

# Real-ESSI Simulator

## Cloud Computing Manual

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<http://real-essi.us/>

This document is an excerpt from: <http://sokocalo.engr.ucdavis.edu/~jeremic/LectureNotes/>

please use google-chrome to view this PDF so that hyperlinks work



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# Chapter 1

# Cloud Computing

(2017-2018-)

(In collaboration with Dr. Yuan Feng and Dr. Han Yang)

## 1.1 Chapter Summary and Highlights

Described in this chapter are details of accessing and using Real-ESSI Simulator using remote computers, the so called "cloud" computational resources. Current focus is on using Amazon Web Services (AWS) computers.

## 1.2 Real-ESSI Cloud Computing Overview

Cloud computing refers to the accessing and computing over the Internet rather than on local computers. Cloud computing is a model for enabling on-demand access to a shared pool of configurable computing resources, which can be setup and released rapidly.<sup>1</sup>

Using Real-ESSI Cloud Service, users can get computing instances on demand without requiring a lot of maintenance and financial resources a common, local parallel computer, cluster would require. In addition, users do not need to go through the installation of the dependent libraries, source-code compilation and the installation of other related software, for example preprocessing and post-processing environment. The complete Real-ESSI Simulator system is pre-configured and built within the image such that Real-ESSI Simulator system is portable over the cloud. A stable, release version of Real-ESSI is built and can be used anywhere and anytime.

There are two ways to obtain a Real-ESSI image on Amazon Web Services (AWS):

- Obtain a Real-ESSI private image from [Prof. Boris Jeremić](#), see Section [1.3.1](#) on page [7](#).
- Use a public image of Real-ESSI on AWS marketplace, as described in Section [1.3.2](#) on page [19](#).

After a Real-ESSI image is launched, a Real-ESSI EC2 instance is generated on AWS. The instance can be accessed through a X2GO client. The procedures are written in Section [1.4](#) on page [19](#).

When the simulation on the Real-ESSi instance is finished and all the output result files are fetched, remember to terminate the running instance so that AWS would not keep charging you. Section [1.5](#) on page [22](#) describes how to terminate a running Real-ESSI instance. See Section [1.8](#) on page [25](#) for more information about the cost of AWS cloud computing services.

### 1.2.1 Real-ESSI Cloud Service Content

One image is built for a single-machine setup, which contains

- Ubuntu 16.04 LTS Desktop and X2GO Server
- Real-ESSI sequential program

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<sup>1</sup>This is an excerpt from [Jeremić et al. \(1989-2025\)](#)

- Real-ESSI parallel program
- Real-ESSI 3C seismic motion developments (SW4)
- Real-ESSI pre-processing (gmESSI)
- Real-ESSI post-processing (PVESSIRReader)
- Real-ESSI Editor, Sublime plug-ins
- Real-ESSI Documentation
- Real-ESSI Examples

## 1.3 Launch Real-ESSI Instance on AWS

A Real-ESSI instance can be launched either from the private image with authorization of Prof. Boris Jeremić or from the public image on AWS market place.

### 1.3.1 Launch Real-ESSI Instance from AWS Private Images

Follow the steps below to launch instances from Real-ESSI Private Image.

1. Create an AWS account.

AWS is the most widely used cloud service provider. If you do not have one, creating an AWS account is easy. You can create an AWS account through their website <https://aws.amazon.com/>. After you login, you can see the services on AWS Console Home as follows.

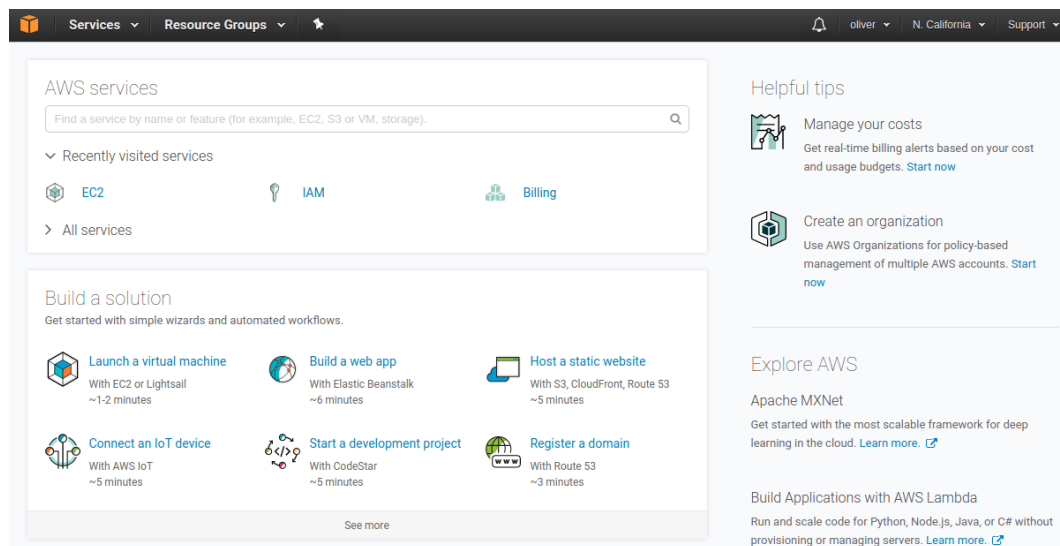


Figure 1.1: AWS Console Home.

## 2. Request the Real-ESSI image.

Real-ESSI image is currently a private Amazon Machine Images (AMI). After you get the 12-digit AWS account ID, email the AWS account ID to [Prof. Boris Jeremić](#) to obtain the Real-ESSI image. From AWS Console Home, go to Services → EC2

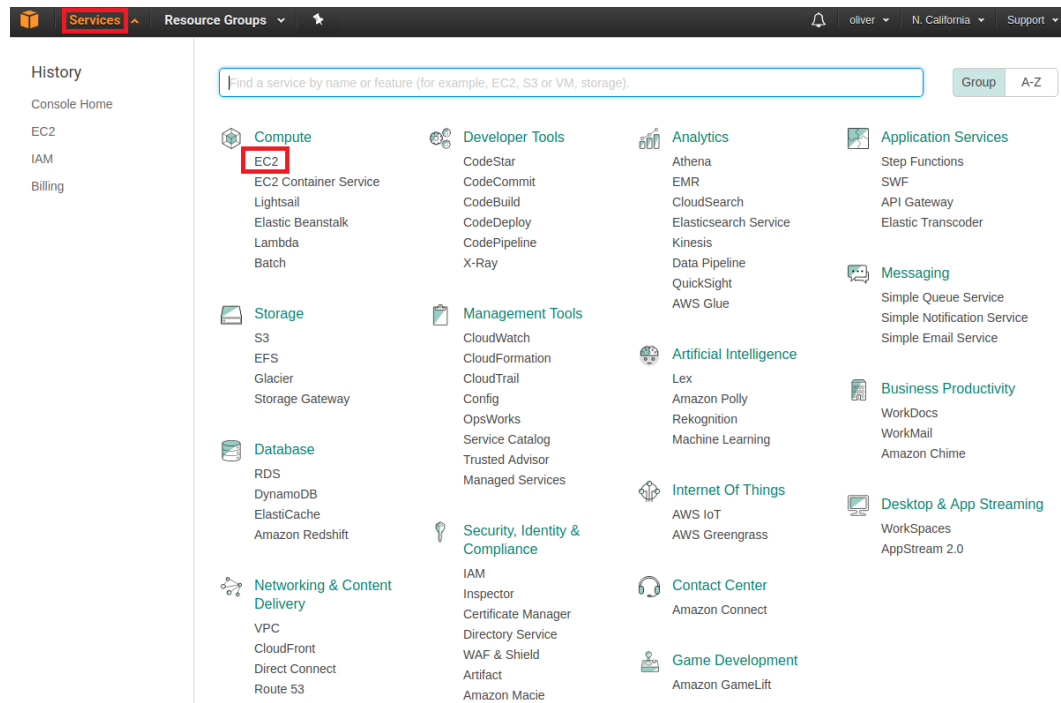


Figure 1.2: AWS Services.



From EC2 Dashboard, go to AMIs to check the Real-ESSI image.

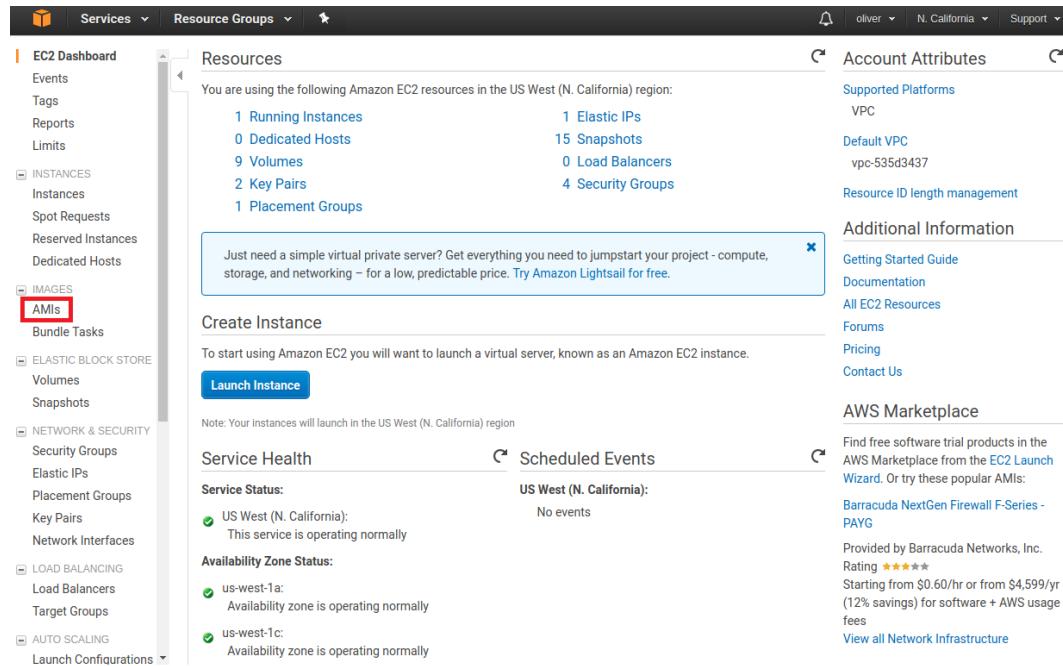


Figure 1.3: AWS EC2 Dashboard AMIs.

If users cannot find the Real-ESSI image, please make sure you are in the same AWS region with Prof. Boris Jeremić, the region is shown in the top-right corner on EC2 dashboard. The current Real-ESSI AMIs region are in both North California and Oregon.

3. Launch the Real-ESSI image.

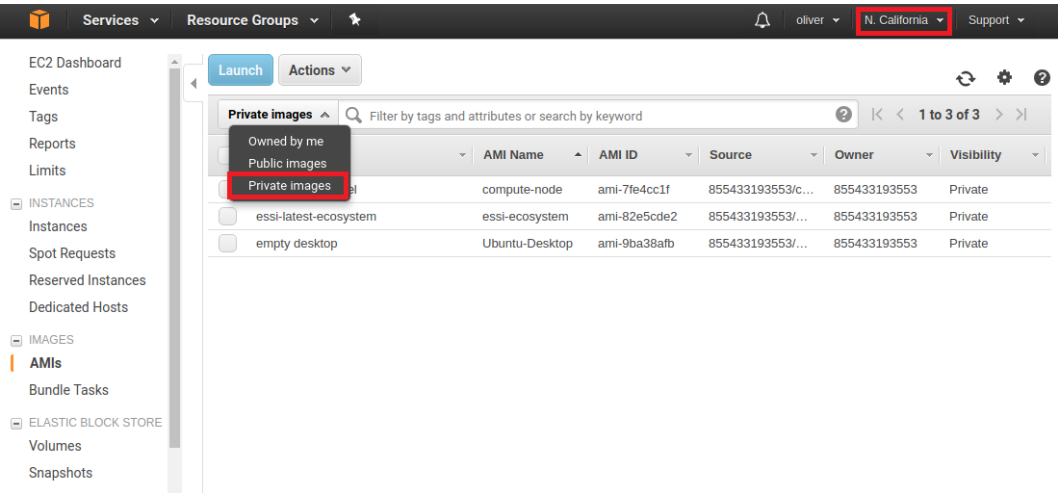


Figure 1.4: AWS EC2 Private AMIs.

Follow the steps below to launch instances from the Real-ESSI image.

(a) Choose AMI.

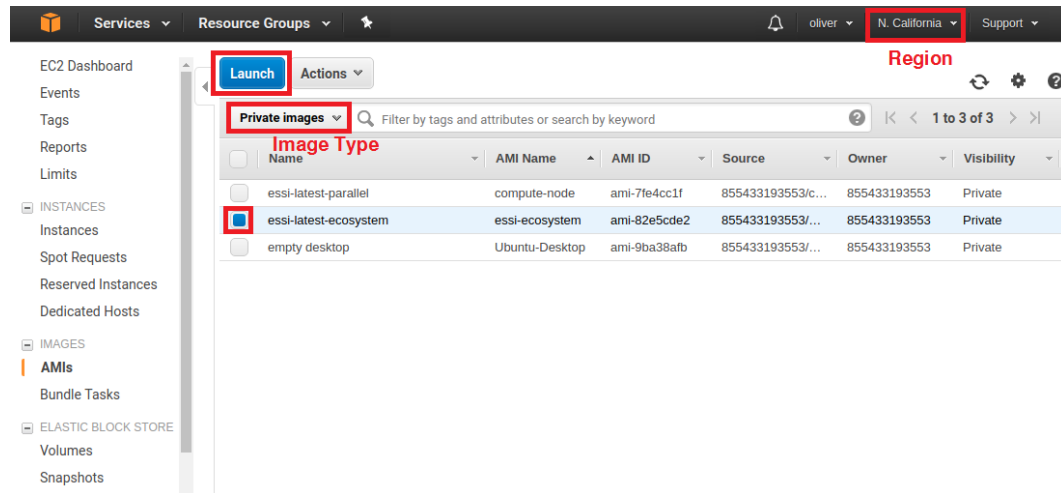


Figure 1.5: EC2 Launch Steps: Choose AMI.

## (b) Choose Instance Type

From AMIs, users can launch any number and type of instances and choose the desired EC2 configurations. In order to have the best experiences, the compute-optimized instances (C4, C5 as the latest one, as of early 2019) are recommended.

**Step 2: Choose an Instance Type**

Amazon EC2 provides a wide selection of instance types optimized to fit different use cases. Instances are virtual servers that can run applications. They have varying combinations of CPU, memory, storage, and networking capacity, and give you the flexibility to choose the appropriate mix of resources for your applications. [Learn more](#) about instance types and how they can meet your computing needs.

Filter by: **All instance types** **Current generation** [Show/Hide Columns](#)

Currently selected: t2.micro (Variable ECUs, 1 vCPUs, 2.5 GHz, Intel Xeon Family, 1 GiB memory, EBS only)

	Family	Type	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance	IPv6 Support
<input type="checkbox"/>	General purpose	t2.nano	1	0.5	EBS only	-	Low to Moderate	Yes
<input checked="" type="checkbox"/>	General purpose	t2.micro <small>Free tier eligible</small>	1	1	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.small	1	2	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.medium	2	4	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.large	2	8	EBS only	-	Low to Moderate	Yes
<input type="checkbox"/>	General purpose	t2.xlarge	4	16	EBS only	-	Moderate	Yes
<input type="checkbox"/>	General purpose	t2.2xlarge	8	32	EBS only	-	Moderate	Yes
<input type="checkbox"/>	General purpose	m4.large	2	8	EBS only	Yes	Moderate	Yes

[Cancel](#) [Previous](#) [Review and Launch](#) [Next: Configure Instance Details](#)

Figure 1.6: EC2 Launch Steps: Choose Instance Type.

