To the 60’s and Back

A modern take on the Apollo Guidance Computer (AGC)

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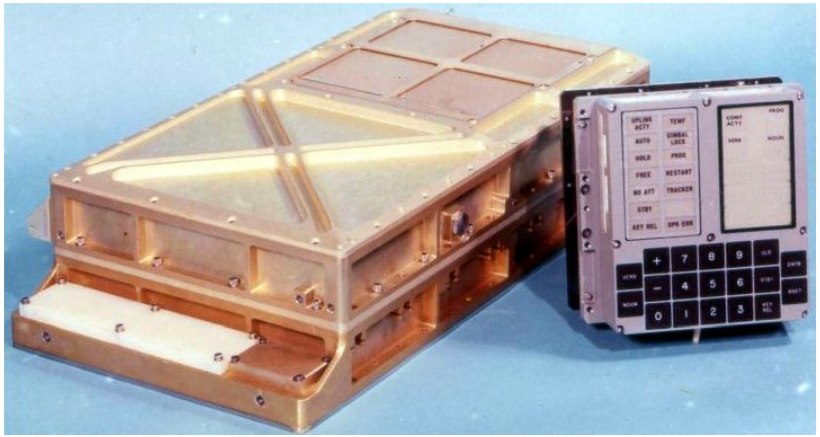
