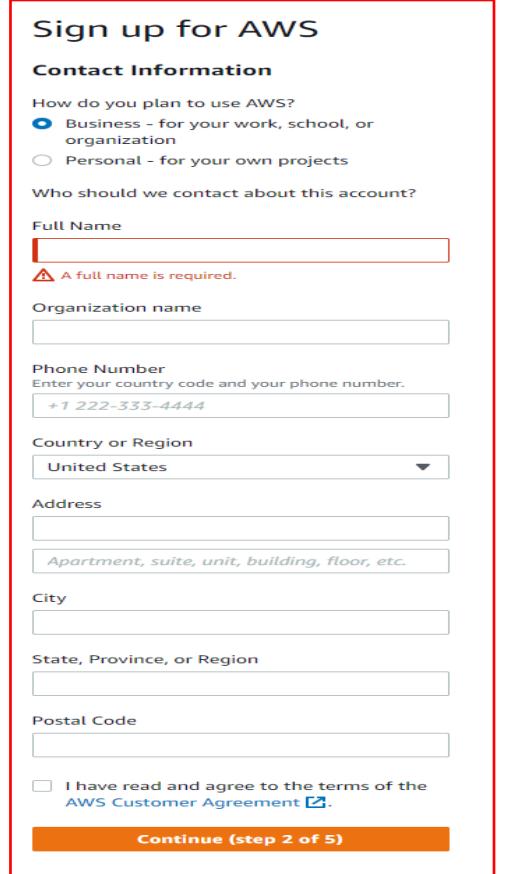
3- Click “Create a new AWS account”

Create AWS account



4- Complete step 1

Create AWS account

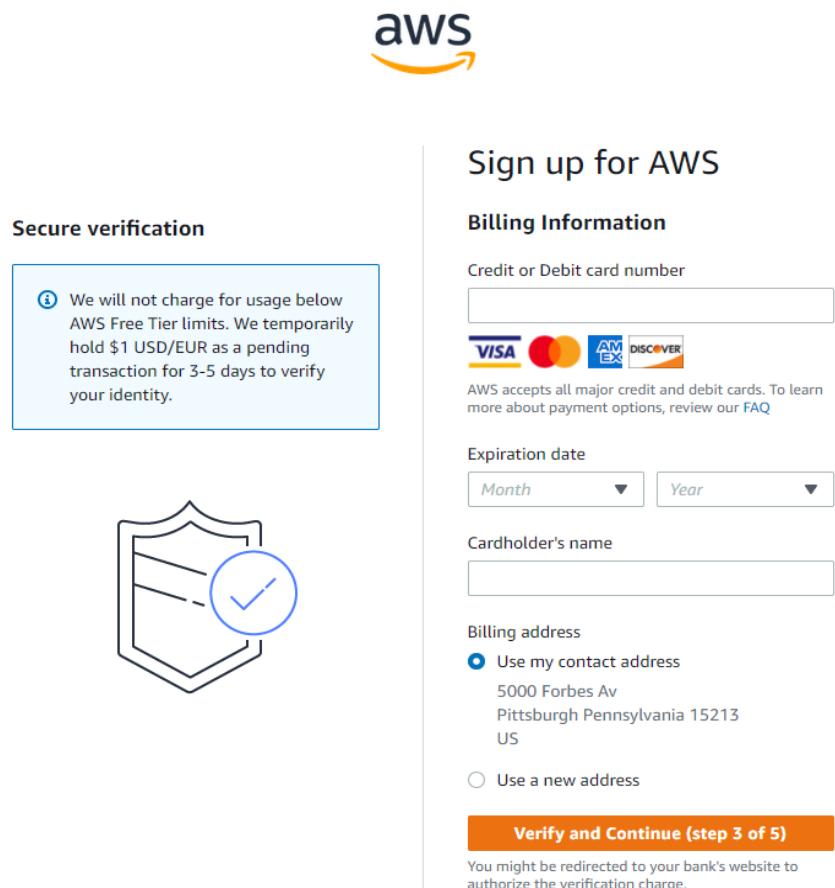


The screenshot shows the AWS sign-up process. On the left, there's a sidebar titled "Free Tier offers" listing three options: "Always free" (never expires), "12 months free" (start from initial sign-up date), and "Trials" (start from service activation date). The main form is titled "Sign up for AWS" and is labeled "Contact Information". It asks "How do you plan to use AWS?" with radio buttons for "Business - for your work, school, or organization" (selected) and "Personal - for your own projects". It also asks "Who should we contact about this account?". The form includes fields for "Full Name" (with an error message "A full name is required."), "Organization name", "Phone Number" (with placeholder "+1 222-333-4444"), "Country or Region" (set to "United States"), "Address" (with placeholder "Apartment, suite, unit, building, floor, etc."), "City", "State, Province, or Region", and "Postal Code". At the bottom, there's a checkbox for "I have read and agree to the terms of the AWS Customer Agreement" and a "Continue (step 2 of 5)" button.

5- Select “Business – for your work, school, or organization”

6- Complete step 2

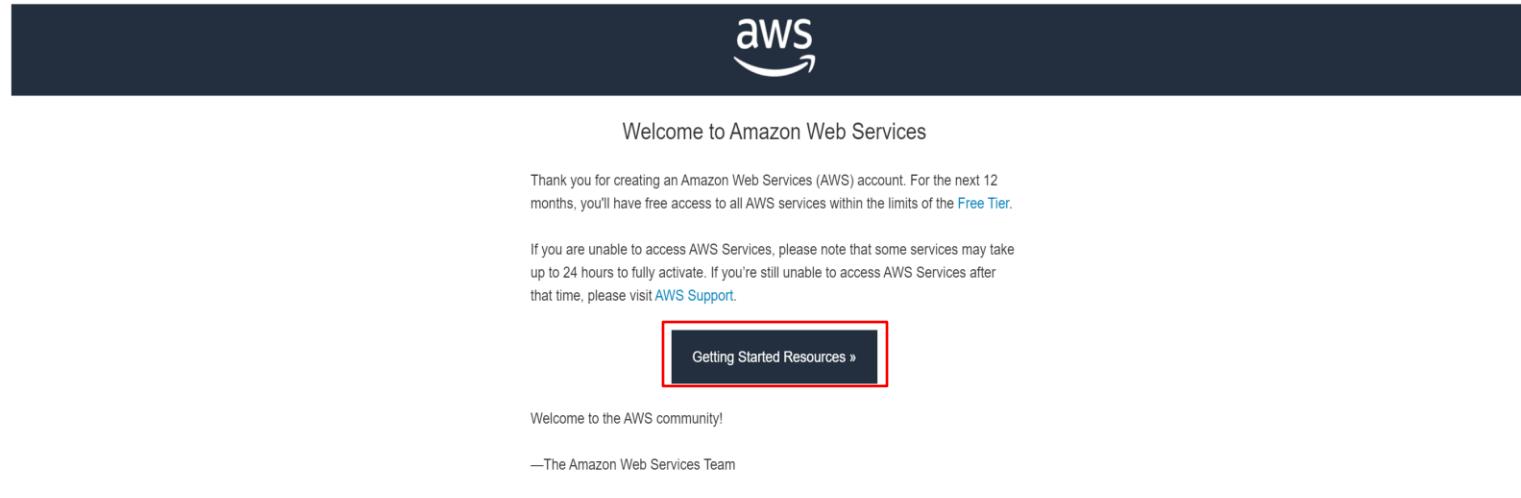
Create AWS account



The image shows the "Sign up for AWS" page. At the top left is the AWS logo. Below it is a "Secure verification" section containing a message: "We will not charge for usage below AWS Free Tier limits. We temporarily hold \$1 USD/EUR as a pending transaction for 3-5 days to verify your identity." To the right is a "Billing Information" section with fields for "Credit or Debit card number" (with icons for VISA, MasterCard, AMEX, and Discover), "Expiration date" (dropdown menus for Month and Year), "Cardholder's name" (text input field), and "Billing address" (radio button options: "Use my contact address" selected, showing 5000 Forbes Av, Pittsburgh Pennsylvania 15213 US; and "Use a new address"). At the bottom is a "Verify and Continue (step 3 of 5)" button. A note at the bottom states: "You might be redirected to your bank's website to authorize the verification charge."

