

Early Lung Imaging Confederation (ELIC) Technical Specifications Manual

February 23, 2023

Version 1.5

Contents

1. Introduction
2. Hub & Spoke Environment Overview
3. Spoke Management
 - 3.1. Spoke Data Preparation
 - 3.2. Spoke Data Upload
4. Client Experiment Processing
 - 4.1 Algorithm Input and Output
 - 4.2 Creating a Docker Image
 - 4.3 Running Experiments In ELIC

1. Introduction

Early detection and size change measurement of suspicious lung nodules are critical to the effective deployment of global CT lung cancer screening services. These clinical tasks are currently being performed using error prone and subjective manual review and analysis methods, greatly inhibiting the deployment and lowering the clinical effectiveness of CT lung cancer screening services throughout the world. Although many automated detection and measurement software applications are regulatory approved and commercially available, their real-world clinical performance has not yet reached a level that they can be recommended for wide-spread use (e.g. Lung-RADS remains based on manual diameter measurements). New Artificial Intelligence lung nodule detection and evaluation methods are now being developed that have the potential to significantly improve performance. However, the cost and time needed to collect, curate and annotate sufficiently large numbers of early lung cancer cases prevents advances in this field. It is also important to ensure that collected cases were acquired within the last five years due to the rapid technological changes occurring with CT scanning equipment. Access to large high-quality databases focused on early image-based detection and measurement of lung cancer is a major barrier to effectively deploying CT lung cancer screening.

The Early Lung Imaging Confederation (ELIC) is a globally distributed lung cancer database and computing environment designed to scale to at least 10x to 100x larger numbers of cases than has been previously achieved. This will be accomplished by using modern computing technologies (e.g. cloud) and respecting the critical need to store datasets in a local region. With this approach ELIC has the potential to efficiently provide international early lung cancer software developers and researchers with more lung cancer imaging cases than has ever before been assembled.

When fully realized ELIC will enable significant improvements in the effectiveness of early lung cancer screening software tools and screening methods. By making a massive, high quality, and global early lung cancer screening data and computational resource available ELIC will greatly accelerate and improve the ability to achieve automated detection and size change measurement software. In addition, ELIC will help standardize the global collection of lung cancer screening data and, by using Radiological Society of North America's (RSNA) Quantitative Imaging Biomarker Alliance (QIBA) conformance certification methods, will ensure that CT lung cancer screening images are acquired at high quality. ELIC data will also be used to perform and scientifically report on global lung cancer research studies and biologically related respiratory diseases (e.g. COPD) with larger numbers of cases than is possible today.

To achieve these goals the International Association for the Study of Lung Cancer (IASLC) has formed the Early Lung Imaging Confederation, Limited Liability Company (ELIC, LLC). The Company is a single member limited liability company with the International Association for the Study of Lung Cancer, a Colorado nonprofit corporation that is exempt from taxation under Section 501(c)(3) of the Internal Revenue Code of 1986, as its sole member and, as such, the Company is a disregarded entity for Federal income tax purposes, resulting in contributions to the Company being treated as contributions to the Member pursuant to Internal Revenue Service Notice 2012-52. ELIC, LLC will be working with IASLC members and business partners to build the governance and infrastructure to fully realize the vision of ELIC.

The ELIC Hub & Spoke Environment (ELIC H&SE) is a new globally distributed lung cancer imaging database and computational analysis environment designed to significantly improve the cost, time, and quality of lung cancer imaging research. This IASLC led initiative and computational infrastructure project, when fully deployed, will allow clinical research groups (Spokes) to securely make their locally stored de-identified lung cancer imaging collections available for computational analysis by other research groups (Clients), all coordinated by a central ELIC, LLC managed server (Hub). Clinical sites will be able to make lung cancer imaging data available for specific types of computational analysis without transmitting the imaging data over national boundaries to other groups and losing control over how the data is used and further distributed. This allows lung cancer screening research groups to more easily make available datasets to large global lung cancer imaging research studies with far more control over data use. This federated data storage and analysis approach will allow the ELIC H&SE to scale to much larger data sizes than a traditional centralized database, one day allowing lung cancer imaging researchers to quickly and easily perform quantitative analysis on global lung cancer imaging studies with larger collections of high quality, standardized data than is attainable today. This is viewed as a critical next step for the development of next generation Artificial Intelligence algorithms for lung cancer imaging, which require large amounts of data for algorithm development and performance evaluation.

