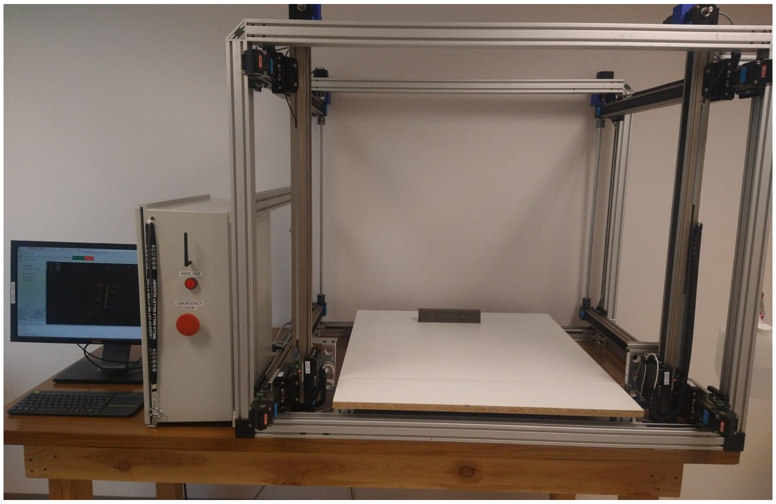


Capabilities and Specifications

- Four axis motion (X/Y1, Y/Z1, U/Y2, V/Z2)
- 810mm minimum wire length
- Work volume 810 x 805 x 765mm
- 0.5mm nichrome wire
- maximum wire tension
- power requirements: 120vac

The Hotwire 2.0 CNC foam cutter is a LinuxCNC controlled machine for producing foam aircraft components, such as wings, rudders, tails, and fuselages. Cutting action is performed by a taut NiChrome wire whose ends are independently moved in parallel vertical planes. This motion is produced by NEMA23 stepper motors driving CCM linear belt actuators. Two horizontal belt actuators in each plane are coupled by a rigid shaft driven by a stepper motor. The vertical belt actuator and its drive motor are carried by these coupled horizontal actuators. A homing sensor is positioned at the front and bottom of each actuator. A home cycle is executed each time the system is restarted.

Tension in the wire is produced by a dead weight consisting of a large water bottle suspended by a pulley system that helps reduce the load on the Z2 motor. The wire is fed through polished tungsten carbide wire guides, with radii larger than the minimum required. The voltage applied across the wire is programmable. Since NiChrome wire has a positive temperature coefficient of resistance, the current will stabilize passively. Current through the NiChrome wire, supplied by an external variable power supply, heats the wire for cutting rigid foam sheets.

Control is provided by an Intel NUC computer running Debian 12 and LinuxCNC 2.9.3. G-code programs are loaded via USB thumb drive or generated by the *winggcode* script. The computer connects to the campus network by wifi, using the WWU-HWAuth ssid network. Make sure the foam cutter table is oriented so the control cabinet door faces towards an access point. The stepper motor drives are connected to the computer by a Mesa Electronics 7I92T interface board. The 7I92T connects to a custom printed circuit board (HOTWIRE1A) to interface to the home switches, stepper motor amplifiers, emergency stop switch, nichrome wire, and wire power status light. This circuit provides electrical isolation for the 24v circuits.

G-code to cut parts is created by an external program, such as *devWing*, *wing.py*, or *https://diyrcwings.com* . In the G-code, the left axes are known as X and Y (corresponding to Y1 and Z1), and the right axes as U and V (corresponding to Y2 and Z2). In addition to moving each end of the wire, the G-code program also sets the wire voltage.