## (c) Configure Instance

The screenshot shows the 'Configure Instance Details' step in the AWS Management Console. The top navigation bar includes 'Services', 'Resource Groups', and a user profile 'oliver' in 'N. California'. The breadcrumb trail shows seven steps: 1. Choose AMI, 2. Choose Instance Type, 3. Configure Instance (active), 4. Add Storage, 5. Add Tags, 6. Configure Security Group, and 7. Review.

**Step 3: Configure Instance Details**  
Configure the instance to suit your requirements. You can launch multiple instances from the same AMI, request Spot instances to take advantage of the lower pricing, assign an access management role to the instance, and more.

**Number of instances** (i) 1 [Launch into Auto Scaling Group](#) (i)

**Purchasing option** (i) ☐ Request Spot instances

**Network** (i) vpc-535d3437 (default) [Create new VPC](#)

**Subnet** (i) No preference (default subnet in any Availability Zone) [Create new subnet](#)

**Auto-assign Public IP** (i) Use subnet setting (Enable)

**IAM role** (i) None [Create new IAM role](#)

**Shutdown behavior** (i) Stop

**Enable termination protection** (i) ☐ Protect against accidental termination

**Monitoring** (i) ☐ Enable CloudWatch detailed monitoring  
[Additional charges apply.](#)

**Tenancy** (i) Shared - Run a shared hardware instance  
[Additional charges will apply for dedicated tenancy.](#)

► **Advanced Details**

Buttons at the bottom: Cancel, Previous, Review and Launch, and Next: Add Storage (highlighted with a red box).

Figure 1.7: EC2 Launch Steps: Configure Instance.

(d) Add Storage

ServicesResource Groups

oliverN. CaliforniaSupport

1. Choose AMI2. Choose Instance Type3. Configure Instance4. Add Storage5. Add Tags6. Configure Security Group7. Review

Step 4: Add Storage

Your instance will be launched with the following storage device settings. You can attach additional EBS volumes and instance store volumes to your instance, or edit the settings of the root volume. You can also attach additional EBS volumes after launching an instance, but not instance store volumes. [Learn more](#) about storage options in Amazon EC2.

Volume Type	Device	Snapshot	Size (GiB)	Volume Type	IOPS	Throughput (MB/s)	Delete on Termination	Encrypted
Root	/dev/sda1	snap-083ee962668b0be97	30	General Purpose S3	100 / 3000	N/A	<input checked="" type="checkbox"/>	Not Encrypted

Add New Volume

Free tier eligible customers can get up to 30 GB of EBS General Purpose (SSD) or Magnetic storage. [Learn more](#) about free usage tier eligibility and usage restrictions.

CancelPreviousReview and LaunchNext: Add Tags

Figure 1.8: EC2 Launch Steps: Add Storage.

## (e) Add Tags

The screenshot shows the 'Add Tags' step in the AWS Management Console. At the top, a navigation bar includes the AWS logo, 'Services', 'Resource Groups', and user information. Below this is a progress bar with seven steps: '1. Choose AMI', '2. Choose Instance Type', '3. Configure Instance', '4. Add Storage', '5. Add Tags' (highlighted), '6. Configure Security Group', and '7. Review'. The main heading is 'Step 5: Add Tags', followed by explanatory text about tags and a link to 'Learn more'. Below the text is a table with two columns: 'Key' (127 characters maximum) and 'Value' (255 characters maximum). To the right of the table are tabs for 'Instances' and 'Volumes'. A message states 'This resource currently has no tags'. Below this, instructions prompt the user to 'Choose the Add tag button or click to add a Name tag' and to ensure their IAM policy includes permissions to create tags. An 'Add Tag' button is present with a note '(Up to 50 tags maximum)'. At the bottom right, a navigation bar contains four buttons: 'Cancel', 'Previous', 'Review and Launch', and 'Next: Configure Security Group' (which is highlighted with a red border).

Key (127 characters maximum)	Value (255 characters maximum)	Instances	Volumes
This resource currently has no tags			

Choose the Add tag button or [click to add a Name tag](#).  
Make sure your [IAM policy](#) includes permissions to create tags.

**Add Tag** (Up to 50 tags maximum)

[Cancel](#) [Previous](#) [Review and Launch](#) [Next: Configure Security Group](#)

Figure 1.9: EC2 Launch Steps: Add Tags.

## (f) Configure Security Group.

Please keep the default Security Group setting.

## (g) Review

You may be asked to create a key-pair for later access of the instance you created. The key-pair can be reused later if you created other instances. Besides, the key-pair is portable across other machines. Last but not least, the key-pair cannot be recreated after you launch the instance, so please make sure you save the key-pair in a safe place.

**Step 7: Review Instance Launch**

**Improve your instances' security. Your security group, vnc-server, is open to the world.**  
 Your instances may be accessible from any IP address. We recommend that you update your security group rules to allow access from known IP addresses only.  
 You can also open additional ports in your security group to facilitate access to the application or service you're running, e.g., HTTP (80) for web servers.  
[Edit security groups](#)

**AMI Details** [Edit AMI](#)

**essi-ecosystem - ami-82e5cde2**  
 ESSI, preprocessing, postprocessing, Use shift1to7 for VNC server  
 Root Device Type: ebs Virtualization type: hvm

**Instance Type** [Edit instance type](#)

Instance Type	ECUs	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance
t2.micro	Variable	1	1	EBS only	-	Low to Moderate

**Security Groups** [Edit security groups](#)

Security Group ID	Name	Description
sg-adcf35cb	vnc-server	open ports for vnc-viewer

All selected security groups inbound rules

[Cancel](#) [Previous](#) [Launch](#)

Figure 1.10: EC2 Launch Steps: Review.



#### 4. Check the launched instances

After the launch, you can view the running instance through EC2 Dashboard → Instances

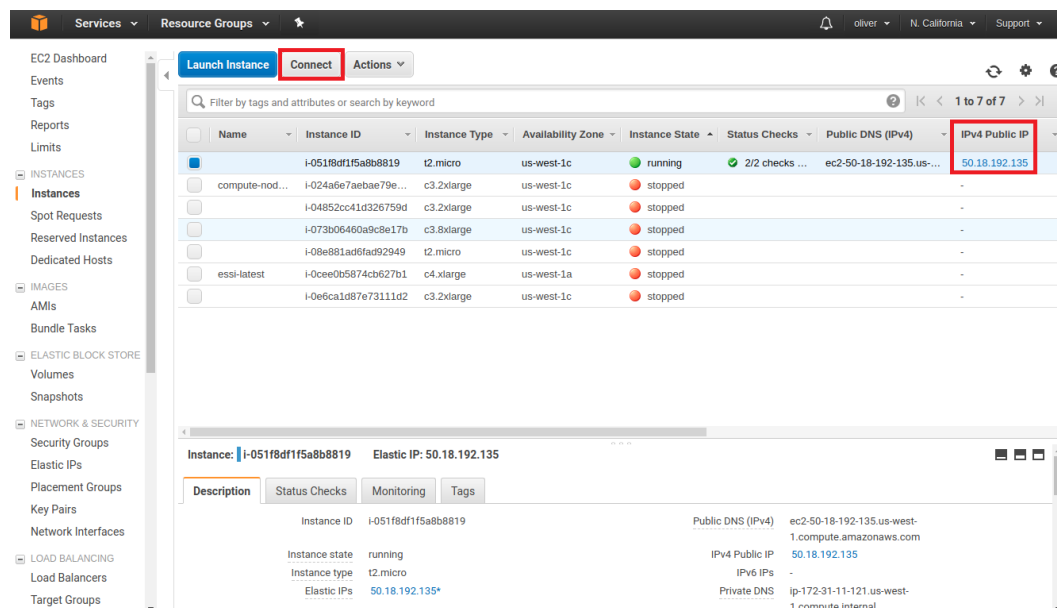


Figure 1.11: EC2 Running Instances.

You can login to your instances either by `ssh` or by using X2GO client 1.4. Please note that every time when you restart the instances, the public IP address will change.

## 5. Fix Public IP Address (Optional)

The public IP address of Real-ESSI instances change for each reboot. If users want to have a fixed public IP address for every login, users can allocate one elastic IP address and associate the IP address to a Real-ESSI instance such that users can have a fixed public IP address for each login.

## 6. Attach more Storage (Optional)

The Real-ESSI Image holds 30GB Hard disk and already uses 15GB. In the case of a real large simulations, this size hard drive might not be enough for the full output. Users can attach more storage through elastic block store.

### 1.3.2 Launch Real-ESSI Instance from AWS Market Place

This section gives a quick start guide for using Real-ESSI on AWS market place.

Real-ESSI Simulator system (pre processing, main Real-ESSI program, post processing) is available on Amazon Web Services MarketPlace. Point your web browser to the [Amazon Web Services Market Place](#), and search for "Real ESSI", "Real-ESSI" or "MS ESSI".

In summary, a quick guide to launching an instance from AWS Market Place is:

- Go to the ESSI Cloud Product Page.
- Click **Continue** to go to Launch ESSI from the Cloud.
- Click **Manual Launch** (use **1-Click Launch**, if comfortable with settings).
- Click **Launch from the EC2 Console** for your **preferred region**.
- Select your **preferred instance** from the table, e.g. t2.micro.
- Click **Review and Launch**.

## 1.4 Connect to Real-ESSI Instance on AWS

### 1.4.1 Install X2GO Client

Before connecting to the Real-ESSI cloud, users should install the client-side of X2GO. X2Go is a remote desktop software that can visualize the launched Real-ESSI instance. Installation of X2GO for different operating systems is fairly straightforward, and users can find installation instructions on their own or follow installation instructions below.

#### Installing X2GO client on Ubuntu Linux

User can directly install X2GO client by using debian install utility, to install x2goclient.

#### Installing X2GO client on Apple Mac

Users can download the package through this link: [http://code.x2go.org/releases/X2GoClient\\_latest\\_macosx\\_10\\_9.dmg](http://code.x2go.org/releases/X2GoClient_latest_macosx_10_9.dmg).

### **Installing X2GO client on Windows**

Users can download the package through this link: [http://code.x2go.org/releases/X2GoClient\\_latest\\_mswin32-setup.exe](http://code.x2go.org/releases/X2GoClient_latest_mswin32-setup.exe).

### **Installing X2GO client on other operating systems**

If you are using a different operating system, please refer to X2GO website for the installation. The X2GO website for client installation is <https://wiki.x2go.org/doku.php/download:start>

### 1.4.2 Configure the Client-Side of X2GO

For all operating systems, users will see the same session when they open the x2goclient new-session, as shown in Fig. 1.12.

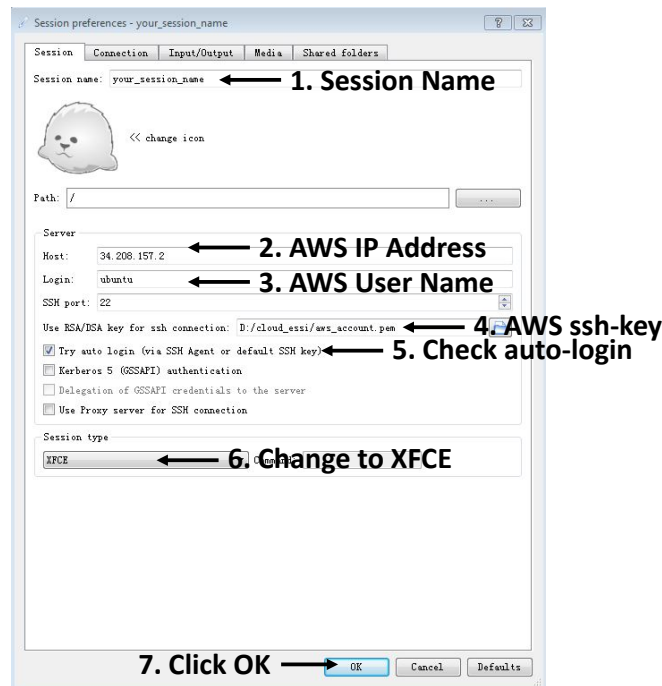


Figure 1.12: Configuration of X2GO client.

1. Users can name their own session.
2. AWS IP address is to be copied from EC2 management console, from the description TAB of launched instance, at the bottom of the page. This is IPv4 Public IP... it goes into Host: ...
3. AWS User Name is "ubuntu".
4. AWS ssh-key is the one saved from before, in .ssh directory
5. Please check the auto-login.
6. Please change the session type to XFCE.
7. Click OK to finish the configuration.

In addition to the Desktop login, users can also use ssh to login the Real-ESSI Terminal.

```
1 chmod 400 your_ssh_key.pem
2 ssh -i your_ssh_key.pem ubuntu@your_AWS_public_IP_address
```

### 1.4.3 Connect to the Launched Instance

Click the configured session to connect to the ESSI instance. You should see a virtual desktop pop up on your local machine, as shown in Fig. 1.13. Now you have successfully connected to the Real-ESSI Simulator instance on AWS. You can now use Real-ESSI Simulator within the virtual desktop.

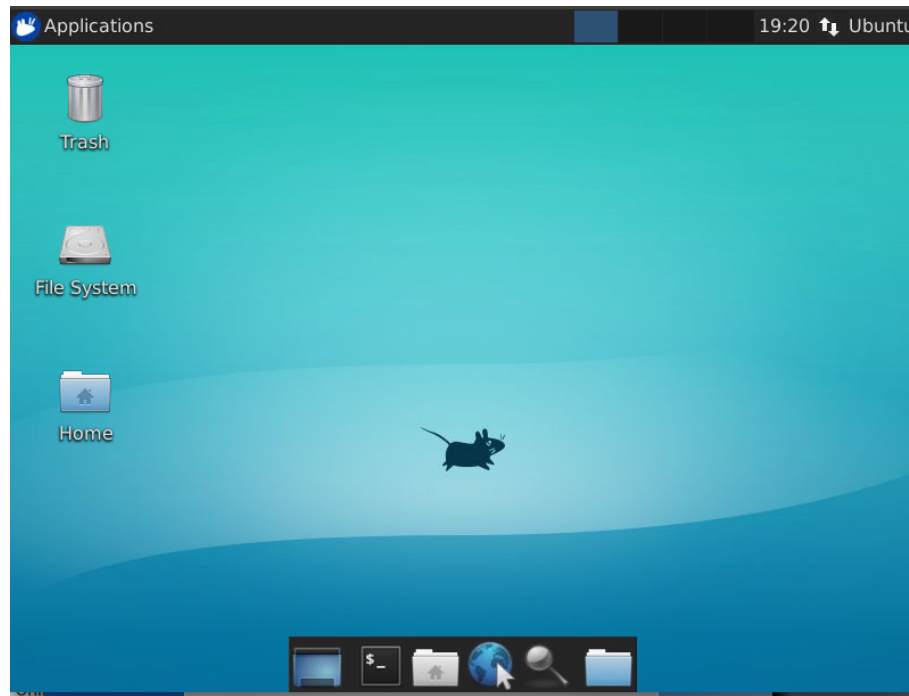


Figure 1.13: Connected to the already launched Real-ESSI instance.

