Installation of RedHawk™ 8.4.5 Gold on the NVIDIA® Jetson AGX Orin

Release Notes

March 17th, 2023

0898003-8.4.5-Orin

READ ME BEFORE INSTALLING THIS PRODUCT

concurrent REAL-TIME

This page intentionally left blank

1. Introduction

This document describes the process of installing the ARM64 version of RedHawk™ 8.4.5 on the Jetson AGX Orin. The directions in this document supersede all others – they are specific to installing the software on Concurrent Real-Time's RedHawk systems.

2. Requirements

- Jetson AGX Orin with Internet access
- An x86_64 host system running Ubuntu 20.04 with Internet access; note that the host system should be up to date with the latest available Ubuntu package updates
- The *RedHawk 8.4.5 for the Jetson AGX Orin* optical media disk

3. Installation

3.1.   Download SDK Manager onto the host system

On an x86_64 host system running Ubuntu 20.04, download version 1.9.1-10844 of SDK Manager from the NVIDIA website via this URL:

> https://developer.nvidia.com/jetpack

Click on the NVIDIA SDK Manager link to download the SDK Manager package (login may be required). You should also click on the Jetson AGX Orin Developer Kit User Guide link to download the User's Guide PDF.

Place these downloaded files into an `orin` directory in the home directory of the current user.

3.2.   Install the downloaded SDK Manager package

Open a terminal window and issue the following commands to install the SDK Manager:

```
$ cd ~/orin
$ sudo apt install ./sdkmanager_1.9.1-10844_amd64.deb
```

3.3.   Connect the Orin to the host system

The Orin must be connected to the host system for SDK Manager to be able to detect it and successfully flash it. Two different USB cables are required:

1. Male USB A 2.0 (host) to Male USB C (Orin) for flashing.
2. Male USB A 2.0 (host) to Male USB Micro B (Orin) for serial console.

Connect the USB C cable to the front of the Orin (to the left of the GPIO pins) and connect the USB Micro B cable to the back of the Orin (to the right of the Display Port connector).

Pictures of these two cables are included below for reference. You must also ensure that power, networking, keyboard, mouse, and video are properly connected to the Orin before proceeding.

For flashing:

For serial console:

3.4.   Put the Orin into recovery mode

Newer versions of SDK Manager work best when the Orin is initially placed into recovery mode. If the Orin is currently installed and booted, issue the `reboot --force forced-recovery` command, otherwise power on the Orin with the middle button pressed, then press the left button, and then release both at the same time.

3.5.   Use SDK Manager to flash the Orin

Invoke the following command as the current user to begin using the SDK Manager:

```
$ sdkmanager
```

The first action required by the SDK Manager is to log into the nvidia.com website using your developer or partner account email address and password. Enter the appropriate information and press LOGIN to continue.

After logging in you may be presented with the following Update Notification dialog:
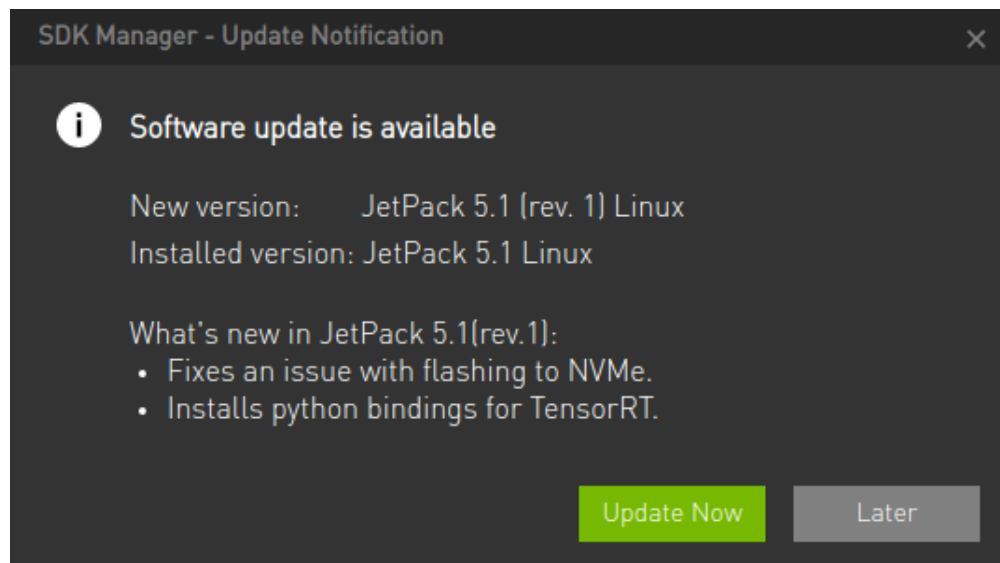
If this dialog appears, choose Update Now to ensure that you will be installing the JetPack 5.1 revision with the latest bugfixes and enhancements from NVIDIA.

NOTE

RedHawk 8.4.5 has been validated with both JetPack 5.1 and JetPack 5.1 Rev. 1.
Other JetPack versions are incompatible with RedHawk 8.4.5 and must not be used.

At this point, you can generally follow the instructions in the *Jetson AGX Orin Developer Kit User Guide* along with the following RedHawk-specific instructions:

1. On the STEP 01 – DEVELOPMENT ENVIRONMENT screen, click on the . . . icon in the Target Hardware box to reveal the list of supported hardware configurations, as shown in the following screenshot:
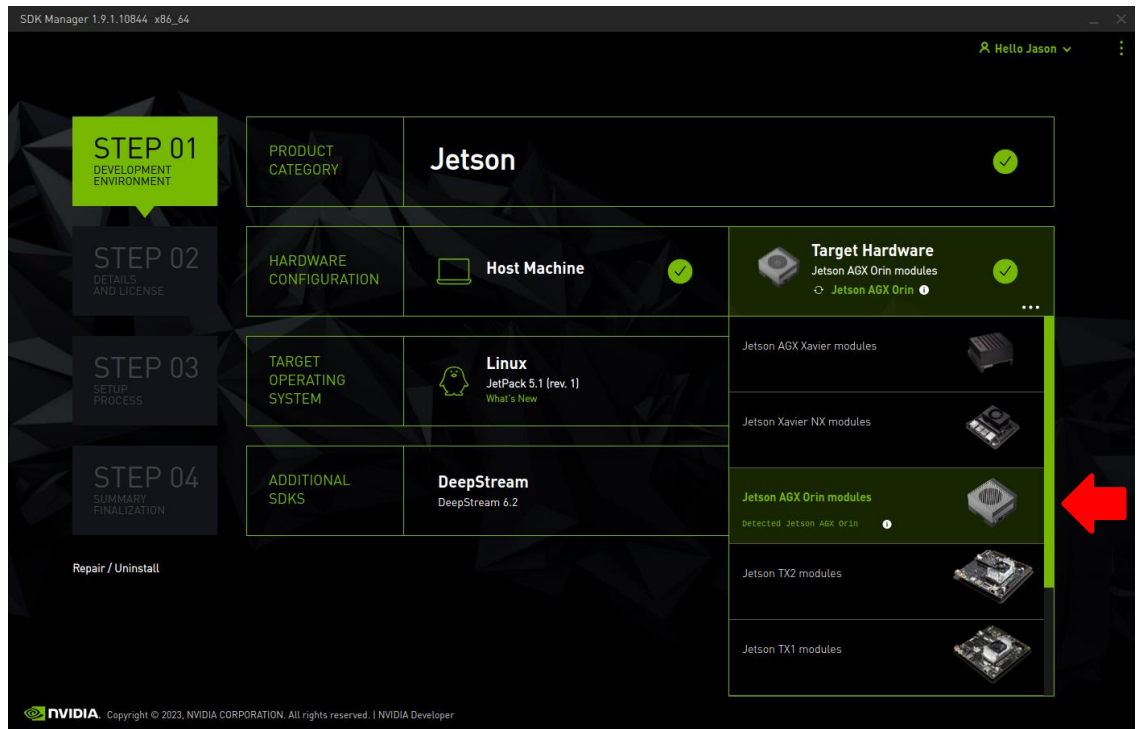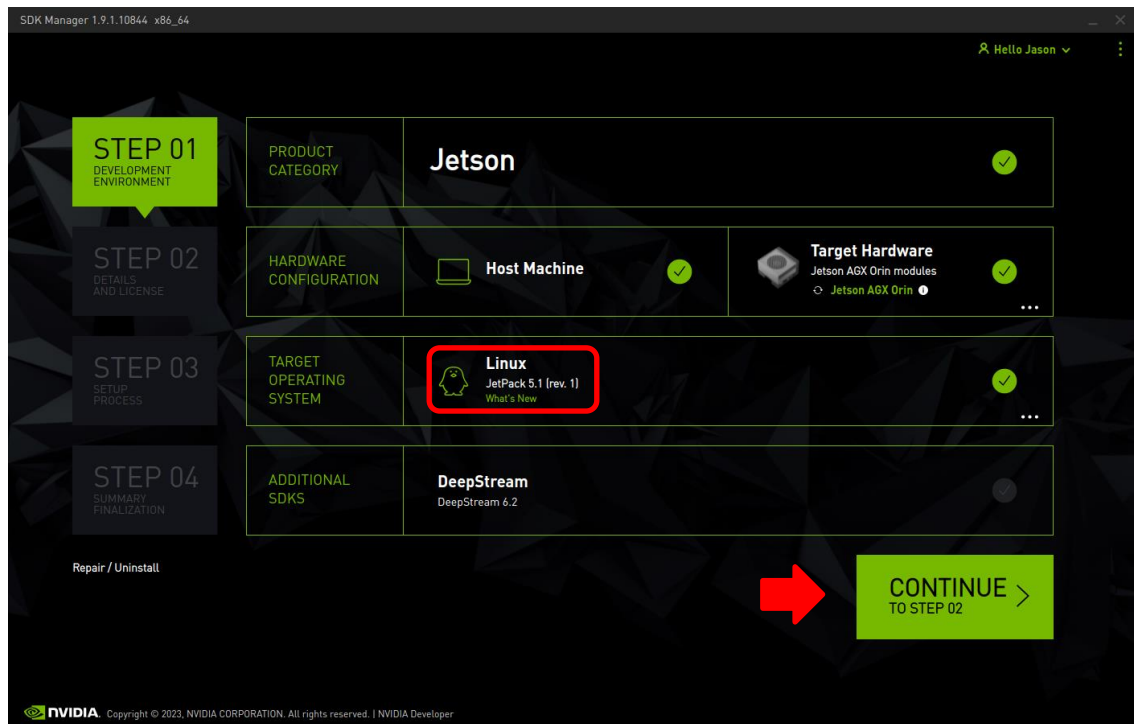

2. Click on the Jetson AGX Orin modules target hardware option to make it the selected target, as shown in the following screenshot:
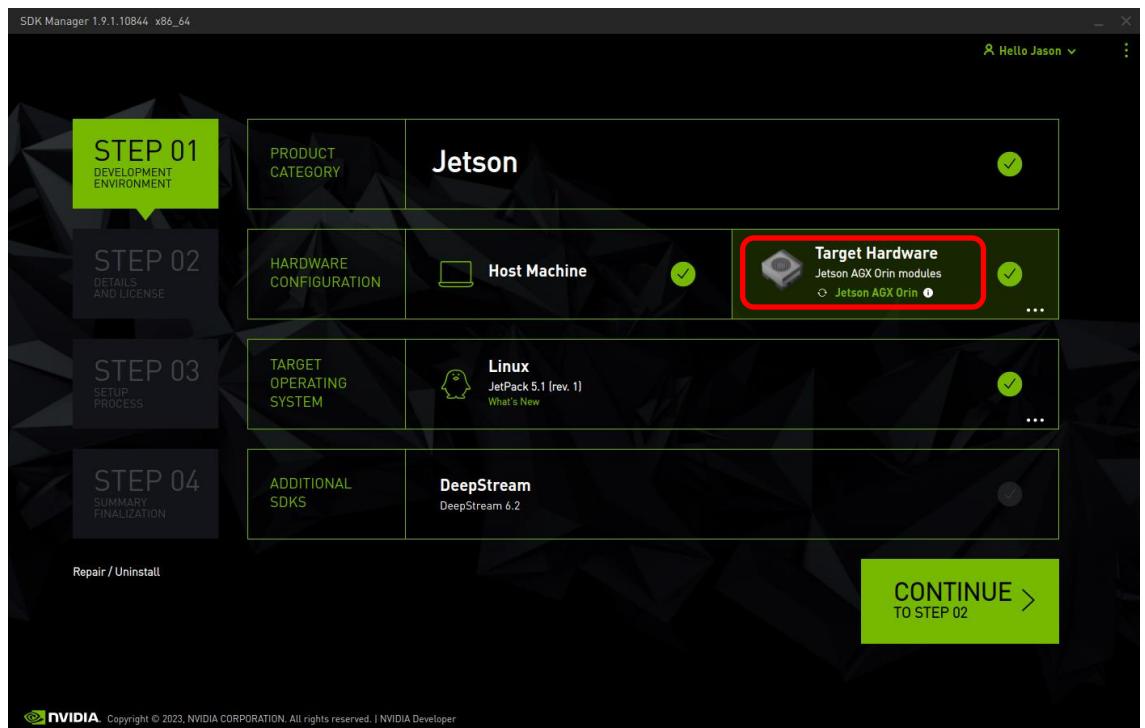