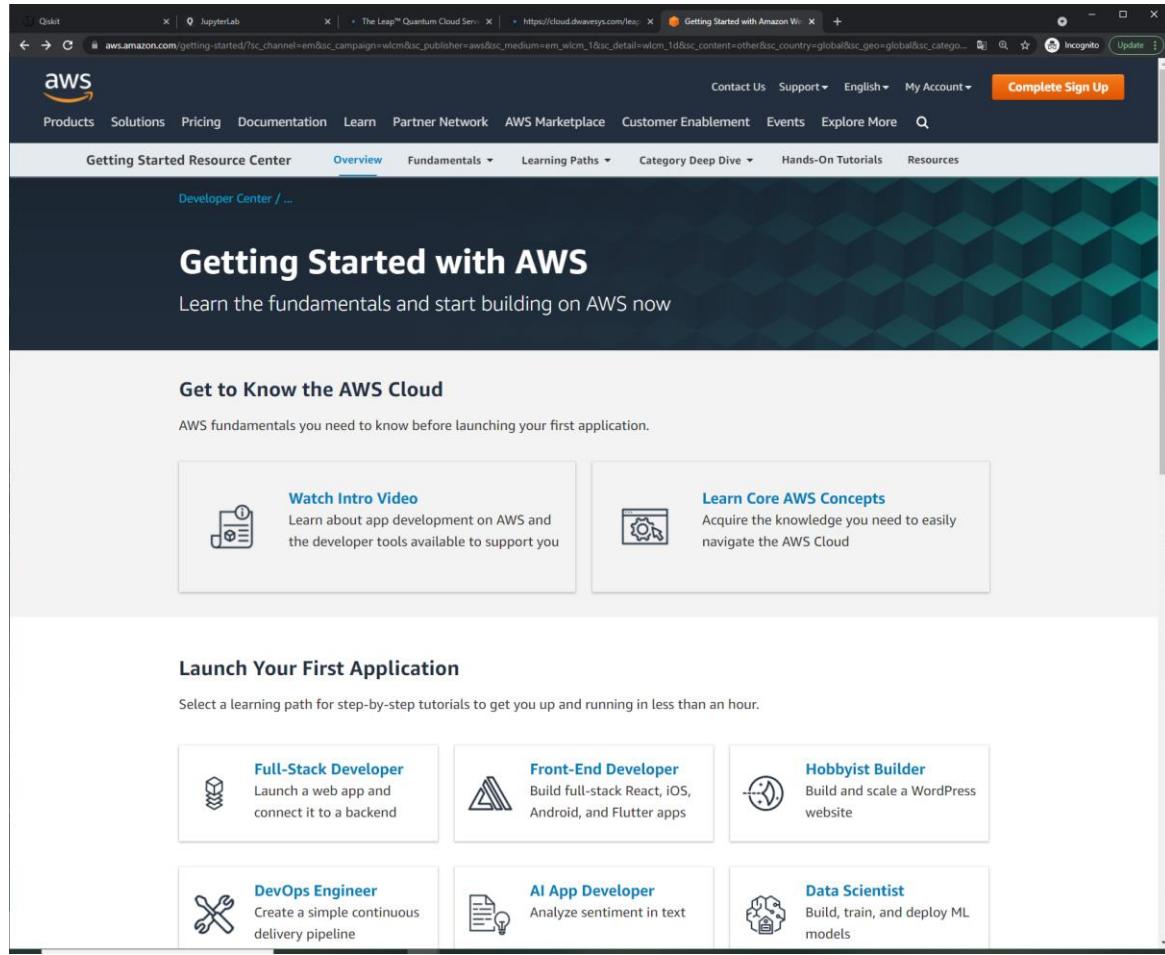
7- Ignore step 3 and wait for the welcome email from AWS.

Create AWS account



8- Click on “Getting Started Resources”

Create AWS account



9- You should be redirected to
aws.amazon.com/getting-started

Create AWS account

Your AWS account has been invited to join an AWS organization [\[External\]](#) [Inbox](#) [Amazon Web Services](#) [Quip & QML](#)

 no-reply-aws@amazon.com
to me ▾


Hello,

CMU Quantum Computing Group (owned by aws-dt-cmu4@dtl.com) would like to add your AWS account (maximilis@andrew.cmu.edu) to their AWS organization as a member account.

Organizations allows customers to easily manage multiple AWS accounts. If you accept the invitation, all activity in your AWS account will be billed to the AWS account of CMU Quantum Computing Group, and CMU Quantum Computing Group will be able to view the AWS usage and charges for your account.

An AWS organization can have one of the following feature sets: all features or consolidated billing only. Most organizations are set up with access to all features, which includes administrative and access controls within the organization. In some cases, an organization may choose to only enable consolidated billing features and later decide to enable all features. Management accounts for consolidated billing organizations may direct AWS to enable all features in the organization with at least 14 days' notice to you that may be sent by email. You can view which feature set the organization has enabled through the console link below. For more information about Organizations features, see the [Organizations documentation](#).

To view the invitation, including what features have been enabled, click this link:

<https://console.aws.amazon.com/organizations/v2/home/invitations>

To learn more about AWS Organizations, see [What is AWS Organizations?](#)

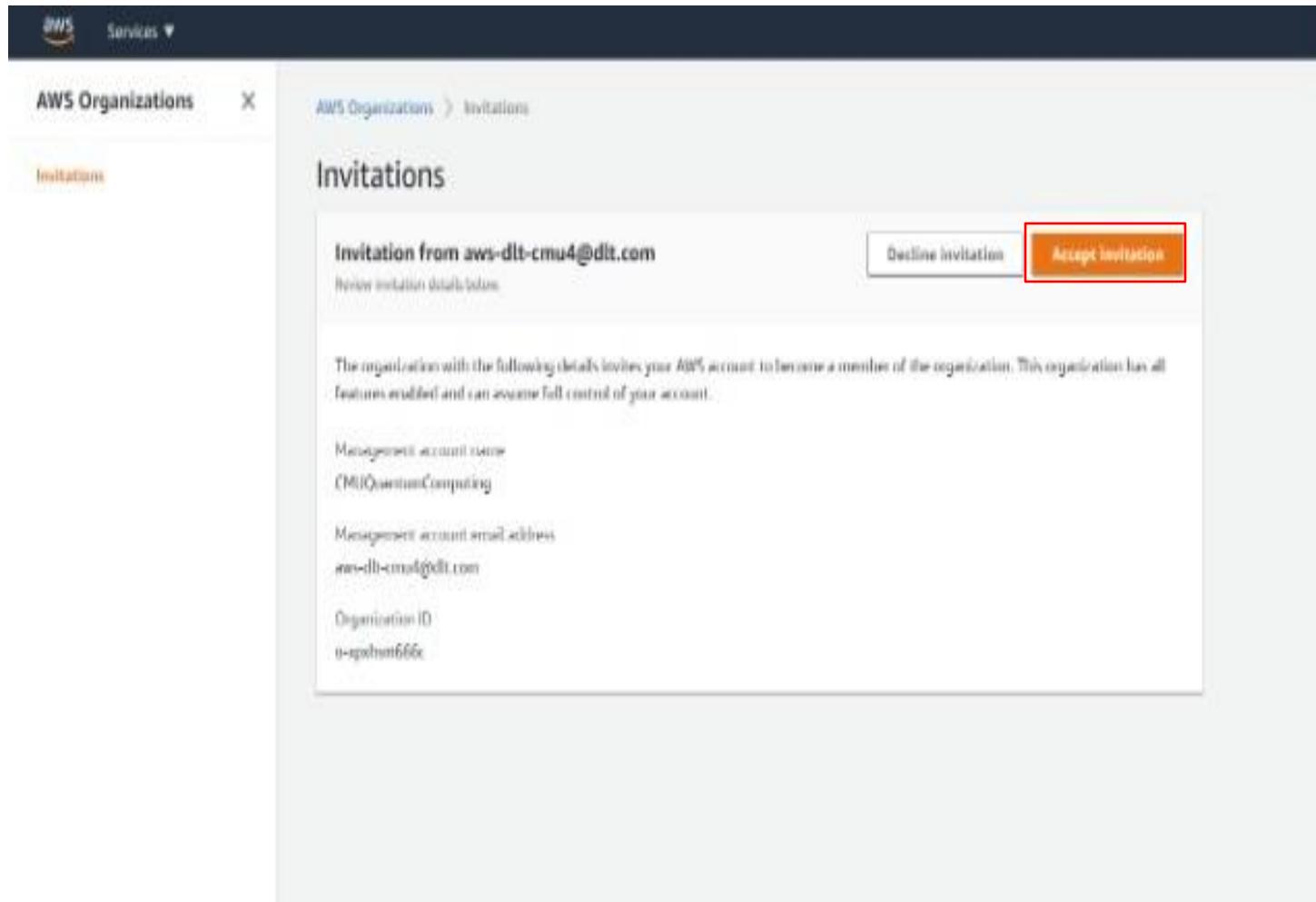
Thank you for using Amazon Web Services.

Sincerely,
Amazon Web Services

Amazon Web Services, Inc. is a subsidiary of Amazon.com, Inc. Amazon.com is a registered trademark of Amazon.com, Inc. This message was produced and distributed by Amazon Web Services, Inc., 410 Terry Ave. North, Seattle, WA 98109-5210.

