

CAMWorks – How To Create CNC G-Code for CO2 Dragster

I.1.

Introduction

This guide is focused on teaching users of SolidWorks and CAMWorks how to create the CNC G-Code tool path files to mill out a CO2 Dragster.

CAMWorks is integrated inside of SolidWorks and has very long and successful legacy of it's integration with SolidWorks. The integration in SolidWorks is critical for ease of use and interoperability between the 3D CAD Model and the CNC process of generating G-Code Tool Paths. Another words, the CAD designer does not have to leave the CAD software to work on the Computer Aided Manufacturing software for creating CNC G-Code. This is an important advantage of using CAMWorks.

In fact, CAMWorks was the first Gold partner CAM product on SolidWorks®. It is also the first CAM solution to offer knowledge-based feature recognition and associative machining capabilities, seamlessly integrated into the SolidWorks 3D mechanical design software. Many top CAM/CNC companies like MasterCAM, SolidCAM and BobCAD are racing to catch up with CAMWorks and the power it's seamless integration with SolidWorks.

In our area, CAMWorks plays an important role in local industry. Tampa Bay Steel, one of Florida's major steel distribution and metal processing companies, ensures that they are always 'ready for business' with CAMWorks. Florida-based Magnus Hi-Tech Industries Inc. (www.magnusht.com), an established world-class precision fabricator, has experienced reduced engineering and CNC programming time by using CAMWorks, an intuitive solids-based CAM solution. There are many other companies in Florida using CAMWorks and SolidWorks.

Other successful companies and organization use CAMWorks and SolidWorks. Companies like:

- Fender Music Instruments – Makers of Electric Guitars.
- Roush Enterprises – Providing high performance products for Ford Mustangs.
- Remington Arms – Manufacturer of high quality American Firearms.
- NASA
- Procter and Gamble

There are many more companies using CAMWorks and SolidWorks, however what is apparent is that we must teach faculty and students to be competent in this powerful technology.

The approach to teaching SolidWorks and CAMWorks will be to use this guide and online video tutorials. Both methods will be found on www.richardplatt.net in the training section of the web site for CAD/CAM. These videos and guides will be updated as soon as possible to keep current on the changes in the software.

The initial application of this training will be in milling a CO2 Dragster. The approach will build on the relevance of the current CO2 Dragster tutorial, found at <http://www.richardplatt.net/training/dragster3d/index.html>. This geometry teaches the relevance of building a basic CO2 Dragster in SolidWorks. Through this tutorial, students learn a tremendous amount of skill with SolidWorks. Students who go completely through this tutorial are very capable of

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moving into the application of CAMWorks. Additionally, working with this model, makes it very relevant to the teacher and student.

It is important to note, by industry standards and types of CNC products industry produces, a CO2 Dragster, with it's unique billet shape and challenging fixture requirements is a very advanced product to manufacture. This has been stated by local manufactures here in Florida after their viewing of CO2 Dragsters manufactured by our students utilizing CAD/CAM/CNC software and hardware.

We will use the geometry of the CO2 Dragster found on that web site. The 3D SolidWorks model of the CO2 Dragster will be provided to students in the class and in turn they will start learning CAMWorks from an existing model. The model of the CO2 Dragster can be seen in the following image.



I.2.

Concepts and Terms:

In this section we will cover the vocabulary and terms commonly found in the CNC machining industry. These terms must be understood because it will aide in working with both software and hardware used everyday in industry.

I.3.

Cutters and Mills – These typically called the “drill bits” by novices and beginners. Remember, drill bits are for making holes. Cutters and Mill look like drill bits, however their purpose is to cut holes and to cut laterally from side to side. These are highly engineered in that they can lift the chip of cut material from the cutting area and that they cut side ways very effectively. Cutters and mills come in a variety of types, sizes, and configurations. Cutters and mill are made of either High Speed steel or carbide steel. Most are tempered for cutting strength and sharpness.

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I.4.

