WHY GO-TO?

• Refiguring and Rebuilding my old 17.5” f/4.5 Telescope (Max II)
• My “Mental Map” of the Heavens is starting to show signs of degradation 😊
• Moore’s Law of computing power
• Discovered the OnStep program and community while building the DSC
• It’s kinda cool...

WHAT I’LL BE COVERING

• The Electronics
• The Software
• The Mount Conversions
• The Telescope Construction
OnStep

- [https://onstep.groups.io/g/main/](https://onstep.groups.io/g/main/)
- Started by [Howard Dutton](https://onstep.groups.io/g/main/) in 2017
- Supports a variety of mounts including Equatorial (GEM, Fork, etc.) and Alt/Azi (Dobsonian, etc.)
- Extensive [Wiki](https://onstep.groups.io/g/main/) that supports a wide variety of Hardware and Software Configurations
- Very active [Message Forum](https://onstep.groups.io/g/main/) with help from many experts (eg. Khalid Baheyeldin, Dave Schwartz)
- Large [Showcase](https://onstep.groups.io/g/main/) of people who have built or converted their telescopes to OnStep
- Low priced kits: [Harold Cushing](https://onstep.groups.io/g/main/) and others
OnStep - Hardware Modules

- Microcomputers – Teensy3.2, 3.5, 4.0, Arduino Mega2560, ESP32, STM32F446...
- Stepper Motor Drivers - Pulolu A4988, LV8729, TMC2130, TMC5160
- WiFi – WeMos D1 Mini
- Ethernet – W5500ToMax2
- BlueTooth – HC-06
- Real Time Clock – Teensy, DS3231
- GPS – Neo-7m
- Weather – BME280
OnStep - Hardware Assemblies: Simple

Schematic

Proto-Board

Solderless Breadboard
Onstep - Hardware Assemblies: Custom PCBs

MiniPCB2 ($40 + 2 Motor Drivers)  MaxPCB  MaxESP3 ($45 + 4 Motor Drivers)
Onstep - Hardware Assemblies:

3D Printer Controllers

Wemos R32 + CNC V3 ($5 + $7 + 4 Motor Drivers)

FYSETC S6 ($40 + 6 Drivers)

MKS Gen_L & RAMPS ($30 + 5 Motor Drivers)

- Focusers & Field Rotators
- Fans & Dew Heaters
- Limit Switches
- Expansion Interfaces (GPS, Weather, etc)
Onstep - MiniPCB2

- Ordered Kit from **George Cushing** ($40)
- Includes everything except the Motor Drivers
- SilentStepStick TMC2130 Drivers ($13 each)
- Easy Pin-Through-Hole solder assembly
Onstep - Smart Hand Controller (SHC)

- **Teensy 4.0** Microcontroller ($19.95) – Aug 2019
  - 32-bit ARM Cortex-M7 running at **600 MHz**
  - 2048KB Flash, 1024KB RAM, 64KB EEPROM
  - Hardware IEEE Floating Point
  - 40 Digital I/O (3.3 Volt only)
  - 14 Analog Pins, 2 ADCs
  - Real Time Clock
  - USB, SPI, Serial, I2C, CAN, I2S Communication
  - Arduino compatible IDE (C, C++)

- Compared to **Teensy 3.2**
  - **14X** Performance
  - **4X** Flash
  - **16X** RAM
  - **32X** EEPROM
  - **$0.15** more expensive 😊

- Plugs into the **ST4 Connector**

- **Catalogs**
  - 408 Bright Stars
  - 5079 Struve Double Stars
  - 4478 Variable Stars
  - 109 Messier Objects
  - 109 Caldwell Objects
  - 400 Hershel Catalog
  - 471 Collinder (open clusters)
  - 8154 NGC Objects
  - 5400 IC Objects
  - Sun, Moon and Planets
Onstep - Smart Hand Controller (SHC)
Onstep - Smart Hand Controller (SHC)
Onstep - Dumb Hand Controller (DHC)
OnStep - Software (by Howard Dutton)