## 1.5 Terminate Real-ESSI Instance on AWS

Once the Real-ESSI simulation on AWS is finished, the user can transfer output files to the local local computer, or leave them on AWS, preferably on cheap S3 storage Section 1.8 on page 25 provides detailed description of storage and transfer options and costs. **NOTE:** Users need to terminate the running Real -ESSI instance on AWS to avoid additional charges. The terminate operation is done on AWS console that is the same place where you launch the Real-ESSI instance. As shown Fig. 1.14, following steps are required:

1. Click 'Instances' from the sidebar to see all your running instances on AWS.
2. Choose the instance you want to terminate.
3. Click 'Actions'.
4. Click 'Instance State'

## 5. Click 'Terminate'

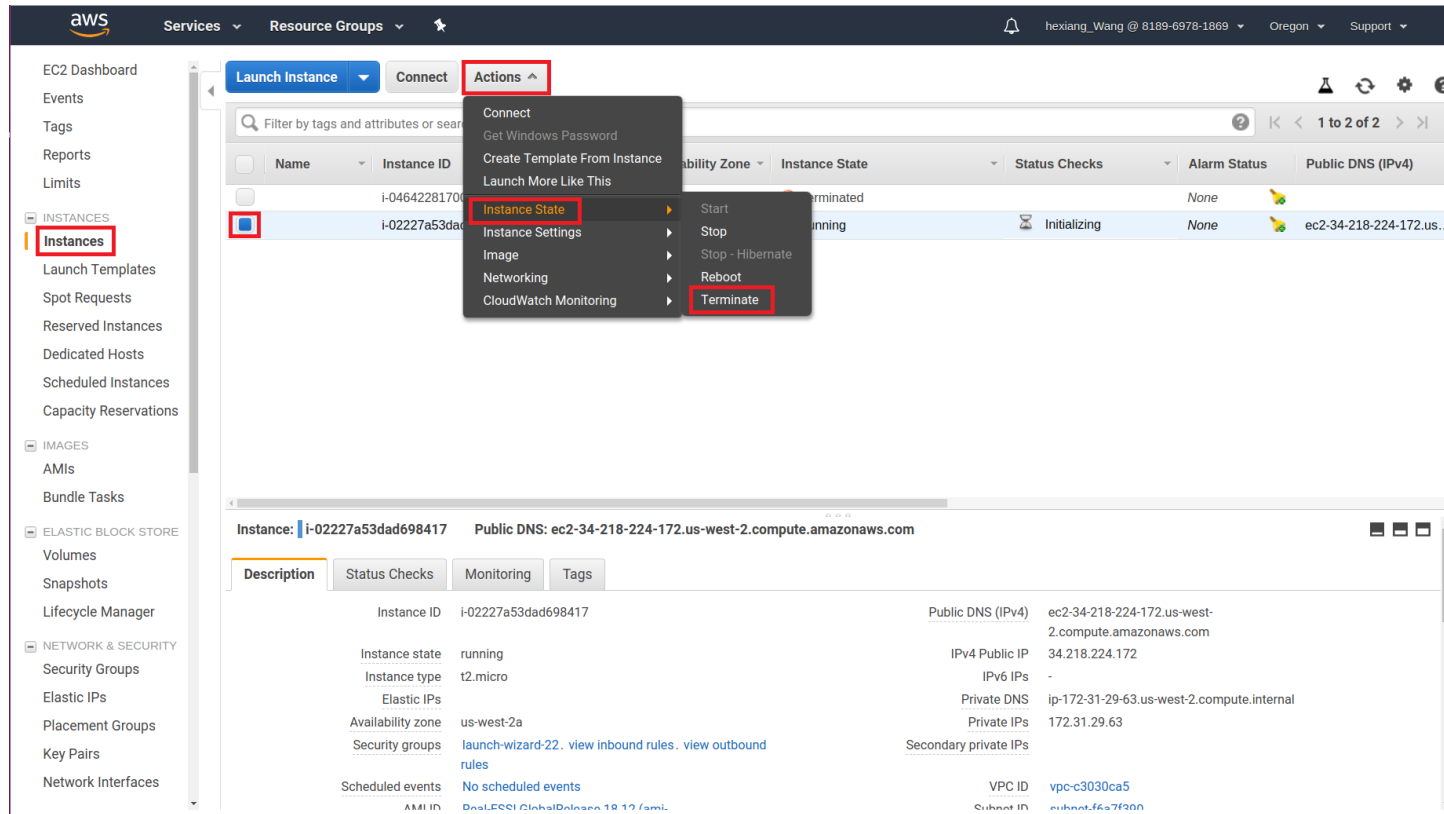


Figure 1.14: Terminate a Real-ESSI Simulator instance.

## 1.6 Adding Permission for Private Real-ESSI Image to User AWS Accounts

login to AWS

sign in to console

go to image in a region, say N, California

then go to EC2

go to AMIs on left side

select image to be shared

go to Actions

go to Modify Image Permissions and put user account number then click Add Permission and then Save...

## 1.7 Real-ESSI Instructional Videos Cloud Computing

This section presents few short instructional videos about how to use Real ESSI on Amazon Web Services (AWS) computers.

### 1.7.1 Installing X2GO for Windows

[Youtube instructional video.](#)

### 1.7.2 Installing X2GO for Macintosh

[Youtube instructional video.](#)

### 1.7.3 Installing X2GO for Linux

[Youtube instructional video.](#)

### 1.7.4 Launch AWS Marketplace

[Youtube instructional video.](#)

### 1.7.5 Access Running Instance on AWS

[Youtube instructional video.](#)

### 1.7.6 Start Real-ESSI Program on AWS

[Youtube instructional video.](#)

### 1.7.7 Run Real-ESSI Example Model on AWS

[Youtube instructional video.](#)

### 1.7.8 Visualize Real-ESSI Example Model on AWS

[Youtube instructional video.](#)

### 1.7.9 Post-Process, Visualize Real-ESSI Results on AWS

[Youtube instructional video.](#)



## 1.8 Cost of AWS EC2

The cost breakdown for using Real-ESSI on AWS (EC2) is:

- **AWS computer cost**

There are 3 ways to pay for AWS computer cost (EC2 instances)

- **On-Demand instance**, offers a real, instant pay-per-use model. On-Demand instance is sold at a fixed price, and AWS computer availability is guaranteed (within the limits of the service-level agreement). **Running Real-ESSI On-Demand Instance:** User prepares simulation runs, and then can simulate problems at hand immediately.
- **Spot instance**, uses spare AWS computers that users can bid for. Prices for those spot instances fluctuate based on the supply and demand of available AWS computers. When a user makes a bid for a Spot instance, a spot instance is launched when the bid exceeds the current Spot market price, and continues until terminated by the user. The user is charged the Spot market price, not the bid price while the instance runs. Spot instances can offer substantial savings over On-Demand instances, as shown in the AWS Spot Bid Advisor. **Running Real-ESSI using Spot instance:** User can prepare simulation runs, and then bid on computer hardware and run simulations at later time, when cost is acceptable.
- **Reserved instance**, uses spare AWS computers during scheduled, later time as determined by AWS and reserved by the user. **Running Real-ESSI using Reserved Instance:** User prepares simulation runs, and then reserves AWS computer to simulate problem at hand at predetermined/reserved time.

- **AWS data storage cost**

Input data/files and output data/files are stored using:

- **Amazon Elastic Block Store (EBS)**, attached to a AWS computer (EC2 instance) during simulation run. Storage cost is charged by the size of storage in GB per month, pro-rated to the hour, until the storage is released. The cost of EBS is typically \$0.10 per GB per month. When running Real-ESSI program on AWS computer, the storage is used during simulation, while the data (input and output) is transferred out of the AWS computer, to other type of storage that is less expensive (the so called S3 storage, see below), or to user's desktop computer, before AWS computer/instance is terminated and storage released.
- **Amazon Simple Storage Service (S3)**, offers better value for longer term data storage. S3 pricing varies by region and frequency of access. Cost of S3 storage is typically between \$0.0125 are \$0.03 per GB per month.

- **Amazon Glacier**, provides storage at an even lower cost of \$0.007 per GB per month for data archiving.

- **AWS data transfer cost**

Data transfer charges are listed as part of the On-Demand EC2 pricing. Transfer is typically charged at \$0.09 per GB beyond the first 1GB of data and up to the first 1TB of a given month. After the first TB, price drops down.

- **Real-ESSI program cost**

Use of Real-ESSI for educational purposes is free. For commercial use of Real-ESSI, please contact Prof. Jeremić or one of the commercial companies that offer access to Real-ESSI on AWS.

### 1.8.1 Cost of Running Real-ESSI on AWS

#### Small Size Real-ESSI Example

**Imposed Motion** Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 5,000
- Number of Time Step: 210
- Running Time: 30 Second
- Disk Space: 25 MB.
- Recommended Machine: Free Instance Amazon EC2 t2.micro

The Real-ESSI input files for this example are available [HERE](#). The compressed package of input files is [HERE](#).

The Modeling parameters are listed below

- Elastic Material Properties
  - Mass density,  $\rho$ , 2000  $kg/m^3$
  - Shear wave velocity,  $V_s$ , 500  $m/s$
  - Young's modulus,  $E$ , 1.1 GPa
  - Poisson's ratio,  $\nu$ , 0.1

The thickness of the shell structure is 2 meters. The simulation model is shown below.

The simulation results:

The time series of simulation results is shown in Fig. [1.17](#).

The response spectrum of motion is shown in Fig. [1.18](#).

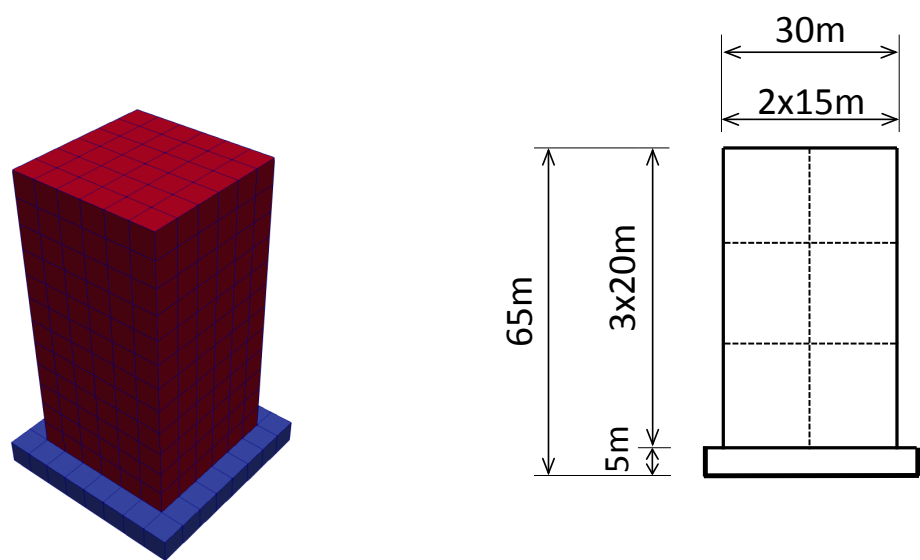


Figure 1.15: Simulation Model.

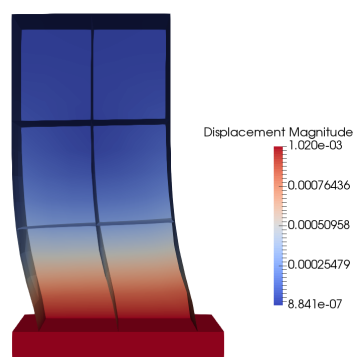


Figure 1.16: Simulation Results.

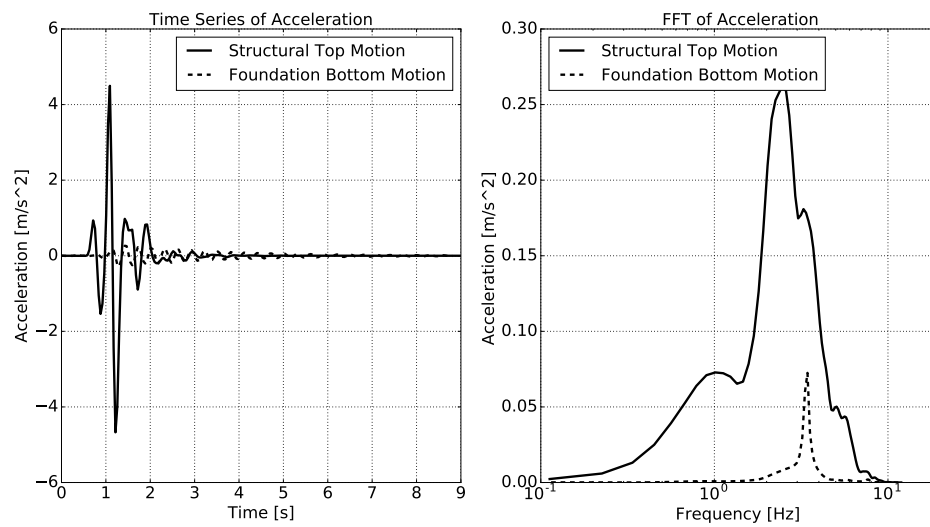


Figure 1.17: Simulation Results: Acceleration Time Series with 1C imposed motion.

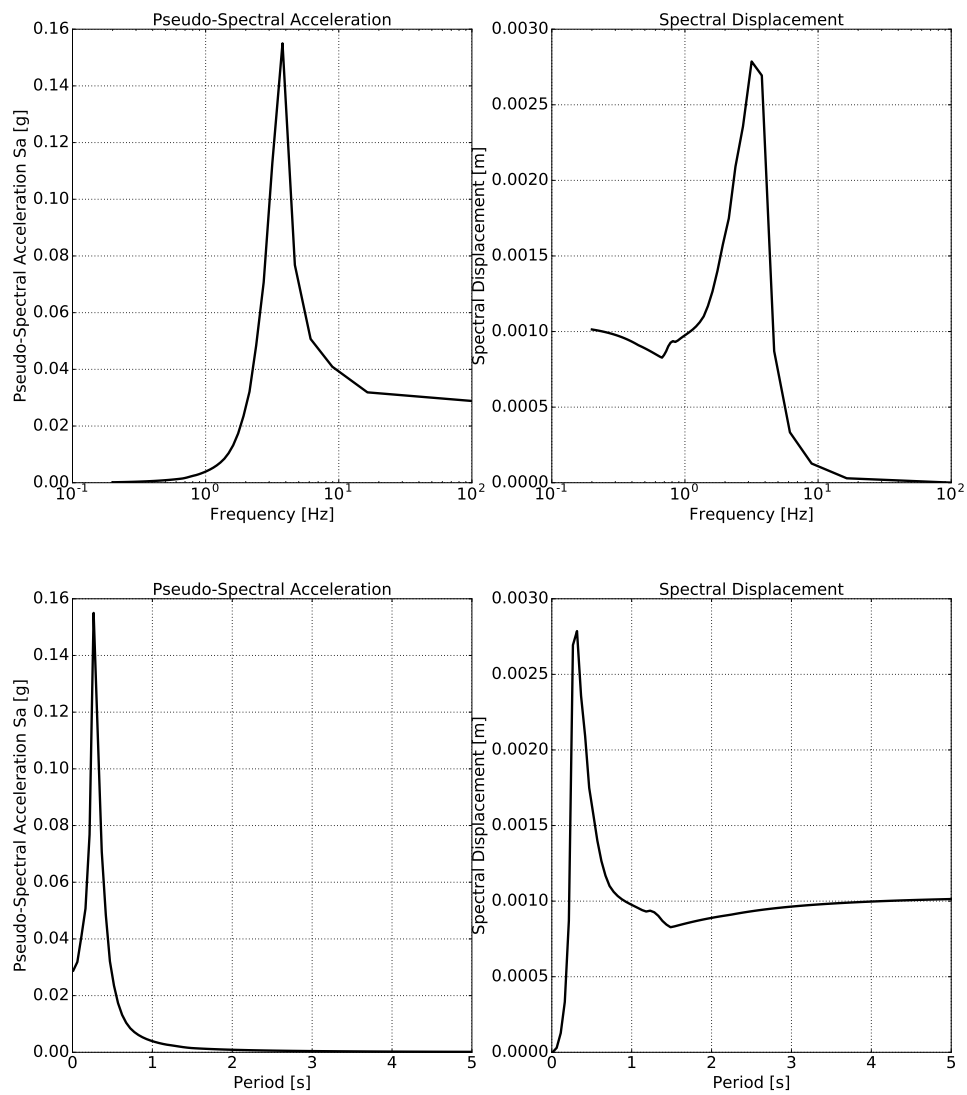


Figure 1.18: Simulation Results: Response Spectrum of Structure Top with 1C imposed motion.

