Flying Rockets with Free Hardware and Free Software

Bdale Garbee
Keith Packard

Altus Metrum

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Metrum

Overview

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Free Software in Rocketry Hobby

- Design of airframes
  - Openrocket overall, OpenSCAD / FreeCAD for parts
- Design of motors
  - Rocketcea, OpenMotor
- Computer assistance in making things
  - CNC machining, 3d printing
- Avionics & Post-flight data
  - This is what Altus Metrum is all about!

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Design Tools: Building Rockets

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Building Rockets

- OpenRocket
  - Rocket design and analysis in Java
  - Master's thesis project from Sampo Niskanen
  - Last stable release in March 2015, a new release is overdue, but “coming soon”
  - Bdale maintains installer package in Debian
- Openscad / FreeCAD for mechanical parts
  - Existing Debian packages work great!

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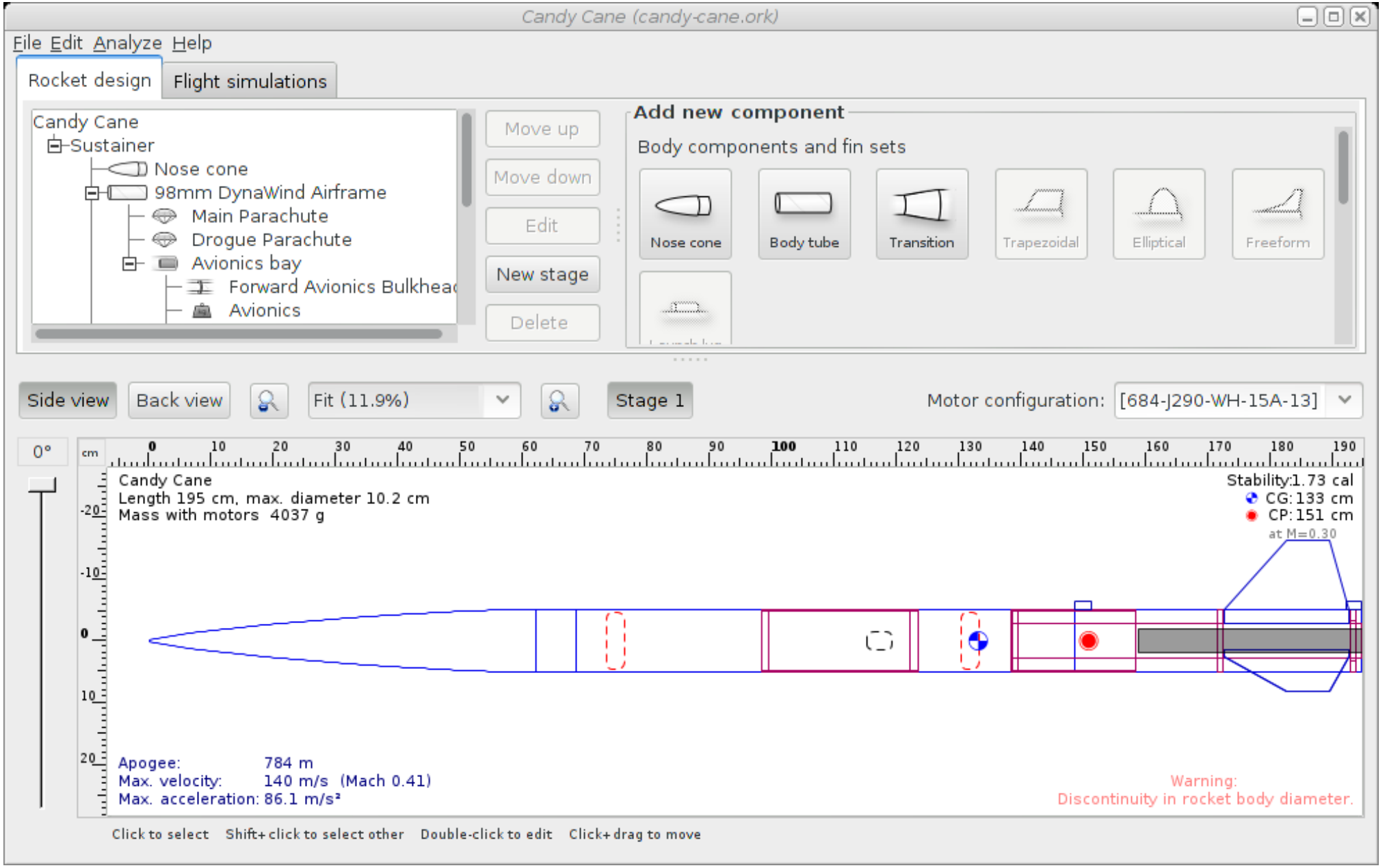
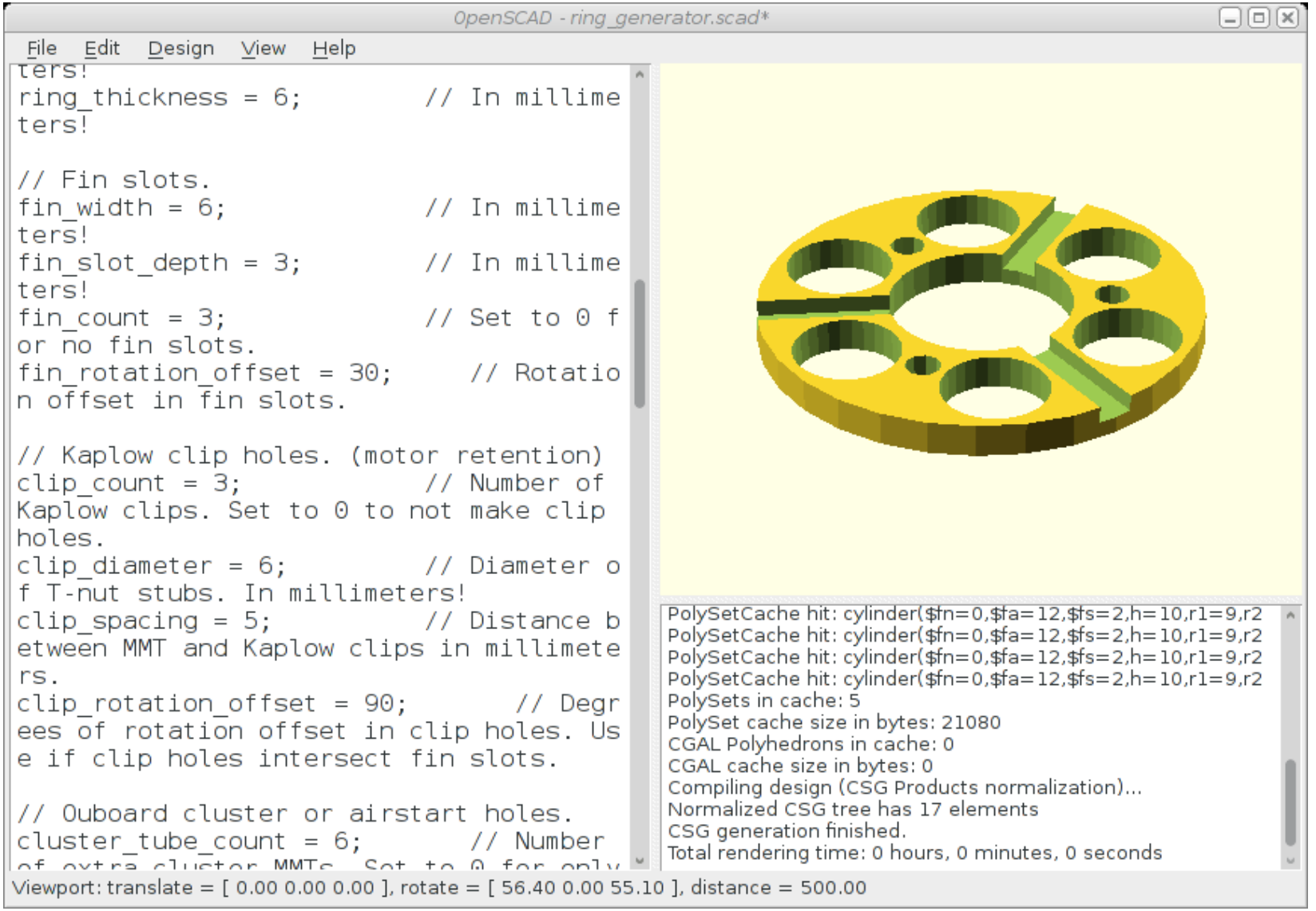
OpenRocket