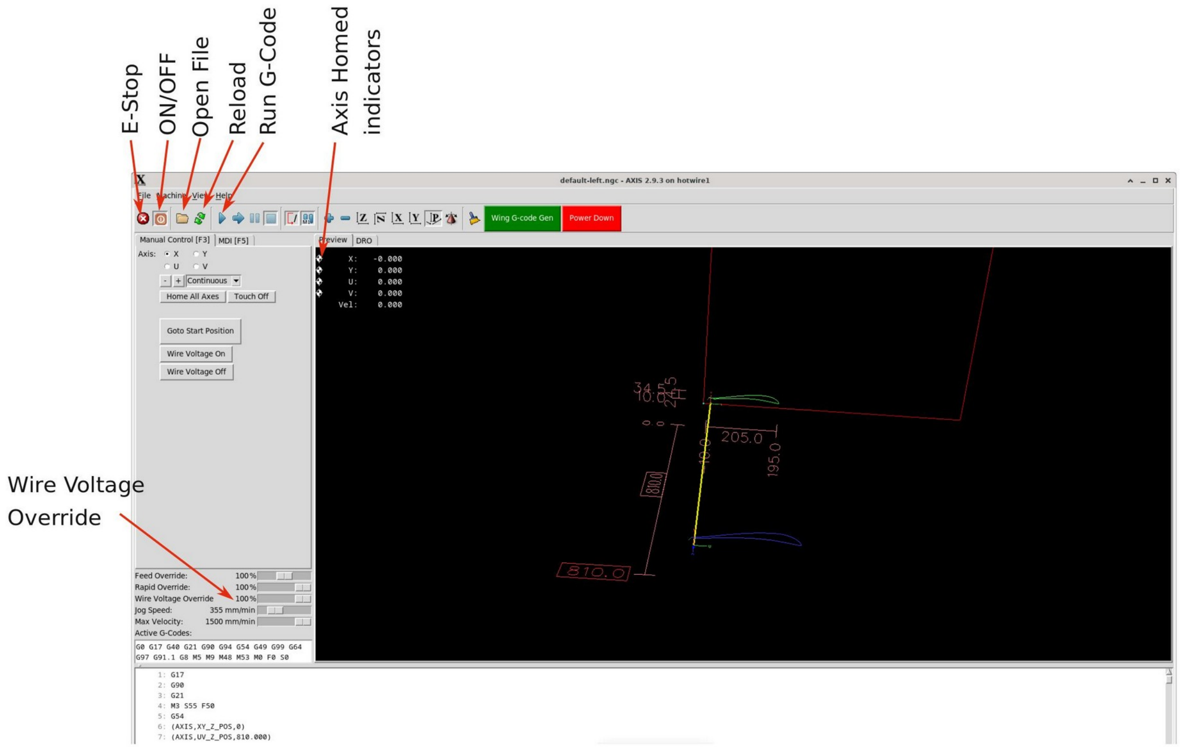


Figure 2: AXIS GUI

System and Usage:

1. Power by plugging in cord, turning on power switch, and turning on monitor and keyboard.
2. Login with 'flightlab' and 'csp307' from login screen.
3. Linuxcnc will run automatically after logging in. From the Linuxcnc AXIS gui screen, you may load a G-code file from File->Open, or create G-code from a design you put in to the *wing.py* script. You may run *wing.py* from inside AXIS by clicking on the green button. Alternatively, you may generate G-code from *https://diyrcwings.com* or *devWingFoam* on the Flightlab Windows PC. If you have your G-code file on Windows OneDrive, you may pull up Applications->Accessories->OneDriver, click '+', set up a mount point, and log in to your OneDrive account.
4. Click on the red E-Stop screen button (see Figure 2) and On/Off button to turn on controller.
5. Be sure table is clear of foam or tools and then click "Home All Axes".
6. When all axes have reached home state, click "Goto Start Position".
7. If you are using a new type of foam or otherwise want to check the temperature setting, you can click "Wire Voltage On", and test a scrap against the wire. If it isn't cutting cleanly, you may raise the temperature some with the "Wire Voltage Override" slider. If it is smoking, you can lower the temperature the same way. This override will be maintained during you session. You can change the "S" value in your g-code program generator for permanent change.
8. Set your pre-cut block of foam (of sufficient thickness and correct width) against the wire and even with the left edge of the table, with a weight on it.

9. When all is ready, click the blue "play" button to run the program. The "Wire Hot" lamp should come on, and the wire should start cutting through the foam. The "Wire Hot" lamp will go out when the program is finished.

Emergency Stop:
The E-stop button on the cabinet can be pressed at any time to stop motion and wire heat. To restart, you must rotate E-stop clockwise until it pops out (1/4 turn) and step #4 of the startup instructions above. If you need to extricate the wire from the foam after an E-stop event, manually turn on the wire voltage and pull your foam free.

