SMRT Link Software Installation (v7.0.1)

Introduction

This document describes the procedure for installing SMRT Link v7.0.1 on a customer system. This document is for use by Customer IT or SMRT Link Administrators.

SMRT Link is the web-based end-to-end workflow manager for the Sequel®/Sequel II System. It includes software applications for designing and monitoring sequencing runs, and analyzing and managing sequence data. SMRT Link provides a web interface that can control multiple Sequel/Sequel II Systems.

SMRT Link is the primary access point for applications used by researchers, laboratory technicians, instrument operators, and bioinformaticians for various interactions with applications related to the Sequel platform. The applications include:

- **Sample Setup**: Calculate binding and annealing reactions for preparing DNA samples for use on the Sequel/Sequel II System.
- **Run Design**: Design runs and create and/or import sample sheets which become available on the Sequel/Sequel II System.
- **Run QC**: Monitor run progress, status and quality metrics.
- **Data Management**: Create Projects and Data Sets; manage access permissions for Projects and users; generate QC reports for Data Sets; view, import, export, or delete sequence, reference, and barcode files.
- **SMRT Analysis**: Perform multiple types of secondary analysis, including sequence alignment, variant detection, de novo assembly, structural variant calling, and RNA analysis.

*Note*: SMRT Link and the Sequel/Sequel II System are for research use only (RUO) and are not guaranteed to be secure.

Overview

1. Install or upgrade the SMRT Link software. (See “Installation Summary” on page 5 and “Configuring LDAP” on page 11 for details.)
2. *(Optional)* Configure SMRT Link to use an SSL Certificate. (See “Step 1: Obtain a domain-specific certificate from the appropriate Certification Authority.” on page 14 for details.)
3. *(Optional)* Add SMRT Link Users and Assign User Roles. (See “Adding SMRT Link Users and Assigning User Roles” on page 12 for details.)
4. *(Optional)* Change the admin and pbicsuser passwords. (See “Changing admin and pbicsuser Passwords” on page 9 for details.)
5. *(Optional)* Configure LDAP. (See “LDAP Integration” on page 10 for details.)
PacBio Compute Infrastructure Partners provide HPC solutions designed to support the Sequel II System.

## Sequel II System Compute Requirements

<table>
<thead>
<tr>
<th>Head Node</th>
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<tbody>
<tr>
<td><strong>Cores</strong></td>
<td>32</td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>64 GB</td>
</tr>
<tr>
<td><strong>tmp_dir (Local Storage)</strong></td>
<td>1 TB recommended, 500 GB minimum</td>
</tr>
<tr>
<td><strong>db_datadir (Local Storage)</strong></td>
<td>250 GB</td>
</tr>
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<table>
<thead>
<tr>
<th>Compute Nodes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cores (Total)</strong></td>
<td>384&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Minimum RAM per Slot (1 slot = 1 core)</strong></td>
<td>4 GB/8 GB &lt;i&gt;de novo&lt;/i&gt; assembly large complex genomes</td>
</tr>
<tr>
<td><strong>tmp_dir (Local Storage)</strong></td>
<td>100 GB</td>
</tr>
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<table>
<thead>
<tr>
<th>Shared Data Storage&lt;sup&gt;b&lt;/sup&gt;</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sequence Data</strong></td>
<td>40 TB</td>
</tr>
<tr>
<td><strong>Analysis Data</strong></td>
<td>70 TB</td>
</tr>
</tbody>
</table>

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<tr>
<th>Network</th>
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<tbody>
<tr>
<td><strong>10 GBE recommended</strong>, 1 GBE required</td>
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</tr>
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</table>

<sup>a</sup> For a standard CCS sequencing collection (300 GB sequencing data, 11 kb insert size, 30-hours movie), CCS Analysis takes 27 hours on this configuration. SMRT Link will work on less powerful compute configurations, however analysis time will be significantly longer.

<sup>b</sup> Storage is calculated for one Sequel II System, assuming 100 human genomes per year at 50-fold coverage, <i>de novo</i> assembly.

### Data Examples

#### Human Assembly

- Genome size: 3.3 GB; Sequence data 400 GB; Analysis data 700 GB; Analysis time: 72 hours wall. This is 50-fold coverage human genome analyzed on the compute configuration listed above.

#### Rice Assembly

- Genome size: 0.43 GB; Sequence data 55 GB; Analysis data 90 GB; Analysis time: 20 hours wall. This is 50-fold coverage rice genome analyzed on the compute configuration listed above.

For Sequel Instrument requirements, see "Appendix C: Sequel System Compute Requirements" on page 21 for details.

### Data storage

- The SMRT Link software **root** directory must be readable and writable by the SMRT Link install user and **must** have the same path across all compute nodes via NFS. PacBio recommends `/opt/pacbio/smrtlink` for the SMRT Link software root directory (referred to as `$SMRT_ROOT`), and `smrtanalysis` for the SMRT Link install user (referred to as `$SMRT_USER`).

- The SMRT Analysis **output** directory is used to store output from SMRT Analysis jobs. The software accesses this directory from a symbolic link at `$SMRT_ROOT/userdata/jobs_root`, which can be modified manually or by using the installation script. The symbolic link destination should be on a shared file system (NFS); it must be writable by the `$SMRT_USER`, and it must be accessible along the same path on all compute nodes. This is usually symbolically linked to a large storage volume.
• The SMRT Analysis database directory is used to store database files and backups. The software accesses this directory from a symbolic link at $SMRT_ROOT/userdata/db_datadir, and it can be modified manually or by using the installation script. This symbolic link destination should be a local directory (not NFS) and be writable by $SMRT_USER. This directory should exist only on the SMRT Link install host.

• The SMRT Analysis temporary directory is used for fast I/O operations during run time. The software accesses this directory from a symbolic link at $SMRT_ROOT/userdata/tmp_dir, and it can be modified manually or using the installation script. This symbolic link destination should be a local directory (not NFS), it must be writable by $SMRT_USER, and it must exist (or be creatable) as an independent directory on all compute nodes. The temporary directory exists on both the head node, and the compute nodes.