- 10- Check your email
- 11- Click the link to view the invitation to join an AWS Organization

Create AWS account



12- Accept invitation

Create AWS account

The screenshot shows the AWS Organizations Dashboard. At the top, a green banner displays the message: "You accepted an invitation to join an organization." Below this, the dashboard header includes "AWS Organizations" and "Dashboard". The main content area is titled "Organization details" and contains the following information:

- Organization ID: o-xpxhsm666c
- Management account email address: aws-dlt-cmu4@dlt.com
- Feature set: Your organization has all features enabled. You can apply policies that can configure and limit what the accounts in the organization can do. Trusted AWS services can access your organization and accounts. The management account can create, manage and pay for the organization's accounts through consolidated billing.

At the bottom of this section is a "Leave organization" button and a note: "If you leave the organization, you become responsible for all billing charges related to this account. If you want to rejoin the organization, you must receive and approve a new invitation. [Learn more](#)".

13- Enjoy!

Amazon Braket

- 1- Go to
<https://aws.amazon.com/es/braket/>
- 2- Complete Sign up

Amazon Braket

Sign in

Root user
Account owner that performs tasks requiring unrestricted access. Learn more

IAM user
User within an account that performs daily tasks. Learn more

Root user email address

Next

By continuing, you agree to the AWS Customer Agreement or other agreement for AWS services, and the Privacy Notice. This site uses essential cookies. See our Cookie Notice for more information.

New to AWS?

Create a new AWS account



Security check

Type the characters seen in the image below

Submit

The screenshot shows the AWS security check page. It displays a CAPTCHA image with the text "6t4c37t" and a magnifying glass icon. Below the CAPTCHA is a text input field containing "6t4c37t" and a "Submit" button. The background features the same "Propel your career" and "Get AWS Certified" branding as the sign-in page.

3- Sign up

Amazon Braket



Sign up for AWS

Select a support plan

Choose a support plan for your business or personal account. [Compare plans and pricing examples](#). You can change your plan anytime in the AWS Management Console.

- Basic support - Free
 - Recommended for new users just getting started with AWS
 - 24x7 self-service access to AWS resources
 - For account and billing issues only
 - Access to Personal Health Dashboard & Trusted Advisor
- Developer support - From \$29/month
 - Recommended for developers experimenting with AWS
 - Email access to AWS Support during business hours
 - 12 (business)-hour response times
- Business support - From \$100/month
 - Recommended for running production workloads on AWS
 - 24x7 tech support via email, phone, and chat
 - 1-hour response times
 - Full set of Trusted Advisor best-practice recommendations

Need Enterprise level support?

From \$15,000 a month you will receive 15-minute response times and concierge-style experience with an assigned Technical Account Manager. [Learn more](#)

[Complete sign up](#)

4- Complete Sign up

Amazon Braket



Congratulations!

Thank you for signing up with AWS.

We are activating your account, which should take a few minutes. You will receive an email when this is complete.

[Go to the AWS Management Console](#)

[Sign up for another account](#) or [Contact Sales](#)

5- Go to the AWS Management Console

As an additional step, tell us more about yourself

We would love to learn more about your preferences so that we can provide recommendations catered to your role and interests.

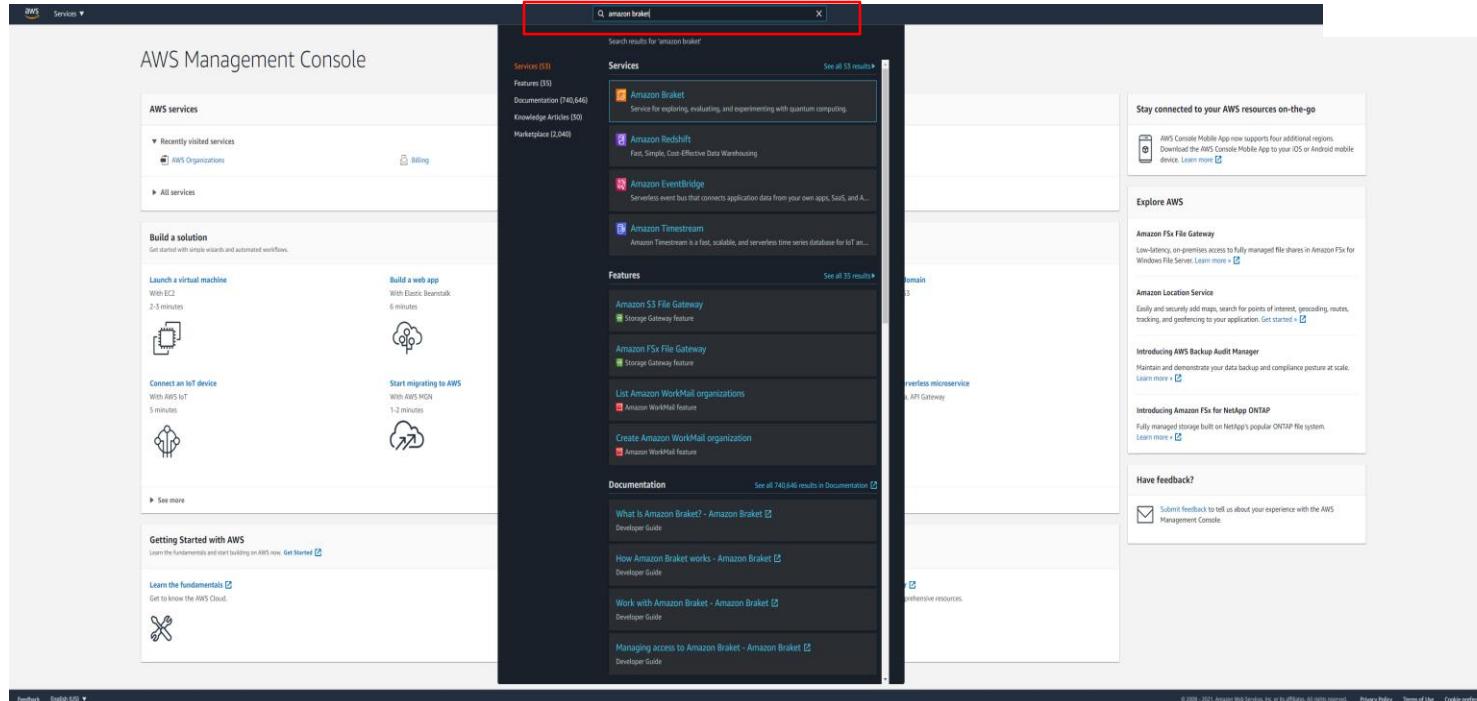
My role is: [select role ▾](#)

I am interested in: [select area ▾](#)

Yes, I'd like Amazon Web Services (AWS) to share the latest news about AWS services and related offerings with me by email, post or telephone.

You may unsubscribe from receiving AWS news and offers at any time by following the instructions in the communications received. AWS handles your information as described in the [AWS Privacy Notice](#).

Amazon Braket



6- Search for Amazon Braket

Amazon Braket



Region Unsupported

Amazon Braket is not available in US East (Ohio). Please select another region.

Supported Regions

[US East \(N. Virginia\)](#)

[US West \(N. California\)](#)

[US West \(Oregon\)](#)

7- Upon opening the Amazon Braket service, the website may say it is unavailable in your location. If so, change to a suitable location, for instance *US East (N. Virginia)*

Amazon Braket

The screenshot shows the 'Getting started with Amazon Braket' wizard. The left sidebar includes links for Devices, Notebooks, Tasks, and Announcements. The main content area has three sections:

- Choose your data storage:** A note states that results are stored in an Amazon S3 bucket starting with "amazon-braket-". Options include "Create new" (selected), "Specify new", and "Select existing". A note below says "We will create the new bucket amazon-braket-de78199c9526."
- Account permissions:** A note explains that a service-linked role is created to access AWS resources. It includes a "Permissions" link.
- Terms & conditions:** A note specifies that if using Braket to access third-party hardware, users must acknowledge processing by the provider and authorize AWS to transfer content. A checkbox "I have read and accepted the above terms & conditions." is present, and an "Enable Amazon Braket" button is at the bottom.

At the bottom, there are links for Feedback, English (US), and legal notices: © 2008 - 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved., Privacy Policy, Terms of Use, and Cookie preferences.

- 8- Accept terms & conditions
- 9- Enable Amazon Braket

Amazon Braket

The screenshot shows the Amazon Braket service interface. On the left, there's a sidebar with 'Amazon Braket' at the top, followed by 'Devices' (selected), 'Notebooks', 'Tasks', and 'Announcements'. The main content area has a search bar at the top. Below it, there are two sections: 'Quantum Processing Units (QPUs)' and 'Simulators'.