- Open Source C/C++
- Arduino Programming Tools
- Highly Configurable
- Under Continuous Development
OnStep - Software Capabilities

- Controls up to 5 Stepper Motors (GoTo, Guide, Track)
  - RA (Azi), DEC (Alt), Field Rotator, Focuser 1 & 2
- ST4 Interface for autoguiding and hand controllers
- Status Indicators
  - Tracking LED, Reticle LED, Buzzer
- Time and Location Sources
  - Teensy, DS3231, GPS, Smart Phone
- Weather and Temperature Sensors
  - BME280, DS1820
- Switch Sensors
  - Home Position, Limit Switches, PEC, PPS
- Tracking
  - Refraction, Backlash, Sidereal/Solar/Lunar Rate
- Initialization
  - Up to 9-Star Alignment
  - Sync to Current Object
- Meridian Flip for GEMs
- WiFi, Bluetooth, Ethernet
  - Web Server (http://192.168.0.1/)
- Android/iOS Apps – Hand Controls
- LX200+ Protocol to Planetarium Programs
OnStep - Planetarium Programs

- Stellarium (Windows, Mac OS X, Linux, iOS, Android)
- Cartes du Ciel (Windows, Mac OS X, Linux, RPi ARM)
- KStars (Linux, Windows, Android)

Sky Planetarium – Windows (by Howard Dutton)
Onstep - Telescope Mount Conversions

**Equatorial & Fork**
- SkyWatcher EQ3, EQ5, NEQ5, EQ6
- Celestron CG4, CG5, CGE, CGE Pro, CGEM
- *Vixen Super Polaris*, Great Polaris, SXD
- Orion AstroView, SkyView Pro
- Meade LXD 75, LXD 600, LXD 650
- Bresser EXOS1
- Losmandy GM8, G11
- Celestron Ci700, CG11
- iOptron iEQ30, EQ45, SmartStar PR EQ
- Takahashi NJP
- Astro-Physics AP400, AP1200
- Meade LX200, LX3

**Dobsonian & AltAzi**
- Orion XT10, XT10 Plus, XT12, StarFinder
- SkyWatcher Stargate 500
- Celestron NexStar
- Vixen Porta II
- Custom DIY Mounts (like mine)
The 17.5” f/4.5 Telescope Construction: Max III

- Sky Optical Mirror (1980’s)
  - Currently being Re-Figure...!
- Rough design in LibreCAD ->
- Uses Bearings instead of Teflon/Formica
- 3 Truss Tube Pairs
- Lightweight Focuser/Diagonal Cage
- Stepper Motors (Stepper Online)
  - 200 Full Step NEMA-17 Motors
  - 50:1 Precision Planetary Reduction Gear
  - Running at 32 Microsteps per Full Step
- GT2 Timing Gears/Pulleys and Belts (McMaster-Carr)
  - Azimuth
    - 40 Tooth Gear on Motor
    - 848 Tooth Belt on Axis Ring
    - 18844 Steps per Degree
  - Altitude
    - 40 Tooth Gear on Motor
    - 686 Tooth Belt on Axis Ring
    - 15222 Steps per Degree

\[ 200 \times 50 \times 32 \times \frac{848}{40} / 360 = 18844 \]
The 17.5” f/4.5 Scope: Ground Triad & Azimuth Gear

848 Teeth (Yes, I counted them!)

Timing Belt attached to ring with Scrapbooking Tape
The 17.5” f/4.5 Scope: Rocker Box & Stepper Motors

- Azimuth Bearings
- Altitude Bearings
- Azimuth Stepper
- Altitude Stepper
- Azimuth Axis
The 17.5” f/4.5 Scope: **Motors & 40-Tooth Gears**

**Azimuth Motor Gear**

**Altitude Motor Gear**
The 17.5” f/4.5 Scope: Mirror Box & Altitude Rings

- 18 Point Flotation Cell
- Ball & Socket mounts for Truss Tubes
- Plan to add Fans to equalize mirror temp
The 17.5” f/4.5 Scope: **Trusses**