3. Click on the . . . in the Linux box to reveal the list of supported JetPack versions, as shown in the following screenshot:
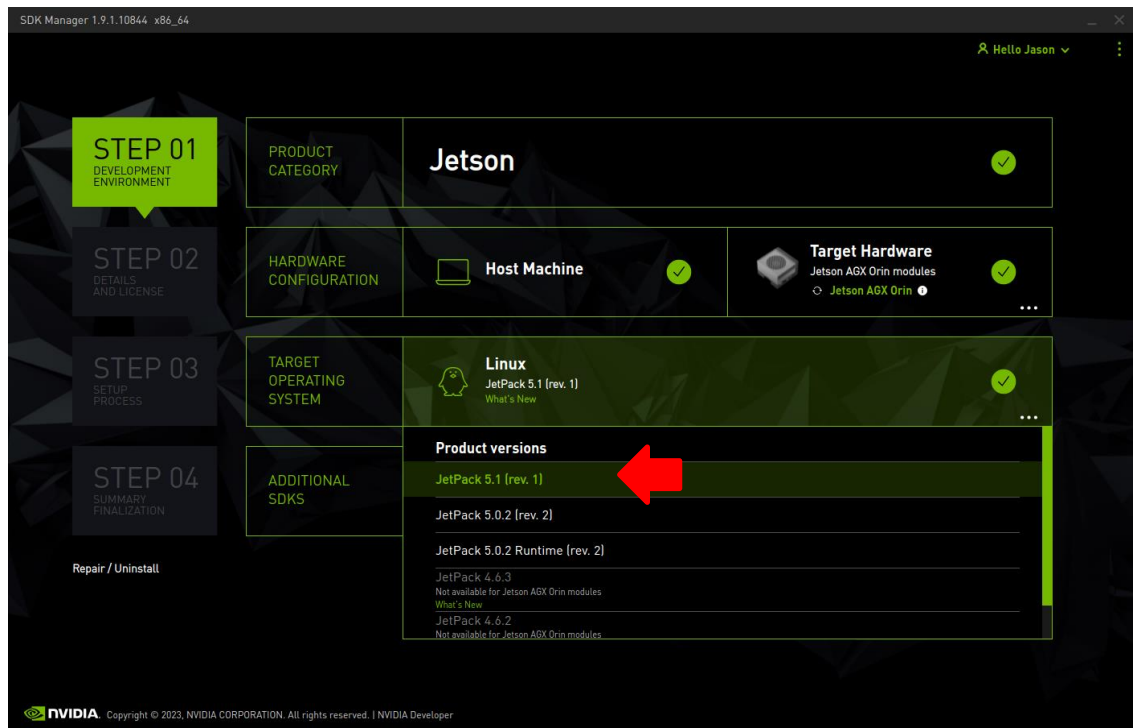
4. Click on the JetPack 5.1 Rev. 1 version to make it the selected version, as shown in the following screenshot:

5. Press Continue to advance to the STEP 02 – DETAILS AND LICENSE screen and click I accept the terms and conditions of the license agreements at the bottom of the window to accept the licenses, as shown in the following screenshot:
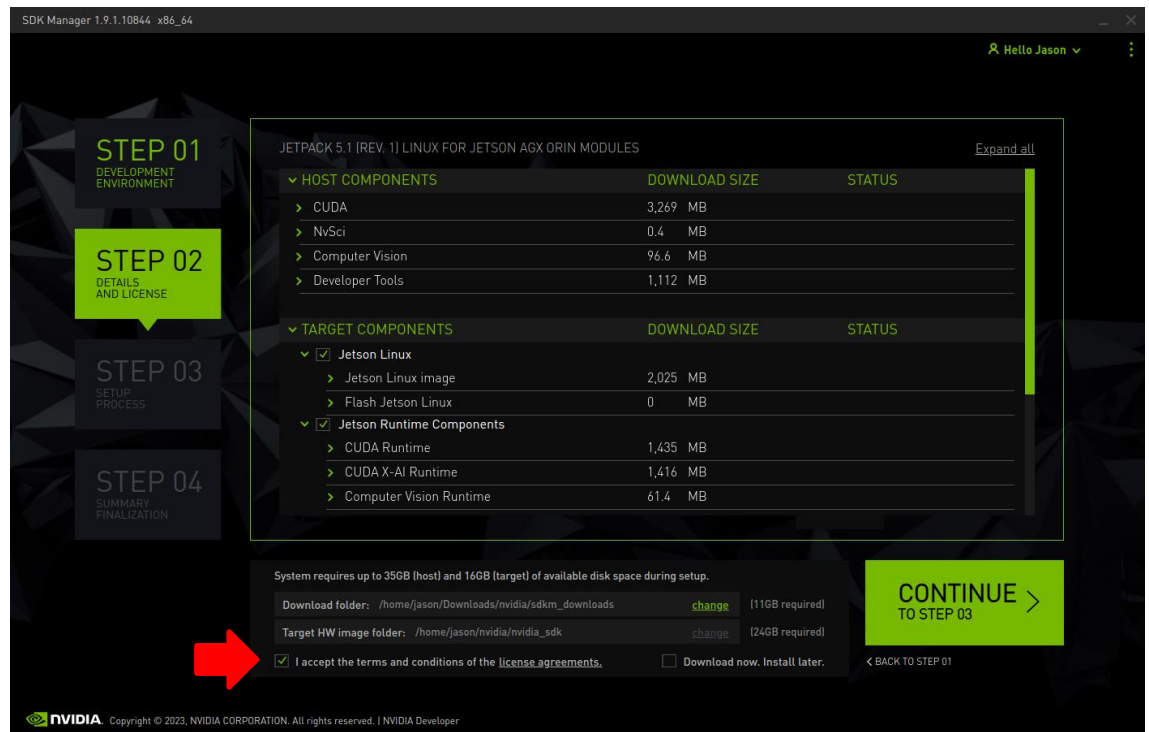
6. Press Continue to advance to the STEP 03 – SETUP PROCESS screen and SDK Manager will begin downloading all the software components from NVIDIA, as shown below:
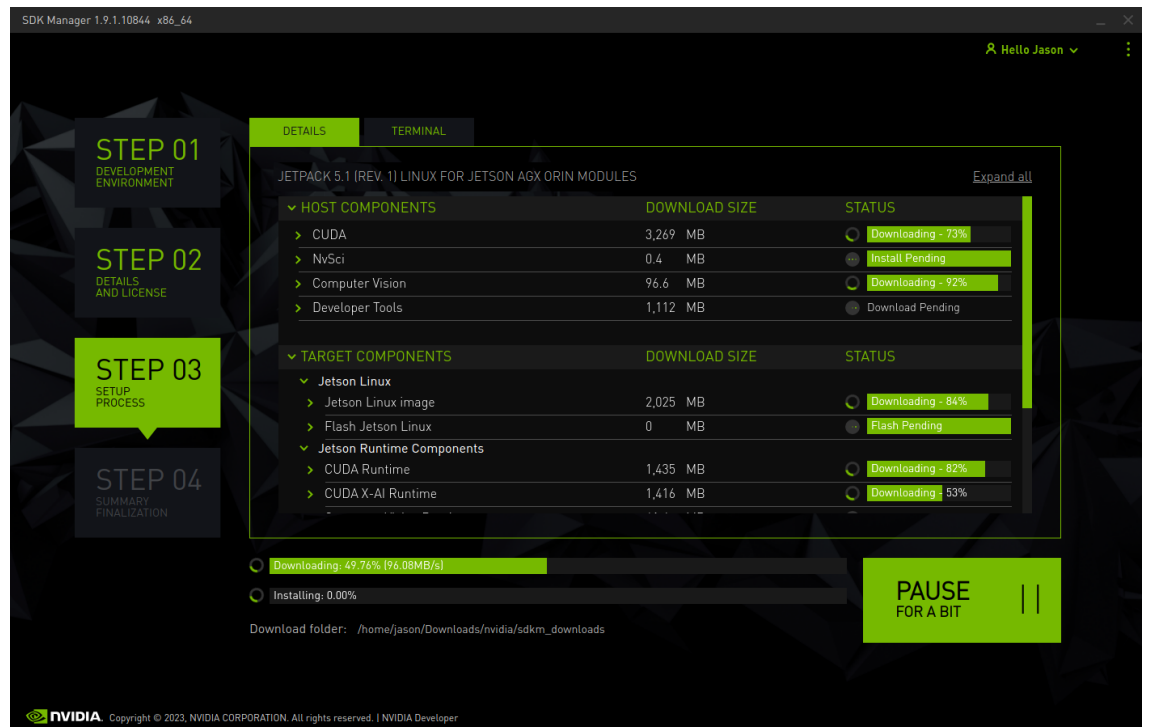
Depending on your network's speed, the download can take 30 minutes or more. During the download and setup, a detailed output log can be viewed under the TERMINAL tab.

7. Once the download and setup has completed, you will be presented with a Flash dialog. Notice the Automatic setup pulldown menu as shown in the following dialog:
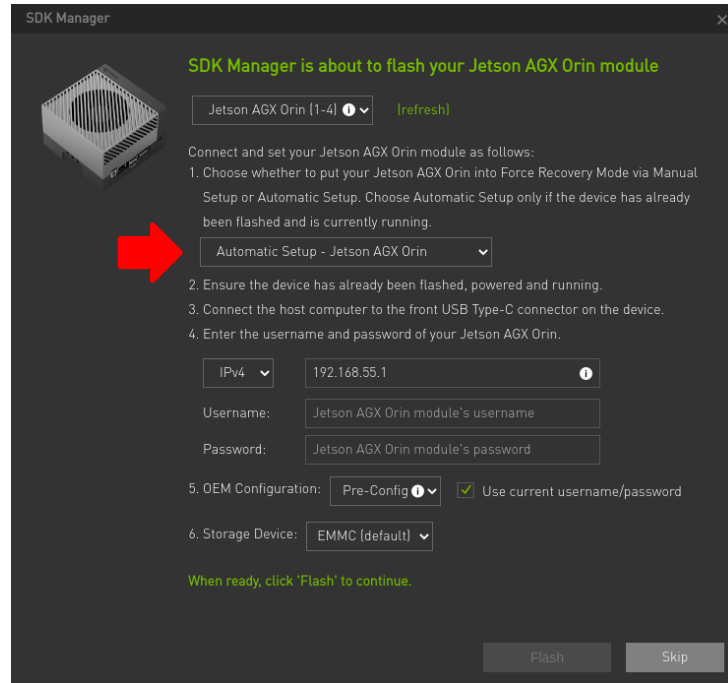
Click on Automatic setup and change the setting to Manual Setup as shown in the following dialog:
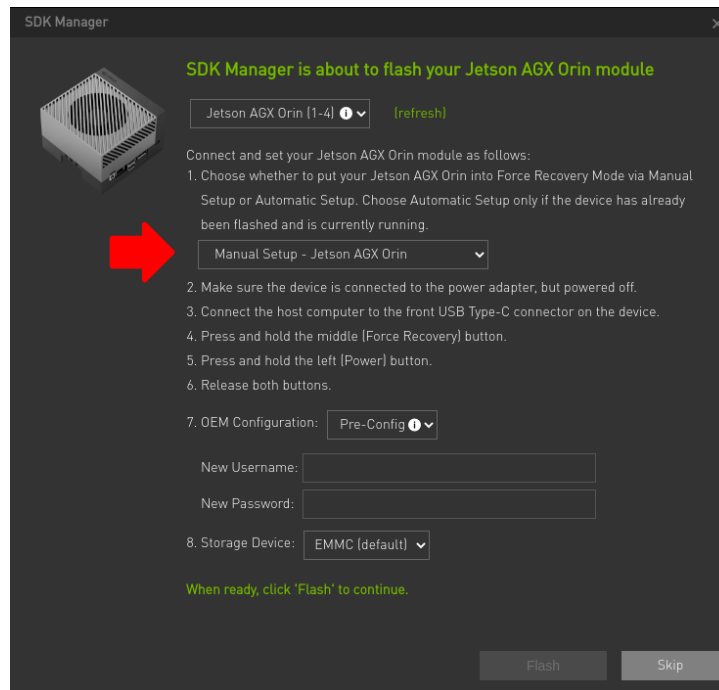
Next, fill in the New Username and New Password fields for the default user that will be created on Orin, as shown in the following dialog:

Follow the steps listed on the Flash dialog to place the Jetson AGX Orin into recovery mode and then click Flash to begin flashing.

NOTE

Issue the `lsusb` command on the host to verify that an `NVidia Corp. APX` entry with device ID `0955:7023` is displayed; this is the best indication that the Orin has successfully entered recovery mode and is ready for flashing.
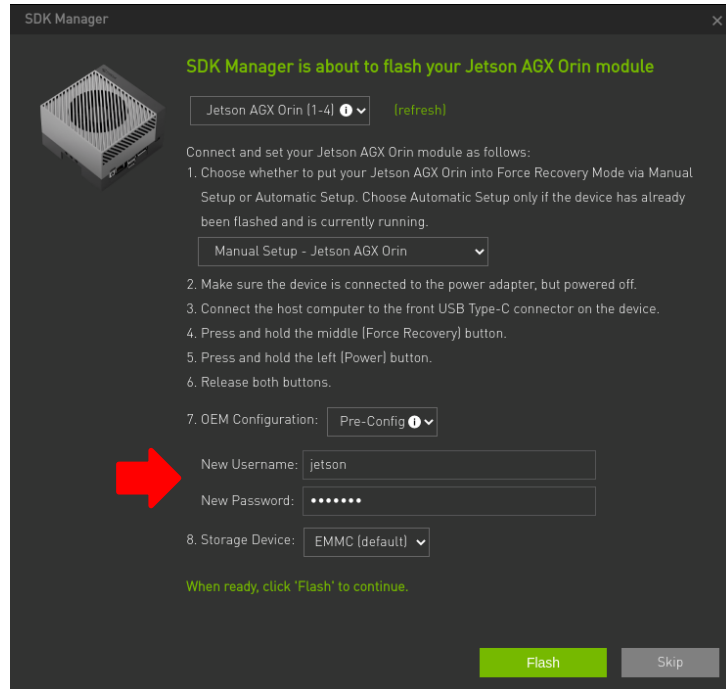
8. During flashing the SDK Manager will prompt you to fill in Username and Password fields as shown in the following dialog:
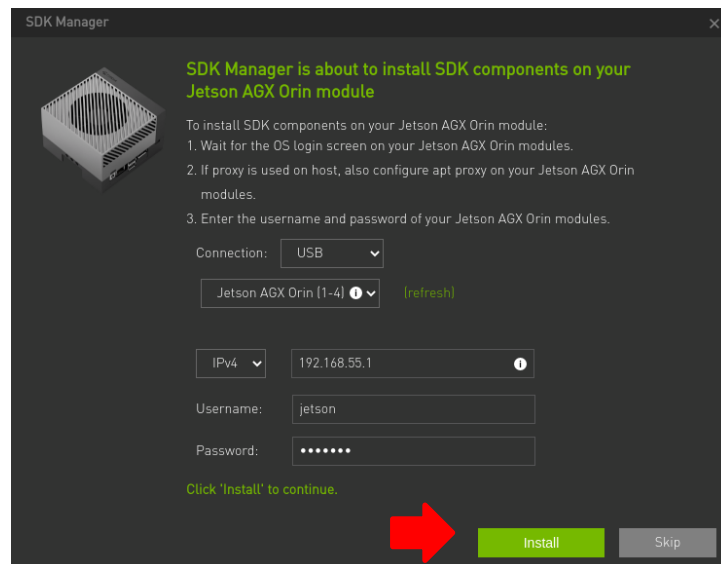
These fields default to the values specified in the previous step, so simply click Install to continue the software installation.