Quantum Processing Units (QPUs):

- D-Wave — Advantage_system1.1:** Quantum Annealer based on superconducting qubits. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-west-2.
- D-Wave — DW_2000Q_6:** Quantum Annealer based on superconducting qubits. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-west-2.
- IonQ:** Universal gate-model QPU based on trapped ions. Status: ONLINE. Next available: 1 day 21:46:25. Region: us-east-1.
- Rigetti — Aspen-8:** Universal gate-model QPU based on superconducting qubits. Status: RETIRED. Next available: UNAVAILABLE. Region: us-west-1.
- Rigetti — Aspen-9:** Universal gate-model QPU based on superconducting qubits. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-west-1.

Simulators:

- Amazon Web Services — SV1:** Amazon Braket state vector simulator. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-east-1, us-west-1, us-west-2.
- Amazon Web Services — TN1:** Amazon Braket tensor network simulator. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-east-1, us-west-2.
- Amazon Web Services — DM1:** Amazon Braket density matrix simulator. Status: ONLINE. Next available: AVAILABLE NOW. Region: us-east-1, us-west-1, us-west-2.

At the bottom, there are links for 'Feedback', 'English (US)', 'Privacy Policy', 'Terms of Use', and 'Cookie preferences'.

10- Start Amazon Braket. Locate home page with various machines and simulators.

Amazon Braket

The screenshot shows the Amazon Braket web interface. The top navigation bar includes the AWS logo, Services dropdown, N. Virginia region, and Support dropdown. The left sidebar has tabs for Devices, Notebooks (which is selected and highlighted in orange), and Tasks. Announcements are listed below. The main content area is titled "Notebooks (0)" and features a search bar with placeholder "Search notebooks" and a filter "Name contains: amazon-braket-". It includes buttons for "Create notebook instance" and "Actions". A table header with columns Name, Instance, Creation time, Status, and URL is shown. Below the table, a message says "No Notebooks" and "Use Jupyter Notebooks to create quantum programs in an interactive coding environment.", followed by a "Create notebook" button. At the bottom, there are links for Feedback, English (US) dropdown, and legal notices: © 2008 - 2020, Amazon Web Services, Inc. or its affiliates. All rights reserved., Privacy Policy, and Terms of Use.

11- Go straight to notebooks on the left pane.

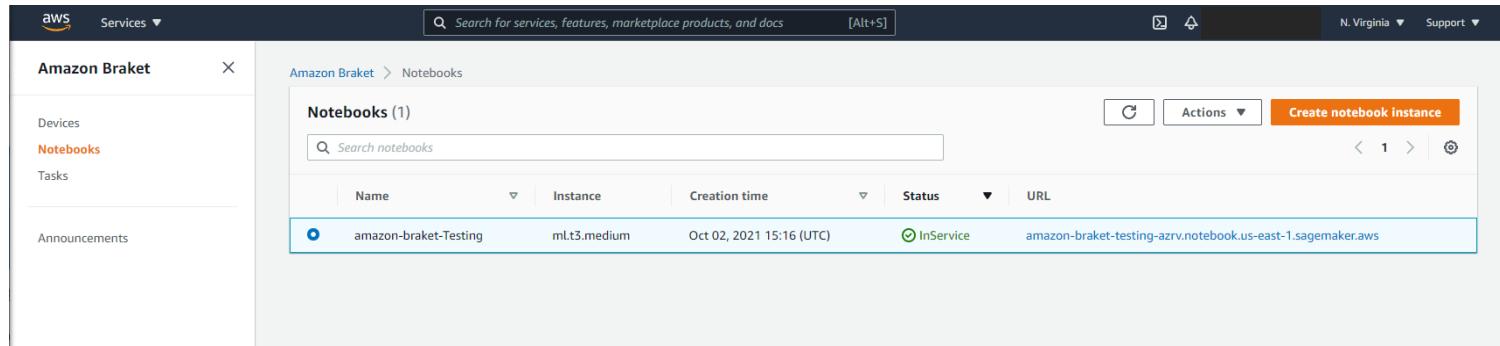
Amazon Braket

The screenshot shows the 'Create notebook instance' wizard in the Amazon Braket console. The left sidebar includes links for Devices, Notebooks, Tasks, and Announcements. The main form has the following sections:

- Notebook instance settings:** Contains fields for 'Notebook instance name' (set to 'amazon-braket-1 Testing') and 'Notebook instance type' (set to 'ml.t3.medium').
- Permissions and encryption:** Includes an 'IAM role' dropdown ('Create a new role') and a note about granting permissions via the 'AmazonBraketFullAccess' policy.
- Root access — optional:** Offers two options: 'Enable - Give users root access to the notebook' (selected) and 'Disable - Don't give users root access to the notebook'.
- Encryption key — optional:** A dropdown menu showing 'No custom encryption key'.
- Network — optional:** A section with a 'Cancel' button and an orange 'Create notebook instance' button.

12- To create Notebook instance provide a name and click “Create Notebook Instance”

Amazon Braket



The screenshot shows the AWS Amazon Braket console. The left sidebar has tabs for Devices, Notebooks (which is selected and highlighted in blue), and Tasks. The main area is titled "Notebooks (1)" and shows a table with one row. The columns are Name, Instance, Creation time, Status, and URL. The row contains: Name "amazon-braket-Testing", Instance "ml.t3.medium", Creation time "Oct 02, 2021 15:16 (UTC)", Status "InService", and URL "amazon-braket-testing-azrv.notebook.us-east-1.sagemaker.aws". There are buttons for Actions and Create notebook instance at the top right of the table.

13- Check status of Notebook. It takes a short amount of time for the notebooks to get created. During this time feel free to check out the devices available to you by clicking on “Devices” in the left tab.

Amazon Braket

The screenshot shows the Amazon Braket Devices page. The left sidebar includes links for AWS Services, Amazon Braket (selected), Devices, Notebooks, Tasks, and Announcements. The main content area is titled "Devices" and "Quantum Processing Units (QPUs)". It displays six items in two rows:

- D-Wave — Advantage_system4.1**: Quantum Annealer based on superconducting qubits. Qubits: 5760, Status: ONLINE, Region: us-west-2.
- D-Wave — Advantage_system1.1**: Quantum Annealer based on superconducting qubits. Qubits: 5760, Status: ONLINE, Region: us-west-2.
- D-Wave — DW_2000Q_6**: Quantum Annealer based on superconducting qubits. Qubits: 2048, Status: ONLINE, Region: us-west-2.
- IonQ**: Universal gate-model QPU based on trapped ions. Qubits: 11, Status: ONLINE, Region: us-east-1.
- Rigetti — Aspen-8**: Universal gate-model QPU based on superconducting qubits. Qubits: 31, Status: RETIRED, Region: us-west-1.
- Rigetti — Aspen-9**: Universal gate-model QPU based on superconducting qubits. Qubits: 32, Status: ONLINE, Region: us-west-1.

Below this section is a "Simulators" header, followed by three items:

- Amazon Web Services — SV1**: Amazon Braket state vector simulator. Qubits: 34, Status: ONLINE, Region: us-east-1, us-west-1, us-west-2.
- Amazon Web Services — TN1**: Amazon Braket tensor network simulator. Qubits: 50, Status: ONLINE, Region: us-east-1, us-west-2.
- Amazon Web Services — DM1**: Amazon Braket density matrix simulator. Qubits: 17, Status: ONLINE, Region: us-east-1, us-west-1, us-west-2.

At the bottom of the page are links for Feedback, English (US), © 2008 - 2021, Amazon Web Services, Inc. or its affiliates. All rights reserved., Privacy Policy, Terms of Use, and Cookie preferences.

14- The Devices Page: Click on each device to see what is under the hood.

Amazon Braket

The screenshot shows the Amazon Braket interface for a D-Wave Advantage_system4.1 device. The left sidebar includes links for Services, Devices (which is selected), Notebooks, Tasks, and Announcements. The main content area displays the device's name, a brief description of its architecture as a Quantum Annealer based on superconducting qubits, and a detailed technical overview. A red box highlights the "Device ARN" field, which contains the value `arn:aws:braket::device/qpu/d-wave/Advantage_system4`. Below this, a "Topology" section shows a JSON configuration for a "pegasus" type shape with 16 tiles.

15- D-Wave. Note the Device ARN,
it may be useful in your Notebooks

Amazon Braket

Universal gate-model QPU based on trapped ions

IonQ's trapped ion QPUs are built on a chain of trapped $^{171}\text{Yb}^+$ ions, spatially confined via a microfabricated surface electrode trap within a vacuum chamber. Gates are performed via a two-photon Raman transition using a pair of counter-propagating beams from a mode-locked pulsed laser. This allows for high-quality single and two-qubit transitions and all-to-all connectivity. Initialization is performed via optical pumping, and readout is performed with a combination of a resonant laser, a high numeric aperture lens, and photomultiplier tubes.

IonQ compiles and optimizes your high-level quantum logic gates into the smallest possible set of laser pulses to realize your program on trapped ions, mapping your gates onto ideal pairs for execution using up-to-the-minute continuous calibrations.