Candy Cane (candy-cane.ork)
File Edit Analyze Help
Rocket design
Flight simulations
Candy Cane
Sustainer
Nose cone
98mm DynaWind Airframe
Main Parachute
Drogue Parachute
Avionics bay
Forward Avionics Bulkhead
Avionics
Move up
Move down
Edit
New stage
Delete
Add new component
Body components and fin sets
Nose cone
Body tube
Transition
Trapezoidal
Elliptical
Freeform
Side view
Back view
Fit (11.9%)
Stage 1
Motor configuration:
[684-J290-WH-15A-13]
0°
cm
Candy Cane
Length 195 cm, max. diameter 10.2 cm
Mass with motors 4037 g
Stability:1.73 cal
CG:133 cm
CP:151 cm
at M=0.30
Apogee: 784 m
Max. velocity: 140 m/s (Mach 0.41)
Max. acceleration: 86.1 m/s²
Warning:
Discontinuity in rocket body diameter.
Click to select
Shift+click to select other
Double-click to edit
Click+drag to move

openscad



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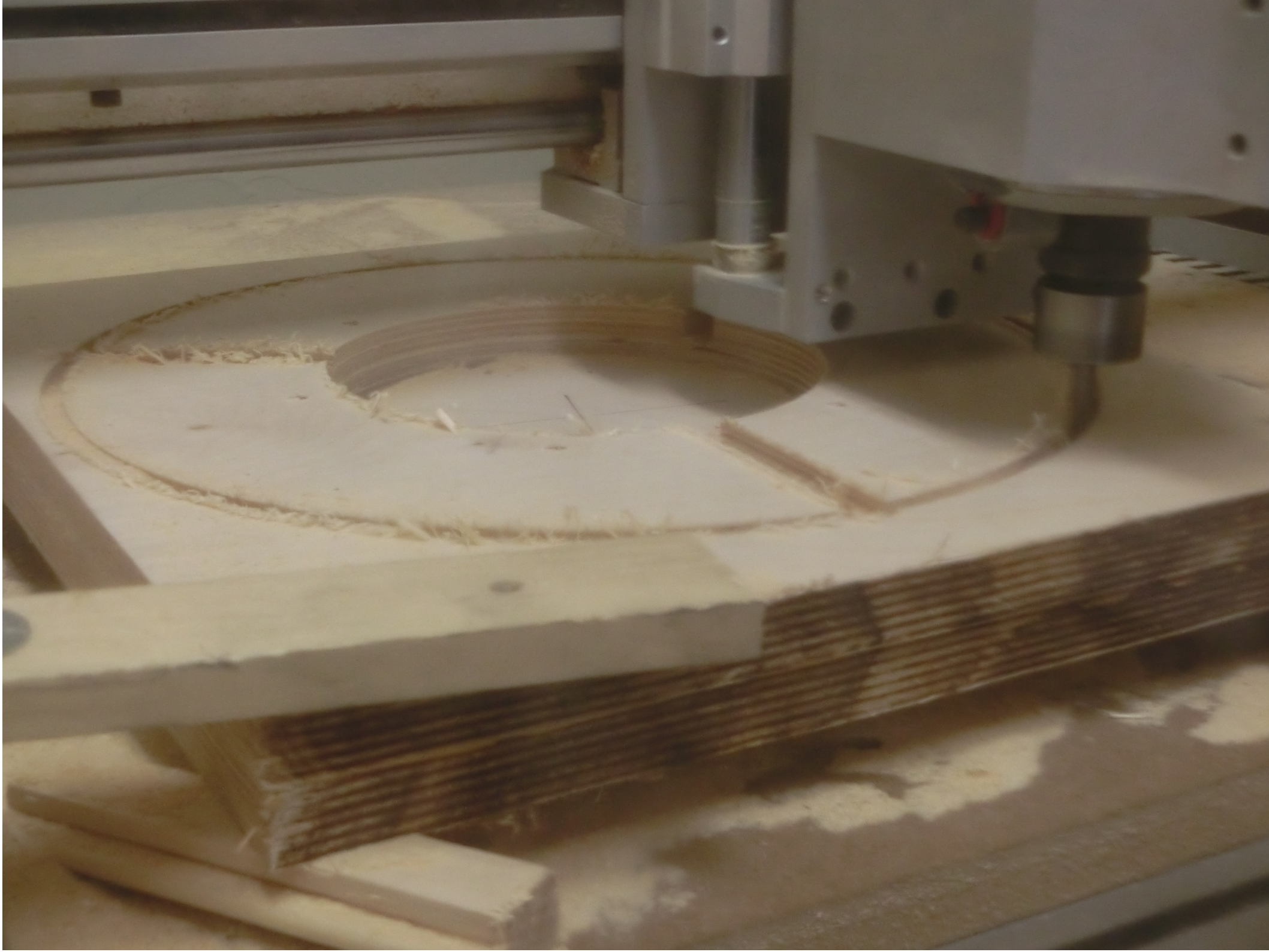
