Apollo 1.0
Preliminary Guide
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About This Guide
The Apollo 1.0 Hardware and System Installation Guide provides the instructions to install all the hardware and software components for the Baidu Apollo Autonomous Vehicle Platform. The system installation information included (thus far) pertains to the procedures to download the Apollo Linux Kernel.

AutonomouStuff Pre-Configuration
These steps can come pre-configured by AutonomouStuff, contact us today to get up and running faster.

Document Conventions
The following table lists the conventions that are used in this document:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Bold</strong></td>
<td>Emphasis</td>
</tr>
<tr>
<td><em>Italic</em></td>
<td>Titles of documents, sections, and headings</td>
</tr>
<tr>
<td><img src="https://example.com/info.png" alt="Info" /></td>
<td>Info. Contains information that might be useful. Ignoring the Info icon has no negative consequences.</td>
</tr>
<tr>
<td><img src="https://example.com/tip.png" alt="Tip" /></td>
<td>Tip. Includes helpful hints or a shortcut that might assist you in completing a task.</td>
</tr>
<tr>
<td><img src="https://example.com/online.png" alt="Online" /></td>
<td>Online. Provides a link to a particular website where you can get more information.</td>
</tr>
<tr>
<td><img src="https://example.com/warning.png" alt="Warning" /></td>
<td>Warning. Contains information that must not be ignored or you risk failure when you perform a certain task or step.</td>
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Introduction
The Baidu Apollo Autonomous Vehicle Project is an initiative to provide an open, complete and reliable software platform for Baidu partners in the automotive and autonomous driving industries. The aim of this project is to enable these entities to develop their own self-driving systems using the information that Baidu is supplying:
• Baidu Apollo Quick Start Guide - A combination tutorial and road map that provide the complete set of end-to-end instructions (or that include the applicable links to the documents containing those instructions) to convert a regular car to an autonomous-driving vehicle

• Baidu Apollo Software Instructions - A set of files that contain:
  • Architecture of the classes and the files within each class
  • Code instructions for:
    • Coordinate system
    • Third-party libraries
    • Calibration table

• Baidu Apollo Hardware Documents - Two separate documents:
  • This document Provides the instructions to install the hardware and software for the vehicle:
    • Vehicle:
      • Industrial PC (IPC)
      • Global Positioning System (GPS)
      • Inertial Measurement Unit (IMU)
      • Controller Area Network (CAN) card
      • Hard drive
      • GPS Antenna
      • GPS Receiver
    • Software:
      • Ubuntu Linux
      • Apollo Linux Kernel
  • Baidu Apollo Hardware Reference Guide - Provides a complete hardware reference for:
    • Vehicle
    • IPC
    • GPS
    • CAN card

• Baidu Apollo How-To Information - The various topics for the How-To information can be found on the following Web site:

  How-To Information [More info to come]

• Baidu Apollo FAQs - The answers to common and unusual questions can be found on the following Web site:

  Baidu Apollo FAQ [More info to come]
**Key Hardware Components**

The key hardware components to install include:

- Onboard computer system  ASstuff Nebula
- Controller Area Network (CAN) Card  ESD CAN-PCIe/402-1
- General Positioning System (GPS) and Inertial Measurement Unit (IMU):
  - You can select one of the following options:
    - NovAtel SPN-IGM-A1
    - NovAtel SPAN® ProPak6™ and NovAtel IMU-IGM-A1

The features of the key hardware components are presented in the subsequent sections.

**Onboard Computer System**

The onboard computer system for the autonomous vehicle is the ASstuff Nebula, an industrial PC (IPC) that is powered by a sixth-generation Intel Skylake core i7-6700 CPU.

The ASstuff Nebula is the heart of the autonomous driving system (ADS).