In preparation for the 2018 IASLC World Conference on Lung Cancer (WCLC) meeting in Toronto, Canada, a proof-of-concept ELIC H&SE was developed and set up using Amazon Web Services (AWS) cloud resources. A hub was set up on a Virginia AWS cloud instance and 10 spokes, each pre-populated with an identical set of 100 de-identified CT lung scans, were globally distributed on AWS cloud locations which included Mumbai, London, Frankfurt, Montreal, Sydney, Tokyo, Paris, Seoul, Sao Paulo, and Virginia (on a separate cloud instance). Two open source lung cancer imaging algorithms, one that automatically computes lung volume for a thoracic CT scan and another for volumetric measurement of small lung nodules, were made available for use by the 10 spoke instances. Live demonstrations of the proof-of-concept system were shown at the 2018 WCLC meeting including the ability to launch computational experiments and receive back quantitative results from the 10 globally distributed spokes. **Figure 1** shows the global distribution of the hub and spokes for these proof of concept demonstrations.

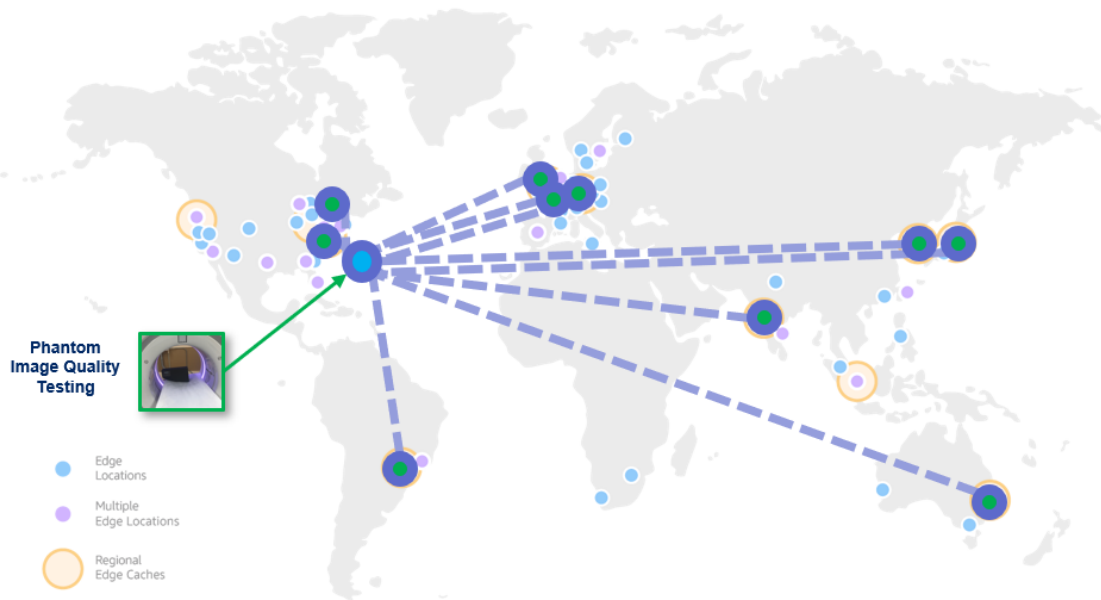


Figure 1: The global distribution of the hub and spokes for the 2018 WCLC ELIC proof of concept demonstrations using the Amazon Web Services (AWS) cloud. The legend shows different types of AWS computing resources available globally.

The live demonstrations showed that the ELIC H&SE could be used to select globally distributed datasets available on the spokes for analysis, run specific computational algorithms on those datasets, and have all of the results aggregated in real-time for viewing on the hub, as shown in **Figure 2**.