Shutdown:
Clicking the red Powerdown button, will cause the system to shutdown after confirmation. Turn off the power switch after the monitor has gone idle.

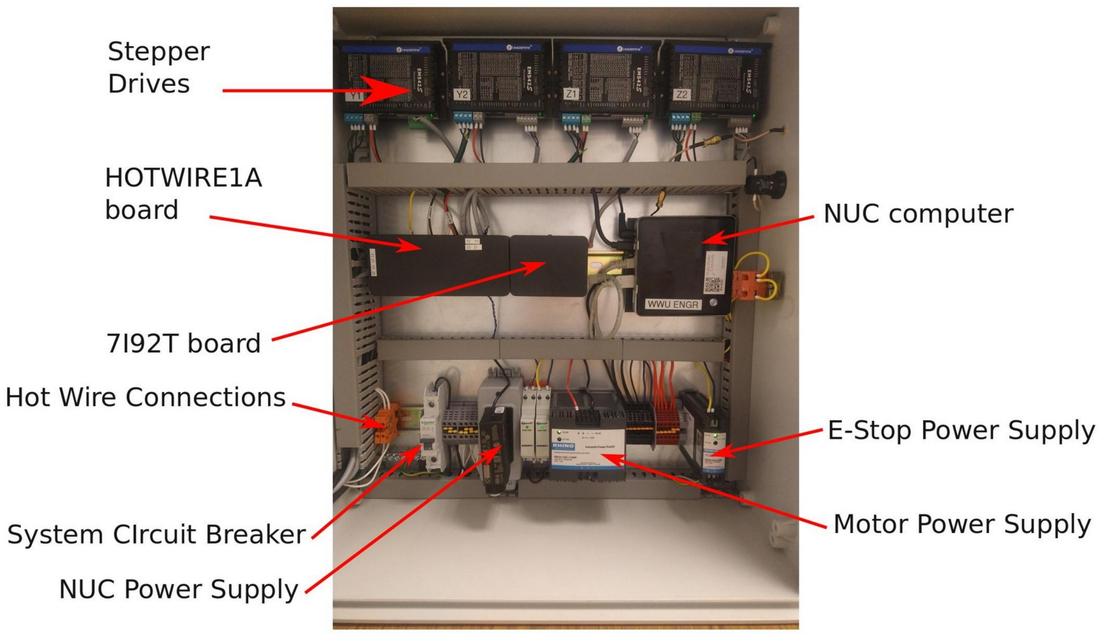
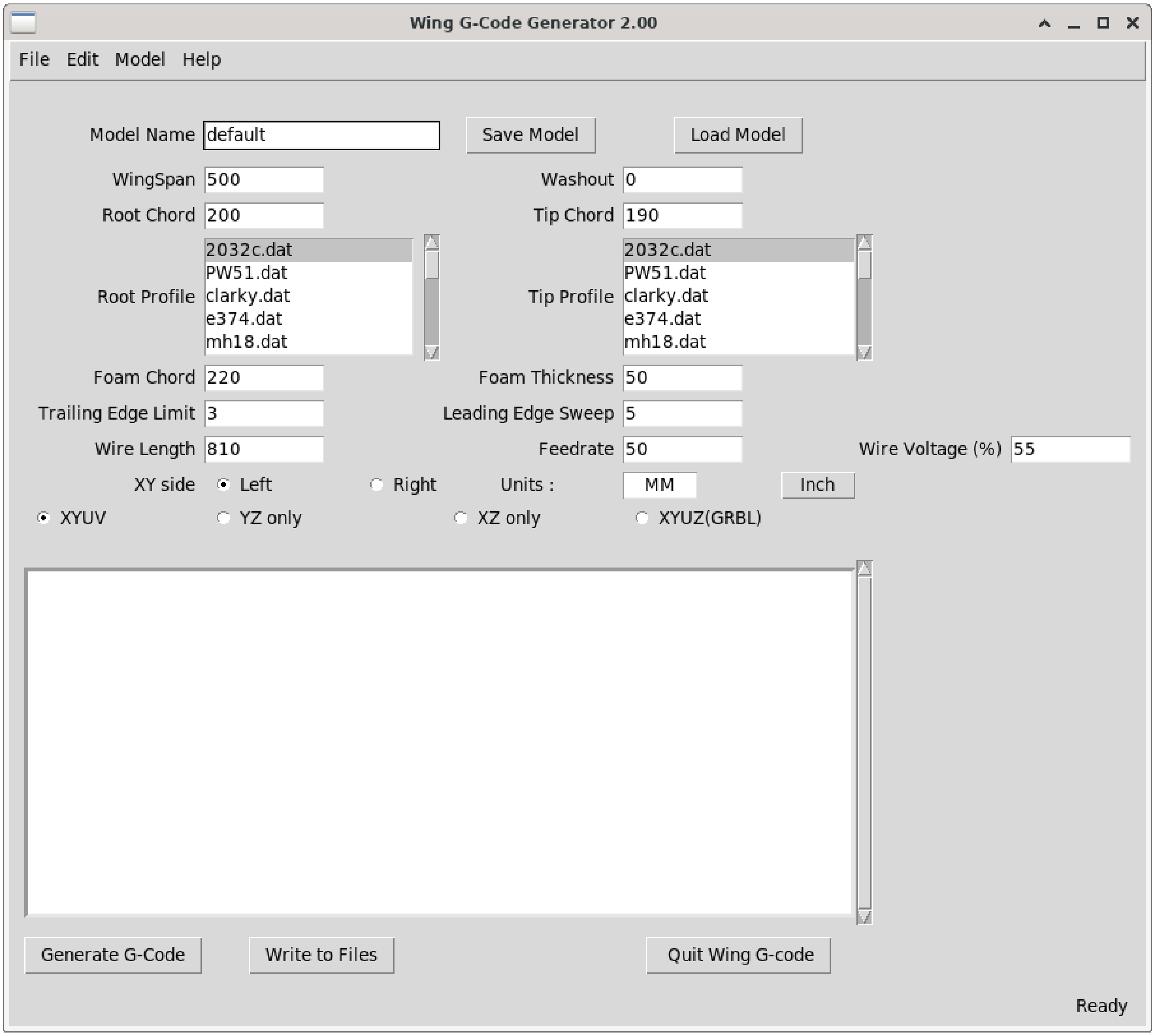