**NOTE:** The onboard computer system, ASstuff Nebula, will also be referred to as the IPC in this document.

**IPC Configuration**

Configure the IPC as follows:

- 32GB DDR4 RAM
- MezIO-V20-EP module (with ignition control for in-vehicle usage)
- PO-160W-0W 160W AC/DC power adapter
- CSM2 module (x16 PCIe expansion Gen3 8-lane cassette)
IPC Front and Rear Views
The front and rear views of the IPC are shown with the Graphics Processing Unit (GPU) installed in the following pictures:

The front view of the AStuff Nebula:

![AStuff Nebula Front View](image)

The rear view of the Nebula:

![AStuff Nebula Rear View](image)

For more information about the AStuff Nebula, see:

[ASuff Nebula product page](#)
Controller Area Network (CAN) Card
The Controller Area Network card used for the IPC is the ESD CAN-PCIe/402.

Global Positioning System (GPS) and Inertial Measurement Unit (IMU)
There are two GPS-IMU options available, and the choice depends upon the one that most suits your needs:
- NovAtel SPAN-IGM-A1
- NovAtel SPAN® ProPak® and NovAtel IMU-IGM-A1

The NovAtel SPAN-IGM-A1
According to the NovAtel Web site: The NovAtel SPAN-IGM-A1 is an integrated, single-box solution that offers tightly coupled Global Navigation Satellite System
[GNSS] positioning and inertial navigation featuring the NovAtel OEM615 receiver.

For more information about the NovAtel SPAN-IGM-A1, see:

NovAtel SPAN-IGM-A1 Product Page

The NovAtel SPAN ProPak6 and NovAtel IMU-IGM-A1

According to the NovAtel Web site: The ProPak6 provides the latest and most sophisticated enclosure product manufactured by NovAtel. From standalone meter-level to centimeter-level positioning, the ProPak6 is flexible to meet your positioning needs. The ProPak6 offers optional GPRS/HSPA cellular modem and/or heading options to provide a solution for many applications.

For more information about the NovAtel SPAN ProPak6, see:

NovAtel SPAN ProPak6 Product Page
The GPS Receiver/Antenna
The GPS Receiver/Antenna that is used with the GPS-IMU component is the NovAtel GPS-703-GGG-HV.

**NOTE:** The GPS NovAtel GPS-703-GGG-HV works with either model of the two GPS-IMU options that are described in the previous section, Global Positioning System (GPS) and Inertial Measurement Unit (IMU).

For more information about the NovAtel NovAtel GPS-703-GGG-HV, see:

[NovAtel GPS-703-GGG-HV Product Page](#)

**Overview of the Installation Tasks**
Installing the hardware and the software components involves these tasks:

**AT THE OFFICE:**

1. Prepare the IPC:
   a. Examine the Graphics Processing Unit (GPU) cassette to determine if you need to remove the GPU card (if it was pre-installed).
   a. Prepare and then install the Controller Area Network (CAN) card by first repositioning the CAN card termination jumper before you insert the card into the slot.
2. Install the hard drive (if one was not pre-installed) in the IPC. You can also choose to replace the hard drive if you prefer.

**Recommendations:**
- Install a Solid-State Drive (SSD) for better reliability.
- Use a high-capacity drive if you need to collect driving data.
3. Prepare the IPC for powering up:
   a. Attach the power cable to the power connector (terminal block).
   b. Connect the monitor, Ethernet, keyboard and mouse to the IPC.
   c. Connect the IPC to a power source.
4. Install the software on the IPC (some Linux experience is required):
   a. Install Ubuntu Linux.
   b. Install the Apollo Linux Kernel.

**IN THE VEHICLE:**

- Make sure that all the modifications for the vehicle, which are listed in the section, Prerequisites, have been performed.
- Install the major components (according to the illustrations and the instructions included in this document):
  - GPS Antenna
  - IPC
  - GPS Receiver

The actual steps to install all the hardware and software components are detailed in the section, Steps for the Installation Tasks.
Steps for the Installation Tasks
This section describes the steps to install:

- The key hardware and software components
- The hardware in the vehicle

At the Office
Perform these tasks:

- Prepare the IPC:
  - Install the CAN card
  - Install or replace the hard drive
  - Prepare the IPC for powering up
- Install the software for the IPC:
  - Ubuntu Linux
  - Apollo Kernel