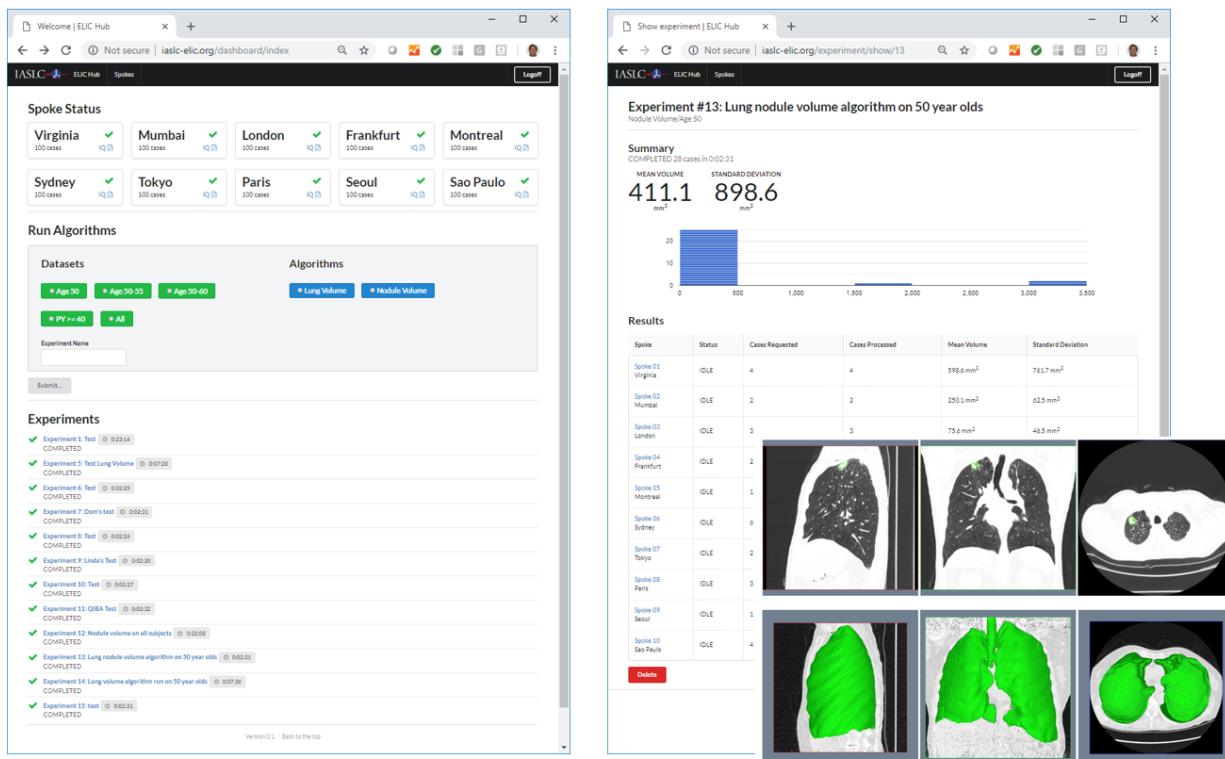


Figure 2: ELIC H&SE live demonstration screenshots showing the ability to view spoke status, select globally distributed datasets for analysis, and view a list of completed experiments (left) as well as drill down and view statistical experiment results including computationally generated images (right).

The ELIC H&SE infrastructure is undergoing further development to bring it from a proof-of-concept pilot to a functional globally distributed database and computational environment capable of performing useful quantitative lung cancer imaging studies. References to tools and resources for performing data de-identification are being added to support research groups that will be uploading lung imaging datasets and metadata into the ELIC H&SE. Standards for lung cancer screening data representation, starting with a lung cancer screening data dictionary developed by the VA-Partnership to increase Access to Lung Screening (VA-PALS) project, are also being added to ensure that global analyses can be performed with common terminology and data formats. In addition, the Radiological Society of North America’s Quantitative Imaging Biomarker Alliance (QIBA) small lung nodule conformance certification phantom, specifications, and methods are being used to help lung cancer screening sites prospectively collect, monitor, and optimize lung cancer imaging studies for high quality volume measurements.

This technical specification document provides the initial technical specifications and methods for spokes and clients to participate in the ELIC H&SE.

2. Hub & Spoke Environment Overview

The ELIC H&SE consists of several computing resources managed by ELIC, LLC including a central coordinating hub and any number of spoke instances. **Figure 3** shows the planned computing resources and main data flows that will be used in the next version of the ELIC H&SE.

Accumetra, LLC, located at 7 Corporate Drive, Clifton Park, NY 12065, is the ELIC Trusted Research Organization (ELIC TRO) that manages the ELIC H&SE on behalf of and as the vendor for ELIC, LLC.

A lung cancer screening Principal Investigator (PI) (A) typically coordinates CT lung cancer screening for a number of screening sites (Ai). The PI is responsible for submitting de-identified lung cancer screening image DICOM data and metadata, including any requested image annotations, within a spoke (B). Each time the data on the spoke (B) is added or corrected, a set of basic demographic and metadata information about the new data is communicated to the hub (C). In this way, the hub and spoke will remain in agreement regarding the data that a PI has made available for analysis on the spoke (B). The computing instance running the spoke (B) is set up on a regional cloud computing instance so the spoke (B) data will remain within the geographic region and will only be analyzed according to strictly administered analysis and reporting rules (D) decided by the PI (A).

As **Figure 3** illustrates, the spoke (B) and the hub (C) and the iaslc-elic.org website are all within the ELIC environment, which is controlled and administered by ELIC, LLC and the ELIC TRO. A Client (E) can view a listing or catalogue of all of the datasets available within the ELIC environment and take the necessary steps to run a quantitative algorithm on all of the data or a subset of the data available within the ELIC Environment. This is referred to as running an “experiment” within the ELIC environment. To run an experiment the Client (E) must provide a quantitative algorithm according to ELIC H&SE specifications to the hub (C) and request that the hub executes the experiment on all of the relevant spokes (B). The hub (C) then coordinates the running of the quantitative algorithm on the spokes and collects results according to the analysis rules (D) agreed to by the PI. The Client’s (E) algorithm, if designated as proprietary or confidential information, may only be used for running of experiments. When the experiment completes, the Client (E) is provided an aggregate summary of all of the data collected from the experiment, including information on any errors or issues encountered while running the experiment.