End Mill:

An endmill is a type of milling cutter, a cutting tool used in industrial milling applications. It is distinguished from the drill bit, in its application, geometry, and manufacture. While a drill bit can only cut in the axial direction, a milling bit can generally cut in all directions, though some cannot cut axially. Endmills are used in milling applications such as profile milling, tracer milling, face milling, and plunging. Several broad categories of end- and face-milling tools exist, such as center-cutting versus non-center-cutting (whether the mill can take plunging cuts); and categorization by number of flutes; by helix angle; by material; and by coating material. Each category may be further divided by specific application and special geometry. There are four critical angles of each cutting tool: end cutting edge angle, axial relief angle, radial relief angle, and radial rake angle.



I.5.

Cutter Characteristics - Shape: Several standard shapes of milling cutter are used in industry today, which are explained in more detail below.

I.6.

Cutter Characteristics - Flutes / teeth: The flutes of the milling bit are the deep helical grooves running up the cutter, while the sharp blade along the edge of the flute is known as the tooth. The tooth cuts the material, and chips of this material are pulled up the flute by the rotation of the cutter. There is almost always one tooth per flute, but some cutters have two teeth per flute.[1] Often, the words flute and tooth are used interchangeably. Milling cutters may have from one to many teeth, with 2, 3 and 4 being most common. Typically, the more teeth a cutter has, the more rapidly it can remove material. So, a 4-tooth cutter can remove material at twice the rate of a 2-tooth cutter.

I.7.

Cutter Characteristics - Helix angle: The flutes of a milling cutter are almost always helical. If the flutes were straight, the whole tooth would impact the material at once, causing vibration and reducing

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accuracy and surface quality. Setting the flutes at an angle allows the tooth to enter the material gradually, reducing vibration. Typically, finishing cutters have a higher rake angle (tighter helix) to give a better finish.

Center cutting: Some milling cutters can drill straight down (plunge) through the material, while others cannot. This is because the teeth of some cutters do not go all the way to the centre of the end face. However, these cutters can cut downwards at an angle of 45 degrees or so.

I.8.

Cutter Characteristics - Roughing or Finishing: Different types of cutter are available for cutting away large amounts of material, leaving a poor surface finish (roughing), or removing a smaller amount of material, but leaving a good surface finish (finishing). A roughing cutter may have serrated teeth for breaking the chips of material into smaller pieces. These teeth leave a rough surface behind. A finishing cutter may have a large number (4 or more) teeth for removing material carefully. However, the large number of flutes leaves little room for efficient swarf removal, so they are less appropriate for removing large amounts of material.

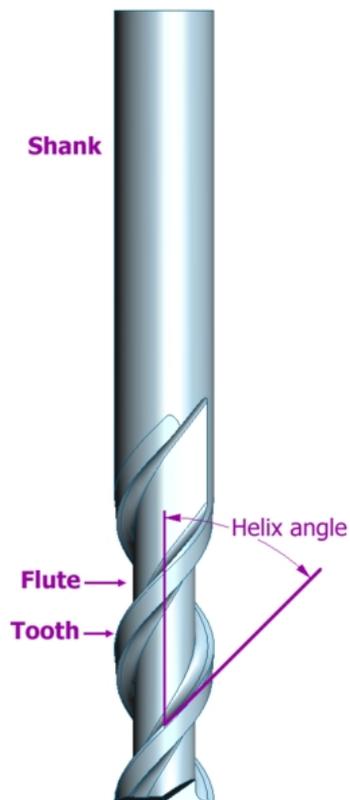
I.9.

Cutter Characteristics - Coatings: The right tool coatings can have a great influence on the cutting process by increasing cutting speed and tool life, and improving the surface finish. Polycrystalline Diamond (PCD) is an exceptionally hard coating used on cutters which must withstand high abrasive wear. A PCD coated tool may last up to 100 times longer than an uncoated tool. However the coating cannot be used at temperatures above 600 degrees C, or on ferrous metals. Tools for machining aluminum are sometimes given a coating of TiAlN. Aluminum is a relatively sticky metal, and can weld itself to the teeth of tools, causing them to appear blunt. However it tends not to stick to TiAlN, allowing the tool to be used for much longer in aluminum.