Software Prerequisites: Server Operating Systems

• SMRT Link server software is supported on English-language CentOS 6.x; 7.x and Ubuntu 16.04; 18.04 64-bit Linux® distributions. (This also applies to SMRT Link compute nodes.)

• SMRT Link is not guaranteed to work on Linux versions that are no longer supported by the Operating Systems’ vendors.

• SMRT Link server software cannot be installed on macOS® or Windows® systems.

Software/Hardware Prerequisites: Client Systems

To use SMRT Link on a client operating system:

• SMRT Link requires the Google® Chrome web browser, version 64 or later.

• SMRT Link requires a minimum screen resolution of 1600 by 900 pixels.

• PacBio recommends 64-bit Java (Version 8 or later) installed on your local Windows or Mac OS host to run SMRT View.

Network Configuration

• Please refer to the IT Site Prep Guide provided with your instrument purchase for more details.

• For network connectivity considerations, see the network diagram in the Computer Requirements section of the IT Site Prep Guide.

SMRT Link Server Environment Assumptions

• The SMRT Link server should run on a dedicated 64-bit Linux host with libc 2.5 or greater.

• Installing as the same non-root user ($SMRT_USER) that will be used to run the system.

• The $SMRT_USER has full permissions in the file system in the $SMRT_ROOT directory and in all linked directories for jobs_root, db_datadir and tmp_dir. (Common problems include NFS setup problems, ACLs, and so on.)

• When running in distributed mode, all other nodes have the same path for $SMRT_ROOT and for all linked directories.

• During the installation, no other daemons/services are bound to the same ports.

• PacBio highly recommends that the system clock be synchronized to a public NTP time server.

• The $SMRT_USER service account must have both the nofile and nproc limits set to a minimum of 8192. (See the ulimit(1) and limits.conf(5) Linux man pages for more information.)

General Security Notes

• PacBio recommends that you install the SMRT Link server on networks that are only accessible to trusted users, and discourages installing SMRT Link on public networks.

• Do not install SMRT Link using root as the user.

SMRT Link v7.0.1 Security Notes

SMRT Link v7.0.1 restricts access to the web services API to clients running on localhost (like the WSO2 server that handles authentication and permissions) or remotely using SSL encryption and password-based
authentication. This change may require several post-upgrade modifications to customer environments and workflows.

**Ports and firewalls**: The SMRT Link GUI requires that web browsers can access the HTTPS port 8243 for access to the password-protected API and static web content services. This port is also used by the Sequel Instrument Control Software (ICS), so it needs to be available to any Sequel Systems as well.

- If your network is already configured to leave this port open, no additional changes are required to use v7.0.1.
- The instrument must be have access to port 8243 of the SMRT Link server.

**Installation/Upgrade Checklist**
Following is a list of items you should have ready before starting a new installation or upgrading an existing installation:

- Full path (without spaces) to the installation root directory, used for the main installation root.
- Job Management System settings.
- Full path (without spaces) to a directory on the shared file system - the jobs_root directory.
- Full path (without spaces) to a directory on the local file system on each node - the tmp_dir directory.
- Full path (without spaces) to a directory on the local file system on the install node - the db_datadir directory.
- (Optional) LDAP Settings. See “Configuring LDAP” on page 11 for details.
- (Optional) SSL Certificate for WS02. See “SMRT® Link and SSL Certificate Procedures” on page 13 for details.
### Installation Summary

Following are the steps for installing SMRT Link v7.0.1 on a new system. (See “Appendix A: SMRT Link Workflow Terminology” on page 19 for details.) To upgrade SMRT Link to v7.0.1 from a previous version, follow the upgrade steps on Page 7.

- **Note:** SMRT Link v7.0.1 can be used with Sequel/Sequel II Systems with Instrument Control Software (ICS) v6.0.0 or v7.0.0 installed.

#### Step 1: Download SMRT Link software:


#### Step 2: Definitions and variables:

For clarity, this document uses these conventions to refer to site-specific information:

- **$SMRT_ROOT**: The SMRT Link Install Root Directory, such as `/opt/pacbio/smrtlink`.
- **$SMRT_USER**: The SMRT Link Install User, such as `smrtanalysis`.
- `smrtlinkhost.mydomain.com`: The fully-qualified domain name of the SMRT Link Install Host.
- `smrtlinkhost`: The short host name of the SMRT Link Install Host.

For `$SMRT_ROOT`, define a convenience variable in the shell so the commands below may be run verbatim. To do so, use something like:

```bash
SMRT_ROOT=/opt/pacbio/smrtlink
```

The fully qualified version of the SMRT Link Install Host may always be used in place of the short host name. But in some cases, particularly when working with WSO2, the fully qualified domain name is required.

#### Step 3: Log onto the SMRT Link Install Host (such as `smrtlinkhost`) as the SMRT Link Install User (such as `$SMRT_USER`.)

#### Step 4: Install SMRT Link by invoking the SMRT Link Installer:

```bash
smrtlink_7.0.1.66975.run --rootdir $SMRT_ROOT
```

**Note:** The `$SMRT_ROOT` directory must not exist when the installer is invoked, as the installer will try to create it, and will abort the installation if an existing `$SMRT_ROOT` location is found.

If a previous installation was canceled or otherwise failed, the installer can be invoked without extraction. Rerun using the `--no-extract` option:

```bash
smrtlink_7.0.1.66975.run --rootdir $SMRT_ROOT --no-extract
```

See “Appendix A: SMRT Link Workflow Terminology” on page 19 for additional information.

#### Step 5: Start SMRT Link services:

```bash
$SMRT_ROOT/admin/bin/services-start
```

#### Step 6: Run the Site Acceptance Test from the command line:

```bash
$SMRT_ROOT/admin/bin/run-sat-services
```

Successful completion of `run-sat-services`, which produces a Site Acceptance Test (SAT) analysis job in the SMRT Analysis module of the SMRT Link GUI, indicates that the HPC configuration is functioning correctly.

#### Step 7: Clear the Browser Cache:

1. Open the Chrome Browser and choose **More Tools > Clear browsing data**, choose **All Time** from the **Time Range** droplist, then check **Cached images and files**. Click **Clear data**.