9. Once the flashing and software installation have completed you will automatically proceed to the STEP 04 – SUMMARY FINALIZATION screen.
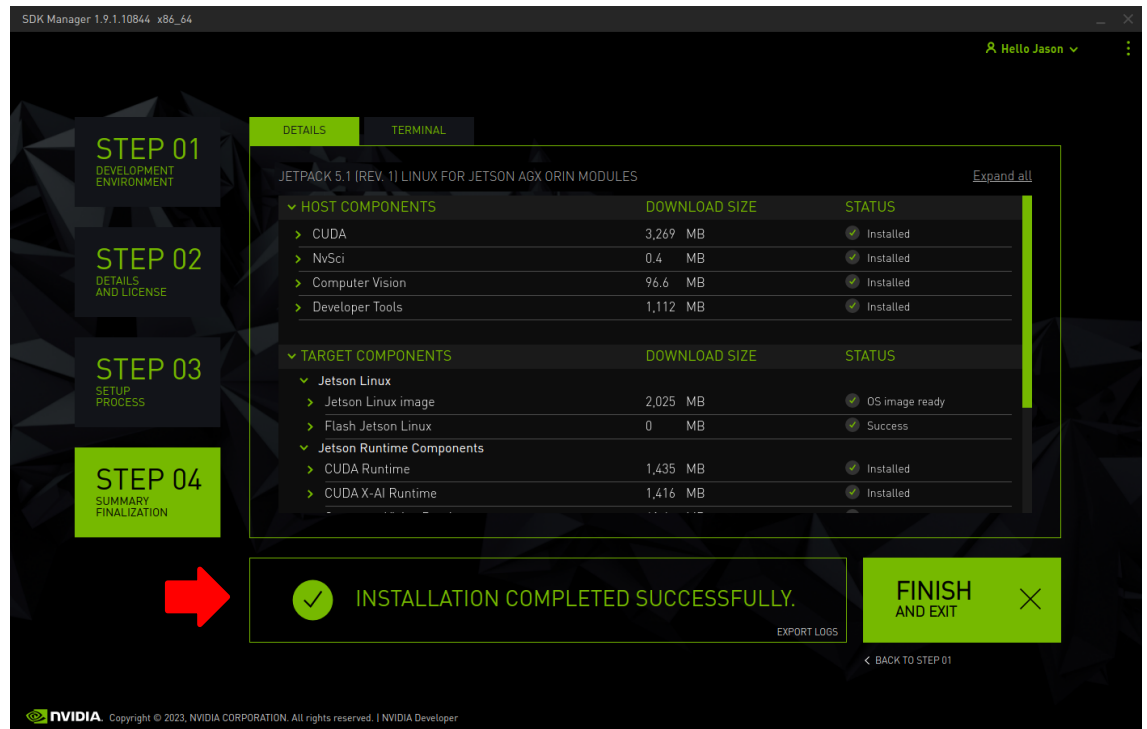
Click Finish and Exit to exit the SDK Manager

3.6.   Set NVIDIA Power Model to Maximum Performance

After SDK Manager has completed the Ubuntu installation on the Orin, and while the Orin is still booted with the NVIDIA stock kernel, log into the Orin using the username and password chosen during flashing and run the following command:

```
$ sudo nvpmodel -m 0
```

The following output should be displayed:

```
NVPM ERROR: Error writing 0 to /sys/devices/gpu.0/tpc_pg_mask: 16
NVPM WARN: Reboot required for changing to this power mode: 0
NVPM WARN: DO YOU WANT TO REBOOT NOW? enter YES/yes to confirm:
```

Type `yes` and press ENTER to reboot the Orin and then log in again and issue the following command:

```
$ sudo nvpmodel -q
```

The following output should be displayed:

```
NV Fan Mode:quiet
NV Power Mode: MAXN
0
```

This confirms that the Orin has been correctly configured for maximum performance.

Note that once the Orin's power mode has been set it will persist across reboots until it is explicitly changed again using the `nvpmodel` command.

3.7. Copy RedHawk packages to the Orin

NOTE

This section assumes you are using the RedHawk 8.4.5 for Jetson AGX Orin optical media disc. Alternatively, if you wish to install RedHawk from the network refer to Appendix A, "Install RedHawk from Concurrent Real-Time Repositories."
Once installed, continue with section 3.8 below to finalize the installation.

After SDK Manager has completed the Ubuntu installation on the Orin, insert the *RedHawk 8.4.5 for Jetson AGX Orin* optical disc into the Ubuntu host's optical drive and it should automatically mount under the `/media/$USER` directory (e.g., `/media/jane/RedHawk 8.4.5 aarch64`).

Change to the mounted directory on the host and use networking to copy the RedHawk packages into the newly installed Orin, as illustrated by the following commands:

```
$ cd /media/jane/RedHawk-8.4.5-aarch64
$ scp *.gz user@Orin-IP-Address:/tmp
```

NOTE

Use the username, hostname and password chosen during flashing.

3.8. Install RedHawk packages on the Orin

To install the RedHawk packages, log into the Orin (either via `ssh` or via the graphical console) and issue the following commands:

```
$ cd /tmp
$ sudo tar -xf core-*.tar.gz
$ cd redhawk
$ sudo ./install
```

Enter the password for the current user if the `sudo` command prompts for it.

NOTE

Warnings may be displayed during package installation, including:

- *Warning: couldn't identify type of root file system for fsck hook*
- *Failed to stop turbo.service: Unit turbo.service not loaded.*
- *Failed to disable unit: Unit file turbo.service does not exist.*

You can safely ignore these messages as they are not relevant to RedHawk 8.4.5 on Jetson AGX Orin embedded installations.

At this point, all RedHawk software should be successfully installed on the Orin, however additional steps in the next section are required before you can boot RedHawk kernels.

3.9. Add RedHawk entries to the `extlinux.conf` file

Perform the following steps on the Orin to create boot entries for the RedHawk kernels:

1. Create a backup of the `/boot/extlinux/extlinux.conf` file.

```
$ cd /boot/extlinux
$ sudo cp extlinux.conf extlinux.bak
```

2. Open the `extlinux.conf` file in your preferred editor. For example, if using `vi`:

    ```
    $ sudo vi extlinux.conf
    ```

3. Duplicate all the `primary kernel` entry text lines to create a second identical entry below the initial entry. For example:

    ```
    TIMEOUT 30
    DEFAULT primary

    MENU TITLE L4T boot options

    LABEL primary
        MENU LABEL primary kernel
        LINUX /boot/Image
        FDT /boot/dtb/kernel_tegra234-p3701-0000-p3737-0000.dtb
        INITRD /boot/initrd
        APPEND ${cbootargs} quiet ...many other boot options...