Preparing the IPC
Follow these steps:

1. In the IPC, examine the GPU cassette to determine if there is a pre-installed GPU card, which you need to remove:
   a. Turn over the IPC to unscrew the four screws (shown in the purple squares) on the bottom of computer that are holding the GPU cassette in place:
b. Remove the GPU cassette from the IPC:

c. Unscrew three additional screws (shown in the purple circles) on the bottom of the GPU cassette to open the cover:
d. Remove the GPU card:

![Image of GPU card being removed](image)

2. Prepare and install the Controller Area Network (CAN) card:
   a. Set the CAN card termination jumper by removing the red jumper cap [shown in yellow circles] from its default location and placing it at its termination position:

![Image of CAN card termination jumper](image)

**WARNING:** The CAN card will not work if the termination jumper is not set correctly.
b. Insert the CAN card into the slot in the IPC:

c. Reinstall the GPU cassette in the IPC:

3. Install or replace the hard drive.

You need to install one or two 2.5" SSD or hard drives if none have been pre-installed. As an alternative, you might want to replace a pre-installed hard drive with one of your own.
An SSD drive is highly recommended for better reliability. Also consider using a high-capacity drive if you need to collect driving data.

To install the hard drive:

a. Unscrew the three screws (shown in the purple circles) to open the hard drive cover (caddy):
b. Install the drive in the caddy (as shown with an Intel SSD):

Observe the way the hard drive is situated in the caddy for the installation. The Serial Advanced Technology Attachment (SATA) and the power connectors should be placed in the caddy facing the end that has the two screw holes showing.

The Hard drive in the caddy is now connected:
c. Reinstall the SSD caddy in the IPC:

4. Prepare the IPC for powering up:
   a. Attach the power cable to the power connector (terminal block) that comes with the IPC:

   **WARNING:** Make sure that the positive [labeled R for red] and the negative [labeled B for black] wires of the power cable are inserted into the correct holes on the power terminal block.
b. Connect the monitor, Ethernet cable, keyboard, and mouse to the IPC:

It is recommended that you use a Video Graphics Array (VGA) connector for the monitor for these reasons:

- If you do not see any screen display when the IPC boots up, switch to the VGA input. The AutonomouStuff Nebula IPC always outputs to a VGA port even if there is no monitor connected. Consequently, the Linux installer might "elect" to output to a VGA port instead of a DVI port.

- If you do not see a dialog window during the installation process when using a dual-monitor, try switching between VGA and DVI to find it. The Linux installer might detect two monitors and use them both.

For better display quality, you have the option to:

- Connect a Digital Visual Interface (DVI) cable to another monitor using a High-Definition Multimedia Interface (HDMI) adapter

- Use the DVI/HDMI port on the same monitor
Installing the Software for the IPC

This section describes the steps to install:

- Ubuntu Linux
- Apollo Kernel

It is assumed that you have experience working with Linux to successfully perform the software installation.

**Installing Ubuntu Linux**

Follow these steps:

1. Create a bootable Ubuntu Linux USB flash drive:
   a. Download Ubuntu (or a variant such as Xubuntu) and follow the online instructions to create a bootable USB flash drive.

   - It is recommended that you use Ubuntu 14.04.3.
   - You can type F2 during the system boot process to enter the BIOS settings. It is recommended that you disable Quick Boot and Quiet Boot in the BIOS to make it easier to catch any issues in the boot process.
2. Install Ubuntu Linux:
   a. Insert the Ubuntu installation drive into a USB port and turn on the system.
   b. Install Linux using the online instructions

3. Perform a software update and the installation:
   a. Reboot into Linux after the installation is done.
   b. Launch the Software Updater to update the latest software packages (for the installed distribution).
   c. Launch a terminal program such as GNOME Terminal and type the following command to install the Linux 4.4 kernel:

```
sudo apt-get install linux-generic-lts-xenial
```

The IPC must have Internet access to update and install software. Make sure that the Ethernet cable is connected to a network with Internet access. You might need to configure the network for the IPC if the network that it is connected to is not using the Dynamic Host Configuration Protocol (DHCP).