For single-qubit gates, IonQ uses the GPI gate, the GPI2 gate, and the GZ gate. The GPI and GPI2 gates are simply Rabi oscillations made by driving the qubits on resonance using laser beams in a Raman configuration. The GZ gate is performed by advancing/retarding the phase of this laser beam, creating a 'virtual' operation.

For entangling, two-qubit gates, IonQ uses the Molmer-Sørensen gate. This entangling gate and the single-qubit gates above constitute a universal gate set. By irradiating any two ions in the chain with a predesigned set of pulses, it is possible to couple ions' internal states with the chain's normal modes of motion to create entanglement.

[More about this device](#)

Hardware provider IonQ	Region us-east-1	Location Maryland, USA
Availability Weekdays, 13:00:00 - 02:00:00 UTC	Next available AVAILABLE NOW	Cost \$0.30 / task + \$0.01 / shot
Device ARN arn:aws:braket::device/qpu/ionq/ionQdevice	Status ONLINE	Qubits 11

Topology

Calibration
Last updated: Sep 21, 2021 13:00 (UTC)

16- IonQ. Note the Device ARN, it may be useful in your Notebooks

Amazon Braket

Universal gate-model QPU based on superconducting qubits

Rigetti quantum processors are universal, gate-model machines based on all-tunable superconducting qubits. Just like the Rigetti Aspen-8 chip, the Aspen-9 chip features tileable lattices of alternating fixed-frequency and tunable superconducting qubits within a scalable 32-qubit node technology. Distinguishing characteristics include direct coupling between one qubit and its three nearest neighbors; fast gate times for multiple entangling gate families; rapid sampling via active register reset; and parametric control.

The Aspen chip topology is octagonal with 3-fold (2-fold for edges) connectivity and features both C2 and XY entangling gates that allow developers to optimize programs for performance and minimize circuit depth. Rigetti's optimizing quic compiler transforms abstract quantum algorithms into this set of native gates and produces optimal circuit implementations to be carried out on a Rigetti QPU. These gates offer fast (60ns and 160ns) 1Q and 2Q gate times and program execution rates within qubit coherence times measuring ~20μs.

Universal gate-based quantum computers powered by superconducting qubits provide users with both fine grained control and efficient variational feedback loops to explore problem spaces in chemical simulation, combinatorial optimization, and machine learning.

[More about this device](#)

Hardware provider Rigetti	Region us-west-1	Location California, USA
Availability Everyday, 15:00:00 - 19:00:00 UTC	Next available 19:00:10	Cost \$0.30 / task + \$0.00035 / shot
Device ARN <code>arn:aws:braket::device/qpu/rigetti/Aspen-9</code>	Status ONLINE	Qubits 32

Topology

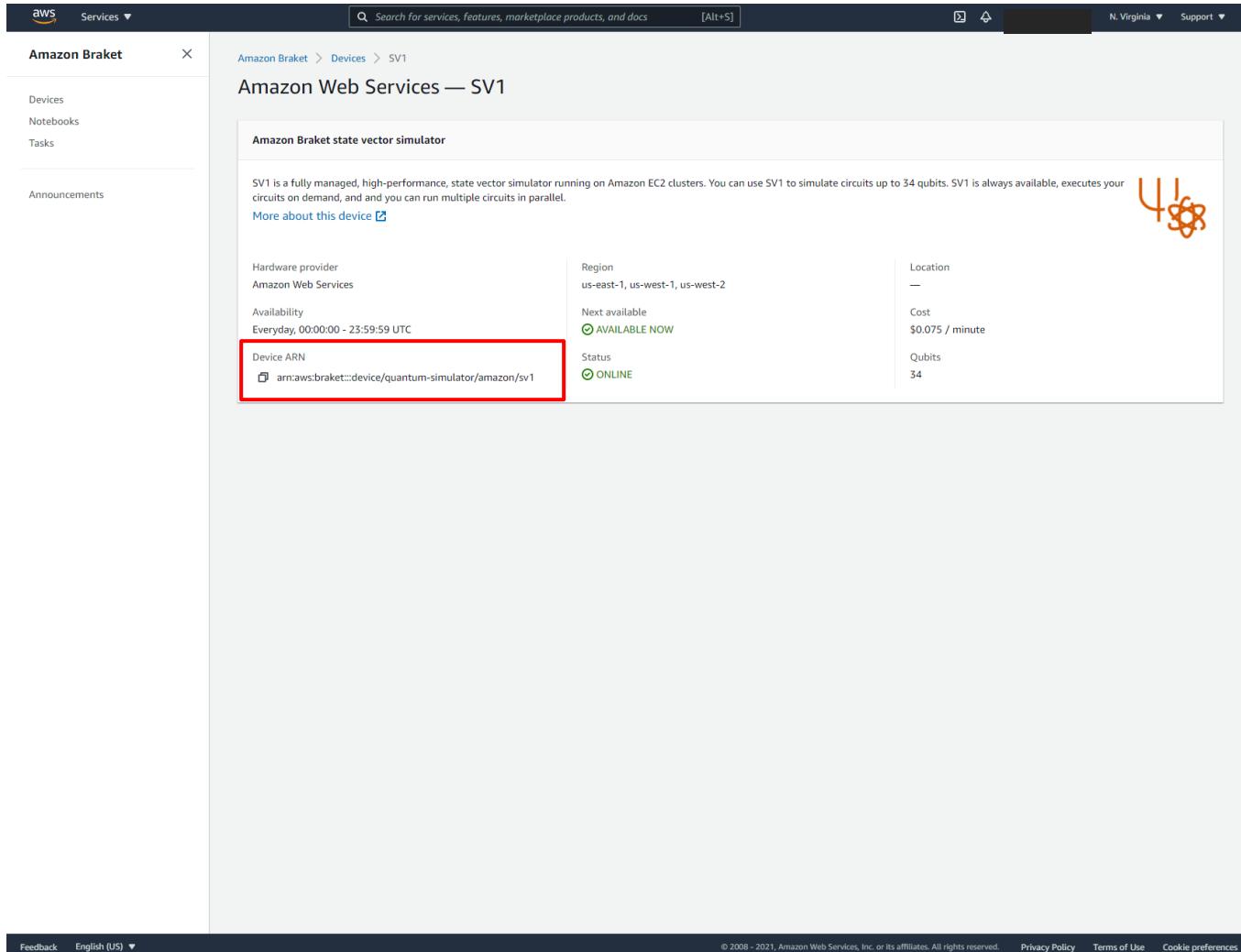
Calibration

Last updated: Oct 12, 2021 19:58 (UTC)

Qubit	T1 (μs)	T2 (μs)	Fidelity (RB) (%)	Fidelity (simultaneous RB) (%)	Readout fidelity (%)	Active reset fidelity (%)
0	27.661	12.521	99.900 ± 0.009	99.612 ± 0.027	97.000	99.850
1	35.419	10.563	97.817 ± 0.120	96.277 ± 0.623	85.800	97.200
2	24.699	4.462	99.759 ± 0.021	99.512 ± 0.027	93.700	99.650