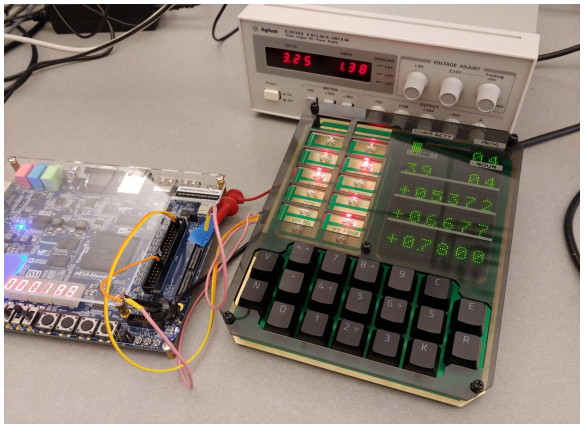
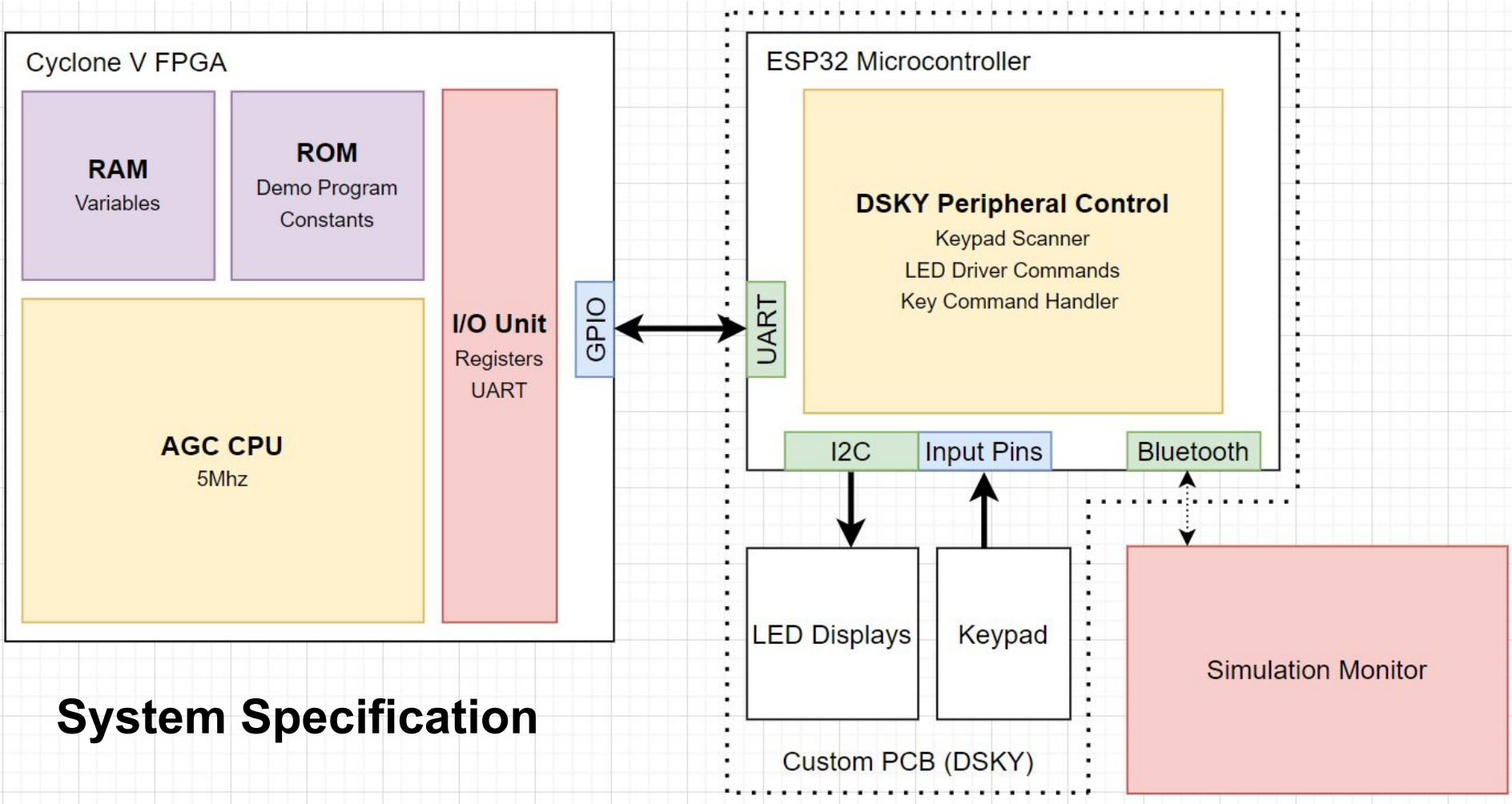
Use-Case and Quantitative Use-Case Requirements