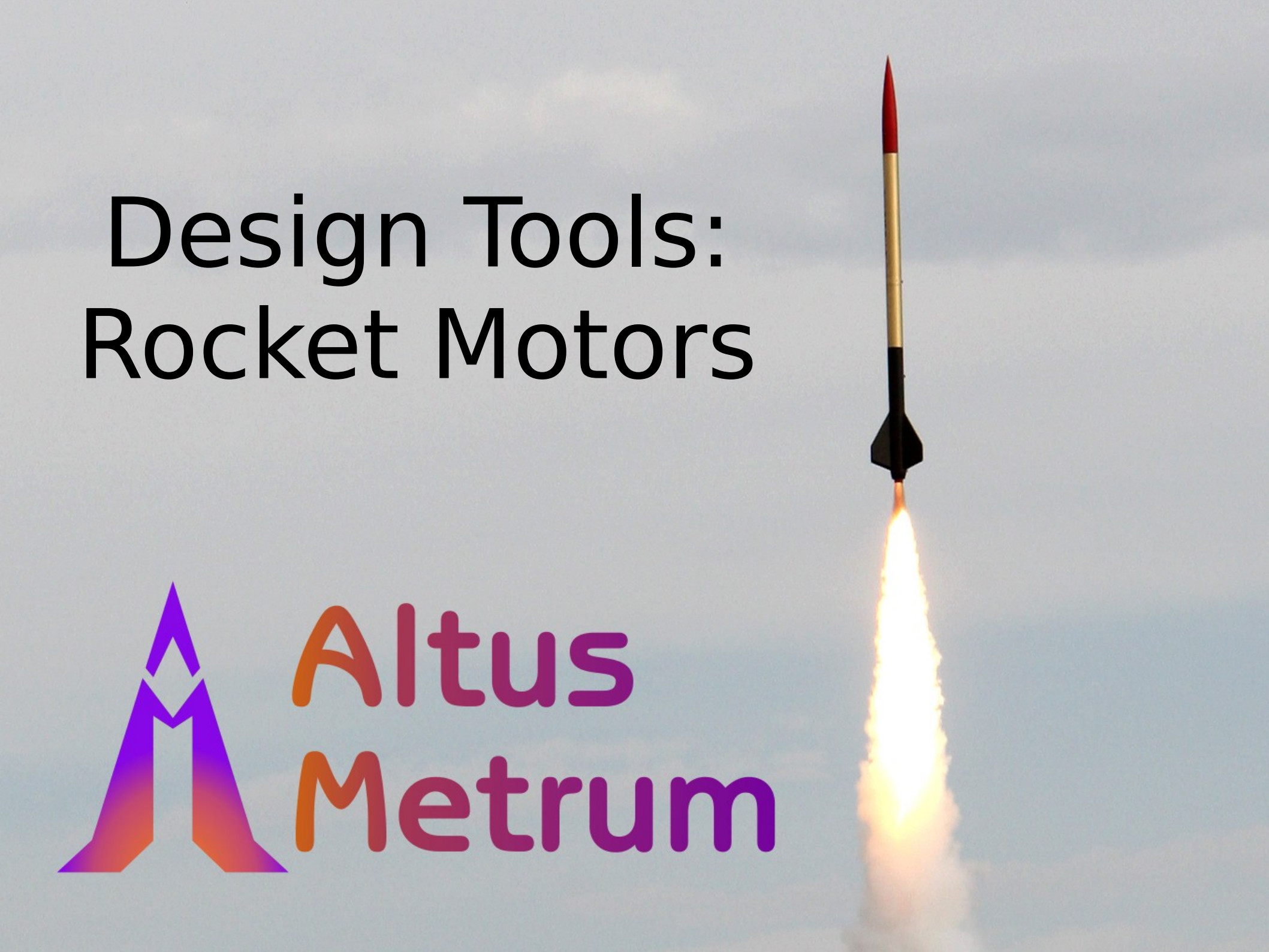


Design Tools: Rocket Motors



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Motor / Propellant Research

- Most flights in the rocketry hobby are made with commercial motor “reload kits”.
- Experimenting with the chemistry and mechanical construction of motors is almost a separate hobby.
- A key to success is the ability to simulate combustion of propellant in a motor casing
- Most experimenters use a well-known application that runs under Windows, but Free Software alternatives exist...

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Free Tools for Motor Design

- RocketCEA
  - NASA’s Chemical Equilibrium, wrapped in Python
  - Used to calculate values needed for burn simulator
- OpenMotor
  - Propellant combustion simulator
  - Can output a motor performance file for OpenRocket
  - Piles of Python under GPLv3
  - Not packaged in Debian (yet!)