I.10.

Cutter Characteristics - Shank: The shank is the cylindrical (non-fluted) part of the tool which is used to hold and locate it in the tool holder. A shank may be perfectly round, and held by friction, or it may have a Weldon Flat, where a grub screw makes contact for increased torque without the tool slipping. The diameter may be different from the diameter of the cutting part of the tool, so that it can be held by a standard tool holder.

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I.11.

Ball Nose Cutter:

Ball nose cutters (lower row in image) are similar to slot drills, but the end of the cutters are hemispherical. **They are ideal for machining 3D contoured shapes in machining centers, for example in molds and dies.** They are sometimes called ball mills in shop-floor slang, despite the fact that that term also has another meaning. They are also used to add a radius between perpendicular faces to reduce stress concentrations. There is also a term bull nose cutter, which refers more to a cutter having a corner radius less than half the cutter diameter; e.g. a 20 mm diameter cutter with a 1 mm radius corner.

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I.12.

Router Bits:

Router bits come in hundreds of varieties to create either decorative effects or joinery aids. Generally, they are classified as either high-speed steel (HSS) or carbide-tipped, however some recent innovations such as solid carbide bits provide even more variety for specialized tasks.

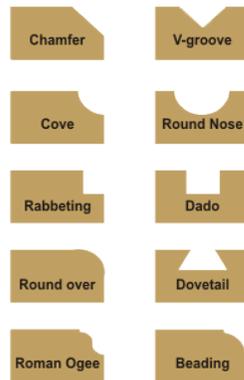
Aside from the materials they are made of, bits can be classified as edge bits or non-edge bits, and whether the bit is designed to be anti-kickback. Edge bits have a small wheel bearing to act as a fence against the work in making edge moldings. These bearings can be changed by using commercially available bearing kits. Changing the bearing, in effect, changes the diameter of the cutting edge. This is especially important with rabbeting bits. Non-edge bits require the use of a fence, either on a router table or attached to the work or router. Anti-kickback bits employ added non-cutting bit material around the circumference of the bit's shoulders which serves to limit feed-rate. This reduces the chance that the workpiece is pushed too deeply into the bit (which would result in significant kickback from the cutting edge being unable to compensate).

Bits also differ by the diameter of their shank, with ½ inch, 12 mm, 10 mm, 3/8 inch, 8 mm and ¼ inch and 6 mm shanks (ordered from thickest to thinnest) being the most common. Half-inch bits cost more but, being stiffer, are less prone to vibration (giving smoother cuts) and are less likely to break than the smaller sizes. The bit shank and router collet sizes must match. Many routers come with removable collets for the popular shank sizes (in the USA ½ in and 1/4 in, in Great Britain ½ in, 8 mm and 1/4 in, and metric sizes in Europe—although in the United States the 3/8-inch and 8 mm sizes are often only available for extra cost).

Many modern routers allow the speed of the bit's rotation to be varied. A slower rotation allows bits of larger cutting diameter to be used safely. Typical speeds range from 8,000 to 30,000 rpm.

Router Bits can be made to match any imaginable profile. Companies that manufacture custom router bits can be found on the Internet. Custom router bits are especially beneficial for home restoration projects, where the original trim and molding of the home is often out of production.

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In CNC milling there is an over lap of the type of cutter one use for both metal milling and CNC wood routing. In most cases a metal cutter or mill will work on wood, however, it may not be the most efficient cutter to use. As an example, for roughing dense wood like maple a 1/2” router is much more efficient.

I.13.

Collets:

A collet is a holding device—specifically, a subtype of chuck—that forms a collar around the object to be held and exerts a strong clamping force on the object when it is tightened, usually via a tapered outer collar. It may be used to hold a workpiece or a tool securely.