Exhibition piece targeting science/history museum displays, classrooms

AGC Architecture	50Mhz, 33 instructions, 15 I/O Channels
Peripheral uC	Keypress scans, LED updates, Bluetooth TX at 100 Hz
DSKY PCB	12 LED Lamps, 25 Displays, 19 Key switches
Dimensions	Compact size of 7.5in by 6in by 1in
Operating Conditions	Ambient temperature of 25°C. Protective Casing.

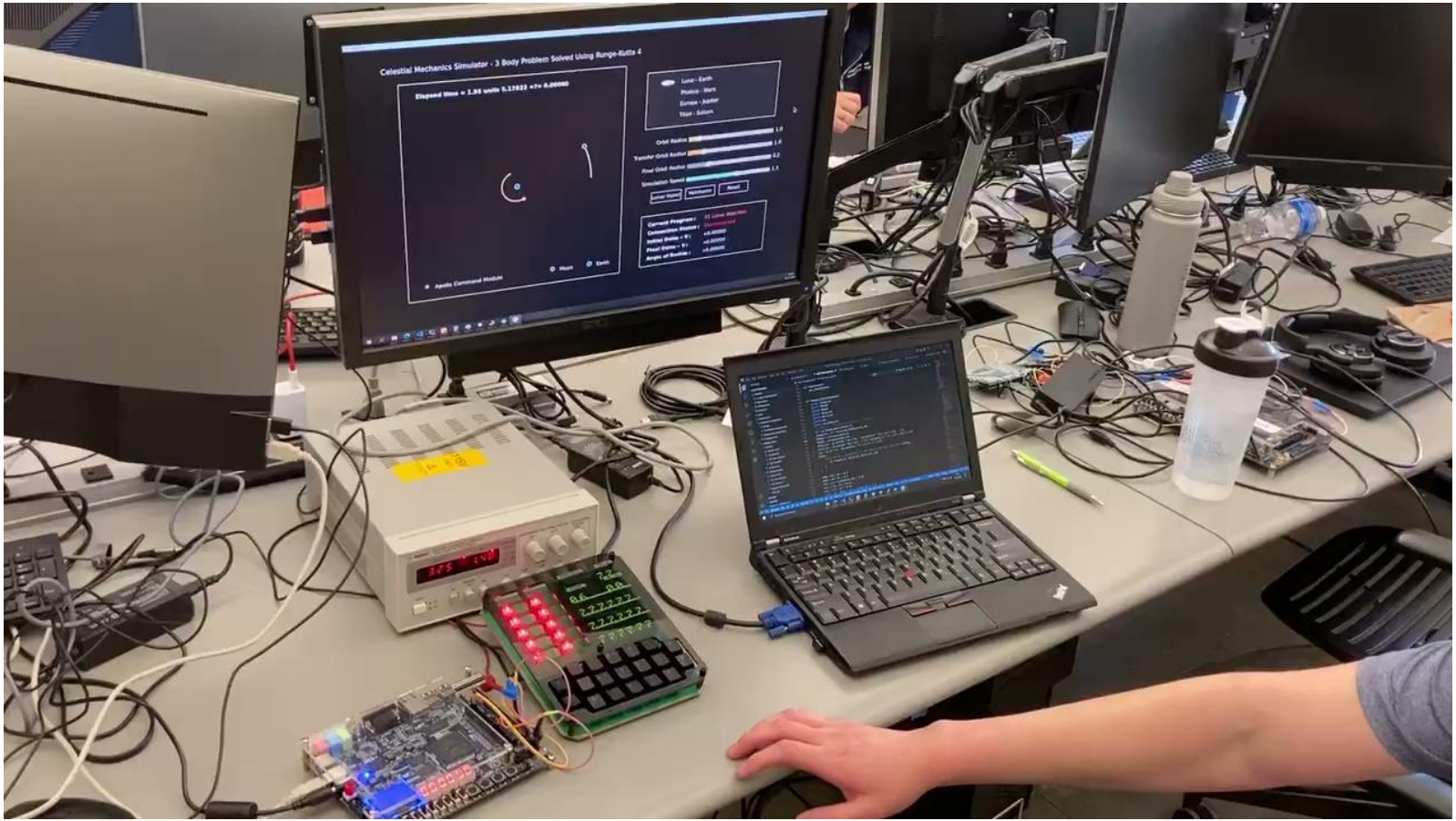