**Eigen Analysis** Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 5,000
- Number of Eigenmodes: 10
- Running Time: 3 Second
- Disk Space: 25 MB.
- Recommended Machine: Free Instance Amazon EC2 t2.micro

The Real-ESSI input files for this example are available [HERE](#). The compressed package of input files is [HERE](#).

The thickness of the shell structure is 2 meters. The simulation model is shown below.

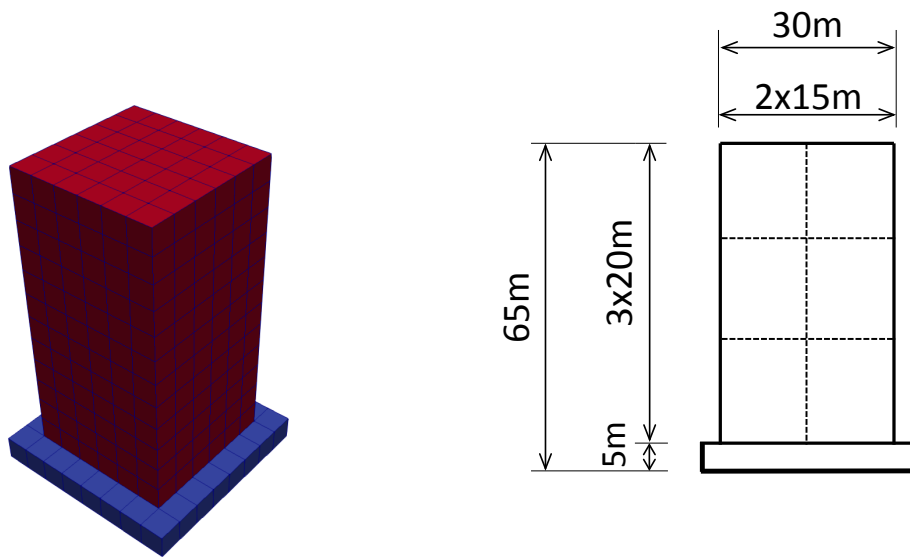


Figure 1.19: Simulation Model.

The eigen results:

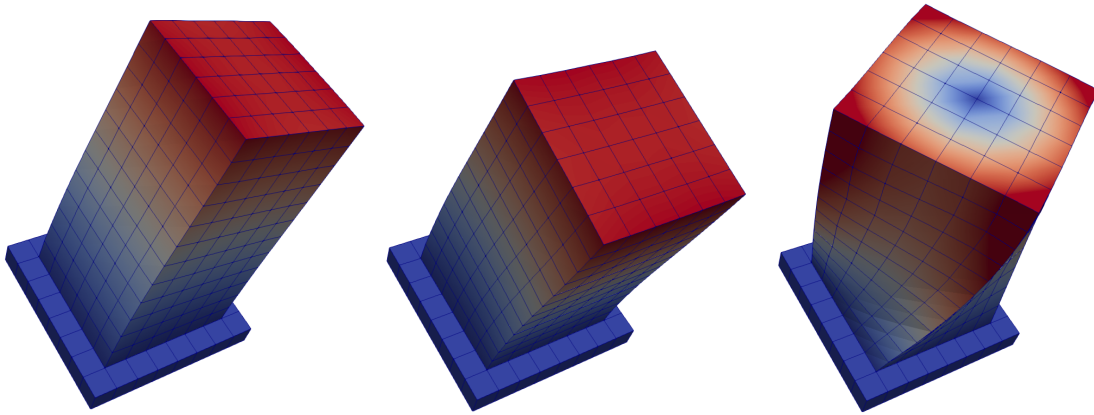


Figure 1.20: Eigen Results (Eigen Mode 1 to 3 from left to right).

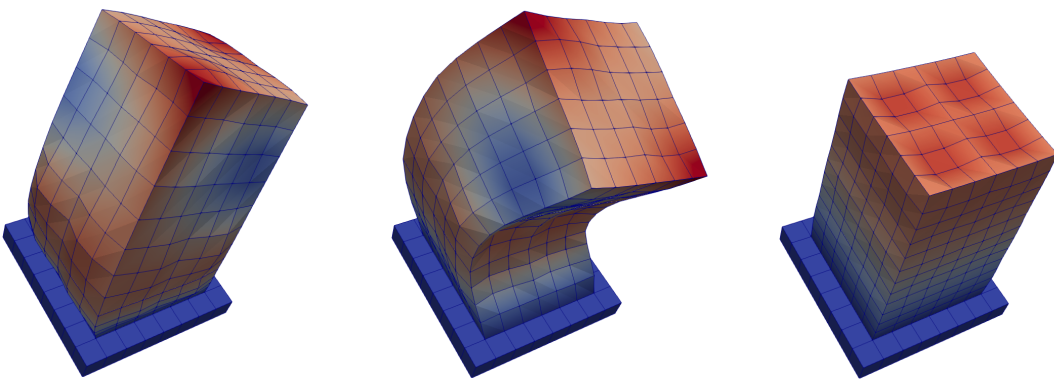


Figure 1.21: Eigen Results (Eigen Mode 4 to 6 from left to right).



## Medium Size Real-ESSI Example

**Elastic Material** The compressed package of input files is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 132,000
- Number of Time Steps: 210
- Running Time: 10 minutes
- Disk Space: 3GB
- Recommended Machine: Amazon EC2 c4.2xlarge instance 8 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time:  $\$0.398 * 10/60 = \$0.07$
  - For General Purpose (SSD) Storage:  $\$0.1 * 3 = \$0.3$  (monthly)
  - For S3 Storage:  $\$0.023 * 3 = \$0.069$  (monthly)

The Modeling parameters are listed below

- Elastic Material Properties
  - Mass density,  $\rho$ , 2000  $kg/m^3$
  - Shear wave velocity,  $V_s$ , 500  $m/s$
  - Young's modulus,  $E$ , 1.1 GPa
  - Poisson's ratio,  $\nu$ , 0.1

The illustration results of the simulation is shown in Fig. 1.23. It is noted that outside the DRM layer, there are no outgoing waves.

**von-Mises Armstrong-Frederick Material** The compressed package of input files is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 132,000
- Number of Time Steps: 210
- Running Time: 46 minutes

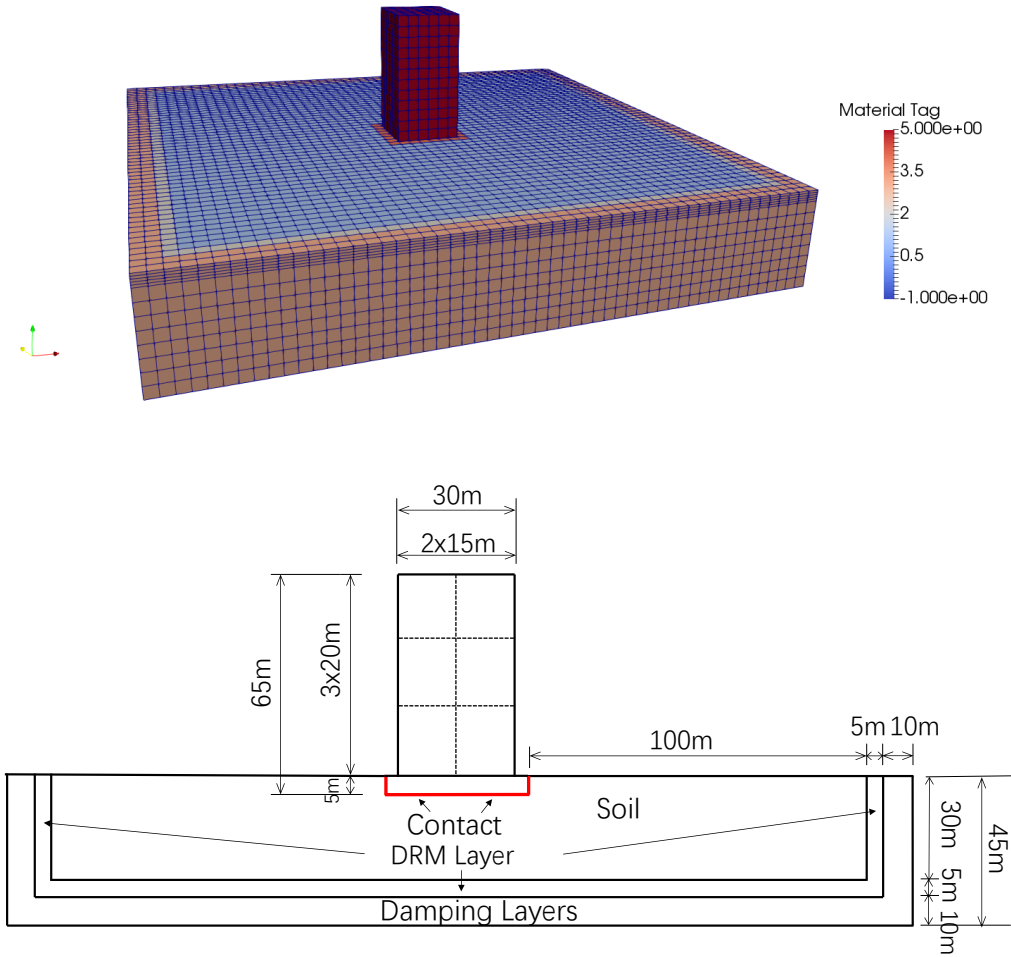


Figure 1.22: Simulation Model.

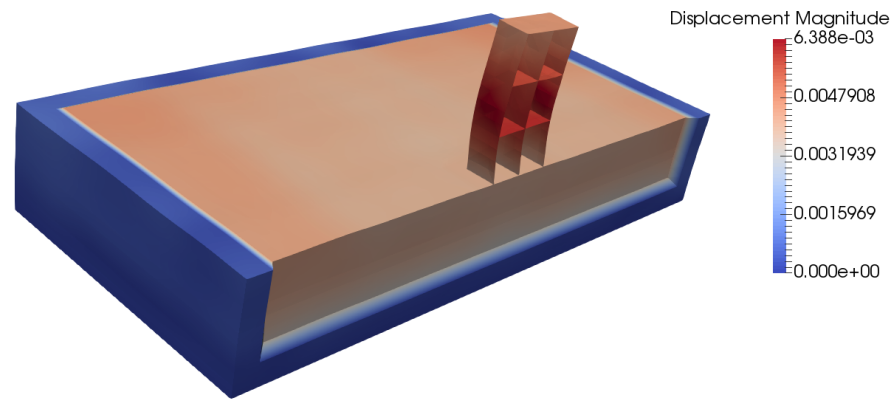


Figure 1.23: Simulation Model.

- Disk Space: 3GB
- Recommended Machine: Amazon EC2 c4.2xlarge instance 8 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time:  $\$0.398 * 46/60 = \$0.31$
  - For General Purpose (SSD) Storage:  $\$0.1 * 3 = \$0.3$  (monthly)
  - For S3 Storage:  $\$0.023 * 3 = \$0.069$  (monthly)

The Modeling parameters are listed below

- von-Mises nonlinear hardening material model
  - Mass density,  $\rho$ , 2000 kg/m<sup>3</sup>
  - Shear wave velocity,  $V_s$ , 500 m/s
  - Young's modulus,  $E$ , 1.1 GPa
  - Poisson's ratio,  $\nu$ , 0.1
  - von Mises radius,  $k$ , 60 kPa
  - Nonlinear kinematic hardening,  $H_a$ , 30 MPa
  - Nonlinear kinematic hardening,  $C_r$ , 60
  - Shear strength ( $\approx \sqrt{2/3} H_a/C_r$ ),  $S_u$ , 408 kPa
  - Isotropic hardening rate,  $K_{iso}$ , 0 Pa

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 46 minutes.

## Large Example

**Elastic Simulation** The Real-ESSI input files for this example are available [HERE](#). The compressed package of Real-ESSI input files for this example is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 210,000
- Number of Time Steps: 2065
- Running Time: 17 hours
- Disk Space: 45GB
- Recommended Machine: Amazon EC2 c4.8xlarge instance 36 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time:  $\$1.591 * 17 = \$27.05$
  - For General Purpose (SSD) Storage:  $\$0.1 * 45 = \$4.5$  (monthly)
  - For S3 Storage:  $\$0.023 * 45 = \$1.035$  (monthly)
  - For Network Bandwidth if transfer:  $\$0.09 * 45 = \$4.05$

**SIMULATION TIME:** With 32 cores on AWS EC2 c4.8xlarge instance, the running time for this example is 17 hours.

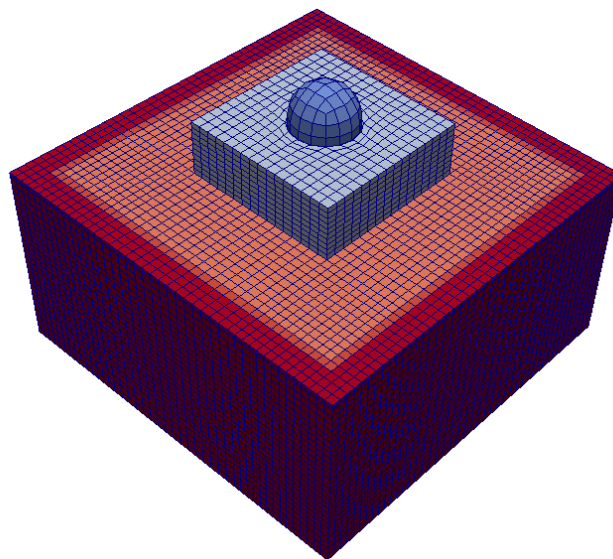


Figure 1.24: Simulation Model.

The Modeling parameters are listed below

- Soil
  - Unit weight,  $\gamma$ , 21.4 kPa
  - Shear velocity,  $V_s$ , 500 m/s
  - Young's modulus,  $E$ , 1.3 GPa
  - Poisson's ratio,  $\nu$ , 0.25
  - Shear strength,  $S_u$ , 650 kPa
  - von Mises radius,  $k$ , 60 kPa
  - kinematic hardening,  $H_a$ , 30 MPa
  - kinematic hardening,  $C_r$ , 25
- Structure
  - Unit weight,  $\gamma$ , 24 kPa
  - Young's modulus,  $E$ , 20 GPa
  - Poisson's ratio,  $\nu$ , 0.21

The input motion is a 3C wave from SW4.