**Installing the Apollo Kernel**

Follow these steps:

1. Download the Apollo Linux Kernel.

2. After downloading the kernel (to ~/apollo, for example), issue the following commands in a terminal to configure and build the kernel:

```
cd apollo/modules/kernel; bash ./build-ng.sh
```

3. Optionally, if you want to configure the kernel manually, change the configuration files under the configs directory (using `config.4.4.32.rt` for the realtime kernel, and `config.4.4.32` for the non-realtime kernel).

4. After building the kernel, issue the following commands in a terminal to install the realtime kernel (the same for a non-realtime kernel):

```
cd output/rt; tar zxvf install.tgz
cd install; ./install_kernel.sh
```
5. Create the CAN device node by issuing the following commands in a terminal:

```
cd /dev; sudo mknod --mode=a+rw can0 c 52 0
```

The IPC is ready to be mounted on the vehicle.

**In the Vehicle**

Perform these tasks:

- Make the necessary modifications to the vehicle as specified in the list of prerequisites
- Install the major components:
  - GPS Antenna
  - IPC
  - GPS Receiver

**Prerequisites**

**WARNING:** Prior to mounting the major components (GPS Antenna, IPC, and GPS Receiver) in the vehicle, certain modifications must be performed as specified in the list of prerequisites. The instructions for making the mandatory changes in the list are outside the scope of this document.

The list of prerequisites are as follows:

- The vehicle must be modified for “drive-by-wire” technology by a professional service company. Also, a CAN interface hookup must be provided in the trunk where the IPC will be mounted.
- A power panel must be installed in the trunk to provide power to the IPC and the GPS-IMU. The power panel would also service other devices in the vehicle such as a 4G LTE router. The power panel should be hooked up to the power system in the vehicle.
- A custom-made rack must be installed to mount the GPS-IMU Antenna on top of the vehicle.
- A custom-made rack must be installed to mount the GPS-IMU in the trunk.
- A 4G LTE router must be mounted in the trunk to provide Internet access for the IPCG. The router must have built-in WiFi access point (AP) capability to connect to other devices, such as an iPad, to interface with the autonomous driving (AD) system. A user would be able to use the mobile device to start AD mode or monitor AD status, for example.
Additional Items to Supply

You must also supply (and properly mount) the following items:

- An iPad or other tablet to interface with the AD system
- A monitor, keyboard and mouse to use for debugging and testing within the vehicle

Diagrams of the Major Component Installations

The following two diagrams indicate the locations of where the three major components (GPS Antenna, IPC and GPS Receiver) should be installed on the vehicle:
Installing the GPS Receiver and Antenna

This section provides general information about installing one of two choices:

- **GPS-IMU**: NovAtel SPAN-IGM-A1
- **GPS-IMU**: NovAtel SPAN® ProPak™ and NovAtel IMU-IGM-A1

Installing the NovAtel SPAN-IGM-A1

The installation instructions describe the procedures to mount, connect, and take the lever arm measurements for the GPS-IMU NovAtel SPAN-IGM-A1.

Mounting

You can place the GPS-IMU NovAtel SPAN-IGM-A1 in most places in the vehicle but it is suggested that you follow these recommendations:

- Place the NovAtel SPAN-IGM-A1 inside the trunk with the Y-axis pointing forward.
- Use the NovAtel GPS-703-GGG-HV antenna, which you should mount in an unobscured location on top of the vehicle.

Wiring

You must connect two cables:

- The antenna cable - Connects the GNSS antenna to the antenna port of the SPAN-IGM-A1
• The main cable:
  • Connects its 15-pin end to the SPAN-IGM-A1
  • Connects its power wires to a power supply of 10-to-30V DC
  • Connects its serial port to the IPC. If the power comes from a vehicle battery, add an auxiliary battery (recommended).