Clients (E) need to be able to reproduce the result of a quantitative imaging experiment run on the exact same lung CT datasets. To help achieve this, Spokes should only request to remove or modify any data uploaded to the Spoke with a very strong justification (e.g. GDPR right to be forgotten). In all cases where a previously available dataset is modified, Spoke PIs will need to work closely with the ELIC TRO to make sure the change is performed without issues and the change is well communicated to all stakeholders.

Confidentiality and trust are critical for this federated and distributed computing environment to be used. The Screening PI datasets must only be analyzed and reported on consistent with the agreement with the PI. Similarly, the Client’s algorithms and results must only be handled with the level of confidentiality agreed to by the Client. Clients must also trust that the data used to perform quantitative lung cancer imaging experiments will not change without a very strong justification. In addition, all parties must abide by the overall Governance rules. The extent and management of the ELIC

environment and its control over the running of experiments is a direct consequence of the need for creating a secure and trust-worthy ELIC H&SE environment.

There are numerous advantages to having the spoke server instance set up in a cloud environment, including improved running cost and significantly greater scalability. **Figure 3** also shows that a spoke (B) can spawn off cloud computing instances as needed (when running on the AWS cloud). This allows the spoke (B) to run with very low computing costs when idle and then (i) ramp up computing resource use only when an experiment is requested by the hub (C) and (ii) search for and acquire the highest cost-efficient computing resources available by a cloud provider. Thus, running of a large compute intensive experiments will be much more cost and time effective than setting up dedicated standalone hardware. In addition, major cloud providers are constantly improving and upgrading their computing hardware and are also continuously enhancing the security provisions of the computing instances that they provide. For these and many other reasons screening PIs are required to have an ELIC H&SE spoke set up with an ELIC, LLC approved regional cloud provider.

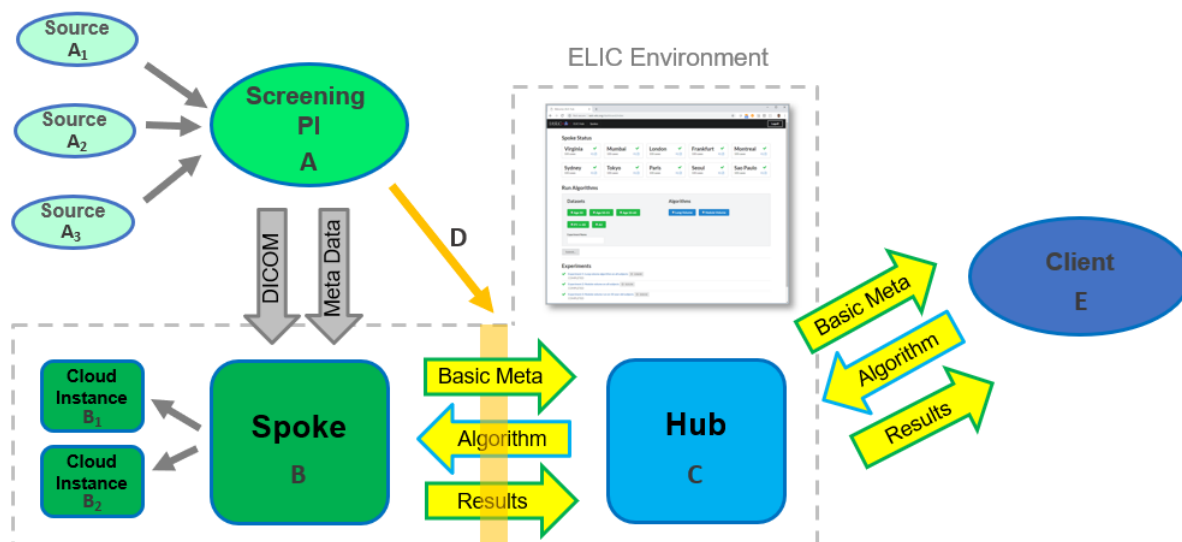


Figure 3: A high level illustration of the ELIC Hub & Spoke Environment and how PIs and Clients will interact with the system.

3. Spoke Management

Each screening PI will be provided with a unique Spoke ID string that identifies the spoke throughout the ELIC H&SE and the necessary login and password information for entering the iaslc-elic.org website as a manager of the PI's Spoke. Each manager of a Spoke will only be able to access information and change settings for the Spoke ID that they have been authorized to manage. The manager of a Spoke will be able to do the following operations on the iaslc-elic.org website:

- View and modify a spoke profile.
- Obtain necessary information and instructions for uploading data to a spoke.
- View and modify spoke data analysis and reporting settings.

- View a listing of all of the image and metadata that their spoke currently contains.
- View the current status of spoke computing resources.
- View a high-level listing of all experiments performed on spoke data (note that experiment results are only shown to the client that initiated the experiment).

The ELIC TRO will launch an instance of the spoke with all of the necessary operating system and ELIC H&SE software configurations already set. The ELIC TRO will fully handle the system administration and maintenance of the spoke cloud computing instance including ensuring security and confidentiality of PI image data as well as Client algorithms and experiment results.