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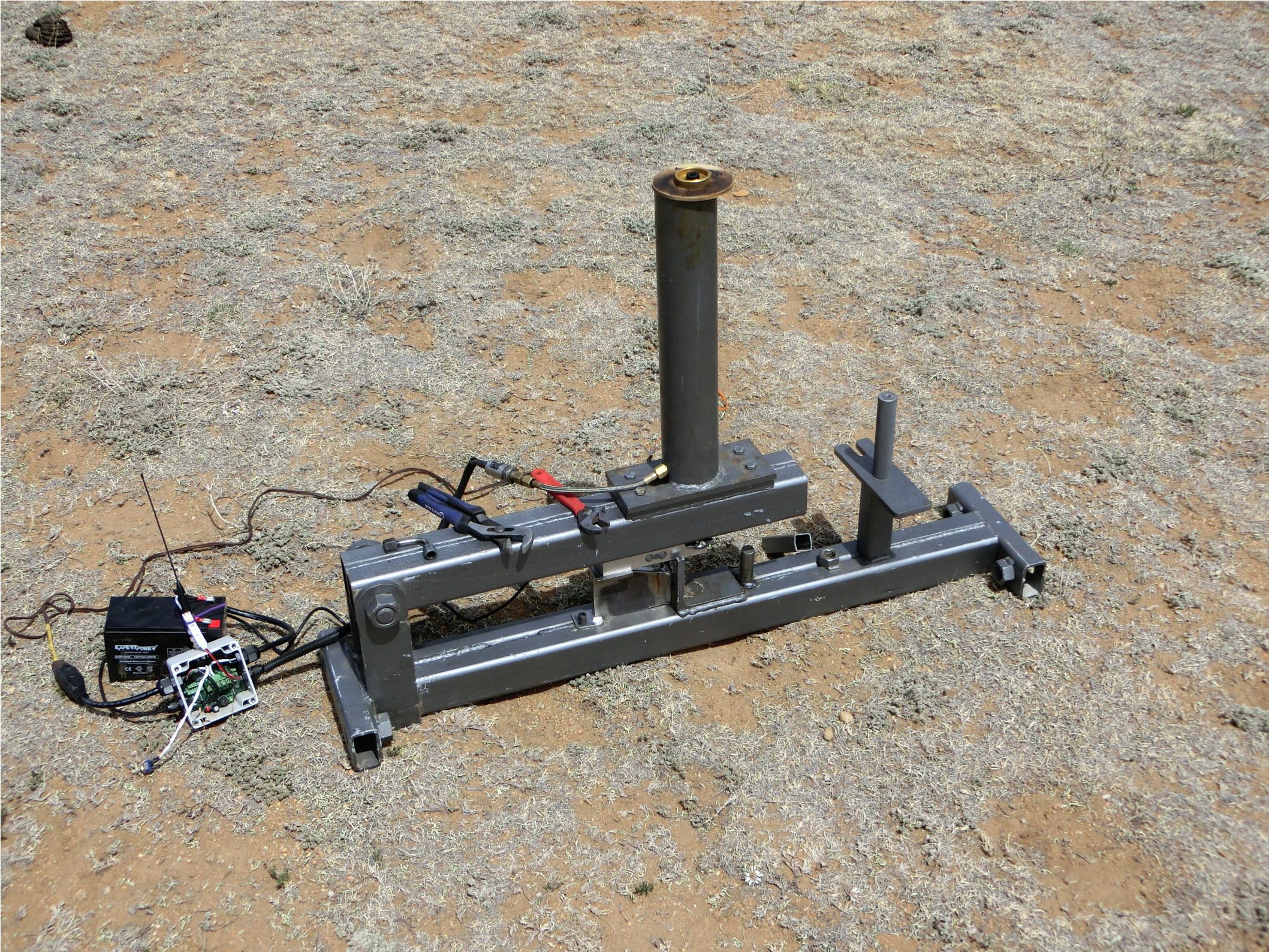
AWS
AC-100
Sharpie


EXPERTPOWER

Avionics

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Role of Avionics

- Control of recovery system
  - Initiating parachute deployment events
  - Initial event at apogee, larger chutes near ground
- Collection of flight data
  - Max altitude – how high did it go?
  - Max acceleration, velocity – did we break Mach?
  - Acceleration and altitude profiles for more thorough analysis of vehicle and motor performance
- Radio link to ground
  - Position and health info, locating rocket after flight

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Altus Metrum Product Line

- Altimeters for model rocket competition, etc
- Flight computers for high power rockets
  - Control of pyrotechnical recovery events
  - RF telemetry downlink during flight including GPS
  - Sensor data logged for later analysis
  - Staging and ignition of additional motors in flight
- Ground stations for USB and Bluetooth
- Laptop and Android applications for flight monitoring and post-flight data analysis, third-party application for iOS users
- Wireless launch control system
- Static test stand and in-flight motor characterization (soon)

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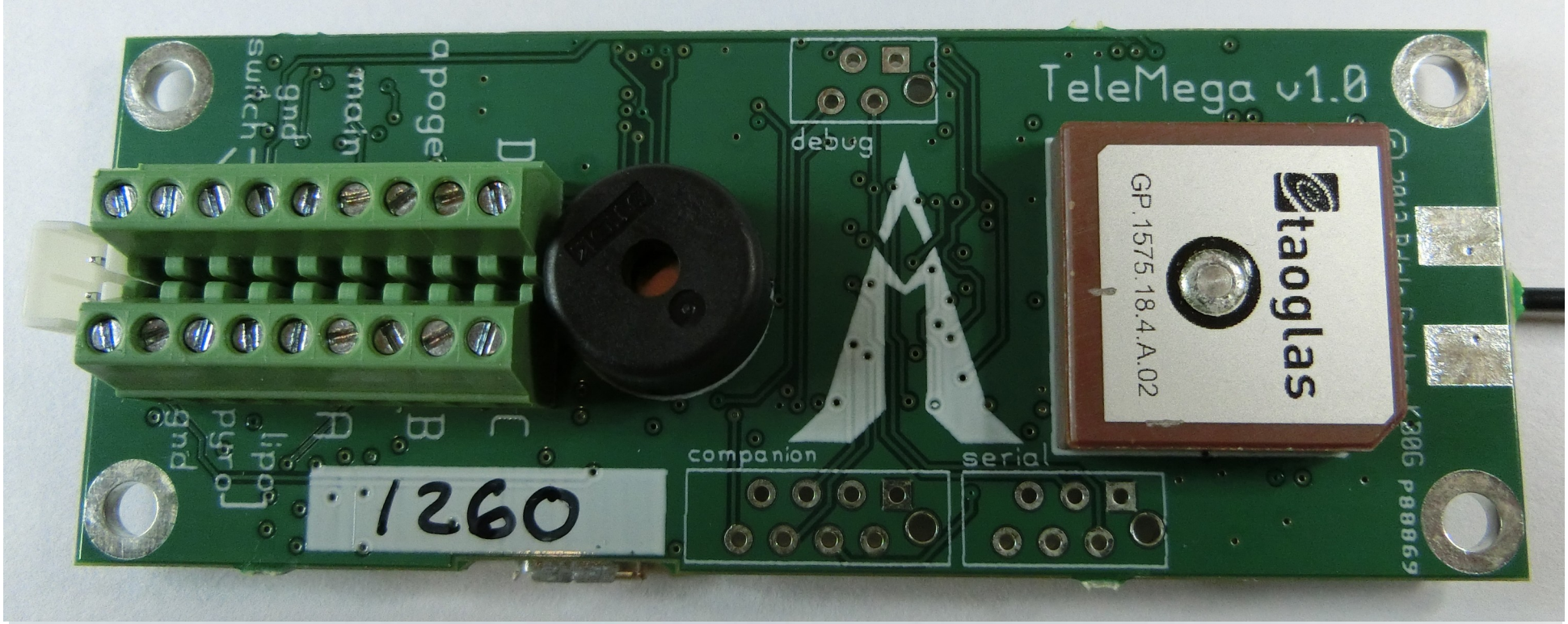
TeleMega v1.0
debug
companion
serial
taoglas
GP.1575.18.4.A.02
1260