Main Cable Connections

For more information, see the SPAN-IGM™ Quick Start Guide, page 3, for a detailed diagram:

SPAN-IGM™ Quick Start Guide

Taking Lever Arm Measurement
When the SPAN-IGM-A1 and the GPS Antenna are in position, the distance from the SPAN-IGM-A1 to the GPS Antenna must be measured. The distance should be measured as: X offset, Y offset and Z offset.

The error of offset must be within one centimeter to achieve high accuracy. For more information, see the SPAN-IGM™ Quick Start Guide, page 5, for a detailed diagram.

For an additional information about the SPAN-IGM-A1:

SPAN-IGM™ User Manual
Installing NovAtel SPAN® ProPak6™ and NovAtel IMU-IGM-A1
The installation instructions describe the procedures to mount, connect and take the lever arm measurements for the GPS NovAtel SPAN® ProPak6™ and the NovAtel IMU-IGM-A1.

Components for the Installation
The components that are required for the installation include:

- NovAtel GPS SPAN ProPak6
- NovAtel IMU-IGM-A
- NovAtel GPS-703-GGG-HV Antenna
- NovAtel GPS-C006 Cable (to connect antenna to GPS)
- NovAtel 01019014 Main Cable (to connect GPS to Nebula serial port)
- Data Transport Unit (DTU) — similar to a 4G router
- Magnetic adapters (for antenna and DTU)
- DB9 Straight Through Cable

Mounting
You can place the two devices, the ProPak6 and the IMU, in most places in the vehicle but it is suggested that you follow these recommendations:

- Place the ProPak 6 and the IMU side-by-side inside the trunk with the Y-axis pointing forward.
- Use the NovAtel GPS-703-GGG-HV antenna, which you should mount on top of the trunk lid as shown:

  ![Antenna Mounting Example](image)

- Use a magnetic adapter to tightly attach the antenna to the trunk lid.
- Install the antenna cable in the trunk by threading the cable through a hole on the trunk lid.
**Wiring**

You must connect three cables:

- The antenna cable GPS-C006 - Connects the antenna to the GPS
- The main cable 010 19014 - Connects to the IPC
- The DB9 cable - Connects the GPS to the IMU. If the power is coming from a vehicle battery, it is recommended that you add an auxiliary battery.

![Cable Connections](image)

**Taking Lever Arm Measurement**

When the IMU and the GPS Antenna are in position, the distance from the IMU to the GPS Antenna must be measured. The distance should be measured as: X offset, Y offset and Z offset.

The error of offset must be within one centimeter to achieve high accuracy.

For an additional information, see:

[NovAtel ProPak6 Installation & Operation Manual](#)
[IMU-IGM-A1 Documentation](#)
Installing the IPC

Follow these steps:

1. Use a power cable to connect the vehicle power source to the IPC:
   Use its power connector as one end and connect the other end to the power panel in the vehicle

2. Place the on-board computer system, the 5059GC, inside the trunk (recommended).
   For example, Baidu uses 4x4 self-tapping screws to bolt the 5059GC to the carpeted floor of the trunk.

3. Mount the IPC so that its front and back sides (where all ports are located) face the right side (passenger) and the left side (driver) of the trunk. This positioning makes it easier to connect all the cables.

4. Connect all the cables, which include:
   • Power cable
   • Controller Area Network (CAN) cable
   • A set of three cables:
     • Ethernet cable from the 4G router to the IPC
     • GPS Receiver to the IPC
     • (Optional) Monitor, keyboard, mouse
a. Connect the power cable to the IPC (as shown):

Connect the other end of the power cable to the vehicle battery (as shown):
The power cable connections on both ends are shown, connecting to the battery (at one end) and to the IPC (at the other end):

b. Connect the DB9 cable to the IPC to talk to the CAN (as shown):
c. Connect:
   - The Ethernet cable from the 4G router to the IPC (labeled as Router)
   - The GPS Receiver to the IPC (labeled as GPS IMU)
   - (Optional) The monitor (labeled as Monitor):

Next Steps
The AutonomouStuff engineering services team will assist on the software installation.

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