**Inelastic Simulation** The Real-ESSI input files for this example are available [HERE](#). The compressed package of Real-ESSI input files for this example is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 210,000
- Number of Time Steps: 2065
- Running Time: 30 hours
- Disk Space: 45GB
- Recommended Machine: Amazon EC2 c4.8xlarge instance 36 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time:  $\$1.591 * 30 = \$47.73$
  - For General Purpose (SSD) Storage:  $\$0.1 * 45 = \$4.5$  (monthly)
  - For S3 Storage:  $\$0.023 * 45 = \$1.035$  (monthly)
  - For Network Bandwidth if transfer:  $\$0.09 * 45 = \$4.05$

**SIMULATION TIME:** With 32 cores on AWS EC2 c4.8xlarge instance, the running time for this example is 30 hours.

The Modeling parameters are listed below

- Soil
  - Unit weight,  $\gamma$ , 21.4 kPa
  - Shear velocity,  $V_s$ , 500 m/s
  - Young's modulus,  $E$ , 1.3 GPa
  - Poisson's ratio,  $\nu$ , 0.25
  - Shear strength,  $S_u$ , 650 kPa
  - von Mises radius,  $k$ , 60 kPa
  - kinematic hardening,  $H_a$ , 30 MPa
  - kinematic hardening,  $C_r$ , 25
- Structure
  - Unit weight,  $\gamma$ , 24 kPa

- Young's modulus,  $E$ , 20 GPa
- Poisson's ratio,  $\nu$ , 0.21
- Contact
  - Initial axial stiffness,  $k_n^{init}$ , 1e9 N/m
  - Stiffening rate,  $S_r$ , 1000 /m
  - Maximum axial stiffness,  $k_n^{max}$ , 1e12 N/m
  - Shear stiffness,  $k_t$ , 1e7 N/m
  - Axial viscous damping,  $C_n$ , 100  $N \cdot s/m$
  - Shear viscous damping,  $C_t$ , 100  $N \cdot s/m$
  - Friction ratio,  $\mu$ , 0.25

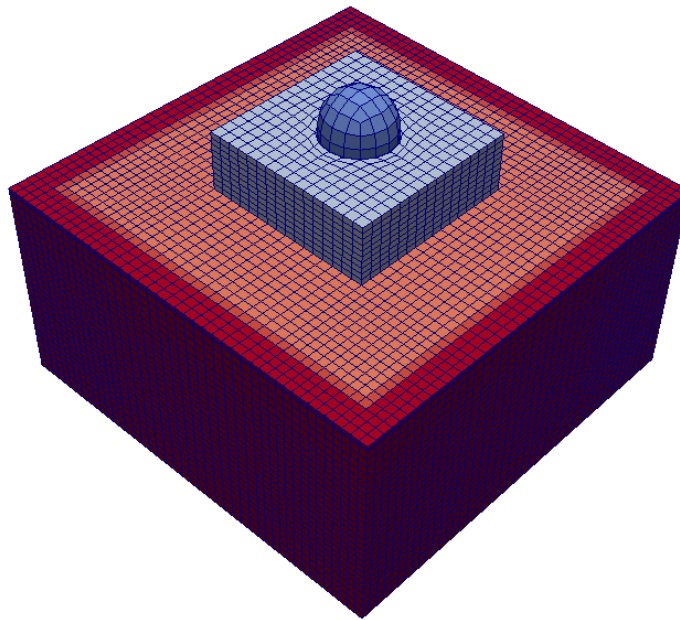


Figure 1.25: Simulation Model.

### 1.8.2 Real-ESSI AWS Manual, April 2023

Real-ESSI AWS manual developed for the Real-ESSI Short Course, in March, April 2023, is provided below.



## 1. Summary and Highlights

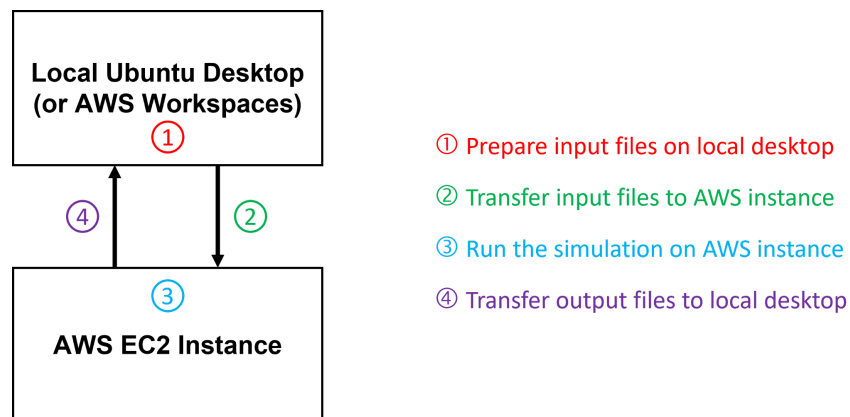
This chapter describes details of accessing and using Real-ESSI Simulator using remote computers, the so-called "cloud" computational resources. The current focus is on using Amazon Web Services (AWS) computers.

Note: If you have a local Ubuntu desktop, you may download and install the Debian package for Real-ESSI. The procedures are documented in [Real-ESSI Simulator System Procurement Procedures](#).

## 2. Real-ESSI Cloud Computing Overview

Cloud computing refers to the accessing and computing over the Internet rather than on local computers. Cloud computing is a model for enabling on-demand access to a shared pool of configurable computing resources, which can be setup and released rapidly.<sup>1</sup>

Using Real-ESSI Cloud Service, users can get computing instances on demand without requiring a lot of maintenance and financial resources a common, local parallel computer cluster would require. In addition, users do not need to go through the installation of the dependent libraries, source-code compilation and the installation of other related software, for example preprocessing and post-processing environments. The complete Real-ESSI Simulator system is pre-configured and built within the image such that the Real-ESSI Simulator system is portable over the cloud. A stable, release version of Real-ESSI is built and can be used anywhere and anytime.



The suggested workflow for Real-ESSI cloud computing using AWS is shown above. The recommended workflow is a client-server style workflow, the most efficient and economical way to perform cloud computing. First, a local Ubuntu desktop (*AWS Workspaces is a good*

<sup>1</sup> This is an excerpt from [Jeremic et al. \(1989-2023\)](#)

*substitute if you don't have a local Ubuntu desktop*) is used to prepare input files, receive output files, and post-processing simulation results. Then, an AWS EC2 instance is used to conduct high-performance parallel computation from the Real-ESSI simulation. We will introduce detailed procedures in the following chapters.

### 3. Create AWS Account

#### 3.1 AWS account types

There are two types of accounts on AWS, the Root user and the IAM user, each with unique credentials.

- The root user in Amazon Web Services (AWS) is the initial administrative user created when creating an AWS account. The root user has full access to all AWS services, financials, and resources in the account and can perform any action on them. **It is highly recommended to avoid using the root user account for regular day-to-day operations in AWS due to security reasons.**
- On the other hand, an IAM (Identity and Access Management) user is a user account that is created within your AWS account, separate from the root account. IAM users have a set of permissions that are defined by an AWS administrator (or yourself) to limit what actions they can perform in AWS. This allows you to grant specific permissions to users or groups of users without giving them full access to the AWS account.

IAM users can be created with unique usernames and credentials, and their permissions can be managed separately from the root user. This provides better security and allows you to grant different levels of access to different users or groups, based on their roles and responsibilities.

If you're a first-time user of AWS, your first step is to sign up for a Root user AWS account. When you sign up, AWS creates an AWS account with the details you provide and assigns the account to you. We also suggest activating multi-factor authentication (MFA) for the root user and assigning administrative access to a user. You can find complete documentation on AWS Account Management [here](#).

#### 3.2 Create a root user account

- To create your AWS account, open the [AWS home page](#) in your browser and choose **Create an AWS account**.
- Supply your email, then the code sent to your email address.

Explore Free Tier products with a new AWS account.

To learn more, visit [aws.amazon.com/free](https://aws.amazon.com/free).



## Sign up for AWS

### Root user email address

Used for account recovery and some administrative functions

### AWS account name

Choose a name for your account. You can change this name in your account settings after you sign up.

Verify email address

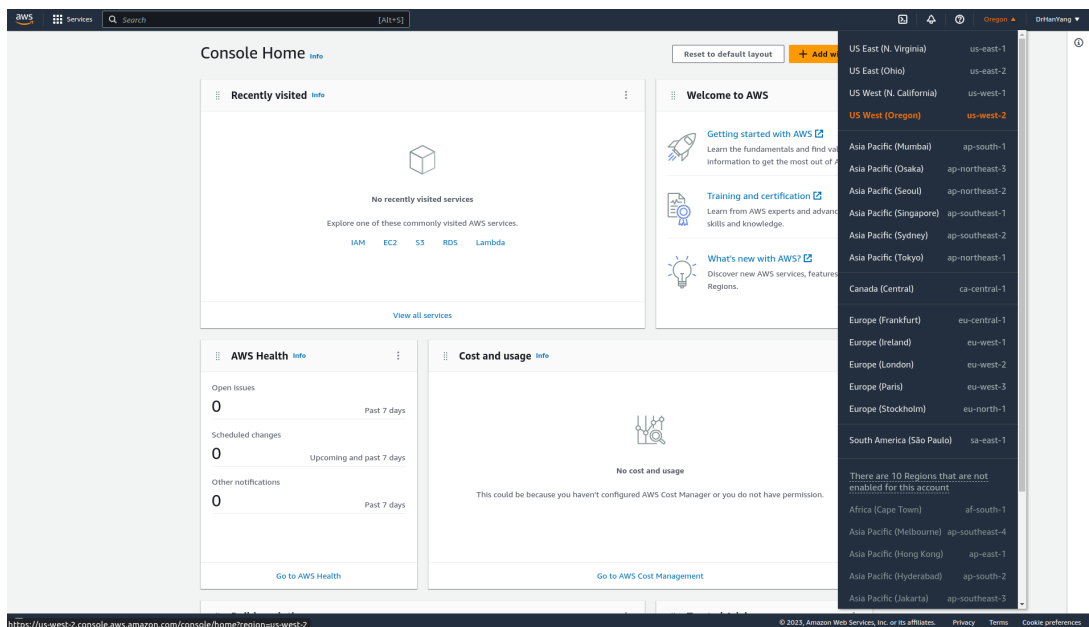
OR

Sign in to an existing AWS account

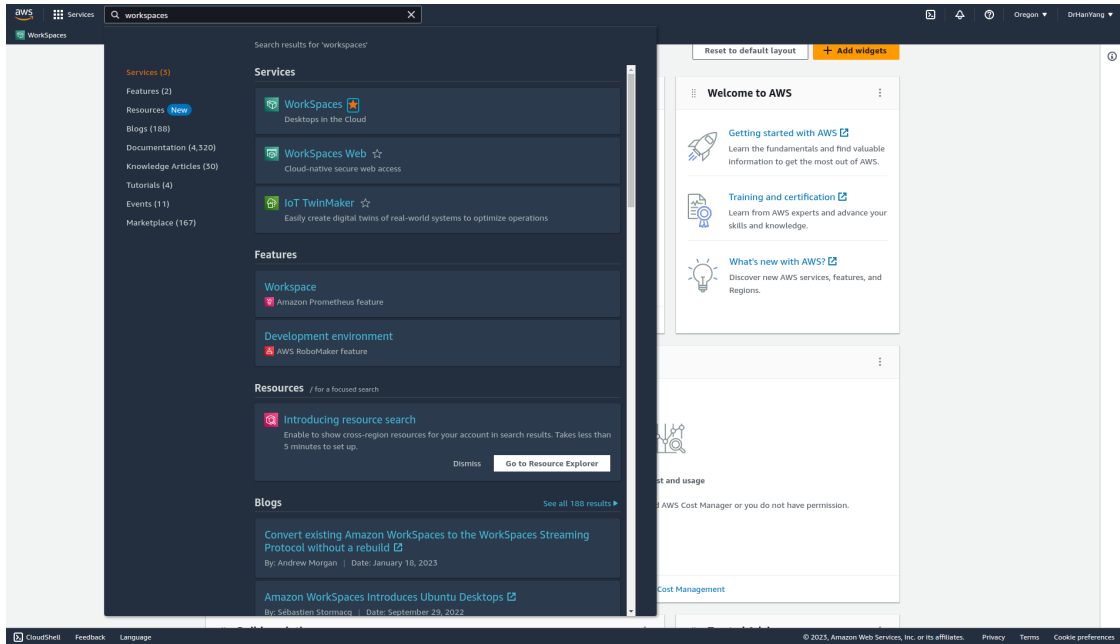
- Create a root user password.
- Provide contact information.
- Provide billing information.
- Confirm your identity.
- Select a support plan. The **Basic support - Free** option is enough for using Real-ESSI.
- Select **Complete sign up**

### 3.3 Initial setups for your new AWS account

- Sign **into** your root account.
- Switch your region to **US West (Oregon)**. Your region is located near the top right corner of your webpage.



- Search and select services for quick access later. In this manual, we will use several different AWS services. We can find them and add them to favorites. Go to the search bar near the top left of your webpage and search for the services we need. Click on the star symbol next to the service name to add it to your favorites. The service should appear near the top of your webpage for future quick access.



The services we need are **Workspaces** and **EC2**.

## 4. Amazon Workspaces

If you already have and want to use your own local Ubuntu desktop, skip this chapter.

*Summary: This chapter presents setting up, launching, and connecting to your Amazon Workspace. Note that Amazon Workspace is used as a substitute for local Ubuntu desktops.*

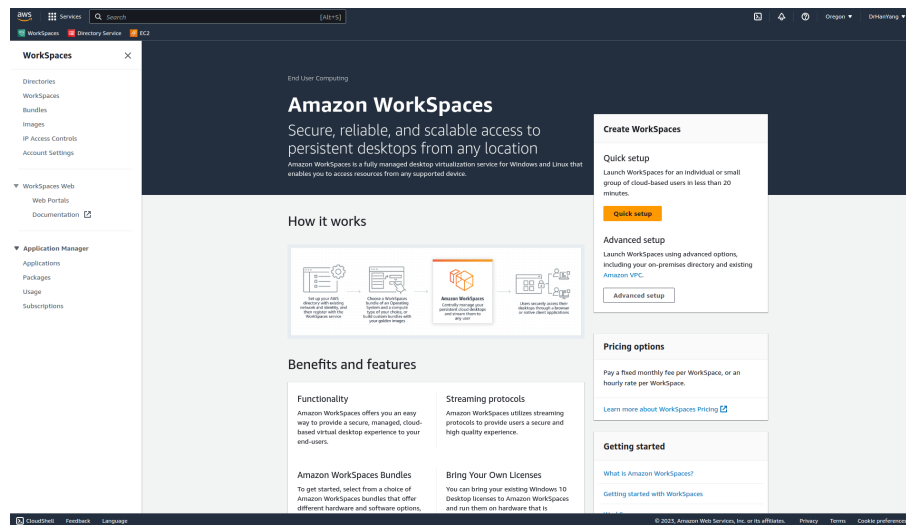
Amazon WorkSpaces enables you to provision virtual, cloud-based Microsoft Windows, Amazon Linux, or Ubuntu Linux desktops, known as *WorkSpaces*. WorkSpaces eliminates the need to purchase and set up your own Ubuntu desktop. Instead, users can access their virtual desktops from multiple devices or web browsers. Complete documentation regarding Amazon Workspaces can be found [here](#).

### 4.1 WorkSpaces quick setup

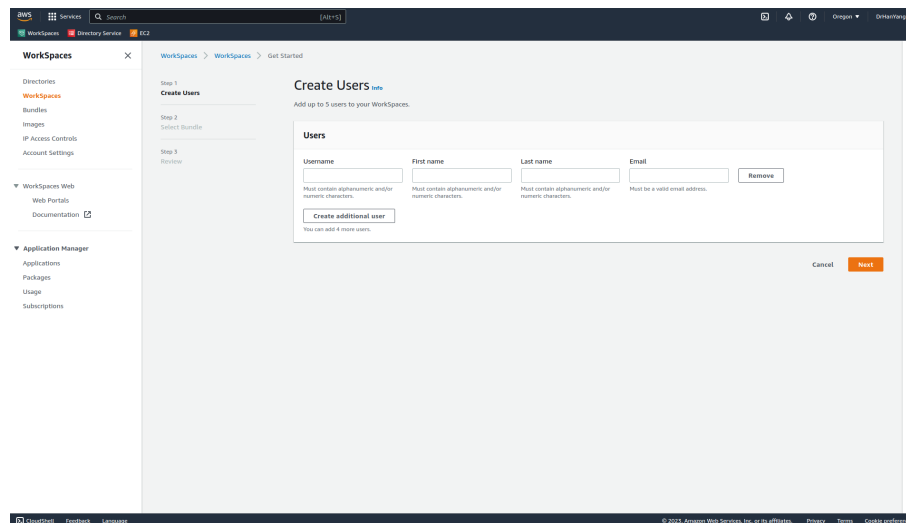
This tutorial uses the **Quick Setup** option to launch your WorkSpace. This option is available only if you have never launched a WorkSpace. Alternatively, for the full documentation see [here](#).