STM32L151
VCT6 A
HPAGC VG
KOR HP 312
ARM
blox

Design Tools: Electronics

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Building Electronics

- Lepton-EDA for schematic capture
  - Netlist and component footprint data for pcb
  - Bill of materials for assembly
- pcb-rnd for circuit board design
  - Data for fabrication of bare circuit boards
  - Position and rotation information for SMT assembly
  - Can export 3D models for use by customers
- Bdale helps maintain these packages in the Debian electronics-team

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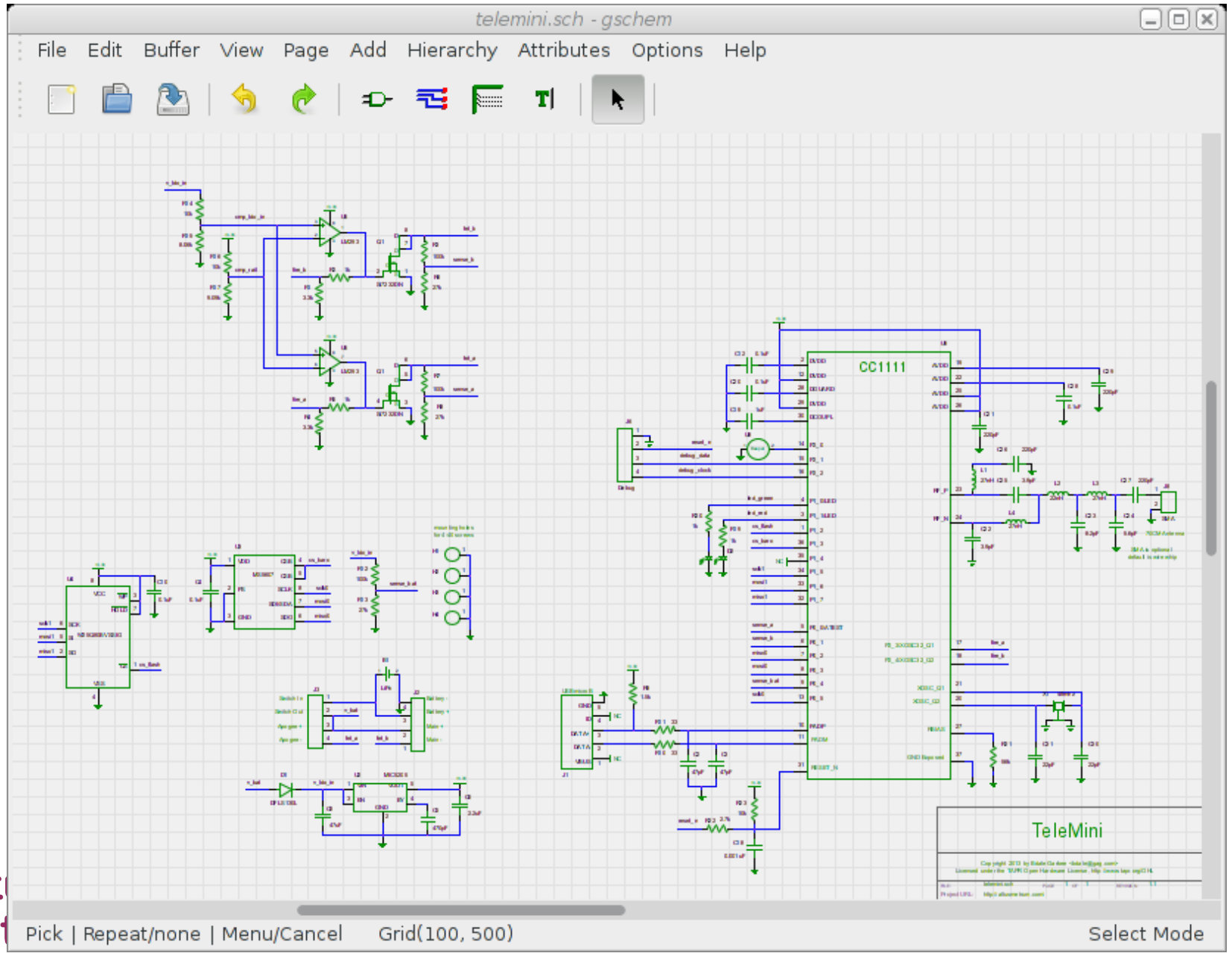
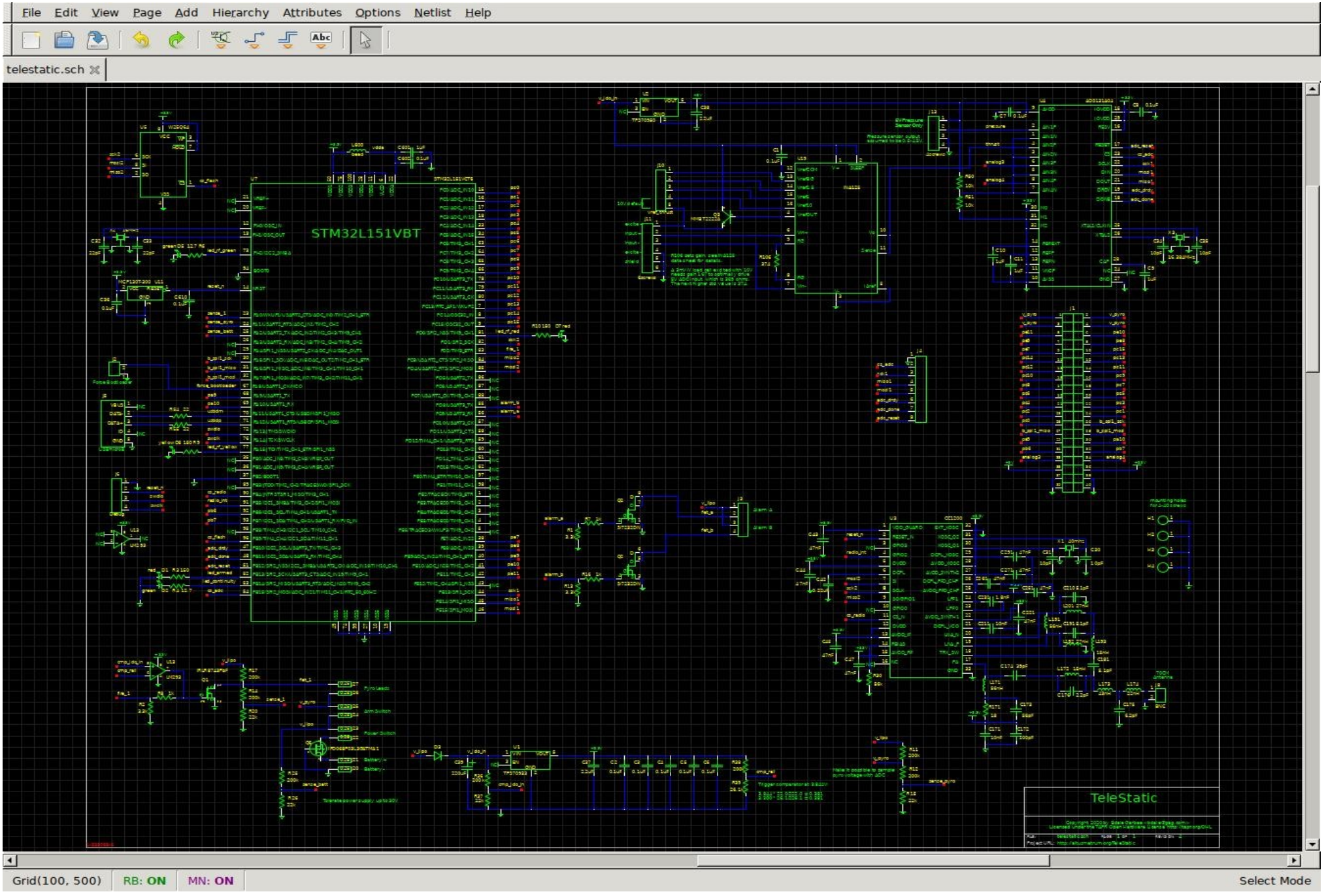
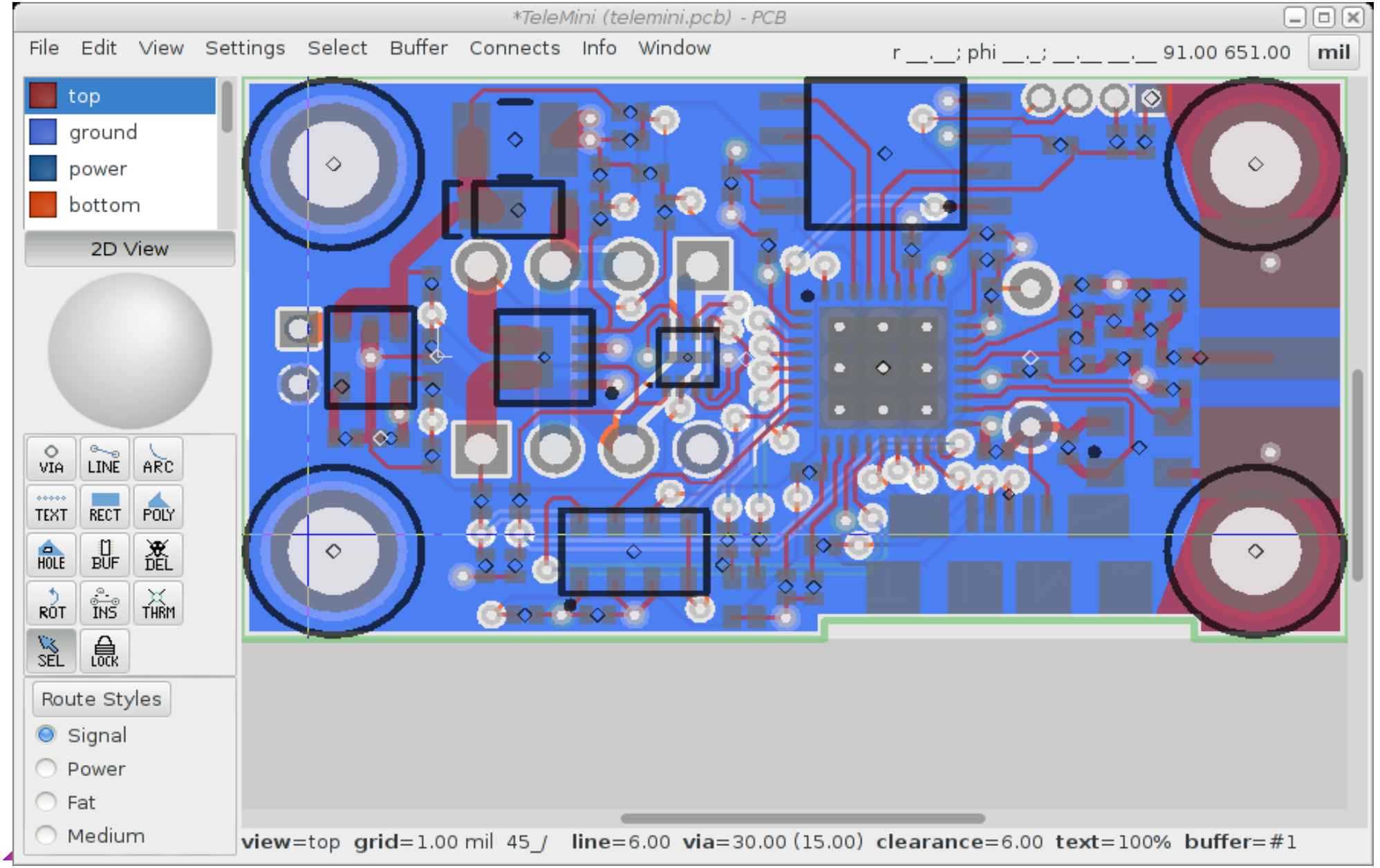
gschem