2. Restart the browser.
Run the Site Acceptance Test from the browser:
   - The port number should match the GUI port defined during installation; the default is 9090. The URL will redirect to a secure URL at hard-coded port 8243. If port 9090 is blocked, go directly to the redirect URL at https://smrtlinkhost.mydomain.com:8243/sl/.
   - Check with your IT group if port 8243 is blocked; access to port 8243 on the SMRT Link Install Host is required.
2. Bypass the Chrome browser’s privacy error check:
   Without an SSL certificate installed, Chrome will issue a “Privacy Error” and state that “Your connection is not private”. Bypass by clicking on the Advanced link on the bottom left of the page. Then click on the Proceed to smrtlinkhost.mydomain.com (unsafe) link. To avoid the “Privacy Error” in the future, follow the instructions for installing the SSL Certificate in Step 10 below.
3. Log in to SMRT Link by entering the default Administrator credentials: admin/admin.
4. Submit SMRT Link notification selections:
   Select options for notifying PacBio of successful installations and for sending ongoing SMRT Link analysis usage information. Click Save.
5. Go to the SMRT Analysis page:
6. Create a new analysis: Click + Create New Analysis.
7. Select analysis settings and start the analysis:
   a) Enter SMRT Link 7.0.1 SAT Test (or any descriptive name) in the Analysis Name field.
   b) Select Sequel Data as the Data Type.
   c) In the Data Sets table, check the box next to lambda/0007_tiny.
   d) Click Next.
   e) Select Site Acceptance Test (SAT) from the Analysis Application drop down list, at the top left. The Reference field will be auto-populated with LambdaNEB.
   f) Click Start in the top right corner to start the analysis.
8. Wait for the analysis to complete successfully. On the Analysis Results - SMRT Link 7.0.1 SAT Test page (https://smrtlinkhost.mydomain.com:8243/sl/#/analysis/job/15):
   - The spinning wheel next to the green text RUNNING on the top status bar indicates that the analysis is in progress.
   - The Analysis Overview page displays by default, and is updated periodically.
   - Upon success, the green RUNNING text changes to SUCCESSFUL.
Successful completion of the Site Acceptance Test (SAT) indicates that SMRT Link analysis is working correctly. It shows that the analysis was configured and started via the browser GUI, through the SMRT Link Services, and dispatched jobs to the HPC cluster (if distributed mode was configured during installation).

(Optional) Configure LDAP:
See “Configuring LDAP” on page 11 for details.

(Optional) Configure SMRT Link to use a Signed SSL Certificate:
See “SMRT® Link and SSL Certificate Procedures” on page 13 for details.

(Optional) Change the pbicsuser and admin passwords:
We recommend that you change the admin and pbicsuser account passwords. See “Changing admin and pbicsuser Passwords” on page 9 for details.
### Upgrading SMRT® Link

**Supported Upgrade Path**

- SMRT Link upgrades **must** be performed sequentially, that is: **3.1.0 > 3.1.1 > 4.0.0 > 5.0.1 > 5.1.0 > 6.0.0 > 7.0.1**.
- You **cannot** upgrade to SMRT Link from SMRT Analysis v2.3.0 or earlier. Additionally, analysis job directories and run history from SMRT Analysis v2.3.0 or earlier are **not** compatible with SMRT Link and **cannot** be imported.

**Note**: SMRT Link v7.0.1 can be used with Sequel/Sequel II Systems with Instrument Control Software (ICS) v6.0.0 or v7.0.0 installed.

<table>
<thead>
<tr>
<th>Step</th>
<th>Upgrading SMRT Link</th>
</tr>
</thead>
</table>
| 1    | **Download SMRT Link software:**  
Download SMRT Link from http://www.pacb.com/support/software-downloads/. |
| 2    | **Definitions and variables:**  
For clarity, this document uses these conventions to refer to site-specific information:  
- **$SMRT_ROOT**: The SMRT Link Install Root Directory, such as /opt/pacbio/smrtlink.  
- **$SMRT_USER**: The SMRT Link Install User, such as smrtanalysis.  
- **smrtlinkhost.mydomain.com**: The fully-qualified domain name of the SMRT Link Install Host.  
- **smrtlinkhost**: The short host name of the SMRT Link Install Host.  
  
For **$SMRT_ROOT**, define a convenience variable in the shell so the commands below may be run verbatim. To do so, use something like:

```bash
SMRT_ROOT=/opt/pacbio/smrtlink
```

The fully qualified version of the SMRT Link Install Host may always be used in place of the short host name. But in some cases, particularly when working with WSO2, the fully qualified domain name is required. |
| 3    | **Log onto the SMRT Link Install Host** (such as **smrtlinkhost**) as the SMRT Link Install User (such as **$SMRT_USER**). |
| 4    | **Stop the SMRT Link services:**  
$SMRT_ROOT/admin/bin/services-stop  
**Note**: Ensure that no active SMRT Link analysis jobs are running before stopping services. |
| 5    | **Upgrade SMRT Link by invoking the SMRT Link installer:**  
smrtlink_7.0.1.66975.run --rootdir $SMRT_ROOT --upgrade  
**Note**: The **$SMRT_ROOT** directory must be an existing SMRT Link installation. Several validation steps will occur to ensure that a valid **$SMRT_ROOT** is being updated.  
If a previous upgrade was canceled or otherwise failed, the installer can be invoked **without** extraction. Rerun using the **--no-extract** option:  
smrtlink_7.0.1.66975.run --rootdir $SMRT_ROOT --upgrade --no-extract  
See "Appendix A: SMRT Link Workflow Terminology" on page 19 for additional information. |
| 6    | **Start the SMRT Link services:**  
$SMRT_ROOT/admin/bin/services-start |
| 7    | **Run the Site Acceptance Test from the command line:**  
$SMRT_ROOT/admin/bin/run-sat-services  
Successful completion of **run-sat-services**, which produces a Site Acceptance Test (SAT) analysis job in the SMRT Analysis module of the SMRT Link GUI, indicates that the HPC configuration is functioning correctly. |
Updating the SMRT Link Chemistry Bundle Using the SMRT Link GUI

SMRT Link Chemistry Bundle updates allow updating of SMRT Link features without having to reinstall the SMRT Link software. The update also updates Sequel® Instrument Control Software (ICS).