Figure 3: Controls

The control cabinet for Hotwire1 is divided into thirds. The top third consists of the stepper motor drives for the four axes of motion. The middle third consists of the NUC5i5RYB computer, Mesa 7i92T digital logic board, and the HOTWIRE1A custom pcb. The bottom third is 120VAC wiring and power supply components, including a circuit breaker that can be used as a power switch. There are two 24VDC power supplies. The larger one supplies the stepper motor drives, hot wire, and home position sensors. The smaller one powers the E-Stop circuit. The NUC computer is set up with the username "flightlab" and password "csp307", although the password may be changed. The bios configuration is set up to boot directly from power on, and hyper threading is turned off to improve real-time performance. All power-management features are turned off for the same reason. The NUC connects to the 7I92T with Ethernet for communications and USB to supply +5V power to the 7I92T. The 7I92T supplies the +5V and discrete digital I/O to the HOTWIRE1A board over a DB25 connector. If the NUC should fail, any other pc can be substituted after installing the Linuxcnc Hotwire1 image.

Winggcode.py

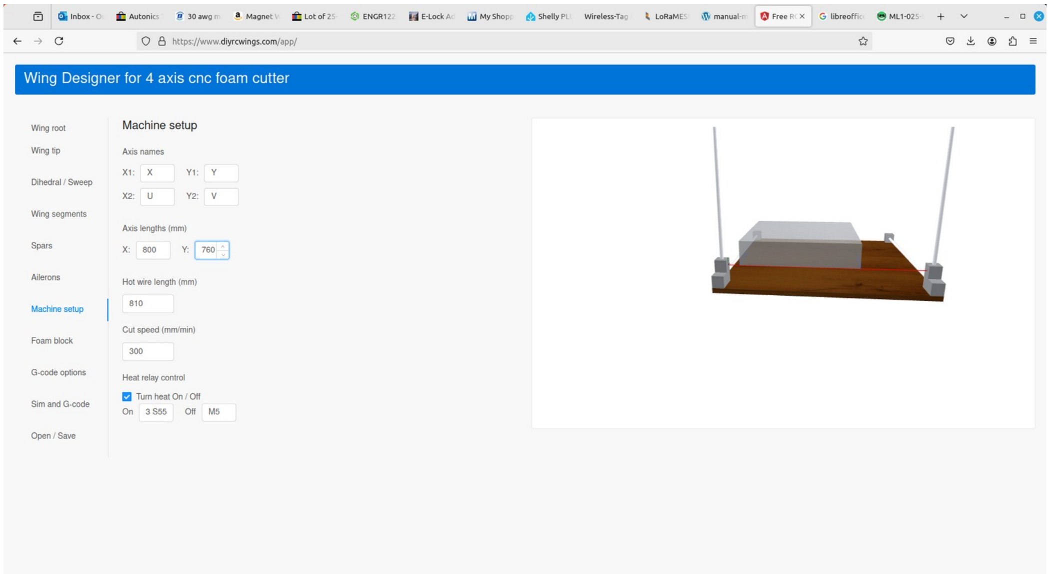


Important fields to note:

Wire Length:	Be sure this is 810mm to match the actual nozzle-to-nozzle minimum distance
Wire Voltage:	This is percent of 24v. 55% has been experimentally found to be reasonable.
XYUV:	Be sure that this coordinate naming convention is selected.
Model Name:	This name will be the prefix for your G-code file.

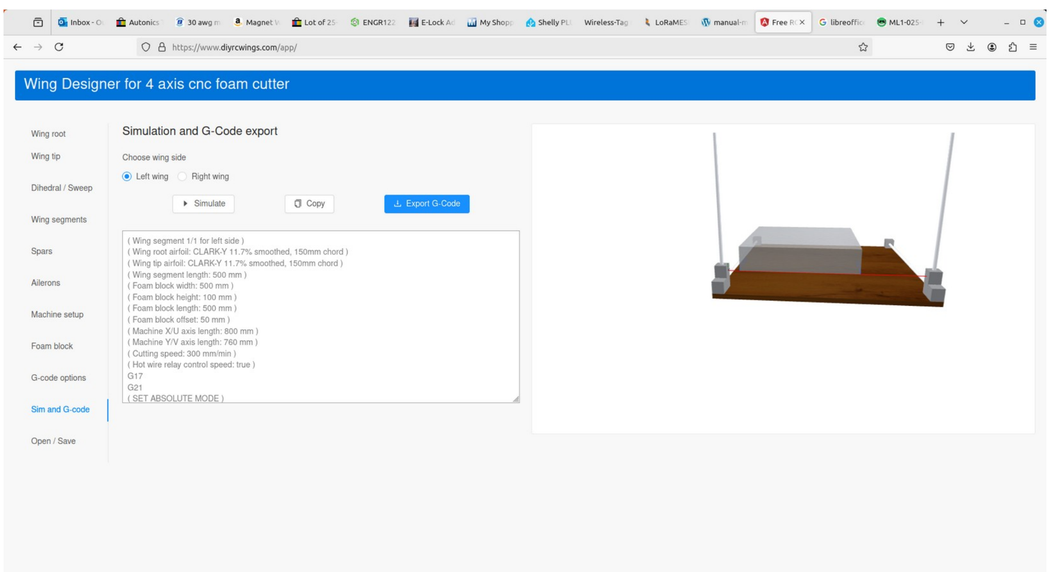
After setting up all your wing parameters, click "Generate G-Code", followed by "Write to Files". You will load your G-code into AXIS with the AXIS File->Open dropdown. You should see your model name in the ~/linuxcnc/nc_files folder.

https://diyrcwings.com



Important fields:

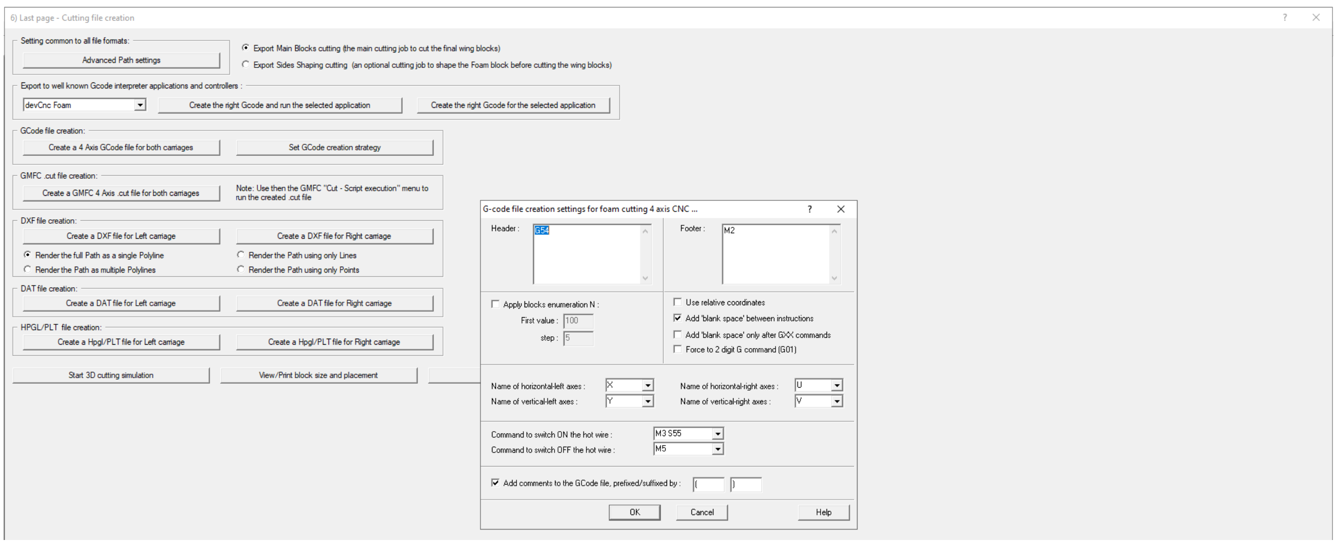
Axis names: X, Y, U, V
Axis lengths: 800 x 760mm
Wire length: 810mm
Heat control: check Turn heat on/off, On=M3 S55, Off=M5



Export G-code, then load from AXIS File->Open. You may have to navigate to ~/Downloads to find it.

devWingFoam

After creating your wing model in *devWingFoam*, click "Create a Foam Cutting Project".



Header: G54
Footer: M2
Axis names: X, Y, U, V
Command to switch on wire: M3 S55
Command to switch off wire: M5
Add comments, prefixed by '(' and suffixed by ')'

Important Files:

/etc/default/grub	Sets up Linux boot for better RT performance
~/.config/autostart/hotwire1.desktop	Starts Linuxcnc after login
~/linuxcnc/configs/hotwire1/hotwire1.ini	Parameters for Linuxcnc
~/linuxcnc/configs/hotwire1/hotwire1.hal	Configuration for Linuxcnc
~/linuxcnc/configs/hotwire1/hotwire1_axis.py	Modifications to the AXIS gui for hotwire1
~/linuxcnc/configs/hotwire1/wing.py	Winggcode wing design script
~/linuxcnc/configs/hotwire1/wing.ini	Parameters for *wing.py*
~/linuxcnc/configs/hotwire1/coord	Airfoil profiles for *wing.py*
kicad project hotwire1a	Electronic design files for HOTWIRE1A board
kicad project system1 (top level wiring diagram)	Wiring diagram
~/Documents/hotwire1_*.stl and .step	3D-printed and machined parts
~/Documents/ccm_rails_w50-25.pdf	Belt actuator datasheet
~/Documents/7i92tman.pdf	Mesa digital interface manual

Links:
https://github.com/swarfer/winggcode
https://linuxcnc.org
https://www.diyrcwings.com

Parts:
CCM 50mm belt actuators
Panasonic GX-H8A-P home sensors
AliExpress wire guides W0505-3010-3009 https://www.aliexpress.us/item/3256802570520464.html
Intel NUC nuc5i5ryb
Mesa 7i92TF
AutomationDirect EM542S stepper drives