telemini.sch - gschem
File Edit Buffer View Page Add Hierarchy Attributes Options Help
CC1111
TeleMini
Pick | Repeat/none | Menu/Cancel
Grid(100, 500)
Select Mode

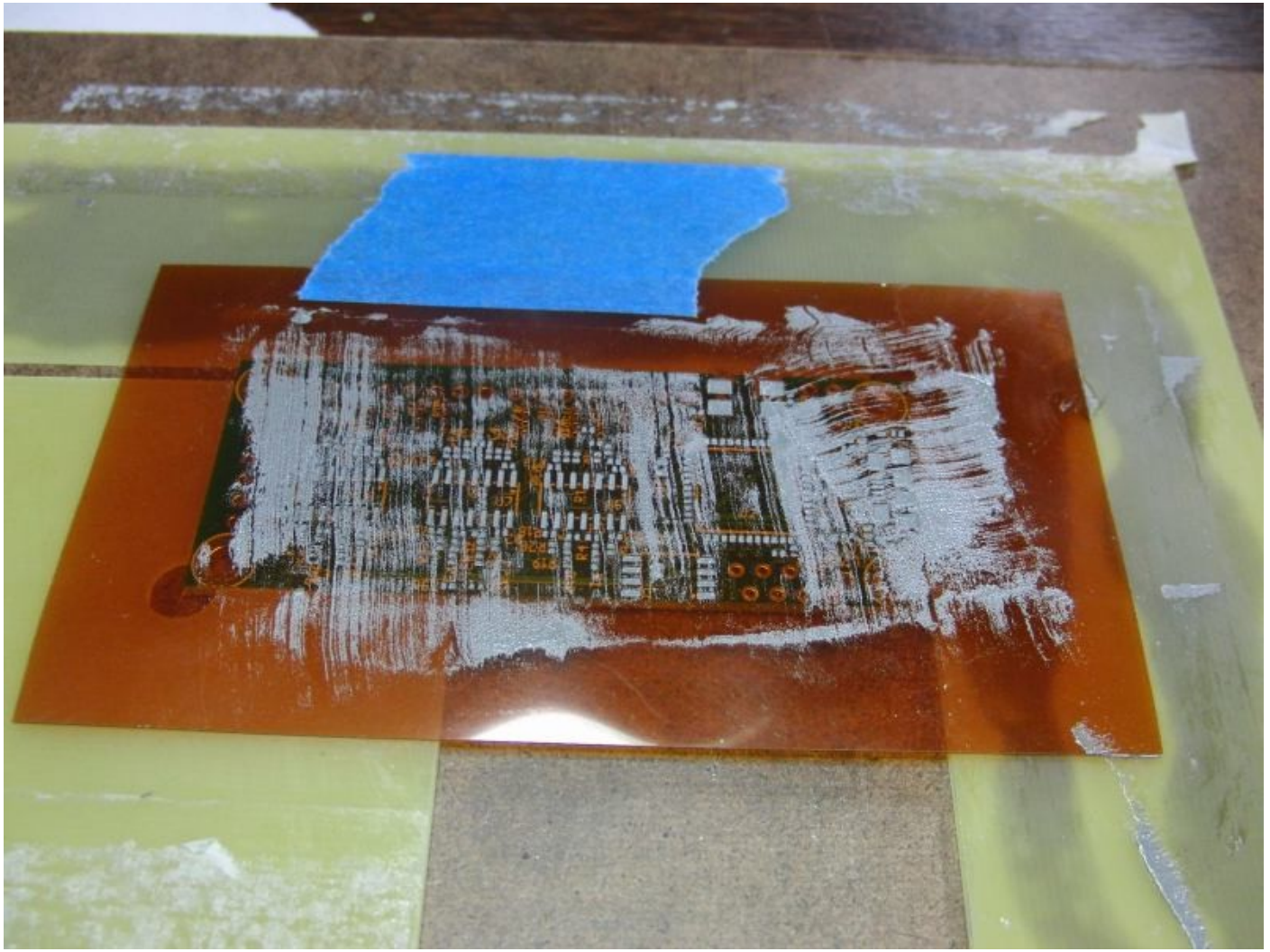
lepton-schematic



pcb


*TeleMini (telemini.pcb) - PCB
File Edit View Settings Select Buffer Connects Info Window
r __.__; phi __._; __.__ __.__ 91.00 651.00
mil
top
ground
power
bottom
2D View
VIA LINE ARC
TEXT RECT POLY
HOLE BUF DEL
ROT INS THRM
SEL LOCK
Route Styles
Signal
Power
Fat
Medium
view=top grid=1.00 mil 45_/ line=6.00 via=30.00 (15.00) clearance=6.00 text=100% buffer=#1

Paste Stencil



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ACE
Denatured Alcohol
XILINX STUDENT EDITION
H2

Design Tools: Software

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AltOS Flight Software Architecture

- Written in C
- Source-level debugging available on target
- Cooperative multitasker
- Flight progress tracked through discrete states
- Connect to host via USB or over radio link
  - Standard USB serial port emulation
  - No kernel driver required
  - Command line interface
- Configuration stored in EEPROM/Flash

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Building Embedded Software

- gcc for arm-none-eabi
  - GCC for embedded ARM not running Linux
  - Keith built initial package for Debian
- picolibc
  - Libc optimized by Keith for this class of device
- Openocd / dfu-util
  - Existing Debian packages work great!

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Software for the OS-disadvantaged

- Alas, some people aren't running Debian **yet**!
- gcc-mingw and nsis for Windows
  - Compile and package C code for Windows on Debian
- genisoimage for Mac OS X
  - Package Java code for Mac OS X on Debian
- Android development tools
  - Develop, compile and package Android packages
- Debian has all the tools to do this!

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Running a Small Business

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Nearly Everything is Free Software

- All design & business data stored in git repos
- Magento for self-hosted web store-front
- Finances handled with plain text accounting
  - Python & beanbag pull data from Magento REST API
  - Ledger-cli for analysis and report generation
- ShipStation (SaaS offering) subscription to handle interface with shipping providers
  - Bulk shipping discounts justify the expense
  - Makes packing and shipping orders fairly easy