Note: Only SMRT Link users with the Admin role can perform this update. In addition, update services must be enabled.

### Upgrading SMRT Link

<table>
<thead>
<tr>
<th>Step</th>
<th>Clear the Browser Cache:</th>
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<tbody>
<tr>
<td>8</td>
<td>1. Open the Chrome Browser and choose More Tools &gt; Clear browsing data, choose All Time from the Time Range dropdown, then check Cached images and files. Click Clear data.</td>
</tr>
<tr>
<td></td>
<td>2. Restart the browser.</td>
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</table>

<table>
<thead>
<tr>
<th>Run the Site Acceptance Test from the browser:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The port number should match the GUI port defined during installation; the default is 9090. The URL will redirect to a secure URL at hard-coded port 8243. If port 9090 is blocked, go directly to the redirect URL at <a href="https://smrtlinkhost.mydomain.com:8243/sl/">https://smrtlinkhost.mydomain.com:8243/sl/</a>.</td>
</tr>
<tr>
<td>- Check with your IT group if port 8243 is blocked; access to port 8243 on the SMRT Link Install Host is required.</td>
</tr>
<tr>
<td>2. Bypass the Chrome browser’s privacy error check:</td>
</tr>
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<td>Without an SSL certificate installed, Chrome will issue a “Privacy Error” and state that “Your connection is not private”. Bypass by clicking on the Advanced link on the bottom left of the page. Then click on the Proceed to smrtlinkhost.mydomain.com (unsafe) link.</td>
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<tr>
<td>3. Log in to SMRT Link by entering the Administrator credentials: admin/admin. (admin is the built-in password, which may have been changed previously.)</td>
</tr>
<tr>
<td>4. Submit SMRT Link notification selections:</td>
</tr>
<tr>
<td>Select options for notifying PacBio of successful installations and for sending ongoing SMRT Link analysis usage information. Click Save.</td>
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<tr>
<td>5. Go to the SMRT Analysis page:</td>
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<td>6. Create a new analysis: Click + Create New Analysis.</td>
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<tr>
<td>7. Select analysis settings and start the analysis:</td>
</tr>
<tr>
<td>a) Enter SMRT Link 7.0.1 SAT Test (or any descriptive name) in the Analysis Name field.</td>
</tr>
<tr>
<td>b) Select Sequel Data as the Data Type.</td>
</tr>
<tr>
<td>c) In the Data Sets table, check the box next to lambda/0007_tiny.</td>
</tr>
<tr>
<td>d) Click Next.</td>
</tr>
<tr>
<td>e) Select Site Acceptance Test (SAT) from the Analysis Application drop down list, at the top left. The Reference field will be auto-populated with LambdaNEB.</td>
</tr>
<tr>
<td>f) Click Start in the top right corner to start the analysis.</td>
</tr>
<tr>
<td>8. Wait for the analysis to complete successfully. On the Analysis Results - SMRT Link 7.0.1 SAT Test page (<a href="https://smrtlinkhost.mydomain.com:8243/sl/#/analysis/job/15">https://smrtlinkhost.mydomain.com:8243/sl/#/analysis/job/15</a>):</td>
</tr>
<tr>
<td>- The spinning wheel next to the green text RUNNING on the top status bar indicates that the analysis is in progress.</td>
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<td>- The Analysis Overview page displays by default, and is updated periodically.</td>
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<td>- Upon success, the green RUNNING text changes to SUCCESSFUL.</td>
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<table>
<thead>
<tr>
<th>(Optional) Change the pbicsuser and admin passwords:</th>
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<tbody>
<tr>
<td>We recommend that you change the admin and pbicsuser account passwords. See “Changing admin and pbicsuser Passwords” on page 9 for details.</td>
</tr>
</tbody>
</table>
1. In SMRT Link, choose **About** from the Main menu. (A red circle indicates that a Chemistry Bundle Update is available.)
2. Click the **Update** button.
3. If there are any problems, clear the browser cache: Choose **More Tools > Clear browsing data**, choose **All Time** from the **Time Range** dropdown list, then check **Cached images and files**. Click **Clear data**.
4. Restart the browser. The SMRT Link Chemistry Bundle for this installation of SMRT Link is updated.

**Updating the SMRT Link Chemistry Bundle On the Instrument**
1. On the instrument, choose **Admin** from the Main menu. (A red circle indicates that a Chemistry Bundle Update is available.)
2. Click the **Updates** tab, then click **Install**. The instrument software then restarts, which will take around 10 minutes.

**Installing only SMRT Tools**
To install only command-line SMRT Tools, use the `--smrttools-only` option with the installation command, whether for a new installation or an upgrade. Examples:

```
smrtlink-*.run --rootdir smrtlink --smrttools-only
smrtlink-*.run --rootdir smrtlink --smrttools-only --upgrade
```

**Updating the SMRT Link Chemistry Bundle for smrttools-only Installations**
Use this procedure only if you have installed the SMRT Link package using the `--smrttools-only` switch.

Download the Chemistry Bundle from the PacBio website, then unpack the files and place them in a user-defined directory. The value of the `$SMRT_CHEMISTRY_BUNDLE_DIR` environment variable then defines where the software finds the updated files. Following are the suggested best practices for installing the Chemistry Bundle:

2. (Optional) Define `$SMRT_ROOT` for convenience:
   ```bash
   SMRT_ROOT=/opt/pacbio/smrtlink
   ```
3. Make directories, unpack, and link:
   ```bash
   mkdir -p $SMRT_ROOT/userdata/chemistry/chemistry-pb-6.0.0.xxxxx
   tar -C $SMRT_ROOT/userdata/chemistry/chemistry-pb-6.0.0.xxxxx -xf /path/to/chemistry-pb-5.1.0.xxxxx.tar.gz
   ln -s ./chemistry-pb-6.0.0.xxxxx $SMRT_ROOT/userdata/chemistry/chemistry-pb-active
   ```
4. Set/export `$SMRT_CHEMISTRY_BUNDLE_DIR` and validate:
   ```bash
   export SMRT_CHEMISTRY_BUNDLE_DIR=$SMRT_ROOT/userdata/chemistry/chemistry-pb-active
   ```
5. Set the variable in the user environment to make it permanent.
   Example: Use `.bashrc` or `.bash_profile`.