A collet is a sleeve with a (normally) cylindrical inner surface and a conical outer surface. The collet can be squeezed against a matching taper such that its inner surface contracts to a slightly smaller diameter, squeezing the tool or workpiece whose secure holding is desired. Most often this is achieved with a spring collet, made of spring steel, with one or more kerf cuts along its length to allow it to expand and contract. An alternative collet design is one that has several tapered steel blocks (essentially tapered gauge blocks) held in circular position (like the points of a star, or indeed the jaws of a jawed chuck) by a flexible binding medium (typically synthetic or natural rubber). The Jacobs Rubber-Flex brand is a name that most machinists would recognize for this type of collet chuck system.

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Regardless of the collet design, the operating principle is the same: squeeze the collet against the tool or workpiece to be held, resulting in high static friction.

On a wood router (a hand-held or table-mounted power tool used in woodworking), the collet is what holds the bit in place. In the U.S. it is generally for 0.25 or 0.5 inch (6.3 or 13 mm) bits, while in Europe bits are most commonly 6 or 8 mm (0.24 or 0.31 in). The collet is hexagonal on the outside so it can be tightened or loosened with a standard wrench, and has threads on the inside so it can be screwed on to the motor arbor.

I.14.

Servo Motors:

A servomotor is a motor which forms part of a servomechanism. The servomotor is paired with some type of encoder to provide position/speed feedback. A stepper motor is one type of servomotor. A stepper motor is actually built to move angular positions based upon each possible step around the entire rotation, and may include microsteps with a resolution such as 256 microsteps per step of the stepper motor.

A servomechanism may or may not use a servomotor. For example, a household furnace controlled by a thermostat is a servomechanism, because of the feedback and resulting error signal, yet there is no motor being controlled directly by the servomechanism.



For CNC applications, a servo motor is more desirable due to the resolution and accuracy of the motor due typical encoders used. Servo motors are very expensive compared to Stepper motors. Stepper motors are becoming very accurate, powerful and are significantly less expensive

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I.15.

Stepper Motors:

A stepper motor (or step motor) is a brushless, electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely without any feedback mechanism (see Open-loop controller), as long as the motor is carefully sized to the application. Stepper motors are similar to switched reluctance motors (which are very large stepping motors with a reduced pole count, and generally are closed-loop commutated).



Stepper motors operate differently from DC brush motors, which rotate when voltage is applied to their terminals. Stepper motors, on the other hand, effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first, one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle.

I.16.

Thread Stock:

A screw thread, often shortened to thread, is a helical structure used to convert between rotational and linear movement or force. A screw thread is a ridge wrapped around a cylinder or cone in the form of a helix, with the former being called a straight thread and the latter called a tapered thread. More screw threads are produced each year than any other machine element.[1]

The mechanical advantage of a screw thread depends on its lead, which is the linear distance the screw travels in one revolution.



Smaller and less expensive hobby CNC mill typically use Thread stock to drive or move the X-Y-Z

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Axis. The thread stock screw will range from 1/4" to 3/8". The down side to using thread stock is these machines are very slow with 20in/min – 30in/min speed. Another down side is the thread stock will wear out much sooner than more advanced linear movement options.

I.17.

Lead Screw:

A leadscrew (or lead screw), also known as a power screw or translation screw, is a screw designed to translate turning motion into linear motion. Common applications are machine slides (such as in



machine tools), vises, presses, and jacks. The mechanical advantage of a leadscrew is determined by the screw pitch and lead. For multi-start screws the mechanical advantage is lower, but the traveling speed is higher.

I.18.

Ball Screw:

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction.

They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The ball assembly acts as the nut while the threaded shaft is the screw. In contrast to conventional leadscrews, ballscrews tend to be rather bulky, due to the need to have a mechanism to re-circulate the balls. The image below is a great example of a ball screw.