    LABEL primary
        MENU LABEL primary kernel
        LINUX /boot/Image
        FDT /boot/dtb/kernel_tegra234-p3701-0000-p3737-0000.dtb
        INITRD /boot/initrd
        APPEND ${cbootargs} quiet ...many other boot options...
    ```

4. Customize the *first* kernel entry to point to the desired RedHawk kernel. For example, to create an entry for the RedHawk trace kernel, modify the lines as follows:

    ```
    LABEL redhawk-trace
        MENU LABEL redhawk-trace kernel
        LINUX /boot/Image-5.10.104-rt63-r35.2.1-tegra-RedHawk-8.4.5-trace
        FDT /boot/dtb/kernel_tegra234-p3701-0000-p3737-0000.dtb
        INITRD /boot/initrd.img-5.10.104-rt63-r35.2.1-tegra-RedHawk-8.4.5-trace
        APPEND ${cbootargs} quiet ...many other boot options...
    ```

NOTE

Modifying the first kernel entry will allow the NVIDIA kernel to be booted as a fallback if any typos were entered during the customization of the first entry. Failure to follow this guideline can render the Orin unbootable and require re-flashing if a typo is accidentally introduced during editing.

5. Change the default kernel to the newly added RedHawk kernel by changing the `DEFAULT` entry at the top of the file:

    ```
    TIMEOUT 30
    DEFAULT redhawk-trace
    ```

NOTE

If the Orin has been set up with a serial console, you may choose to skip this step and instead interactively decide which kernel to boot when you are presented with the boot menu on the serial console.

3.10. Verify RedHawk kernel installation

Upon reboot, the Orin should now be running the selected RedHawk kernel. To verify this, issue the following command:

```
$ uname -r
```

You should see output displayed like the following:

```
5.10.104-rt63-r35.2.1-tegra-RedHawk-8.4.5-trace
```
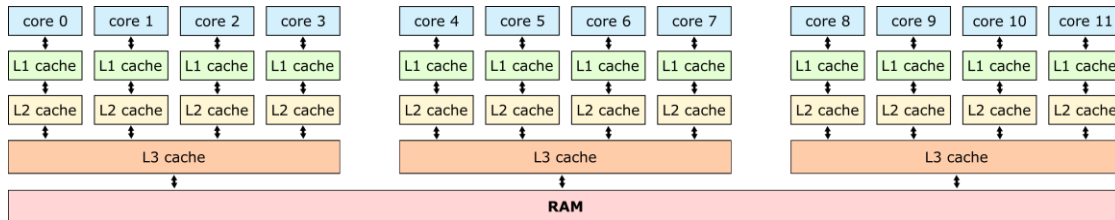
Please contact Concurrent Real-Time technical support if you had any problems during this installation (support@concurrent-rt.com or 1-800-245-6453).

4. Known Issues

Special consideration should be given to the following areas.

4.1. Sibling cores can interfere with shielding

Orin cores utilize a 3-tier cache as shown in the following diagram:

Each core has its own L1 and L2 caches, but L3 caches are always shared between four sibling cores. In the above diagram, cores 0, 1, 2, and 3 are siblings, cores 4, 5, 6, and 7 are siblings, and cores 8, 9, 10, and 11 are siblings.

When shielding a core on the Orin for a real-time application, activity on the shielded core's sibling cores can modify the shared L3 cache and impact the determinism and performance of the real-time application. To achieve maximum real-time performance, all sibling cores must be shielded, with the unused sibling cores kept idle.

4.2. Maximizing clock speeds

NVIDIA provides the `jetson_clocks` utility to control the speeds of various hardware clocks on the Orin. This utility provides several options and must be run as the root user. Invoke the utility with the `--show` option to view all current clock speeds. For example:

```
root@ubuntu:~# jetson_clocks --show 2>/dev/null
SOC family:tegra234  Machine:Jetson AGX Orin
Online CPUs: 0-11
cpu0: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu1: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu10: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu11: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu2: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu3: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=1420800 IdleStates: WFI=1 c7=1
cpu4: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=1728000 IdleStates: WFI=1 c7=1
cpu5: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=1728000 IdleStates: WFI=1 c7=1
cpu6: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu7: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu8: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
cpu9: Online= Governor=schedutil MinFreq=729600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=1 c7=1
GPU MinFreq=306000000 MaxFreq=1300500000 CurrentFreq=306000000
EMC MinFreq=204000000 MaxFreq=3199000000 CurrentFreq=2133000000 FreqOverride=0
DLA0_CORE:   Online=1 MinFreq=0 MaxFreq=1600000000 CurrentFreq=1600000000
DLA0_FALCON: Online=1 MinFreq=0 MaxFreq=844800000 CurrentFreq=844800000
DLA1_CORE:   Online=1 MinFreq=0 MaxFreq=1600000000 CurrentFreq=1600000000
DLA1_FALCON: Online=1 MinFreq=0 MaxFreq=844800000 CurrentFreq=844800000
PVA0_VPS0: Online=1 MinFreq=0 MaxFreq=1152000000 CurrentFreq=1152000000
PVA0_AXI:  Online=1 MinFreq=0 MaxFreq=832000000 CurrentFreq=832000000
FAN Dynamic Speed control=active hwmon2_pwm=56
NV Power Mode: MAXN
root@ubuntu:~#
```

Notice that, by default, some of the current frequency values above are significantly lower than the maximum frequencies supported by the hardware.

To achieve the best Orin performance, set all clock speeds to their maximum values by invoking the `jetson_clocks` utility without any options. Then, to verify that all clock speeds have been maximized, run the `jetson_clocks` utility again with the `--show` option. For example:

```
root@ubuntu:~# jetson_clocks
root@ubuntu:~# jetson_clocks --show 2>/dev/null
SOC family:tegra234  Machine:Jetson AGX Orin
Online CPUs: 0-11
cpu0: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu1: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu10: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu11: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu2: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu3: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu4: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu5: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu6: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu7: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu8: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
cpu9: Online= Governor=schedutil MinFreq=2201600 MaxFreq=2201600 CurrentFreq=2201600 IdleStates: WFI=0 c7=0
GPU MinFreq=1300500000 MaxFreq=1300500000 CurrentFreq=1300500000
EMC MinFreq=204000000 MaxFreq=3199000000 CurrentFreq=3199000000 FreqOverride=1
DLA0_CORE:   Online=1 MinFreq=0 MaxFreq=1600000000 CurrentFreq=1600000000
DLA0_FALCON: Online=1 MinFreq=0 MaxFreq=844800000 CurrentFreq=844800000
DLA1_CORE:   Online=1 MinFreq=0 MaxFreq=1600000000 CurrentFreq=1600000000
DLA1_FALCON: Online=1 MinFreq=0 MaxFreq=844800000 CurrentFreq=844800000
PVA0_VPS0: Online=1 MinFreq=0 MaxFreq=1152000000 CurrentFreq=1152000000
PVA0_AXI:  Online=1 MinFreq=0 MaxFreq=832000000 CurrentFreq=832000000
FAN Dynamic Speed control=active hwmon2_pwm=56
NV Power Mode: MAXN
root@ubuntu:~#
```

Notice that all the current frequency values above have been configured to their maximum speeds.