It should be noted that since all data uploaded to the ELIC H&SE is required to be thoroughly de-identified by the Spoke PI and the identity table is held in confidence by a Spoke PI outside of the ELIC H&SE, the ELIC H&SE has no method that would allow ELIC, LLC or ELIC TRO personnel to determine the identify of any of the screening participants available within the H&SE. In the event that the ELIC TRO finds data on a Spoke that appears to have an identification breach, the Spoke PI, Spoke manager, and the ELIC TRO will work toward helping the Spoke PI de-identify the data in question. Every case of a participant identification breach will result in the creation of an ELIC H&SE report describing the identification breach and the steps taken to resolve the issue.

Finally, all Spoke PIs and Clients, including supporting personnel, will be required to sign a document stating that they will not take any action that conflicts with the goals and objectives of the ELIC H&SE. This includes a declaration stating that all data placed within the ELIC H&SE must not knowingly contain any malicious code, viruses, worms, or spyware and if any data or program is suspected of containing anything that is in conflict with the trust and security goals of the ELIC H&SE, the person(s) must immediately report the suspected data to ELIC, LLC and the ELIC TRO.

3.1. Spoke Data Preparation

To add data to a Spoke, the Spoke manager will need to prepare CT lung cancer screening DICOM data and metadata for upload. To do this the Spoke manager will first create an upload directory with the following naming convention:

“<SpokeName>-DataUpload-<Date>”

where Date is provided in YYYYMMDD format. The ELIC TRO will work with each Spoke PI to establish a unique SpokeName for the Spoke. Secure upload of a compressed tar file containing this directory (and all of its sub-directories) is how the Spoke manager adds and modifies lung cancer screening participant cases to the ELIC H&SE.

Each lung cancer screening participant that is to be added to the ELIC H&SE will need to be assigned a unique Participant ID according to the following naming convention:

“<SpokeName>-<ParticipantNumber>”

where ParticipantNumber is a unique integer string starting with “000001” (zero padded as shown) and monotonically increases as new participants are added to the Spoke.

It is expected that the Spoke PI and Spoke Manager will locally maintain a listing of true participant names with assigned ELIC H&SE Participant IDs and will not share this information with ELIC, LLC or the ELIC TRO.

CSV File Preparation

The upload directory must contain a CSV file with the following naming convention:

“metadata.csv”

As mentioned earlier, the CSV file will contain a single row for each screening participant containing the following comma separated information (in the following order):

Participant Columns:

- 1: “<SpokeName>-<ParticipantNumber>”
- 2: Sex (“M” or “F”)
- 3: Lung Cancer History (one of “None”, “Adenocarcinoma”, “Adenosquamous”, “Large cell”, “Squamous cell”, “Small cell”, Specify if the participant has ever been diagnosed with one of these lung cancer types)
- 4: Number of Days Between Lung Cancer Diagnosis And First Study Date (any integer, enter “0” if no lung cancer diagnosed and use a negative number if lung cancer was diagnosed prior to the first CT study listed below)
- 5: Number of CT Studies (integer >= 1)

The following additional comma separated values must be provided for each CT Study being uploaded (studies are listed in date/time order):

CT Study Columns:

- 1: Age (at the time of this CT study)
- 2: Pack Years (at the time of this CT study)
- 3: Smoking Status (one of “Never”, “Past”, or “Current”)
- 4: Study Sub-Directory Path (Use relative paths: ./Spoke1-0000002/Study1)
- 5: Lung Cancer Status (at the time of this CT study, may be “None”, “Suspicious Nodule(s)”, or “Lung Cancer”)
- 6: Number of CT Series in this study (integer >=1)

The following additional comma separated values must be provided for the main 3D axial CT series used to determine the radiological findings for this CT Study.

CT Series Columns:

- 1: Number of Lung Nodules (visible in this 3D axial CT series, must be an integer >= 0, lung nodules must all have a diameter >= 4mm)

- 2: Series Sub-Directory Path (Use relative paths: ./Spoke1-0000002/Study1/Series1)
- 3: [OPTIONAL] Lung-RADS Category (May be one of “Not applicable”, “0 (incomplete)”, “1 (negative)”, “2 (benign appearance or behavior)”, “3 (probably benign)”, “4A (suspicious)”, “4B (suspicious)”, “4X (suspicious)”
- 4: [OPTIONAL] Lung-RADS S Modifier (either “Yes” or “No”, Yes means clinically significant or potentially clinically significant findings (non lung cancer)
- 5: [OPTIONAL] Lung-RADS C Modifier (either “Yes” or “No”, Yes means prior diagnosis of lung cancer who return to screening)

Note that each CT series directory is named “Series<N>” (where N is an integer >= 1) within the study subdirectory path listed in the CT Study Columns. Only one axial DICOM series is allowed in each of these series sub-directories.