Ball screws are used in aircraft and missiles to move control surfaces, especially for electric fly by wire and in automobile power steering to translate rotary motion from an electric motor to axial motion of the steering rack. They are also used in machine tools, robots and precision assembly equipment. High precision ball screws are used in steppers for semiconductor manufacturing.

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Low friction in ball screws yields high mechanical efficiency compared to alternatives. A typical ball screw may be 90 percent efficient, versus 50 percent efficiency of an Acme lead screw of equal size. The higher cost of ball screws may thus be offset by lower power requirements for the same net performance.

I.19.

Tool Changer:

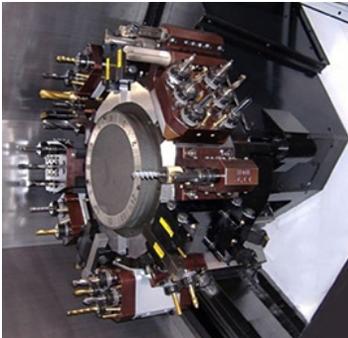
A tool changer is a means to mechanically change a tool in a CNC Mill or CNC Router. In the image below you see a rack of quick change collets.



With this machine, it can mechanically change the tool needed to mill out the part. In the G-Code tool file, a call can be coded in to change the tool and the gantry will move the Y-Axis over the right and the position the X-Axis to unload a tool and then load another tool. This very efficient and a significant time saver.

I.20.

Tool Turret:



A tool turret saves a tremendous amount of time in switching from one tool to another. In the image above this turret holds a lot of different types of cutters and mills. This is very impressive to see in operation and the amount of time that is saved in milling operations.z

I.21.

Fixture:

A fixture is a device that is mounted on the milling surface of the CNC Mill and CNC Router. The

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purpose of the fixture is to mount the billet into the CNC Mill or CNC Router so that it is precise for the milling of the part and that the billet would not come loose. Fixtures can be purchased or they can be manufactured and fabricated using a variety of materials. The image below shows two fixtures mounted on the same table. This optimizing the millable area of this CNC Router. Additionally it saves time in set up and setting Off Sets, thus the CNC Router can be in constant production.



As you see in this image two different fixtures are mounted on the table, supporting the milling of two different parts. If you look closer, in an attempt to optimize manufacturing production, there are five parts being milled out of the two billets.

I.22.

Off Set:

The Off Set is the location you established for the origin start point of your part to mill. Your G-Code tool path file x,y,z cartesian plane 0,0,0 is the Off Set location. In all CNC Mills and CNC Routers one has to established an Off Set for each part that is planned to be milled. The CNC Mill and CNC Router has to have a consistent place to start for all parts.

I.23.

Touch Off Plate:

A Touch Off Plate is a device in a CNC Machine that automates the setting of the Z-Axis for the Off Set

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location. It automates the lowering of the Z-Axis to where it touches the plate at the precise Z location for the Off Set. This Z-Axis location is added to the Off Set setting for the CNC Mill or CNC Router cartesian plane location.

I.24.

Home Position:

The Home Position of a CNC Mill or CNC Router is where the spindle or router returns to prior and after the milling operation. The Home Position should not be confused with the Off Set. It is the position of the start point on the CNC Router.

I.25.

CNC Controller:

The CNC Controller is a combination of hardware and Software used to interface a computer with the CNC Mill and or CNC Router. Some CNC Machines have very complex controller systems. With the proliferation of less expensive CNC Mills and CNC Routers that are connected to desktop or laptop computers, most use either a simple computer add in card with a parallel cable card converted to either a serial, usb or SCSI cable. Additionally, the CNC Mill or CNC Router has a driver board that connects the wires to the stepper motors to control the movement of the CNC Mill or CNC Router in the X-Y-Z Axis. More and more the CNC Controllers are generic and the software is either open source or can be purchased very inexpensively.

I.26.