NOTE

Unlike `nvpmodel`, clock speed changes made by `jetson_clocks` do <u>not</u> persist across a reboot. Thus, you must always run `jetson_clocks` again after a reboot to ensure that all clock speeds are maximized.

4.3.   Maximizing fan speed during heavy loads

By default, the speed of Orin's CPU cooling fan will be dynamically adjusted, as needed, to always ensure proper cooling. This default dynamic fan behavior should be more than adequate for almost all use cases.

However, for periods of prolonged benchmarking and/or stress testing, Concurrent recommends maximizing the CPU cooling fan speed before starting tests to prevent fast temperature rises. Temperatures that rise too quicky may result in slowing down CPU speeds, which can negatively impact benchmarking.

Invoke `jetson_clocks` with the `--fan` option to maximize the speed of the CPU cooling fan.

4.4.   Entropy gathering daemon interferes with real-time

Ubuntu 20.04 enables the Hardware Volatile Entropy Gathering daemon (`haveged`) that continuously samples various hardware resources (e.g., cache, branch predictions, memory translation tables) to collect entropy and improve random number generation.

This daemon's constant hardware probing activity can negatively impact real-time performance even on shielded CPU cores, and the daemon should be stopped before starting real-time workloads by invoking the following command as the root user:

```
# systemctl stop haveged.service
```

Do not disable the entropy gathering service because various Ubuntu startup services require a minimum level of entropy to be gathered before they will start; this includes services required for the X Server to properly initialize. However, after the Orin has started with graphics displaying you can safely stop the service to improve real-time performance.

4.5. Kernel debugger not accessible via serial console

The KGDB kernel debugger for the Orin is currently unable to communicate over the serial console interface (`/dev/ttyACM0`). Concurrent is working with NVIDIA to address this issue and hopefully it will be corrected in future NVIDIA kernels.

4.6. Change to PAM Capability module directory

The PAM Capability module directory that is documented in some versions of the *RedHawk User's Guide* is incorrect for the Orin. The correct PAM Capability module location should be shown as:

```
/lib/aarch64-linux-gnu/security/pam_capability.so
```

If you wish to use the PAM Capability feature with services in the `/etc/pam.d` directory, then you should refer to the PAM Capability module as follows:

```
session required /lib/aarch64-linux-gnu/security/pam_capability.so
```

A. Install RedHawk from Concurrent Real-Time Repositories

RedHawk can be installed over the network utilizing the Concurrent Real-Time software repositories. This has the advantage that it will install the latest updates that have been released, however some up-front setup is required to perform the installation; follow the steps below to complete this setup.

A.1.　Install Concurrent Real-Time Public Keys

Concurrent Real-Time signs its APT repositories with a GPG-generated DSA and ElGamal key pair. You need to install Concurrent Real-Time's public key so that the APT system can authorize usage of the repositories.

You can download the ccur-public-keys file and import the key file as needed into APT's key ring. You should import the key file before attempting to access software from Concurrent Real-Time's repositories.

The following commands will download the public key and install it.

```
wget -q http://redhawk.concurrent-rt.com/network/ccur-public-keys
apt-key add ccur-public-keys
```

If you wish to check the authenticity of the public keys file you downloaded from Concurrent Real-Time's web site, request the key fingerprints from Concurrent Software Support and compare them to the fingerprints of the keys you downloaded.

You can obtain the fingerprints of the keys you downloaded with the following command:

```
gpg --with-fingerprint ccur-public-keys
```

A.2.　Install Repository Definition Files

Repository definition files tell the APT installation and update system how to access specific repositories. The definition files must reside in the `/etc/apt/sources.list.d/` directory and the file name must end `.list`; e.g. `/etc/apt/sources.list.d/ccur.list`.

Use the following format for the repository definition of the RedHawk 8.4.5 for Jetson AGX Orin product:

```
deb [arch=arm64] http://redhawk.concurrent-rt.com/ubuntu/login/passwd/redhawk/agx-orin 8.4.n core
```

For example, the following entry substitutes a fictional login and password:

```
deb [arch=arm64] http://redhawk.concurrent-rt.com/ubuntu/L12345/xyzzy/redhawk/agx-orin 8.4.n core
```

Note that if the NightStar tools have been purchased for this machine, then you should also add a repository definition for the NightStar tools below the previously added line. For example:

```
deb [arch=arm64] http://redhawk.concurrent-rt.com/ubuntu/L12345/xyzzy/nightstar 5.0 rt ubu20
```

Once the repository definition file is in place the repository setup is complete. Run the following command as root to ensure that the software repositories have been added correctly:

```
sudo apt update
```

If you see errors or warnings produced that reference the newly added `ccur.list` file, then verify that all the above steps have all been completed as documented.

A.3. Install RedHawk Packages

Now that the setup is done, simply issue the following command to install all the latest RedHawk 8.4.5 packages (and NightStar 4.6 packages if purchased) onto the current system:

```
apt install 'ccur-*'
```

Once this command completes the RedHawk packages are installed. Continue with Section 3.8, "Add RedHawk entries to the `extlinux.conf` file," to finalize the RedHawk installation.

A.4. Support

If you need assistance, please contact the Concurrent Real-Time Software Support Center at our toll-free number 1-800-245-6453. For calls outside the continental United States, the number is 1-954-283-1822. The Software Support Center operates Monday through Friday from 8 a.m. to 5 p.m., Eastern Standard Time.

You may also submit a request for assistance at any time by using the Concurrent Real-Time website at http://concurrent-rt.com/support or by sending an email to support@concurrent-rt.com.