## Step 1: Launch the WorkSpace

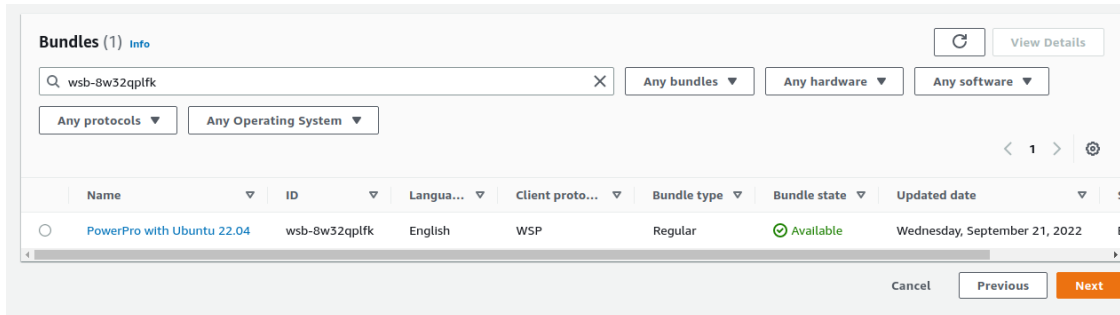
- Open the WorkSpaces console at <https://console.aws.amazon.com/workspaces/>.
- Choose **Quick setup**. If you don't see this button, either you have already launched a WorkSpace in this Region, or you aren't using one of the [Regions that support Quick Setup](#). In this case, see [Launch a virtual desktop using WorkSpaces](#).



- For **Create Users**, enter the **Username**, **First Name**, **Last Name**, and **Email**. Then choose **Next**. Note that you can enter multiple users here, but this doesn't mean they can use the same Workspace. Instead, multiple Workspaces will be created, one for each user.



- For **Bundles**, select a bundle (hardware and software) for the user with the appropriate protocol (PCoIP or WSP). For Real-ESSI cloud computing, choose PowerPro with Ubuntu 22.04 with the WSP protocol. You can find this bundle by its ID `wsb-8w32qplfk`.



- Review your **information**. Then choose **Create Workspace**.
- It takes approximately 20 minutes, up to 40 minutes, for your Workspace to be created. When the launch is complete, the status is **AVAILABLE** and an invitation is sent to the email address that you specified for each user. If the users don't receive their invitation emails, see [Send an invitation email](#).

## Step 2: Connect to the Workspace

After you receive the invitation email, you can connect to the Workspace using the client of your choice. After you sign in, the client displays the Workspace desktop.

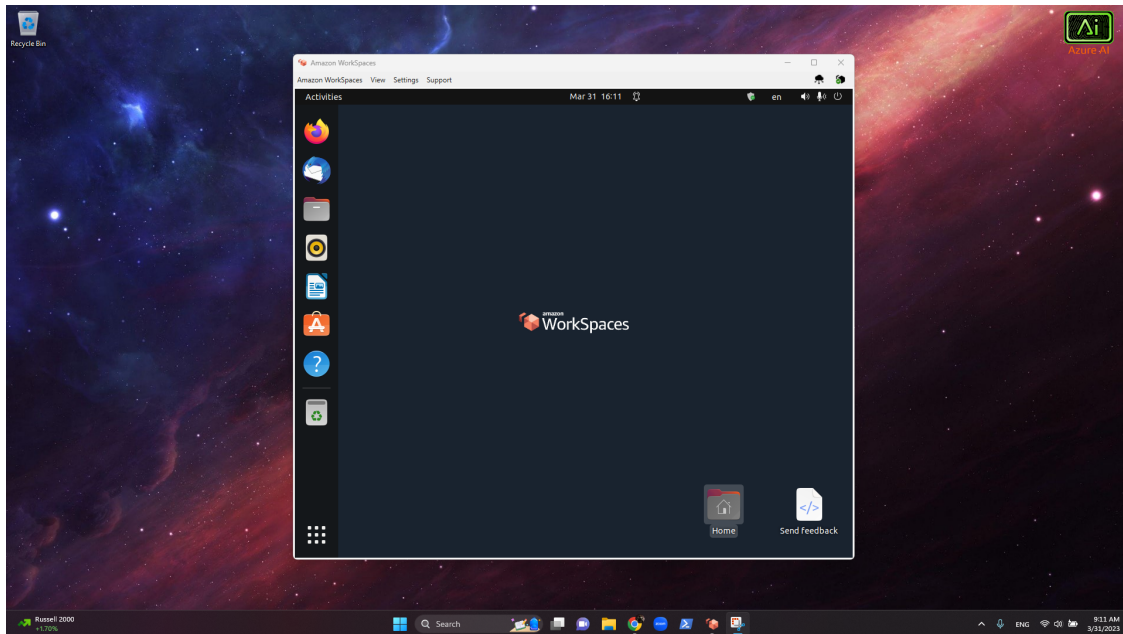
- If you haven't set up credentials for the user already, open the link in the invitation email and follow the directions. Remember the password that you specify as you will need it to connect to your Workspace.
- When prompted, download one of the client applications or launch **Web Access**. If you aren't prompted and you haven't installed a client application already, open <https://clients.amazonworkspaces.com/> and download one of the client applications or launch **Web Access**.
- Start the client, enter the registration code from the invitation email, and choose **Register**.
- When prompted to sign in, enter the sign-in credentials, and then choose **Sign In**.
- (Optional) When prompted to save your credentials, choose Yes.

## Step 3: Clean up (Optional)

If you are finished with the Workspace that you created for this tutorial, you can delete it. For more information, see [Delete a Workspace](#).

## 4.2 Install Real-ESSI Debian package on your Workspace

Once you successfully connect to your Workspace, it will be the same as if you are working with a local Ubuntu desktop.



The next step is to install Real-ESSI on your Workspace. Full documentation can be found in Section 1.3 of the [Real-ESSI Simulator Procurement Manual](#). Quick setup steps are summarized below.

### Step 1: System libraries update/upgrade

Open a terminal and use the following commands.

```
sudo apt update
sudo apt upgrade
sudo apt autoremove
```

You will be asked to provide a password. The password is the same one you used to connect to your Workspace.

### Step 2: Real-ESSI Debian package download

The Real-ESSI program Debian package can be downloaded [here](#). Alternatively, contact Prof. Jeremic to arrange for a customized Real-ESSI Debian package.

### Step 3: Real-ESSI Debian package install

Start the Real-ESSI Simulator Debian package install by removing the old installations of Real-ESSI. Then, go to the directory where you have downloaded the Real-ESSI Debian package. Install the Debian package, for example use the following command.

```
sudo apt install ./real-essi_23.01-1_amd64.deb
```

Note that some warning messages might appear but they don't affect the installation. After a successful installation, the sequential and parallel Real-ESSI executables, gmsh/gmESSI preprocessor, paraview/pvESSI post-processor/visualizer, Gmsh, and ParaView are all installed and ready to use.

### Step 4: Load pvESSI plugin in ParaView

Start ParaView. Click **Tools**, then **Manage Plugins**. Click **Load New** and find the plugin **PVESSIRReader.so** under directory `/opt/paraview/lib/paraview-5.10/plugins/PVESSIRReader/`. Also, check the box **Auto Load** then close ParaView. Next time when ParaView is started, Real-ESSI output files can be visualized and post-processed.

### Step 5: Install other useful programs

- **HDFView** can be used to open Real-ESSI output files, which are in HDF5 format.
- **Sublime Text** is the recommended editor for Real-ESSI input files and pre-processing files.

Documentation on how to install these programs can be found in Section 1.3.5 of the [Real-ESSI Simulator Procurement Manual](#).

## 4.3 Build your model and prepare the input files

Once you have installed Real-ESSI on your Workspace, you are ready to start building your Real-ESSI model. You should finish preparing all the input files on your Workspace before moving on to the next Chapter. Full documentation on Real-ESSI pre-processing and input file formats is [available](#).

Note that if the model is sufficiently small, you can simply run the simulation on your Workspace, without using the AWS Real-ESSI instance which is designed to be used in cases with large models.

## 5. Launch Real-ESSI Instance on AWS

A Real-ESSI instance can be launched either from the private image with authorization of [Prof. Boris Jeremic](#) or from the public image on AWS Marketplace (coming soon). Full documentation regarding launching an instance on AWS can be found [here](#).



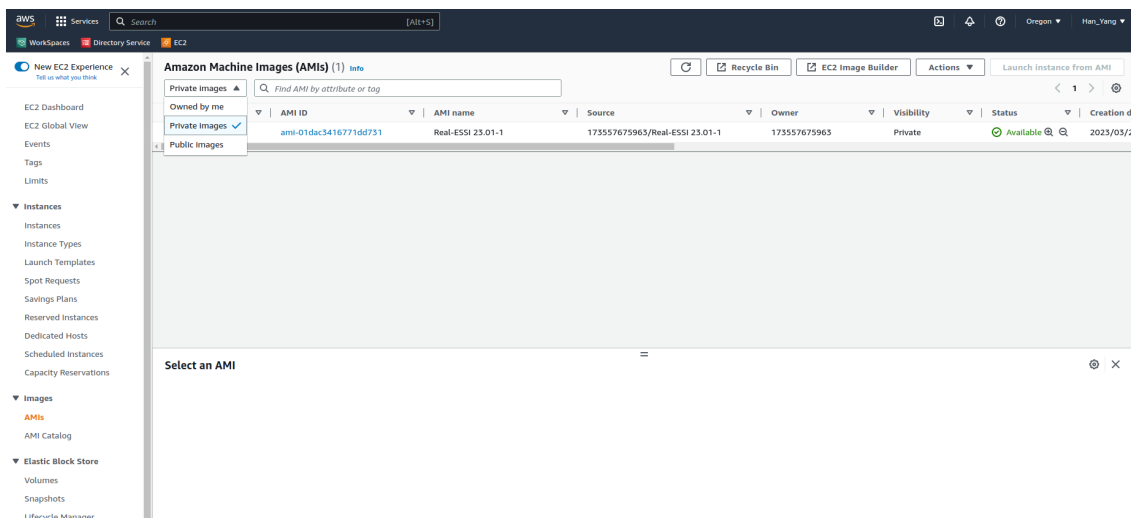
## 5.1 Launch Real-ESSI instance from AWS private images

Follow the steps below to launch instances from Real-ESSI Private Image.

### Step 1: Request the Real-ESSI image

Real-ESSI image is currently a private Amazon Machine Images (AMI). After you get the 12-digit AWS account ID, email the AWS account ID to Prof. Boris Jeremic to obtain the Real-ESSI image.

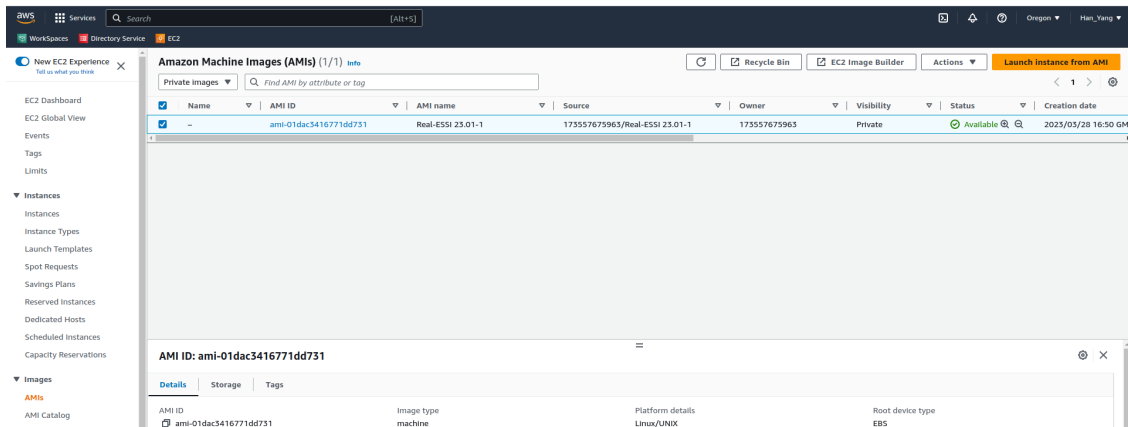
To check if you have access to the Real-ESSI image, open the Amazon EC2 console at <https://console.aws.amazon.com/ec2/>. Go to **AMIs** and choose **Private images** to see the Real-ESSI image. Currently, the Real-ESSI AMIs are available in the **Oregon** region. The region is shown in the top-right corner on the EC2 dashboard.



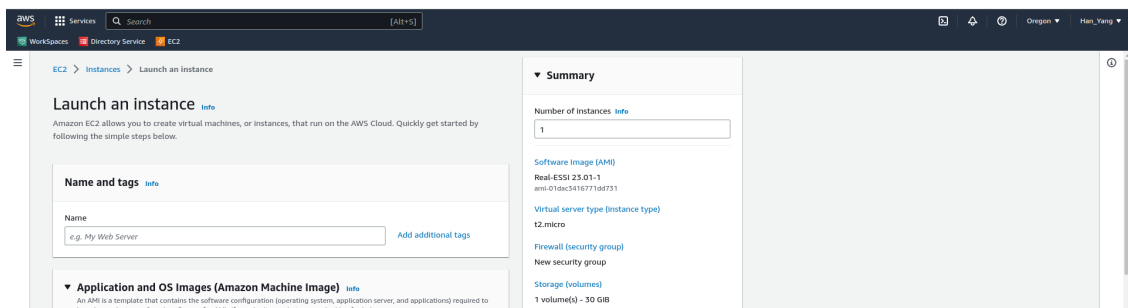
### Step 2: Launch the Real-ESSI instance

You can launch the Real-ESSI instance using the AWS Management Console as described in the following procedure. This tutorial is intended to help you quickly launch your first instance, so it doesn't cover all possible options. For information about advanced options, see [Launch an instance using the new launch instance wizard](#). For information about other ways to launch your instance, see [Launch your instance](#).

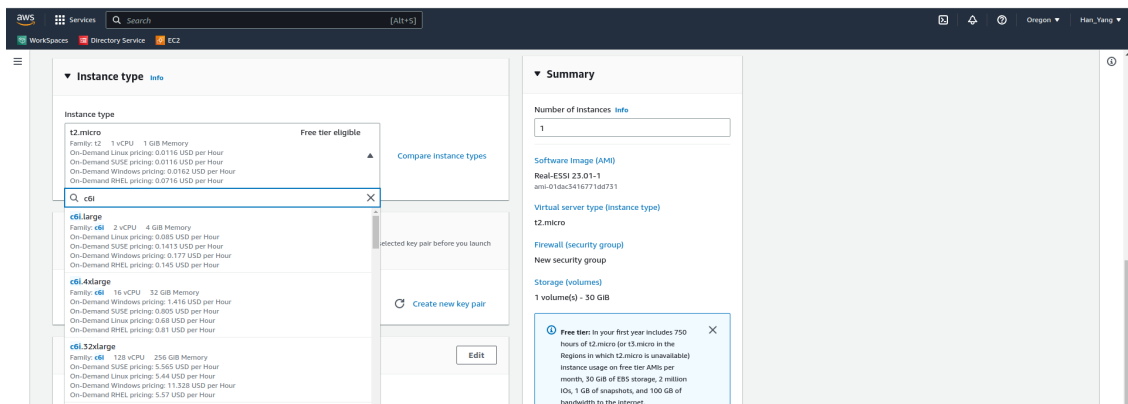
- Open the Amazon EC2 console at <https://console.aws.amazon.com/ec2/>.
- From the EC2 console dashboard, Go to **AMIs** and choose **Private images** to see the Real-ESSI image. Choose the image and choose **Launch instance from AMI**.