For each lung nodule found within the main axial CT series the following information must be provided:

Lung Nodule Columns:

- 1: Lung Nodule Number (unique integer between 1 and Number of Lung Nodules for the CT series, the order of the nodules should not change for later studies)
- 2: Type of Lung Nodule (at the time of this CT study, may be one of “Solid”, “Part-solid”, “Nonsolid” or “Other”)
3. [CONDITIONAL] Lung Nodule Type other explanation (Required if lung nodule type is “Other”)
- 4: X Position of Nodule (pixel units, integer, inside the 3D axial series extent)
- 5: Y Position of Nodule (pixel units, integer, inside the 3D axial series extent)
- 6: Z Position of Nodule (mm slice position units, decimal (1 digit of precision, use a period “.” to denote the decimal separator, using a comma “,” is not allowed), inside the 3D axial series extent)
- 7: Longest Diameter of Nodule (mm units, decimal (1 digit of precision, use a period “.” to denote the decimal separator, using a comma “,” is not allowed), position of nodule must fall on diameter line)
- 8: Status of Nodule (may be one of “Benign”, “Malignant”, or “Unknown”)
- 9: Pathology Type (Only provide this for pathologically confirmed nodules. May be one of “AAH”. “Atyp bronch prolif”, “AIS”, “MIA”, “Unspec. non-small cell”, “Adenocarcinoma”, “Adenosquamous”, “Large cell”, “Squamous cell”, “Small cell”, “Carcinoid - typical”, “Carcinoid - atypical”, “Not malignant”, “Benign specific”, “Other”)
10. [CONDITIONAL] Pathology type other explanation (additional text is required here if pathology type is “Other”)

Using these specifications, uploading a single CT lung cancer screening participant to a Spoke where the participant's dataset contains two CT studies, each with 2 CT series, each with one lung nodule visible would result in the upload of a CSV file with a single row and 47 columns (5 + (6 + (5 + 10) + (6 + 5 + 10))).

In the future additional radiological findings as well as outcome information may be added for each participant and this information will be uploaded within a separate CSV file.

DICOM Data Preparation

In addition to providing a CSV file for data upload to a Spoke, a Spoke manager must also provide a directory containing all of the DICOM data for the screening participants to be added to the spoke. The accompanying CSV file and the DICOM data directory for a data upload must correspond exactly with respect to all information provided including naming conventions, dates, and times.

Spokes will need to curate their DICOM data into separate directories for each CT participant / study / series to successfully add them to the ELIC H&SE. This can be performed automatically using recommended open source tools and guidance resources distributed by ELIC, LLC.

Participant cases being added to a Spoke must follow the data directory hierarchy below. Note that a name inside a "<>" means that the Spoke can use any string in between the "<" and ">" symbols, provided that the name/string meets the ELIC H&SE specifications. For example, the Study Sub-Directory Paths provided in the CSV file must match the actual sub-directories in the DICOM folders.

Directory Structure & Contents

```
Spoke1-DataUpload-YYYYMMDD/  
  metadata.csv  
  Spoke1-000001/  
    <Study1>/  
      <Series1>/  
        <DICOM image 1>  
        <DICOM image 2>  
        ...  
      <Series2>/  
        <DICOM image 1>  
        <DICOM image 2>  
        ...  
  Spoke1-000002/  
    <Study1>/  
      <Series1>/  
        <DICOM image 1>  
        <DICOM image 2>  
        ...
```

3.2. Data Upload

Each Spoke is set up to support SFTP file transfers, which performs data transfers using secure encrypted methods. The upload of de-identified CT lung image and metadata to a Spoke will require the generation of a tar file containing:

1. A CSV file containing the metadata associated with each screening participant being added.
2. The de-identified DICOM data for the screening participants in a specific directory structure.

The CSV file will contain a single row for each screening participant to be added to the ELIC H&SE.

The tar file can be created for files in the ./UploadDirectory on a Linux system using the following command:

```
tar -cvpf <SpokeName>-DataUpload-`date +%Y%m%d`.tar ./UploadDirectory
```

The Spoke manager must contact the TRO for the username and password to perform an SFTP file transfer. Transfer of the tar file to the Spoke server is performed with the following commands:

```
sftp spoke-manager@<SpokeServer>
cd upload
put <tar_file>
```

After successful upload, the tar file will be extracted and analyzed by the ELIC TRO for errors or problems. If a problem is encountered with the provided data the ELIC TRO will contact the Spoke manager to resolve the issue. If no issues are encountered, the ELIC TRO will then place the uploaded data within the Spoke directory structure (using automated scripts). In addition, metadata elements for the added or modified screening participant cases will be updated for the Spoke as well as the ELIC H&SE data catalogue available on the Hub.

4 Client Processing

ELIC allows clients to submit and run an analysis algorithm on the data available within the ELIC environment. ELIC accomplishes this by running the algorithm on data within a Docker virtual machine environment.