17- Rigetti. Note the Device ARN, it may be useful in your Notebooks

Amazon Braket

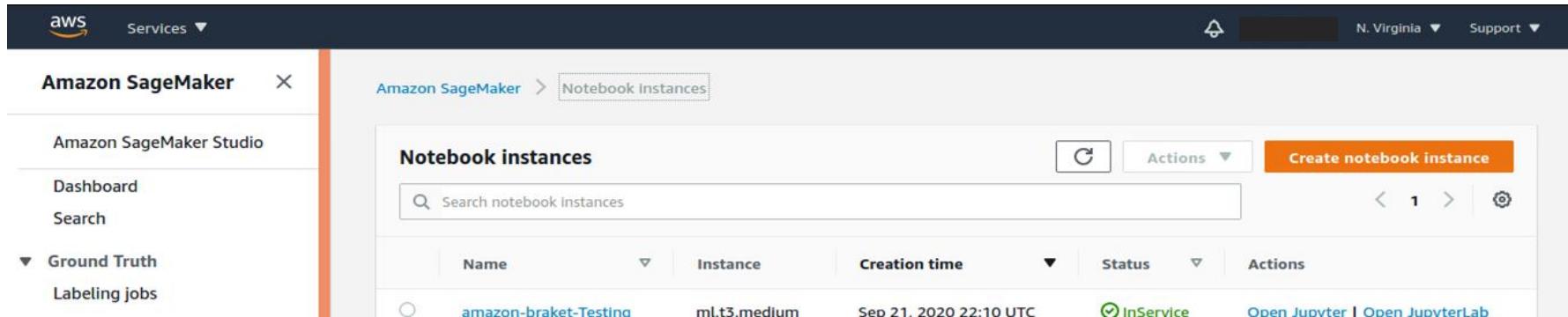


The screenshot shows the Amazon Braket web interface. The top navigation bar includes the AWS logo, Services dropdown, search bar ('Search for services, features, marketplace products, and docs'), and [Alt+S] key. The top right has N. Virginia dropdown and Support dropdown. The left sidebar shows 'Amazon Braket' with a close button, 'Devices', 'Notebooks', 'Tasks', and 'Announcements'. The main content area shows 'Amazon Web Services — SV1' under 'Amazon Braket > Devices > SV1'. A sub-header 'Amazon Braket state vector simulator' is shown with a small orange logo. Below it, a text block says 'SV1 is a fully managed, high-performance, state vector simulator running on Amazon EC2 clusters. You can use SV1 to simulate circuits up to 34 qubits. SV1 is always available, executes your circuits on demand, and you can run multiple circuits in parallel.' followed by a 'More about this device' link. A red box highlights the 'Device ARN' section, which contains the value 'arn:aws:braket:::device/quantum-simulator/amazon/sv1'. Other details listed include 'Hardware provider: Amazon Web Services', 'Region: us-east-1, us-west-1, us-west-2', 'Next available: AVAILABLE NOW', 'Cost: \$0.075 / minute', 'Location: —', 'Status: ONLINE', and 'Qubits: 34'. At the bottom, there are links for Feedback, English (US), and footer text: '© 2008–2021, Amazon Web Services, Inc. or its affiliates. All rights reserved.', 'Privacy Policy', 'Terms of Use', and 'Cookie preferences'.

18- Braket Simulator. Note the Device ARN, it may be useful in your Notebooks

Go back to Notebooks tab

19. Your Notebook may be green i.e. “In Service”



The screenshot shows the 'Notebook instances' section of the Amazon SageMaker Studio interface. A single notebook instance is listed:

Name	Instance	Creation time	Status	Actions
amazon-braket-Testing	ml.t3.medium	Sep 21. 2020 22:10 UTC	InService	Open Jupyter Open JupyterLab

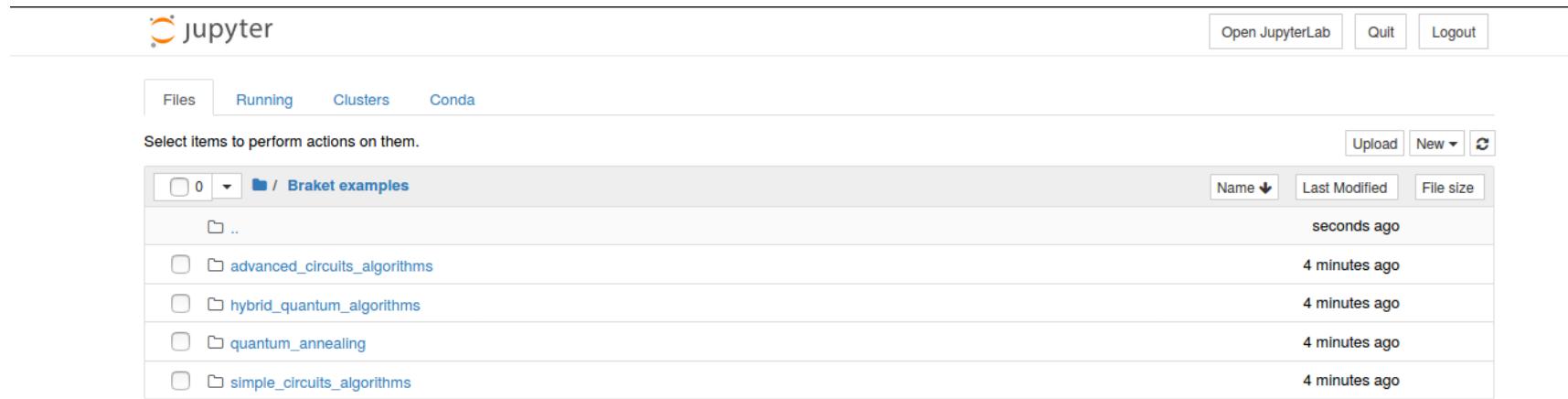
20. Under Actions, click on the notebook



The screenshot shows the Jupyter Notebook interface. The top navigation bar includes 'Open JupyterLab', 'Quit', and 'Logout'. Below the navigation bar, there are tabs for 'Files', 'Running', 'Clusters', and 'Conda'. The main area displays a file list with the following details:

Name	Last Modified	File size
Braket examples	3 minutes ago	

Open Braket Examples



Explore the set of notebooks provided by Amazon Braket.

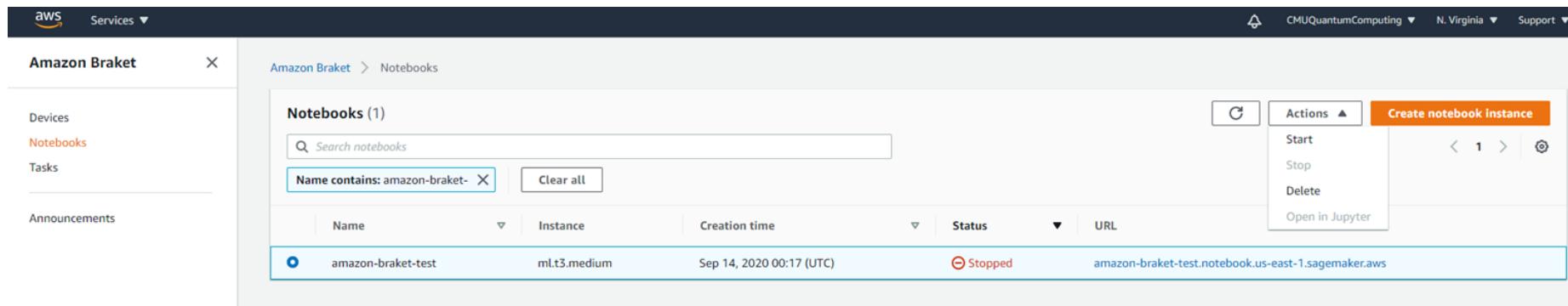
The results are preloaded. You can execute the code yourself, keep in mind that it costs money!
First simulate classically and then use the quantum devices (preferably DWave, Rigetti and IonQ in that order)

Make sure to Stop your notebooks before you Log Out!

Play Around.
You are ALL SET Here!

We will be covering during this class

- quantum_annealing/D-Wave_anatomy.ipynb
- hybrid_quantum_algorithms/QAOA.ipynb

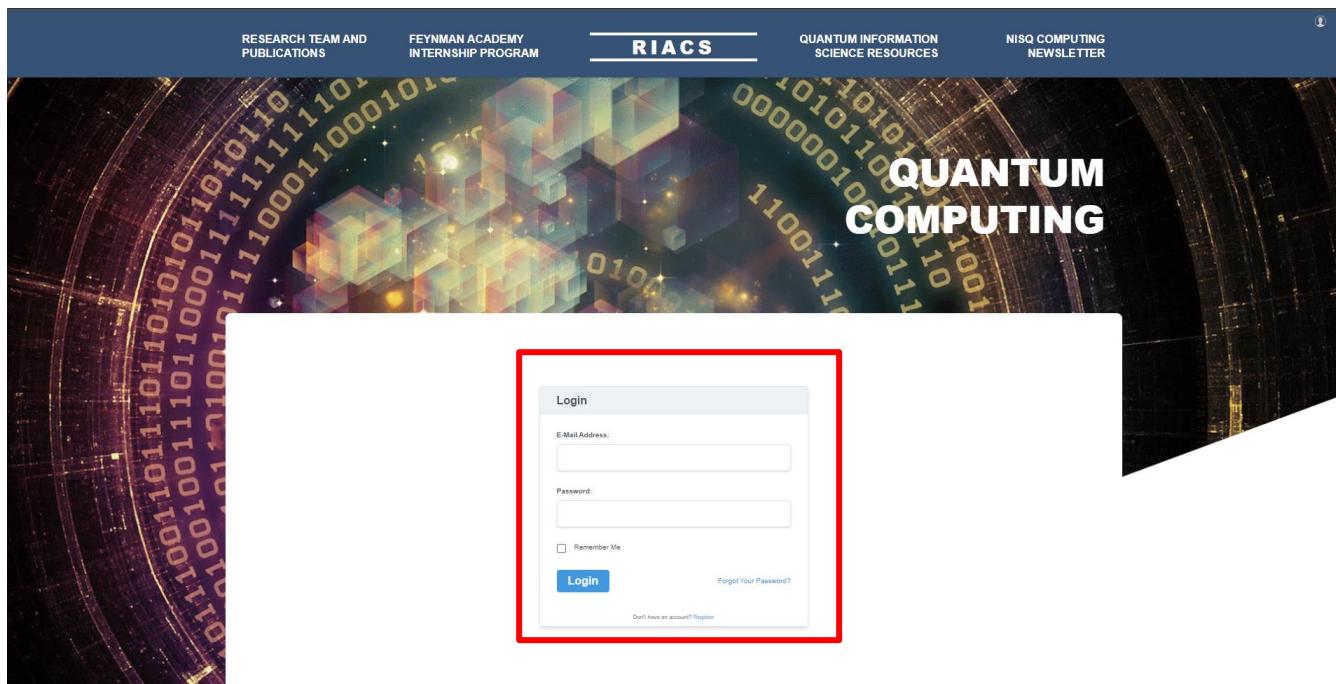


The screenshot shows the Amazon Braket console interface. On the left, there's a sidebar with 'Amazon Braket' selected under 'Notebooks'. The main area displays a table titled 'Notebooks (1)'. The table has columns for Name, Instance, Creation time, Status, and URL. One row is visible: 'amazon-braket-test' (Instance: ml.t3.medium, Creation time: Sep 14, 2020 00:17 (UTC), Status: Stopped, URL: amazon-braket-test.notebook.us-east-1.sagemaker.aws). To the right of the table is a 'Actions' dropdown menu with options: Start, Stop, Delete, and Open in Jupyter.