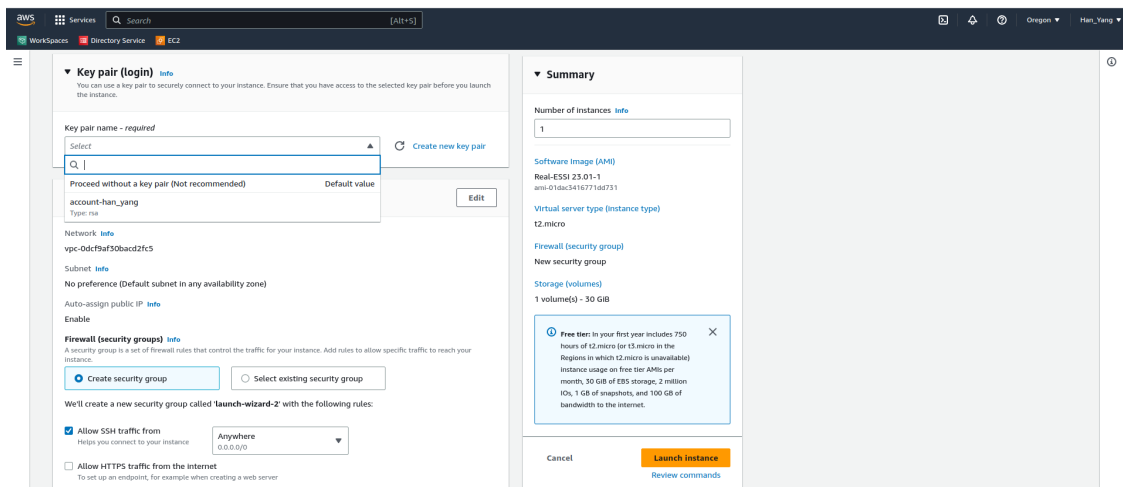
- Under **Name and tags**, for **Name**, enter a descriptive name for your instance.



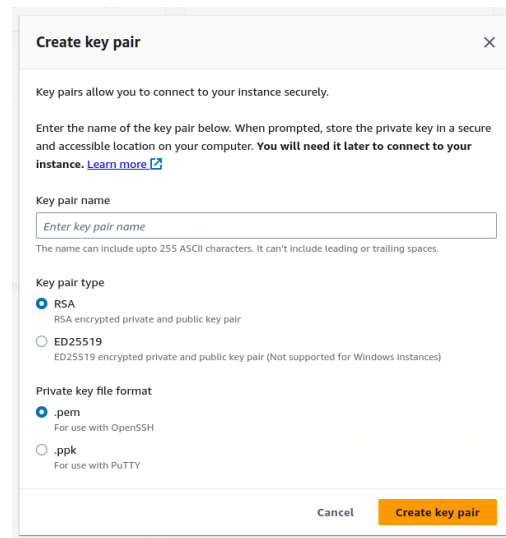
- Under **Instance type**, you can select the hardware configuration for your instance. For Real-ESSI instances, the compute-optimized **c6i** series is recommended. Click the drop-down list under **instance type** and type **c6i** in the search bar. Depending on the size of your model, you can choose an instance type with appropriate computing power.



- Under **Key pair (login)**, select the key pair for your instance.

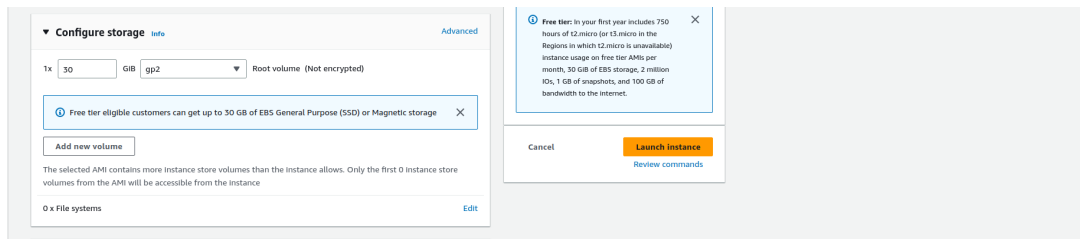


If you have not created a key pair before, choose **Create new key pair**.

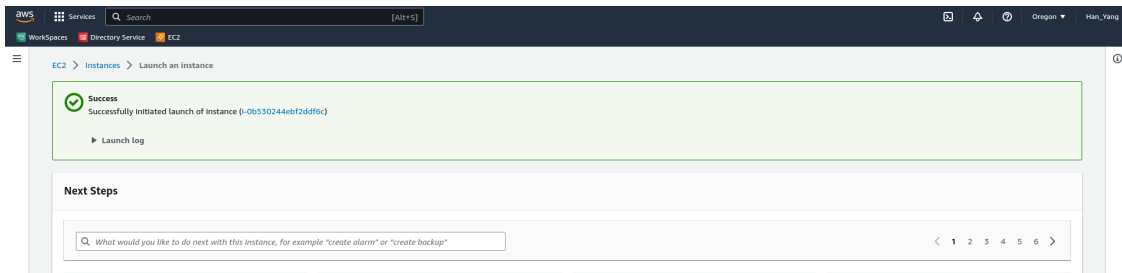


Enter a descriptive name for your key pair. Leave everything else the same. Then click **Create key pair**. You will be prompted to save the key pair. Note that the key pair cannot be recreated after you launch the instance, so please make sure you save it in a safe place. The key pair can be reused later when you launch other instances.

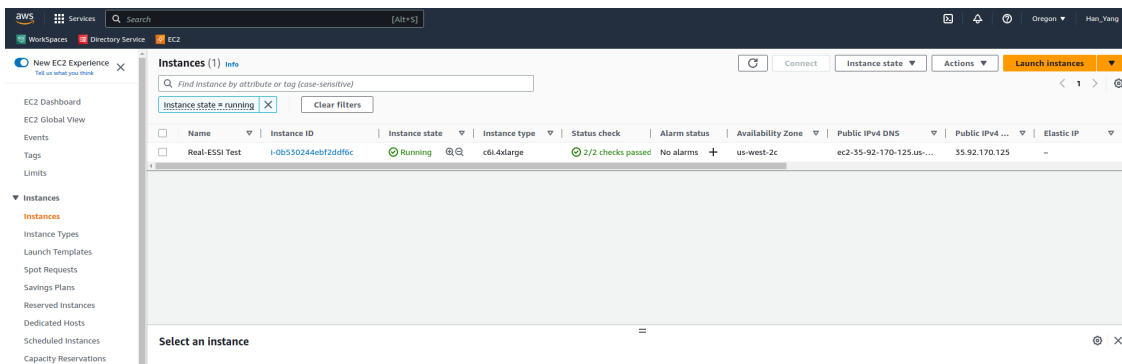
- Under **Configure storage**, change the Root volume depending on the size of your model and simulation options.



- Click **Launch instance**. You should see the message below if the launch is successful.



- You can view your running instances by clicking **Instances** on the left side list of your screen.



## 5.2 Launch Real-ESSI instance from AWS Marketplace

Coming soon...

## 6. Connect to Real-ESSI Instance

This chapter provides information about how to connect to a Real-ESSI instance after you have launched it, and how to transfer files between your local computer and your instance. For more information, please refer to the AWS documentation [here](#). To troubleshoot connecting to your instance, see [Troubleshoot connecting to your instance](#).

After you launch your instance, you can connect to it and use it the way that you'd use a computer sitting in front of you. The following instructions explain how to connect to your instance using an SSH client. For more connection options, see [Connect to your Linux instance](#).

## 6.1 Prerequisites

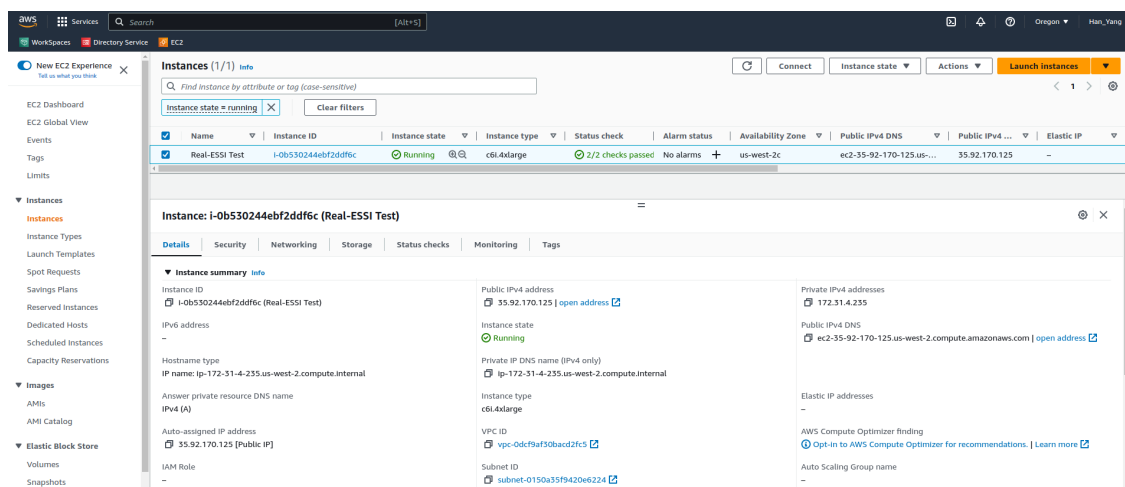
Before you connect to your Linux instance, complete the following prerequisites.

### Check your instance status

After you launch an instance, it can take a few minutes for the instance to be ready so that you can connect to it. Check that your instance has passed its status checks. You can view this information in the **Status check** column on the **Instances** page.

### Get the public IP address to connect to your instance

Click on your instance to show more information about it. You can find the public IPv4 address from either the summary or details. For example, the public IPv4 address is 35.92.170.125 for the instance shown below.



### Locate the private key and set the permissions

You must know the location of your private key file to connect to your instance. For SSH connections, you must set the permissions so that only you can read the file.

Get the fully-qualified path to the location on your computer of the `.pem` file for the key pair that you specified when you launched the instance.

Use the following command to set the permissions of your private key file so that only you can read it. Replace `key-pair-name` with the actual name of your key pair.

```
chmod 400 key-pair-name.pem
```

If you do not set these permissions, then you cannot connect to your instance using this key pair. For more information, see [Error: Unprotected private key file](#).

## 6.2 Connect to your Real-ESSI instance using an SSH client

Use the following procedure to connect to your Linux instance using an SSH client. If you receive an error while attempting to connect to your instance, see [Troubleshoot connecting to your instance](#).

- In a terminal window, use the **ssh** command to connect to the instance. You specify the path and file name of the private key (**.pem**) and the IPv4 address for your instance. To connect to your instance, use the following command.

```
ssh -i /path/key-name.pem ubuntu@IPv4-address
```

Replace **/path/** with the full absolute path to your key pair. Replace **key-name** with the actual name of your key pair. Replace **IPv4-address** with the public IPv4 address of your instance.

You will see a response like the following:

```
The authenticity of host 'ec2-198-51-100-1.compute-1.amazonaws.com
(198-51-100-1)' can't be established.
ECDSA key fingerprint is 14UB/neBad9tvkgJf1QZWxheQmR59WgrgzEimCG6kZY.
Are you sure you want to continue connecting (yes/no)?
```

- (Optional) Verify that the fingerprint in the security alert matches the fingerprint that you previously obtained in [\(Optional\) Get the instance fingerprint](#). If these fingerprints don't match, someone might be attempting a man-in-the-middle attack. If they match, continue to the next step.
- Enter **yes**.

You will see a response like the following:

```
Warning: Permanently added 'ec2-198-51-100-1.compute-1.amazonaws.com'
(ECDSA) to the list of known hosts.
```

- (Optional) Create a directory to organize your Real-ESSI simulation files. Replace **test\_folder** with your folder name.

```
mkdir test_folder
```

## 6.3 Transfer Input Files to Real-ESSI Instance

This section describes how to transfer files with the secure copy protocol (SCP). The procedure is similar to the procedure for connecting to an instance with SSH.

- Open a terminal on your local Ubuntu desktop (or Amazon Workspace).
- Determine the file location on your local Ubuntu desktop (or Amazon Workspace) and the destination path on the instance. In the following example, the name of the private key file is `key-name.pem`, the file to transfer is `main.fei`, and the IPv4 address of the instance is `IPv4-address`. Enter the following command in your terminal.

```
scp -i /path1/key-name.pem /path2/main.fei ubuntu@IPv4-address:/path3/
```

There are three paths in this command.

- Replace `/path1/` with the full absolute path to your key pair on your local desktop.
- Replace `/path2/` with the full absolute path to the file to transfer on your local desktop.
- Replace `/path3/` with the full absolute path to the destination on the Real-ESSI instance.

For example, your **scp** command may be:

```
scp -i /home/han/Documents/han-key.pem /home/han/My_Model/main.fei  
ubuntu@52.26.2.245:/home/ubuntu/Test/
```

- If you haven't already connected to the instance using SSH, you will see a response like the following:

```
The authenticity of host 'ec2-198-51-100-1.compute-1.amazonaws.com  
(10.254.142.33)' can't be established.  
RSA key fingerprint is  
1f:51:ae:28:bf:89:e9:d8:1f:25:5d:37:2d:7d:b8:ca:9f:f5:f1:6f.  
Are you sure you want to continue connecting (yes/no)?
```

(Optional) You can optionally verify that the fingerprint in the security alert matches the instance fingerprint. For more information, see [\(Optional\) Get the instance fingerprint](#).

Enter `yes`.

- If the transfer is successful, the response is similar to the following:

```
Warning: Permanently added 'ec2-198-51-100-1.compute-1.amazonaws.com' (RSA)  
to the list of known hosts.  
main.fei                                100%  164KB   1.3MB/s   00:00
```

- It's also possible to transfer entire folders using the **scp** command. In the following example, the name of the private key file is `key-name.pem`, the folder to transfer is `folder`, and the IPv4 address of the instance is `IPv4-address`. Enter the following command in your terminal.

```
scp -i /path1/key-name.pem -r /path2/folder ubuntu@IPv4-address:/path3/
```

There are three paths in this command.

- Replace `/path1/` with the full absolute path to your key pair on your local desktop.
- Replace `/path2/` with the full absolute path to the folder to transfer on your local desktop.
- Replace `/path3/` with the full absolute path to the destination on the Real-ESSI instance.