Algorithms may be executables, scripts, or combinations of executables and scripts that have been designed to accept an ELIC specific JSON document as input and produce an ELIC specific JSON document as output.

4.1 Algorithm Input and Output

Algorithm developers must provide an algorithm to ELIC within a docker image that will run on a single ELIC case which typically contains two or more CT DICOM studies. Algorithms must accept a JSON input document and return a JSON output document. The algorithm may use any number of input parameters; these will be configured on the hub when the algorithm is added to the system.

Regardless of the parameters configured for your algorithm, the **last argument** will always be an absolute path to a JSON document representing the participant. The participant file will contain all studies, and within those studies all series and nodules, if any. The algorithm should run on each series in the document. For each result calculated, the correlation between the input and output is the series “id” highlighted in [Appendix A](#).

The response document is noted in [Appendix B – Algorithm Result](#). If an error occurs executing the algorithm, this should be reported in the top level “errorMessage” property. Otherwise, this can be omitted, and responses provided in the “results” section. For each series, provide the seriesId field to indicate which series in the participant record the result refers to. You can then provide a number of error messages, if any; as well as the results in a key/value format. Note that the result keys are also defined at the Hub and names must match. The hub also maintains the unit of measure, so this does not

need to be provided in the result (e.g. mm³). Finally, if your algorithm produces images, these can be provided in the attachments section. Use appropriate MIME types.

The response document is expected to be located at an absolute path. The HUB will provide an additional argument called "OutputJSONFile" to your algorithm to indicate where that path should be. The value is typically /data/output.json (see Docker image below for references to /data mount).

4.2 Preparing a Docker image

Once the coding is ready to test, it's time to create an image on which to run the algorithm. This process involves minimal knowledge of Docker and the most common steps and commands are noted below. The project provides a base image (`FROM iaslc-elic-base:latest`) on which to start from which is based on Ubuntu 16.04. **You may also use your own publicly available base image as well.** If you choose to use the IASLC-ELIC image, in addition to the operating system, the image provides:

- Git
- WGET
- Cmake 3.12
- Oracle Java 8
- VTK 8.1.0 (<https://gitlab.kitware.com/vtk/vtk.git>)
- ITK 4.13.0 (<https://github.com/InsightSoftwareConsortium/ITK.git>)
- Mesa 17.2.8 <https://www.mesa3d.org>
- Open GL Utility 9.0 (<https://www.opengl.org/resources/libraries/glut/>)

On top of these libraries, you may add any other dependencies your algorithm requires.

It's important to note that the Dockerfile you provide may NOT be the final version. The support team will modify accordingly if the image is missing any of the following:

- Add your binary algorithm to the image
- Provide a /data mount to participant information provided at runtime.
- Create an entrypoint to run a specific case on that image
- Build and host the image on a private repository accessible only to Spoke clients
 - To expedite development and testing, the support team may provide you with credentials to upload the image to the repository.

An algorithm submission will have the following artifacts:

1. Algorithm binary
2. Dockerfile
3. List of arguments and output values

You can find an example working example algorithm and its source code at the following GitHub repository: <https://github.com/accumetra/IASLC-ELIC-Algorithm-Example>

4.3 Uploading A Client Algorithm

The support team may provide you with credentials and a repository to host your algorithm image.

Authenticate into the AWS repository:

```
aws ecr get-login-password --region us-east-1 | docker login --
username AWS --password-stdin 1234567890.dkr.ecr.us-east-
1.amazonaws.com
```

Tag the existing image with the repository

```
docker tag myImage:myVersion 1234567890.dkr.ecr.us-east-
1.amazonaws.com/myProject
```

Finally, push that tag to the repository

```
docker push 1234567890.dkr.ecr.us-east-1.amazonaws.com/myProject
```

[4.4 Running Experiments with a Client Algorithm](#)

Please refer to the example algorithm for instructions on running a case against your algorithm.