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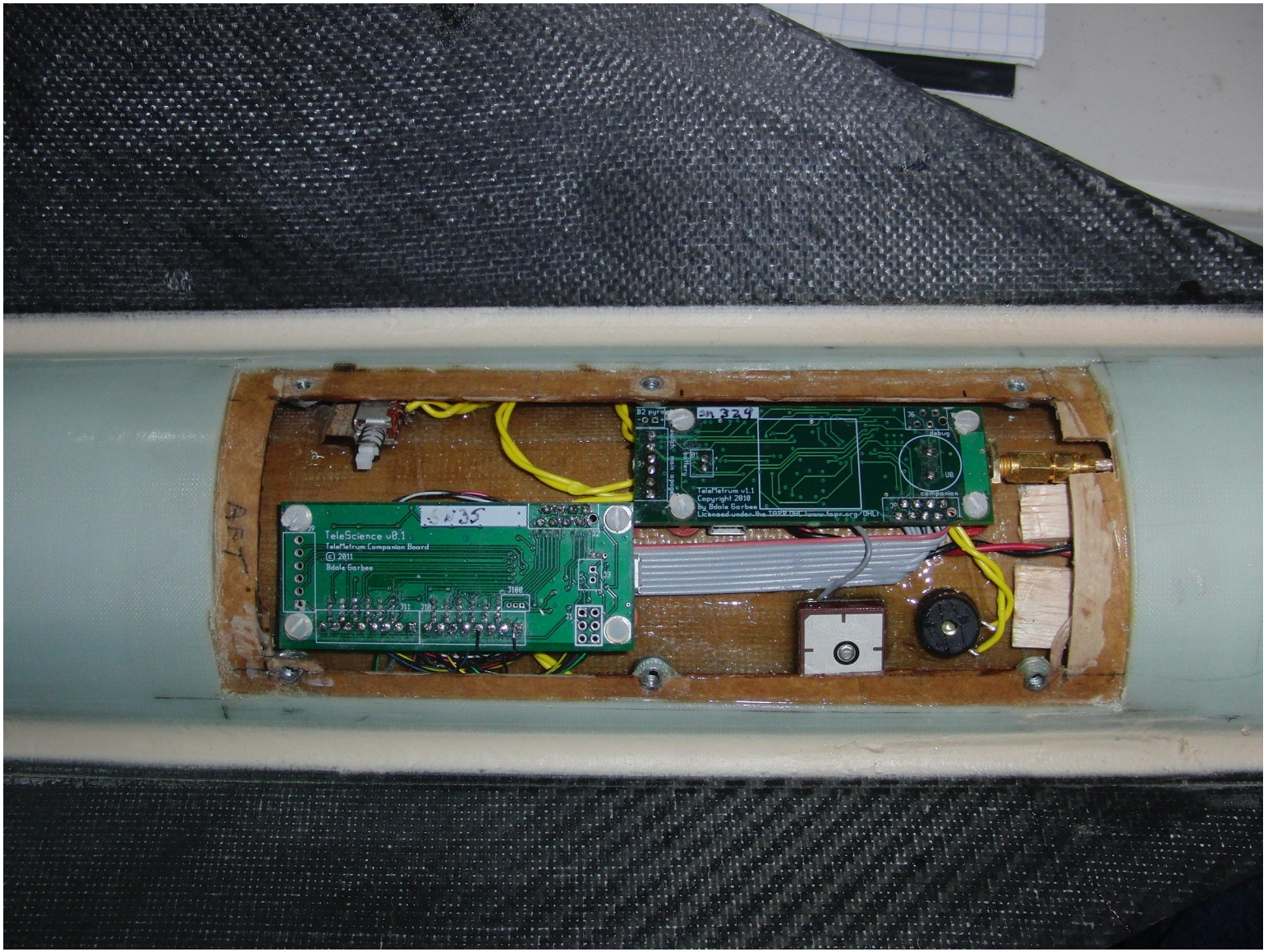
Just for Fun

As a matter
of fact, I am a
rocket scien

Rocket Science!



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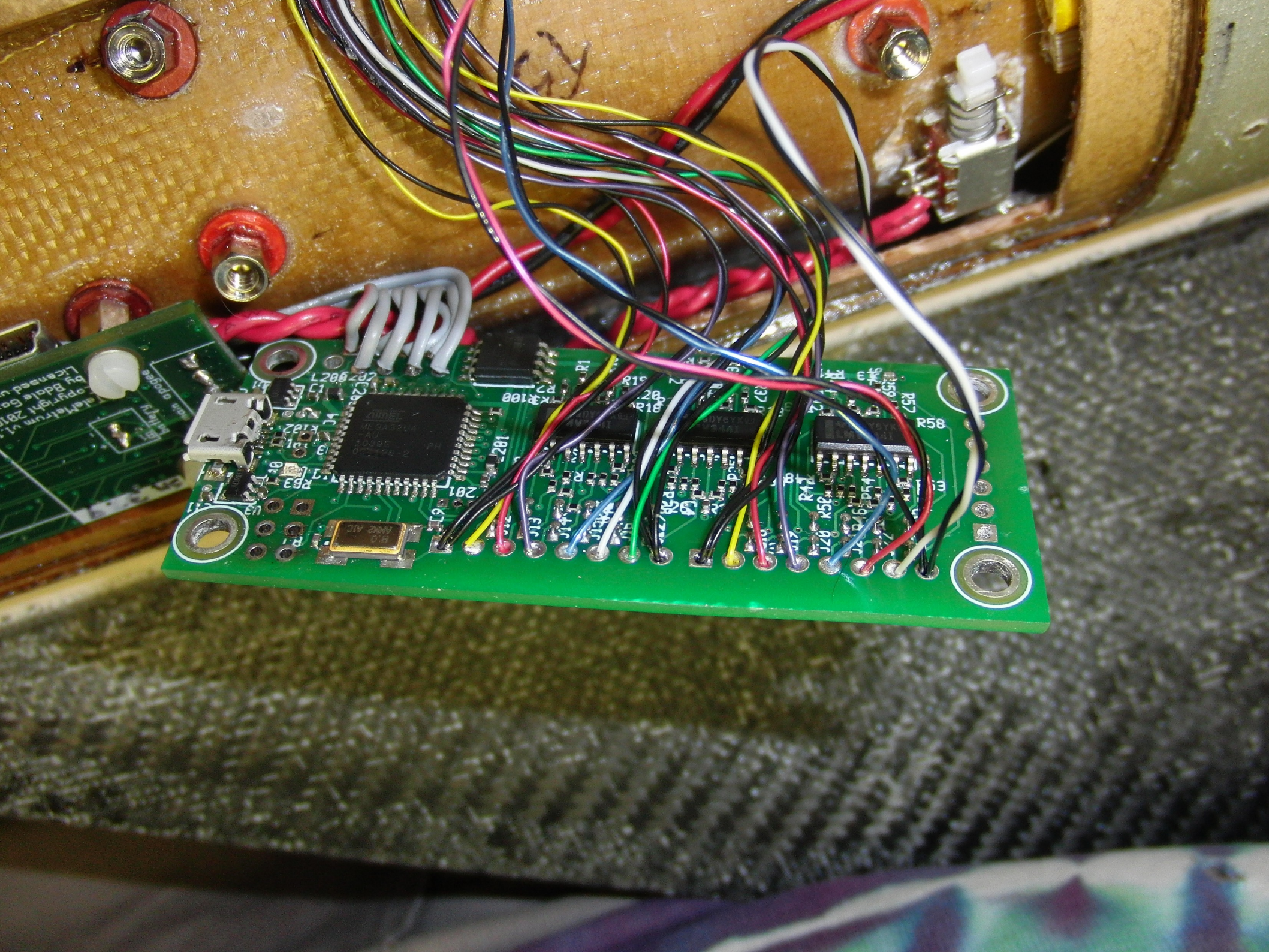

AIRFEST
XVIII
ARGONIA, KANSAS
63
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Learning More

- Hardware Design and Software
  - All details can be found at altusmetrum.org
  - Other information at gag.com/rockets
- Licenses
  - The hardware designs carry the TAPR Open Hardware License (OHL), which was created to be “GPL-like” for hardware designs, see tapr.org/ohl
  - Our software and firmware are all licensed GPL v2+
  - Documentation (including rocket designs!) CCbySA
- Questions?

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