Accessing USRA resources

1. Go to
<https://riacs.usra.edu/quantum/qisprogram>
2. Click on “log in”

Accessing USRA resources



3. Log in with the next credentials:
Username: AFRLguest@AFRL
Password: USRApass1

Accessing USRA resources



DARPA ONISQ Project: Scheduling Applications with Advanced Mixers (SAAM)

Universities Space Research Association (USRA) [announced](#) that DARPA has awarded the organization and its partners Rigetti Computing and the NASA Quantum Artificial Intelligence Laboratory (QuAIL) to work as a team to advance the state of art in quantum optimization. USRA, as the prime contractor of the award, will manage the collaboration.

The collaboration will focus on developing a superconducting quantum processor, hardware aware software and custom algorithms that take direct advantage of the hardware advances to solve scheduling and asset allocation problems. In addition, the team will design methods for benchmarking the hardware against classical computers to determine quantum advantage.

In particular, the work will target scheduling problems whose complexity goes beyond what has been done so far with the quantum approximate optimization algorithm (QAOA). USRA's Research Institute for Advanced Computer Science (RIACS) has been working on quantum algorithms for planning and scheduling for NASA QuAIL since 2012. RIACS as the prime contractor will manage the collaboration between NASA QuAIL and Rigetti Computing.

The grant is a part of the DARPA Optimization with Noisy Intermediate-Scale Quantum program (ONISQ). The goal of this program is to establish that quantum information processing using NISQ devices has a quantitative advantage for solving real-world-combinatorial optimization problems using the QAOA method.

NSF SpecEES Project: Advancing the Wireless Spectral Frontier with Quantum-Enabled Computational Techniques (QENeTs)

This project running 2019-2021 is investigating a multitude of new communications receiver decoding algorithms that are amenable to be used in hybrid setting with NISQ quantum computers. The designed methods will be tested on real hardware and benchmarked against the best known classical approaches. In addition to spectral efficiency, the project will also consider how quantum-enabled techniques can improve the energy efficiency of massive multiple-input/multiple-output (MIMO) algorithms. More info on the [project website](#).

NSF Expeditions in Computing Project: Coherent Ising Machines

USRA has received a subaward from NSF, in team with Stanford, Caltech and Cornell University, to work on the prestigious 5-year program Expeditions in Computing. Collaborators include NASA QuAIL, NTT, NII and Microsoft. This Expeditions award exploits unconventional computing architectures, called Coherent Ising Machines (CIMs), to solve a class of optimization problems. CIMs provide a platform to test ideas for computer engineering in the post-Moore's Law era. Next-generation CIMs also hold great promise to drive substantial practical advances in artificial intelligence (AI) capabilities in multiple fields. In addition, the unconventional memory format used by these machines may establish a pathway towards novel quantum information technologies. More info on [NSF press release](#) and [Project Website](#).

[Program Modules](#)



4. Go back to
<https://riacs.usra.edu/quantum/qisprogram>
5. Click on Program Modules

Accessing USRA resources

The screenshot shows a white web page with a dark blue header bar at the top. The header bar contains the text "QIS DEVELOPMENT PROGRAM" on the left and "MENU" with a three-line icon on the right. Below the header, there is a section titled "AFRL Quantum Information Science Workforce Development Program". This section includes a paragraph about the program's objective and its connection to the 2019 Q2B conference and Airforce Institute of Technology. It also mentions access to training modules, seminars, and a newsletter. At the bottom of this section, there are two buttons: "TRAINING" and "SEMINARS". At the very bottom of the page, there is a small line of text: "Development of this site was supported by AFRL NYSTEC Contract (FA8750-19-3-6101)".

There are plenty of seminars and training available to you!

Accessing USRA resources

The screenshot shows the RIACS Quantum Information Science Resources website. At the top, there are links for "RESEARCH TEAM AND PUBLICATIONS", "FEYNMAN ACADEMY INTERNSHIP PROGRAM", "RIACS", "QUANTUM INFORMATION SCIENCE RESOURCES", and "NISQ COMPUTING NEWSLETTER". The main banner features the text "QUANTUM COMPUTING" over a background of binary code and 3D quantum cubes.

The page title is "QIS DEVELOPMENT PROGRAM / TRAININGS / QUANTUM INTEGER PROGRAMMING". On the left, there's a diagram of a graph with red and green nodes connected by lines. Below it, a section titled "Overview" lists course modules: "Lecture 0 - Course Overview (Part 1)", "Lecture 0 - Course Overview (Part 2)", "Lecture 1 - Integer programming (Part 1)", "Lecture 1 - Integer programming (Part 2)", "Lecture 2 - Test-set methods - Gröbner Basis (Part 1)", "Lecture 2 - Test-set methods - Gröbner Basis (Part 2)", and "Lecture 3 - Test-set methods - Gröbner Basis".

The central content area is titled "Quantum Integer Programming". It includes a detailed description of the course objectives, prerequisites, and topics covered. It also lists the instructors: Davide Venturelli, David E. Bernal, Sridhar Tayur, Peter McMahon, and Anil Prabhakar. The number of lessons is 25, and there are 14 interactive lessons. A thumbnail image shows a geometric diagram with labels like "optimal solution", "approximating step", and "current solution". Below the description, there's a "Lecture 0 - Course Overview (Part 1)" section with a list of course details and a "Show more..." link. At the bottom, there are profiles for Dr. Sridhar Tayur and Dr. Davide Venturelli.

Including last years edited videos, codes, and notes!

Accessing USRA resources

The screenshot shows the homepage of the RIACS website. At the top, there is a dark blue header bar with white text and icons. The header includes links for "RESEARCH TEAM AND PUBLICATIONS" (which is highlighted with a red border), "FEYNMAN ACADEMY INTERNSHIP PROGRAM", "RIACS" (with a small gear icon), "QUANTUM INFORMATION SCIENCE RESOURCES", and "NISQ COMPUTING NEWSLETTER". Below the header is a large banner with a dark background featuring binary code and glowing geometric shapes. The text "QUANTUM COMPUTING" is prominently displayed in the center of the banner. A white callout box contains text about RIACS's history and mission. Below the banner, there are sections for "Funding" (with logos for NASA, AFRL, NSF, USRA, and DARPA) and "News" (with a link to a "Best Paper Award MDPI Algorithms Journal").

RESEARCH TEAM AND PUBLICATIONS

FEYNMAN ACADEMY
INTERNSHIP PROGRAM

RIACS

QUANTUM INFORMATION
SCIENCE RESOURCES

NISQ COMPUTING
NEWSLETTER

QUANTUM COMPUTING

Since its inception in June 1983, RIACS has conducted basic and applied research in computer science for the nation's aeronautics and space-related missions and programs. In 2012, USRA partnered with NASA and Google to found the Quantum Artificial Intelligence Laboratory (QuAIL): the space agency's hub to evaluate the near term impact of quantum technologies.

The mission of RIACS quantum computing team is to advance the industry and the body of knowledge in quantum information related sciences, and to continue to provide to its partners the most qualified technical support to address hard challenges in applied computer science.