For example, your **scp** command may be:

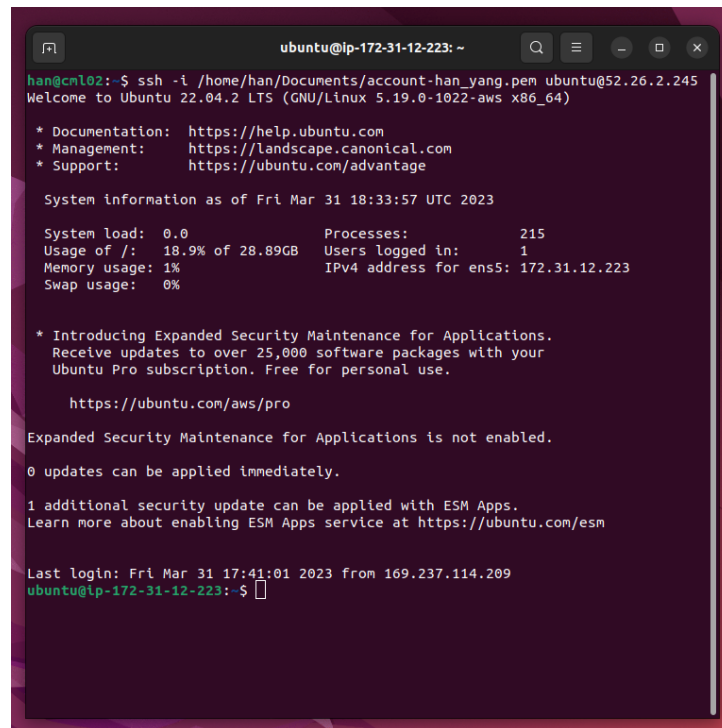
```
scp -i /home/han/Documents/han-key.pem -r /home/han/My_Model_Folder  
ubuntu@52.26.2.245:/home/ubuntu/Test/
```

## 8. Run Simulations on Real-ESSI Instance

This chapter provides information about running your simulations on a launched Real-ESSI instance. Note that you should only attempt to do this after you have done the following:

- Create [an AWS account](#)
- Have access to a local Ubuntu desktop (or [Amazon Workspace](#))
- Launch [a Real-ESSI instance on AWS](#)
- [Connect to the Real-ESSI instance you have launched](#)

Once you have successfully transferred your input files, open a new terminal and [connect to the Real-ESSI instance](#). Your terminal should look like the following:



```
ubuntu@ip-172-31-12-223: ~  
han@cn102:~$ ssh -i /home/han/Documents/account-han_yang.pem ubuntu@52.26.2.245  
Welcome to Ubuntu 22.04.2 LTS (GNU/Linux 5.19.0-1022-aws x86_64)  
  
* Documentation:  https://help.ubuntu.com  
* Management:    https://landscape.canonical.com  
* Support:        https://ubuntu.com/advantage  
  
System information as of Fri Mar 31 18:33:57 UTC 2023  
  
System load:  0.0          Processes:      215  
Usage of /:   18.9% of 28.89GB  Users logged in:  1  
Memory usage: 1%          IPv4 address for ens5: 172.31.12.223  
Swap usage:   0%  
  
* Introducing Expanded Security Maintenance for Applications.  
  Receive updates to over 25,000 software packages with your  
  Ubuntu Pro subscription. Free for personal use.  
  
  https://ubuntu.com/aws/pro  
  
Expanded Security Maintenance for Applications is not enabled.  
  
0 updates can be applied immediately.  
  
1 additional security update can be applied with ESM Apps.  
Learn more about enabling ESM Apps service at https://ubuntu.com/esm  
  
Last login: Fri Mar 31 17:41:01 2023 from 169.237.114.209  
ubuntu@ip-172-31-12-223:~$
```



- Go to the directory where you transferred your input files. Use the following command:

```
cd /path/
```

Replace `/path/` with the full absolute path to your input files on the Real-ESSI instance.

- Change the permission of your file so that it can be read and executed. Use the following command:

```
chmod a+rx main.fei
```

- Enter the following command to start your simulation:

```
mpirun -np num_pro essi-parallel -f main.fei
```

Replace `num_pro` with the number of processes you want to use to run the simulation. Note that this number must be smaller than the number of available processes on your Real-ESSI instance. Consider using a different instance type with more available processes if your current set up is not enough for your model.

- Once the simulation has successfully started, you should see something like the following:

```

ubuntu@ip-172-31-12-223: ~/Test/Input_Files
-----
ubuntu@ip-172-31-12-223:~/Test/Input_Files$ mpirun -np 8 essi-parallel -f main.fei
-----
The Finite Element Interpreter Project, 1989-present

The Real-ESSI Simulator:

Realistic Modeling and Simulation of
Earthquakes, Soils, Structures and their Interaction

Parallel processing mode. Main machine!

Version Name      : Real-ESSI Simulator; GLOBAL_RELEASE, version 23.01; Release date: Feb 3 2023 at 10:05:14. Tag: 1e6256f523
Version Branch    : GLOBAL_RELEASE
Compile Time      : Mar 28 2023 at 23:46:17
Compile User      : ubuntu
Compile Sysinfo   : ip-172-31-3-21 5.19.0-1022-aws x86_64 GNU/Linux
Runtime User      : ubuntu
Runtime Sysinfo   : ip-172-31-12-223 5.19.0-1022-aws x86_64 GNU/Linux
Current Time      : Mar 31 2023 at 18:51:29
PreProcessing Compatible Version: Gmsh 3.0.6
PreProcessing Compatible Version: Real-ESSI-gmESSI Date: Oct 2020.
PostProcessing Compatible Version: ParaView 5.11.0
PostProcessing Compatible Version: Real-ESSI-pvESSI Date: Mar 2022.
Days: 59 / 730 / 823
For more information, see :      http://real-essi.info/

Static startup tips:
* Remember: Every command ends with a semicolon ';'.
* Type 'quit;' or 'exit;' or 'bye;' or 'zdravo;' or
* 'voljno;' or 'zaijian;' or 'tschuess;' or 'geia-sou;' or
* 'tchaus' or 'sair' or 'khoda-hafez' or 'doel'
* to finish.
* Run 'essi -h' to see available command line options.

Including: "main.fei"

Model name is being set to "Ventura_Hotel"
Including: "Nodes.fei"

Done including: "Nodes.fei" (83577 lines included).
Continuing with "main.fei" at line 7.

Including: "Elements.fei"

Done including: "Elements.fei" (88745 lines included).
Continuing with "main.fei" at line 64.

Including: "Contact_Elements_Bonded.fei"

Done including: "Contact_Elements_Bonded.fei" (683 lines included).

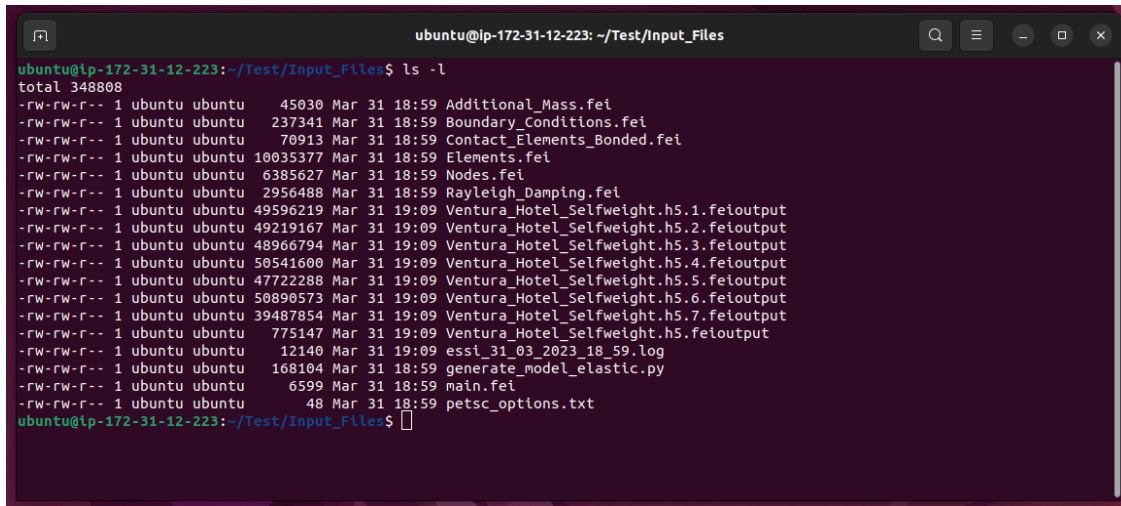
```

Now you just need to wait for the simulation to finish.

- Once the simulation is finished, you can use the following command to list all the files in your current directory:

```
ls -l
```

You should see something like the following:



```

ubuntu@ip-172-31-12-223: ~/Test/Input_Files
ubuntu@ip-172-31-12-223:~/Test/Input_Files$ ls -l
total 348808
-rw-rw-r-- 1 ubuntu ubuntu 45030 Mar 31 18:59 Additional_Mass.fel
-rw-rw-r-- 1 ubuntu ubuntu 237341 Mar 31 18:59 Boundary_Conditions.fel
-rw-rw-r-- 1 ubuntu ubuntu 70913 Mar 31 18:59 Contact_Elements_Bonded.fel
-rw-rw-r-- 1 ubuntu ubuntu 10035377 Mar 31 18:59 Elements.fel
-rw-rw-r-- 1 ubuntu ubuntu 6385627 Mar 31 18:59 Nodes.fel
-rw-rw-r-- 1 ubuntu ubuntu 2956488 Mar 31 18:59 Rayleigh_Damping.fel
-rw-rw-r-- 1 ubuntu ubuntu 49596219 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.1.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 49219167 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.2.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 48966794 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.3.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 50541600 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.4.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 47722288 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.5.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 50890573 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.6.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 39487854 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.7.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 775147 Mar 31 19:09 Ventura_Hotel_Selfweight.h5.feiooutput
-rw-rw-r-- 1 ubuntu ubuntu 12140 Mar 31 19:09 essi_31_03_2023_18_59.log
-rw-rw-r-- 1 ubuntu ubuntu 168104 Mar 31 18:59 generate_model_elastic.py
-rw-rw-r-- 1 ubuntu ubuntu 6599 Mar 31 18:59 main.fel
-rw-rw-r-- 1 ubuntu ubuntu 48 Mar 31 18:59 petsc_options.txt
ubuntu@ip-172-31-12-223:~/Test/Input_Files$

```

Notice that all the output files and a log file are now present in your working directory. Note that all Real-ESSI output files have the suffix `.feiooutput`. For more information, refer to the [Real-ESSI Simulator Output Format Manual](#).

## 9. Transfer Output Files to Local Desktop (or Amazon Workspace)

This chapter provides information about how to transfer the output files of your Real-ESSI simulation back to your local desktop (or Amazon Workspace). Note that you should only attempt to do this after your simulation has finished.

The **scp** command is used to transfer the output files from the launched Real-ESSI instance to your local Ubuntu desktop (or Amazon Workspace).

- Open a terminal on your local Ubuntu desktop (or Amazon Workspace).
- In the following example, the name of the private key file is `key-name.pem` and the IPv4 address of the instance is `IPv4-address`. Enter the following command in your terminal.

```
scp -i /path1/key-name.pem ubuntu@IPv4-address:/path2/*.feiooutput /path3/
```

There are three paths in this command.

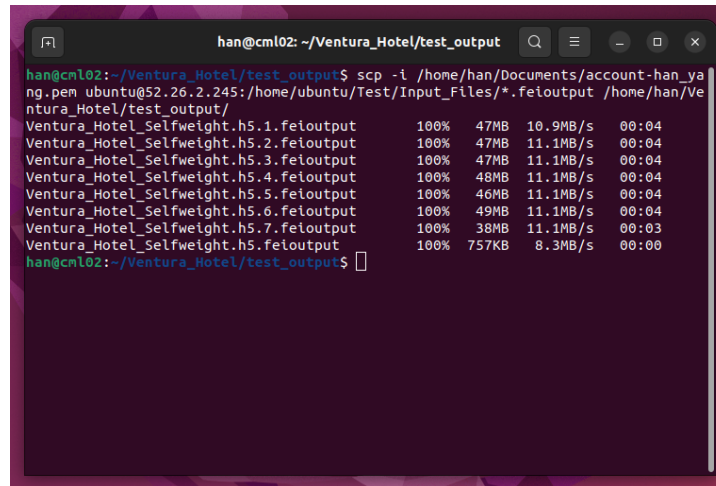
- Replace `/path1/` with the full absolute path to your key pair on your local desktop.
- Replace `/path2/` with the full absolute path to the location on the Real-ESSI instance.
- Replace `/path3/` with the full absolute path to the location on your local desktop.

Note that the format `*.feiooutput` means that the `scp` command will be executed for all the files with the suffix `.feiooutput`. This is useful since you will have multiple output files that need to be transferred.

For example, your **scp** command may be:

```
scp -i /home/han/Documents/han-key.pem  
ubuntu@52.26.2.245:/home/ubuntu/Test/*.feiooutput /home/han/output/
```

- If the transfer is successful, you should see something like the following:



A terminal window titled 'han@cm102: ~/Ventura\_Hotel/test\_output' displays the output of an SCP command. The command is: `han@cm102:~/Ventura_Hotel/test_output$ scp -i /home/han/Documents/account-han_ya ng.pem ubuntu@52.26.2.245:/home/ubuntu/Test/Input_Files/*.feiooutput /home/han/Ve ntura_Hotel/test_output/`. The output shows a list of files being transferred with their progress (100%), size, speed, and time. The files are: Ventura\_Hotel\_Selfweight.h5.1.feiooutput (47MB, 10.9MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.2.feiooutput (47MB, 11.1MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.3.feiooutput (47MB, 11.1MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.4.feiooutput (48MB, 11.1MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.5.feiooutput (46MB, 11.1MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.6.feiooutput (49MB, 11.1MB/s, 00:04), Ventura\_Hotel\_Selfweight.h5.7.feiooutput (38MB, 11.1MB/s, 00:03), and Ventura\_Hotel\_Selfweight.h5.feiooutput (757KB, 8.3MB/s, 00:00). The prompt is `han@cm102:~/Ventura_Hotel/test_output$`.

File	Progress	Size	Speed	Time
Ventura_Hotel_Selfweight.h5.1.feiooutput	100%	47MB	10.9MB/s	00:04
Ventura_Hotel_Selfweight.h5.2.feiooutput	100%	47MB	11.1MB/s	00:04
Ventura_Hotel_Selfweight.h5.3.feiooutput	100%	47MB	11.1MB/s	00:04
Ventura_Hotel_Selfweight.h5.4.feiooutput	100%	48MB	11.1MB/s	00:04
Ventura_Hotel_Selfweight.h5.5.feiooutput	100%	46MB	11.1MB/s	00:04
Ventura_Hotel_Selfweight.h5.6.feiooutput	100%	49MB	11.1MB/s	00:04
Ventura_Hotel_Selfweight.h5.7.feiooutput	100%	38MB	11.1MB/s	00:03
Ventura_Hotel_Selfweight.h5.feiooutput	100%	757KB	8.3MB/s	00:00

- Now that you have all the output files on your local Ubuntu desktop (or Amazon Workspace), you can proceed to work with them as you wish, e.g. post-processing. For more information on what you can do with your output files, refer to the [Real-ESSI Simulator Post-Processing Manual](#).

### 1.8.3 AWS for Education

Amazon Web Services provides grants for educators and students from member institution<sup>2</sup> through AWS Educate program. AWS Educate offers cloud content, training, collaboration tools and AWS technology **at no cost**. Some of the AWS Educate program benefits:

- For Educators
  - \$200 in AWS credits per educator - at member institutions.
  - \$75 in AWS credits per educator - at non-member institutions.
  - Free AWS Technical Essentials eLearning course.
  - Free access to AWS content for classes.
- For Students
  - \$100 in AWS credits per student - at member institutions.
  - \$40 in AWS credits per student - at non-member institutions.
  - Access to AWS Technical Essentials Training Course (a \$600 value).

If you have an email address from an educational institutions, you can use Real-ESSI on AWS for free through AWS Educate.

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<sup>2</sup>List of member institution is available at this [LINK](#).

## **1.8.4 AWS for Government**

**AWS GovCloud**

**AWS Secret Region**

# Bibliography

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