**Changing admin and pbicsuser Passwords**
The SMRT Link `admin` account has full access to SMRT Link, and is used to create users and grant users access.

SMRT Link comes with a default Instrument Control Software (ICS) user account (`pbicsuser`) which is used by the Sequel/Sequel II Systems to communicate with SMRT Link Web Services over a secure, encrypted connection. The `pbicsuser` account is **required** for instruments to communicate with SMRT Link. (Note that the `pbicsuser` credentials can only be used to access SMRT Link resources – it is not a Unix shell account.)
The passwords for the admin and pbicsuser accounts are set to default values that are the same for all SMRT Link installations. Because the passwords can be used to access SMRT Link accounts and information, the passwords should be changed and only given to trusted users who require access.

To change the admin and pbicsuser passwords, use the following procedure:

```bash
$SMRT_ROOT/admin/bin/services-stop
$SMRT_ROOT/admin/bin/set-wso2-creds -u admin -p NEW-PASSWORD
$SMRT_ROOT/admin/bin/set-wso2-creds -u pbicsuser -p NEW-PASSWORD
```

To verify the admin and pbicsuser passwords, use the following procedure:

```bash
$SMRT_ROOT/admin/bin/services-start
$SMRT_ROOT/smrtcmds/bin/pbservice status --host localhost --user admin --ask-pass
$SMRT_ROOT/smrtcmds/bin/pbservice status --host localhost --user pbicsuser --ask-pass
```

**Note:** Printing pbservice status information and exiting with an exit status of 0 indicates success.

You must also change the pbicsuser account password in the Instrument Control Software (ICS) to match the new password. To do so: Select **Menu > Admin > SMRT Link** on the instrument touch screen to change the password.

### Changing Your Usage Tracking Settings

When first logging in to the SMRT Link GUI after a successful installation or upgrade, users are prompted to notify PacBio of the upgrade/installation, and asked to enable the sending of SMRT Link analysis usage information to PacBio. Once set, these settings may only be viewed and modified from the command line using the accept-user-agreement tool.

To use the accept-user-agreement tool, services must be running:

```bash
$SMRT_ROOT/admin/bin/services-start
```

To set new settings, use the following command, specifying true or false for the options accordingly. For example:

```bash
$SMRT_ROOT/admin/bin/accept-user-agreement --install-metrics true --job-metrics true
```

PacBio will be notified of a successful installation or upgrade immediately if the install metrics setting is true.

To view the current settings, run the command without any arguments:

```bash
$SMRT_ROOT/admin/bin/accept-user-agreement
```

**Note:** If accept-user-agreement is run without arguments and the settings have not been previously set (either in the GUI or on the command line), both the install and job metrics settings will automatically be set to true and PacBio will be immediately notified of the installation or upgrade.

### LDAP Integration

SMRT Link supports integration with LDAP for user login authentication. Without LDAP integration with SMRT Link, only one user (with the login admin/admin) is enabled.

If you are interested in configuring SMRT Link integration with your organization’s LDAP, PacBio recommends that you consult your LDAP administrator to help determine the correct LDAP settings.

**Note:** Existing LDAP configurations are automatically migrated during upgrade.
Configuring LDAP

- LDAP is configured after SMRT Link v7.0.1 is installed, using the WSO2 API Manager software, as shown below.
- You must first configure LDAP before you can enable a network user to be a SMRT Link user, and specify their role.

1. Enter the following in your browser: https://<hostname>:9443/carbon/ where <hostname> is the host where SMRT Link is installed.
2. Login using admin/admin.
3. Click User Stores > Add.

4. Edit the fields as necessary for your site.

The following fields are required. (Note: Values provided in the example above are listed below for clarity. Actual values should be provided by your LDAP administrator):

- **User Store Manager Class**: org.wso2.carbon.user.core.ldap.ReadOnlyLDAPUserStoreManager
- **Domain Name**: university.edu
- **Connection URL**: ldap://ldap.university:389
- **Connection Name**: CN=ldapadmin,CN=users,DC=university,DC=edu
- **Connection Password**: <password>
- **User Search Base**: CN=users,DC=university,DC=edu
- **Username Attribute**: uid
- **User Search Filter**: 
  
  ```
  (&(objectClass=person)(uid=*))
  ```
- **User List Filter**: (objectClass=person)
- **Display name attribute**: uid
For more information on LDAP, consult the following web pages:

https://en.wikipedia.org/wiki/LDAP_Data_Interchange_Format  

Problems with the LDAP server may be debugged by looking at the log file located here:

$SMRTLINK/current/bundles/smrlink-analysisservices-gui/current/private/pacbio/smrlink-analysisservices-gui/wso2am-2.0.0/repository/logs/wso2-apigw-errors.log

SMRT® Link User Roles

SMRT Link supports three user roles: Admin, Lab Tech, and Bioinformatician. (A fourth role, Instrument, displays in the User Management page. The Sequel Instrument Control Software uses this role to communicate with SMRT Link. Do not assign any SMRT Link users to this role.) Roles define which SMRT Link modules a user can access. The following table lists the privileges associated with the three user roles:

<table>
<thead>
<tr>
<th>Tasks/Privileges</th>
<th>Admin</th>
<th>Lab Tech</th>
<th>Bioinformatician</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add/Delete SMRT Link Users</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Assign roles to SMRT Link users</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Update SMRT Link software</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Access Sample Setup Module</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Access Run Design Module</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Access Run QC Module</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Access Data Management Module</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Access SMRT Analysis Module</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

PacBio recommends the following role assignments:

- Assign at least one user per site the Admin role. That individual is responsible for enabling and disabling SMRT Link users, as well as specifying their roles. The Admin can also access all SMRT Link modules, as well as every file in the system. (SMRT Link supports multiple users with the Admin role per site.)
- Assign users who work in the lab preparing samples and performing runs the Lab Tech role. Lab Tech can also access all SMRT Link modules.
- Assign users who work only on data analysis the Bioinformatician role. Bioinformatician can only access the Run QC, Data Management and SMRT Analysis modules; this is the lowest access level.