Appendix A – Participant input file

```
{
  "id": "a5ab82a1-71aa-41d7-b7a1-8d739ec4322a",
  "spokeId": "df3a788d-b719-48e6-bb6e-c71c54d4bea7",
  "name": "SPOKE1-000100",
  "gender": "M",
  "history": "NONE",
  "daysUntilDiagnosis": -51,
  "studies": [
    {
      "id": "4b28ccef-280e-4dbf-b7d8-3f84f5468cbe",
      "participantId": "a5ab82a1-71aa-41d7-b7a1-8d739ec4322a",
      "number": 1,
      "age": 30,
      "packYears": 6.3,
      "smokingStatus": "NEVER",
      "pathOnSpoke": "SPOKE1-000100/Study1",
      "lungCancerStatus": "SUSPICIOUS_NODULE",
      "series": [
        {
          "id": "0780aba6-57d7-442e-a497-b5c2777a3577",
          "studyId": "4b28ccef-280e-4dbf-b7d8-3f84f5468cbe",
          "number": 1,
          "noduleCount": 2,
          "pathOnSpoke": "SPOKE1-000100/Study1/Series1",
          "lungRadsCategory": "SUSPICIOUS_4A",
          "lungRadsS": true,
          "lungRadsC": false,
          "nodules": [
            {
              "id": "471a15cb-fdde-4fde-8b37-1c03e5304cc9",
              "seriesId": "0780aba6-57d7-442e-a497-b5c2777a3577",
              "number": 1,
              "noduleType": "SOLID",
              "noduleTypeOther": "",
              "x": -6.4,
              "y": 94.1,
              "z": -53.0,
              "diameter": 37.1,
              "status": "MALIGNANT",
              "pathologyType": "BENIGN_SPECIFIC",
              "pathologyTypeOther": ""
            },
            {
              "id": "a80e773e-ba6f-4aac-98bf-d7a31c9e545b",
              "seriesId": "0780aba6-57d7-442e-a497-b5c2777a3577",
              "number": 2,
              "noduleType": "NON_SOLID",
              "noduleTypeOther": "",
              "x": 40.5,
```

```

        "y": -182.1,
        "z": 56.0,
        "diameter": 23.2,
        "status": "UNKNOWN",
        "pathologyType": "AAH",
        "pathologyTypeOther": ""
    }
  ],
},
{
  "id": "8225aaa4-f867-494a-ae96-938de357d3fc",
  "studyId": "4b28ccef-280e-4dbf-b7d8-3f84f5468cbe",
  "number": 2,
  "noduleCount": 2,
  "pathOnSpoke": "SPOKE1-000100/Study1/Series2",
  "lungRadsCategory": "INCOMPLETE",
  "lungRadsS": false,
  "lungRadsC": false,
  "nodules": [
    {
      "id": "73ab3746-5d42-4eea-bf0c-677beda7b3a6",
      "seriesId": "8225aaa4-f867-494a-ae96-938de357d3fc",
      "number": 1,
      "noduleType": "OTHER",
      "noduleTypeOther": "Other Nodule Type",
      "x": 18.3,
      "y": 118.5,
      "z": -119.6,
      "diameter": 27.3,
      "status": "UNKNOWN",
      "pathologyType": "ATYPICAL_BRONCH_PROLIF",
      "pathologyTypeOther": ""
    },
    {
      "id": "b8f89421-bee3-4dc6-86cc-932576487d28",
      "seriesId": "8225aaa4-f867-494a-ae96-938de357d3fc",
      "number": 2,
      "noduleType": "NON_SOLID",
      "noduleTypeOther": "",
      "x": -49.0,
      "y": -187.5,
      "z": 164.0,
      "diameter": 49.4,
      "status": "BENIGN",
      "pathologyType": "SMALL_CELL",
      "pathologyTypeOther": ""
    }
  ]
},
]
}
]

```

```
}
```

Appendix B – Algorithm Result

```
{  
  "errorMessage": "Overall execution error",  
  "results": [  
    {  
      "seriesId": "7cfc6642-a739-4005-bdef-241132f7e824",  
      "errorMessages": [  
        "Error number 1",  
        "Error number 2",  
        "Error number 3",  
        "Error number 4"  
      ],  
      "values": {  
        "volume": 3.7,  
        "example": "lorem ipsum"  
      },  
      "attachments": [  
        {  
          "mimeType": "image/jpeg",  
          "content": "{BASE64 encoded string here}",  
          "fileName": "myfile.jpg",  
          "binary": true  
        },  
        {  
          "mimeType": "application/text",  
          "content": "simple text file",  
          "fileName": "myfile.txt",  
          "binary": false  
        }  
      ]  
    },  
    {  
      "seriesId": "0780aba6-57d7-442e-a497-b5c2777a3577",  
      "errorMessages": [],  
      "values": {  
        "volume": 5.3,  
        "example": "lorem ipsum"  
      },  
      "attachments": [  
        {  
          "mimeType": "image/jpeg",  
          "content": "{BASE64 encoded string here}",  
          "fileName": "myfile.jpg",  
          "binary": true  
        },  
        {  
          "mimeType": "application/text",  
          "content": "simple text file",
```

```

        "fileName": "myfile.txt",
        "binary": false
    }
]
},
{
    "seriesId": "8225aaa4-f867-494a-ae96-938de357d3fc ",
    "errorMessages": [],
    "values": {
        "volume": 2.7,
        "example": "lorem ipsum"
    },
    "attachments": [
        {
            "mimeType": "image/jpeg",
            "content": "{BASE64 encoded string here}",
            "fileName": "myfile.jpg",
            "binary": true
        },
        {
            "mimeType": "application/text",
            "content": "simple text file",
            "fileName": "myfile.txt",
            "binary": false
        }
    ]
}
]
}
}

```