Paper Gauge:

This is an inexpensive and very precise method of touching off the Off Set locations for the X-Y-Z Axis. A piece of paper is 3,000th of an inch thick. When the tool touches the piece of paper and you can feel pressure on the paper then you have compressed the paper to the point the tool is touching the billet. Then that location gauges the calibration of the axis the machine operator is trying to set.

I.27.

Fanuc Based Controller:

FANUC LTD, headquartered at the foot of Mt. Fuji, Japan, is the most diversified manufacturer of FA (Factory Automation), robots and Robomachines in the world. Since its inception in 1956, FANUC has contributed to the automation of machine tools as a pioneer in the development of computer numerical control equipment. FANUC technology has contributed to a worldwide manufacturing revolution, which evolved from the automation of a single piece of machine to the automation of entire production lines.

Fanuc technology is a combination of software standards and hardware for controlling CNC systems. Many CNC machine manufacturers build their CNC machines with Fanuc controllers and or emulate Fanuc software and hardware, because so many people have been trained on Fanuc technology.

I.28.

G-Code:

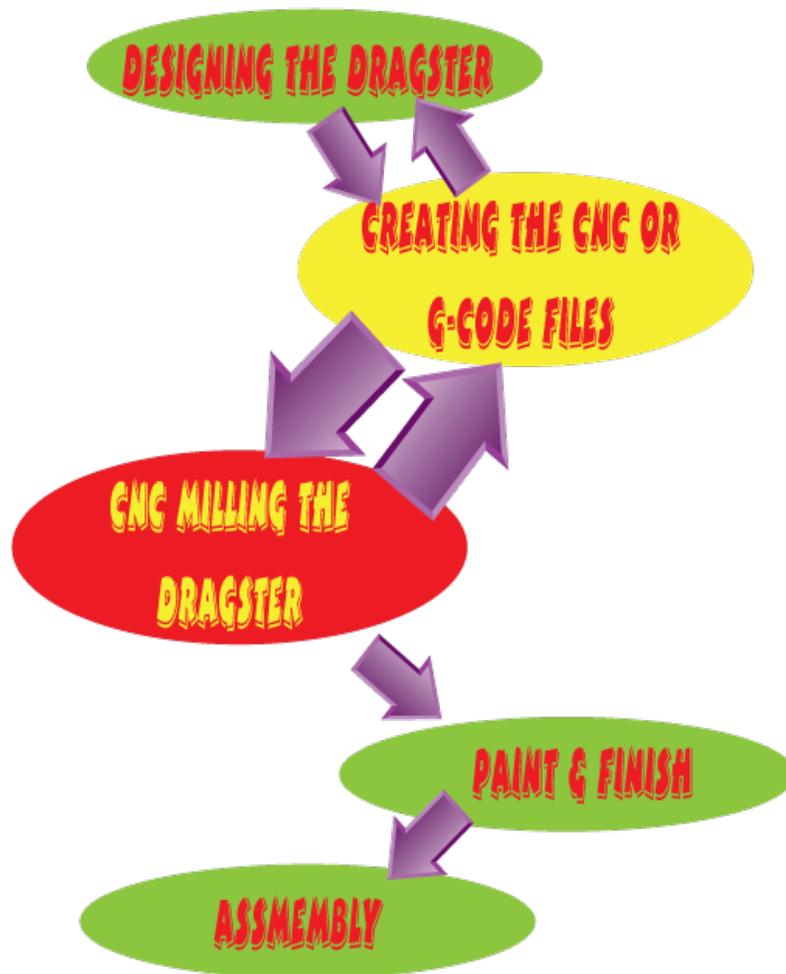
G-code is the common name for the most widely used computer numerical control (CNC) programming

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language, which has many implementations. Used mainly in automation, it is part of computer-aided engineering. G-code is sometimes called G programming language. In decades past G-code was the more common term, and remains such among many users.

I.29.

Process of Manufacturing A Dragster:



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I.30.

The next 5 chapter will focus on the CNC, creating G-Code Process. Please take your time to understand and practice the process on the your designs.