Adding SMRT Link Users and Assigning User Roles

- You must first configure LDAP before you can manage users and assign SMRT Link roles to users.
- After LDAP is configured, if you do not assign a SMRT Link role to a user, that user will not be able to login to SMRT Link.

1. Access SMRT Link: Enter http://<hostname>:9090, where <hostname> is the host where SMRT Link is installed.
2. Choose Configure from the SMRT Link menu and click User Management.
3. There are 2 ways to find users:
   - To display all SMRT Link users: Click Display all Enabled Users.
   - To find a specific user: Enter a user name, or partial name and click Search By Name.
4. Click the desired user. If the Status is **Enabled**, the user has access to SMRT Link; **Disabled** means the user **cannot** access SMRT Link.

   - To **add** a SMRT Link user: Click the **Enabled** button, then assign a role. (See Step 5.)
   - To **delete** a SMRT Link user: Click the **Disabled** button.

5. Click the **Role** field and select one of the three roles. (A blank role means that this user **cannot** access SMRT Link.)

6. Click **Save**. The user now has access to SMRT Link, based on the role just assigned.

---

**SMRT® Link and SSL Certificate Procedures**

SMRT Link v7.0.1 uses SSL (Secure Sockets Layer) to enable access via HTTPS (HTTP over SSL), so that your SMRT Link logins and data are encrypted during transport to and from SMRT Link. SMRT Link includes an Identity Server, which can be configured to integrate with your LDAP/AD servers and enable user authentication using your organizations’ user name and password. To ensure a secure connection between the SMRT Link server and your browser, the SSL Certificate can be installed after completing SMRT Link installation.

It is important to note that PacBio will **not** provide a Signed SSL Certificate. However, once your site has obtained a Signed SSL Certificate, PacBio’s tools can be used to install it and configure SMRT Link to use it. **(Note:** PacBio recommends that you consult your IT administrator about obtaining an SSL Certificate.**)** You will need a certificate issued by a Certificate Authority (CA, sometimes referred to as a “certification authority”). PacBio has tested SMRT Link with certificates from the following certificate vendors: VeriSign, Thawte and DigiCert.

If your site **does not** provide an SSL Certificate, SMRT Link v7.0.1 will use a PacBio self-signed SSL Certificate. If you use the self-signed SSL Certificate, **each** user will need to accept the browser warnings related to access in insecure environment. You can also have your IT administrator configure desktops to **always trust** the provided self-signed Certificate. Note that SMRT Link is installed within your organization’s secure network, behind your organization’s firewall.

See “Using SMRT Link with a PacBio Self-Signed SSL Certificate” on page 16 for details on how to handle the security warnings when accessing SMRT Link.

Use the following procedures **only** if your site provides an SSL Certificate. These procedures are **not** applicable if you are using PacBio’s Self-Signed SSL Certificate.

**Note:** If you have already setup an SSL Certificate in SMRT Link v4.0.0 or later, those settings will be carried over automatically when upgrading to SMRT Link v7.0.1.

**Prerequisites**
The following programs are supplied with the SMRT Link installation: openssl, and keytool.
Step 1: Obtain a domain-specific certificate from the appropriate Certification Authority.

Step 2: Download the new certificate in .p7b format from the DigiCert website hostname_domain_com.p7b.

Step 3: Combine the certificate and the keystore files:

$ keytool -import -trustcacerts -alias server -file ${KEYNAME}.p7b -keystore ${KEYNAME}.jks
Enter keystore password:
Certificate reply was installed in keystore

Step 4: Generate an intermediate file in .pem format:

$ keytool -export -alias server -keystore ${KEYNAME}.jks -file ${KEYNAME}.pem
Enter keystore password:
Certificate stored in file <hostname_nanofluidics_com.pem>

Step 5: Generate the WSO2 truststore client-truststore.jks file using the .pem file:

$ keytool -import -alias server -file ${KEYNAME}.pem -keystore client-truststore.jks -storepass $KEYPW

Trust this certificate? [no]: y
Certificate was added to keystore

Step 6: Stop the services by entering ${SMRT_ROOT}/admin/bin/services-stop.

Step 7: Install the new .jks files and update the configuration files:

${SMRT_ROOT}/admin/bin/install_ssl_cert.sh ${FQDN} ${KEYSTORE} ${TRUSTSTORE} ${KEYPW}

This script will install a signed SSL certificate to SMRT Link, removing the browser warnings that occur when using the default certificate. To run this script, you will need two files in Java Key Store (.jks) format:

• One containing the SSL keys and certificate.
• A separate client-truststore.jks required by the authentication manager.

Usage: install_ssl_cert.sh $FQDN $KEYSTORE $TRUSTSTORE $KEYPW where:

• $FQDN is the fully-qualified domain name appropriate to the signed SSL Certificate, such as smrtlink.university.edu.
• $KEYSTORE is the path to the keystore file generated from the SSL Certificate (.jks extension); this will be copied to the SMRT Link installation.
• $TRUSTSTORE is the path to client-truststore.jks.
• $KEYPW is the password used for generating keys.

The FQDN must match the dnsname specified in the installer The shorthand (such as "smrtlinkhost") will not work because the certificate is for a domain name, not an unqualified host name. When running the SMRT Link installer, do this by passing the arguments --dnsname $FQDN.

Also note that if you are using LDAP authentication, you may need to reenter the password for the LDAP connection in the WSO2 administrative interface once SMRT Link has been started again, for example: https://smrtlink.pacb.com:9443/carbon.
This is because the password is stored encrypted with the SSL certificate key, which has now changed.
Step 8: Start SMRT Link services by entering `$SMRT_ROOT/admin/bin/services-start`.

Step 9: Final Check:

Go to `http://hostname:9090` and login as admin/admin (if LDAP is not enabled). Note that SSL is not used on the UI port (i.e. 9090) because this only serves static content; the actual login credentials are sent to port 8243 which only uses SSL.

You will be redirected to `https://hostname.domain.com:8243/sl/#/welcome`, and should see a padlock sign in front of the URL which indicates that the site is secure.