Funding

NASA AFRL NSF USRA DARPA

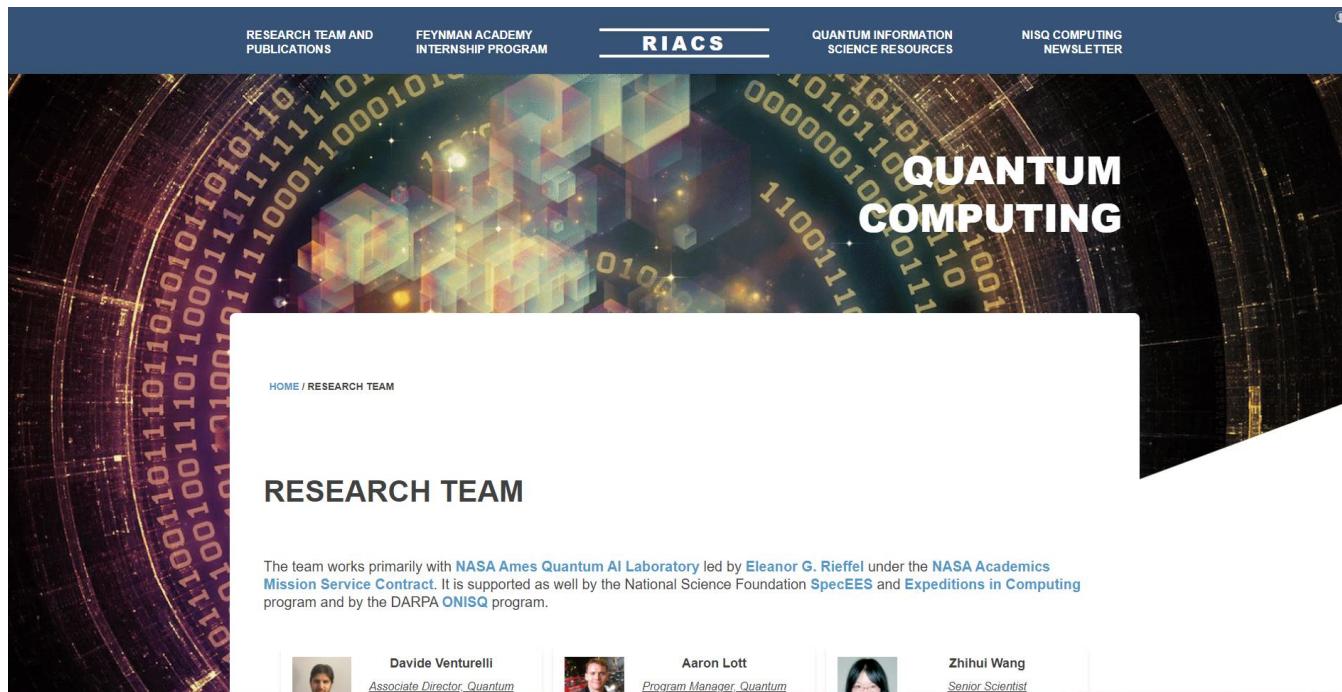
News

NEWS

Best Paper Award MDPI Algorithms Journal

Extra: Go to “Research Team and Publications”

Accessing USRA resources



Scroll down to
Quantum Integer Programming (QuIP) 47-779:
Lecture Notes

Accessing USRA resources

[arXiv preprint arXiv:2103.07036, 2021-03-12](#) Jeffrey Marshall, Gianni Mossi, Eleanor G Rieffel

Quantum-accelerated constraint programming

[arXiv preprint arXiv:2103.04502, 2021-03-08](#) Kyle EC Booth, Bryan OGorman, Jeffrey Marshall, Stuart Hadfield, Eleanor Rieffel

Entanglement across separate silicon dies in a modular superconducting qubit device

[arXiv preprint arXiv:2102.13293, 2021-02-26](#) Alysson Gold, JP Paquette, Anna Stockklauser, Matthew J Reagor, M Sohaib Alam, Andrew Bestwick, Nicolas Didier, Ani Nersisyan, Feyza Oruc, Armin Razavi et al.

Quantum Annealing for Large MIMO Downlink Vector Perturbation Precoding

[arXiv preprint arXiv:2102.12540, 2021-02-24](#) Srikar Kasi, Abhishek Kumar Singh, Davide Venturelli, Kyle Jameson

Information scrambling in computationally complex quantum circuits

[arXiv preprint arXiv:2101.08870, 2021-01-21](#) Xiao Mi, Pedram Roushan, Chris Quintana, Salvatore Mandra, Jeffrey Marshall, Charles Neill, Frank Arute, Kunal Arya, Juan Atalaya, Ryan Babbush et al.

Quantum Integer Programming (QuIP) 47-779: Lecture Notes

[arXiv preprint arXiv:2012.11382, 2020-12-17](#) David E Bernal, Sridhar Tayur, Davide Venturelli

Quantum annealing speedup of embedded problems via suppression of Griffiths singularities

[Physical Review B, 2020-12-10](#) Sergey Knysh, Eugeniu Plamadeala, Davide Venturelli

Classical symmetries and QAOA

[arXiv preprint arXiv:2012.04713, 2020-12-08](#) Ruslan Shaydulin, Stuart Hadfield, Tad Hogg, Ilya Safro

Quantum algorithms with local particle number conservation: noise effects and error correction

[arXiv preprint arXiv:2011.06873, 2020-11-13](#) Michael Streif, Martin Leib, Filip Wudarski, Eleanor Rieffel, Zhihui Wang

Augmented fidelities for single-qubit gates

[Physical Review A, 2020-11-12](#) Filip Wudarski, Jeffrey Marshall, Andre Petukhov, Eleanor Rieffel

Click on

[Quantum Integer Programming \(QuIP\) 47-779: Lecture Notes](#)

Accessing USRA resources

Cornell University

arXiv.org > quant-ph > arXiv.2012.11382

We gratefully acknowledge support from the Simons Foundation and member institutions.

Quantum Physics

(Submitted on 17 Dec 2020 (v1), last revised 11 Jan 2021 (this version, v2))

Quantum Integer Programming (QuIP) 47-779: Lecture Notes

David E. Bernal, Sridhar Tayur, Davide Venturelli

This lecture series on Quantum Integer Programming (QuIP) – created by Professor Sridhar Tayur, David E. Bernal, and Dr. Davide Venturelli, a collaboration between CMU and USRA, with the support from Amazon Braket during Fall 2020 – is intended for students and researchers interested in Integer Programming and the potential of near term quantum and quantum-inspired computing in solving optimization problems. Originally created for Tepper School of Business course 47-779 (at CMU), these were also used for the course ID5840 (at IIT-Madras, by Professors Anil Prabhakar and Prabha Mandayam) whose students (listed at the beginning of each lecture) were scribes. Dr. Vilesh Siddhu, post-doc in CMU Quantum Computing Group, assisted during the lectures, student projects, and with proof-reading this scribe. Through these lectures one will learn to formulate a problem and map it to a Quadratic Unconstrained Binary Optimization (QUBO) problem, understand various mapping and techniques like the Ising model, Graver Augmented Multiseed Algorithm (GAMA), Simulated or Quantum Annealing and QAOA, and ideas on how to solve these Integer problems using these quantum and classical methods.

Comments: The course website (with lecture videos and Google Colab notebooks): this https URL.
 Subjects: Quantum Physics [quant-ph]
 Cite as: arXiv.2012.11382 [quant-ph] (or arXiv.2012.11382v2 [quant-ph] for this version)

Submission history

From: David E. Bernal Neira [view email]
 [v1] Thu, 17 Dec 2020 19:56:06 UTC (4,180 KB)
 [v2] Mon, 11 Jan 2021 21:29:49 UTC (4,180 KB)

Bibliographic Tools Code & Data Related

Bibliographic and Citation Tools

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- Litmaps (What is Litmaps?)
- scite Smart Citations (What are Smart Citations?)

Quantum Integer Programming (QuIP) 47-779: Lecture Notes
 David E. Bernal, Sridhar Tayur, Davide Venturelli
 Fall 2020

Abstract

This lecture series on Quantum Integer Programming (QuIP) – created by Professor Sridhar Tayur, David E. Bernal and Dr. Davide Venturelli, a collaboration between CMU and USRA, with the support from Amazon Braket during Fall 2020 – is intended for students and researchers interested in Integer Programming and the potential of near term quantum and quantum-inspired computing in solving optimization problems. Originally created for Tepper School of Business course 47-779 (at CMU), these were also used for the course ID5840 (at IIT-Madras, by Professors Anil Prabhakar and Prabha Mandayam) whose students (listed at the beginning of each lecture) were scribes. Dr. Vilesh Siddhu, post-doc in CMU Quantum Computing Group, assisted during the lectures, student projects and with proof-reading this scribe. Through these lectures one will learn to formulate a problem and map it to a Quadratic Unconstrained Binary Optimization (QUBO) problem, understand various mapping and techniques like the Ising model, Graver Augmented Multiseed Algorithm (GAMA), Simulated or Quantum Annealing and QAOA, and ideas on how to solve these Integer problems using these quantum and classical methods.

The course website (with lecture videos and colab notebooks): <https://bernalde.github.io/QuIP/>

Keywords: Ising model, Integer Programming, Computational Algebraic Geometry, Graver Basis, Quantum Annealing, Simulated Annealing, Combinatorial Optimization, Graph coloring, discrete nonlinear optimization.

arXiv:2012.11382v2 [quant-ph] 11 Jan 2021

You will see the arXiv preprint with the scribed notes from last year Quantum Integer Programming.