Viewing a Java Keystore File

The keystore files for SSL certificates are binary files. Use the following command to verify if the same password was used in the SSL certificate generation and install process. If the same password was not used in the certificate installation process, this command will give an error. To list the contents of a Java keystore file, use the `keytool -list` command, as shown below:

**Usage:** `keytool -list -v -keystore keystore.jks`

**Example:** `keytool -list -v -keystore smrtlink-test_nanofluidics_com.jks`

```
Enter keystore password:
Keystore type: JKS
Keystore provider: SUN
Your keystore contains 1 entry
Alias name: server
Creation date: Feb 13, 2017
Entry type: PrivateKeyEntry
Certificate chain length: 3
Certificate[1]:
   Owner: CN=smrtlink-release-test.nanofluidics.com, O="Pacific Biosciences of California, Inc.",
   L=Menlo Park, ST=CA, C=US
   Issuer: CN=DigiCert SHA2 Secure Server CA, O=DigiCert Inc, C=US

Errors/logs related to certificate installation can be found here:

$SMRT_ROOT/current/bundles/smrtlink-analysisservices-gui/current/private/pacbio/smrtlink-analysisservices-gui/

Installing an Existing Certificate

If you already have a complete .jks file (suitable for Apache Tomcat, for example), including the signed certificate, you just need to change the alias of the keystore/certificate to `server` using the `keytool` command (`-keyclone` or `-changealias` subcommands).

Set the password to whatever you will supply to the install script in SMRT Link. Then, follow the instructions in "Adding the public key to client-truststore.jks" in [https://docs.wso2.com/display/IS500/Creating+New+Keystores](https://docs.wso2.com/display/IS500/Creating+New+Keystores) again with the same changes.

If you already have the SSL key in a .jks file and have obtained a certificate for this key in PKCS #7 Certificate format (.p7b), run this command to combine them:

    $ keytool -import -trustcacerts -alias server -file star.university.edu.p7b -keystore star.university.edu.jks

Then follow the instructions above to generate the `client-truststore.jks` file, and run the install script.
Recovering from the SSL Certificate Installation
It may sometime be necessary to uninstall the user-provided SSL certificate and restore the default certificate. The following steps will revert changes made by $SMRT_ROOT/admin/bin/install_ssl_cert.sh:

1. Stop SMRT Link services:
   $SMRT_ROOT/admin/bin/services-stop

2. Check that all SMRT Link processes have terminated by running ps -ef | grep smrtlink. Remaining processes should be terminated with kill <PID> or kill -9 <PID>.

3. Restore backup settings:
   cd ${SMRT_ROOT}/current/bundles/smrtlink-analysisservices-gui/current/private/pacbio/smrtlink-analysisservices-gui/wso2am-2.0.0/repository
   mv conf conf.new
   mv conf.orig conf
   mv resources/security/client-truststore.jks.orig resources/security/client-truststore.jks

4. Start SMRT Link services:
   ${SMRT_ROOT}/admin/bin/services-start

Using SMRT Link with a PacBio Self-Signed SSL Certificate
SMRT Link v7.0.1 ships with a PacBio self-signed SSL Certificate. If your site does not have a Signed SSL Certificate and you use the self-signed SSL Certificate, each user will need to accept the browser warnings related to access in insecure environment. You can also have your IT administrator configure desktops to always trust the provided self-signed Certificate. Note that SMRT Link is installed within your organization’s secure network, behind your organization’s firewall.

Security messages display when users try to login to SMRT Link for the first time using the Chrome browser. These messages may also display other times when accessing SMRT Link. Each SMRT Link user in your organization should address these browser warnings following the procedure below.

1. The first time you start SMRT Link after installation, you see the following text. Click the Advanced link.

2. Click the Proceed... link. (You may need to scroll down.)
3. Close the window by clicking the Close box in the corner.

4. The Login dialog displays, where you enter the User Name and Password. The next time you access SMRT Link, the Login dialog displays directly.

Client Software: Installing 64-bit Java 8 to run SMRT® View

SMRT View is a genome browser that visualizes sequencing data generated by the Sequel/Sequel II System.

• **Note:** To run SMRT View, 64-bit Java (Version 8 or later) **must** be installed on your local Windows or Macintosh host.

Installing 64-bit Java 8 on Windows

1. Use **Control Panel > Programs and Features** to check for and uninstall **all** existing versions of Java.
3. Click **Windows Offline (64-bit)**. This downloads a `.exe` file. **(Note:** Other Java versions are 32-bit, and will **not** work with SMRT View.)
4. Double-click the `.exe` file to start the Java installer, and follow the installer directions.
5. After the installation is finished, restart the browser.

Installing 64-bit Java 8 on Mac OS

**Note:** This requires Mac OS 10.7.3 or later.

1. Use the Finder to search for all existing versions of Java, then drag them to the Trash to uninstall.
3. Click **Mac OS X**. This downloads a `.dmg` file.
4. Double-click the `.dmg` file to mount the installer volume.
5. Double-click the Java icon to start the Java installer, and follow the installer directions.
6. After the installation is finished, restart the browser.
Importing Data into SMRT® Link

If you have a Sequel/Sequel II System installed and it is linked to the SMRT Link software during the instrument installation, your data will be automatically imported in SMRT Link.

You can manually import the following types of files directly, using the SMRT Link GUI:

- **Sequel Data**: XML file (.subreadset.xml) or ZIP file containing information about Sequel sequence data, such as paths to the BAM files.
- **CCS Data**: XML file (.subreadset.xml) or ZIP file containing information about CCS sequence data.
- **RS II Sequence Data**: RS II XML (.hdfsubreadset.xml), RS II Metadata XML (.metadata.xml), or RS II Sequence Data (ZIP). These files contain information about PacBio RS II sequence data from a single cell.
- **Barcodes**: FASTA (.fa or .fasta), XML (.barcodeset.xml), or ZIP files containing barcodes.
- **References**: FASTA (.fa or .fasta), XML (.referenceSet.xml), or ZIP files containing a reference sequence for use in starting analyses.

You can also import data in SMRT Link using the pbservice command-line utility, as shown below.

- The host and port for the Analysis Services are optional and default to localhost:9090. You can change these settings using the --host and --port arguments.

<table>
<thead>
<tr>
<th>Importing</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BAM Data Sets</strong></td>
<td><strong>Generated by the Sequel/Sequel II System</strong></td>
</tr>
<tr>
<td></td>
<td>Import individual SubreadSet XML files:</td>
</tr>
<tr>
<td></td>
<td>$&gt; pbservice import-dataset --host $HOST --port $PORT /path/to/</td>
</tr>
<tr>
<td></td>
<td>subreads.subreadset.xml</td>
</tr>
<tr>
<td></td>
<td>Import a directory of SubreadSet XML files:</td>
</tr>
<tr>
<td></td>
<td>$&gt; pbservice import-dataset --host $HOST --port $PORT /path/to/tree/</td>
</tr>
<tr>
<td></td>
<td>containing/subreadssets.xml</td>
</tr>
<tr>
<td><strong>PacBio RS II Data</strong></td>
<td><strong>created with SMRT Analysis versions prior to v3.0.0</strong></td>
</tr>
<tr>
<td></td>
<td>Import a Dataset XML file (Subreads, reference sequences, or barcode files):</td>
</tr>
<tr>
<td></td>
<td>$&gt; pbservice import-dataset --host smrtlink-release --port 9091 /path/to/</td>
</tr>
<tr>
<td></td>
<td>dataset.xml</td>
</tr>
<tr>
<td><strong>A FASTA Reference</strong></td>
<td>Creating a ReferenceSet XML file from a FASTA file:</td>
</tr>
<tr>
<td></td>
<td>fasta-to-reference hg38.fasta /opt/smrtlink/references hg38 --organism</td>
</tr>
<tr>
<td></td>
<td>Homo_sapiens &gt; fasta2ref.log 2&gt;&amp;1</td>
</tr>
</tbody>
</table>

Sending Log Files to Technical Support

Troubleshooting information can be sent to PacBio Technical Support multiple ways. If there is a connection to the PacBio Event Server, do the following:

- From the SMRT Link menu: **About > Troubleshooting Information > Send.**
- From a SMRT Link “Failed” analysis Results page: Click **Send Log Files.**

If there is a connection to the PacBio Event Server, run the following command to generate the information and automatically send it to PacBio Technical Support:

```
$SMRT_ROOT/admin/bin/tsreport-install --bundle --update
```
If there is no connection to the PacBio Event Server, run the following command to generate a .tgz file and email the file to support@pacb.com to file a case:

```
$SMRT_ROOT/admin/bin/tsreport-install --bundle
```

**Appendix A: SMRT Link Workflow Terminology**

Management of all SMRT Link activity is handled by the SMRT Link Services. The services spawn an independent `pbsmrtpipe` process for each SMRT Link analysis job. `pbsmrtpipe` is the workflow engine used to process a single SMRT Link analysis job and pipeline. `pbsmrtpipe` is responsible for splitting jobs into pipeline tasks and distributing them to the compute cluster. A representation of the SMRT Link Services hierarchy is shown below.

**NWORKERS**: A SMRT Link Services setting that specifies the maximum number of simultaneous `pbsmrtpipe` processes that may be run.

**NPROC**: A `pbsmrtpipe` setting that limits the maximum number of slots that any single JMS cluster submission may request.

**TOTAL_NPROC**: A `pbsmrtpipe` setting that limits the total number of slots the `pbsmrtpipe` process may request across all JMS cluster submissions.

**MAXCHUNKS**: A `pbsmrtpipe` setting that limits the maximum number of pieces a large Data Set may be broken into for parallelized analysis.

**Appendix B: Distributed Computing Setup**

PacBio supports the following Job Management Systems (JMS): Sun Grid Engine (SGE), PBS, LSF, and SLURM. You may attempt to manually configure for alternate job management systems, but these are not guaranteed to work.
A Job Management System may be used to dispatch jobs to a distributed compute environment. If no Job Management System is specified, the system will run in non-distributed Mode, and all compute jobs will be run locally on the install host.

Available Job Management Systems are detected from the PATH environment variable, but may also be selected manually.

For more information on customizing all of the Job Management Systems, see the comments in the file $SMRT_ROOT/userdata/user_jmsenv/user.jmsenv.ish. Note that changes to this file will apply to every job submitted to the cluster.
Appendix C: Sequel System Compute Requirements

<table>
<thead>
<tr>
<th>Head Node</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cores</strong></td>
</tr>
<tr>
<td><strong>RAM</strong></td>
</tr>
<tr>
<td><strong>tmp_dir</strong> (Local Storage)</td>
</tr>
<tr>
<td><strong>db_datadir</strong> (Local Storage)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shared Data Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sequence Data</strong></td>
</tr>
<tr>
<td><strong>Analysis Data</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 GBE recommended, 1 GBE required</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compute Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Targeted Applications</strong></td>
</tr>
<tr>
<td><strong>HPC</strong></td>
</tr>
<tr>
<td>Cores (Total)</td>
</tr>
<tr>
<td>Minimum RAM per Slot (1 slot = 1 core)</td>
</tr>
<tr>
<td><strong>tmp_dir</strong> (Local Storage)</td>
</tr>
</tbody>
</table>

a. Targeted Sequencing applications (LAA, Resequencing), assembly of bacterial genomes, targeted Iso-Seq application.

b. Targeted Sequencing applications as noted above, plus occasional large-genome de novo assemblies, whole-transcriptome Iso-Seq. Storage is calculated based on moderate usage of Sequel® System per year.

c. For a standard CCS sequencing collection (300 GB sequencing data, 11 kb insert size, 30-hours movie), CCS Analysis takes 27 hours on this configuration. SMRT Link will work on less powerful compute configurations, however analysis time will be significantly longer.

Data Examples

Human Assembly
- Genome size: 3.3 GB; Sequence data 400 GB; Analysis data 700 GB; Analysis time: 72 hours wall. This is 50-fold coverage human genome analyzed on the compute configuration listed above.

Rice Assembly
- Genome size: 0.43 GB; Sequence data 55 GB; Analysis data 90 GB; Analysis time: 20 hours wall. This is 50-fold coverage rice genome analyzed on the compute configuration listed above.

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