System Specification

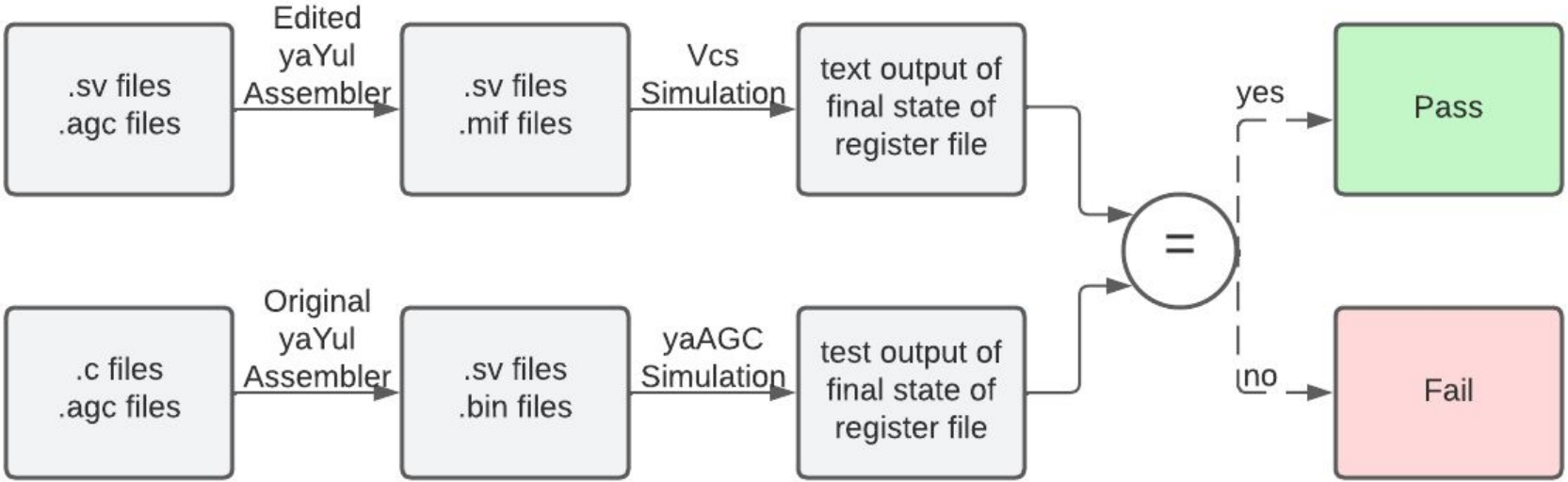
Complete Solution



RTL Correctness Verification

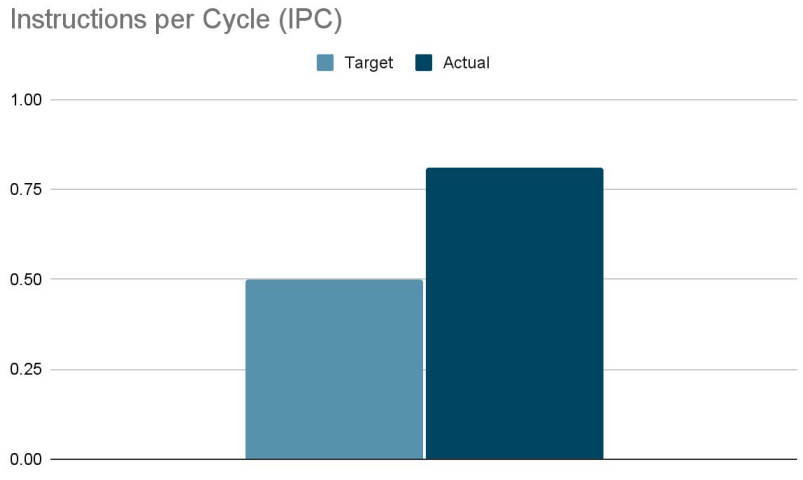
The AGC Architecture

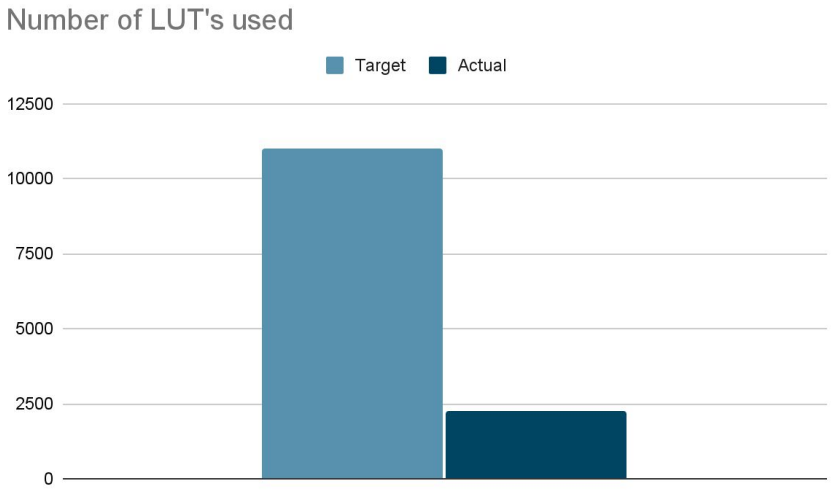
- The registers state of our ISA matched a simulated AGC for **30** instruction specific tests
- Using the same agc file in both prongs we used the below process to test for correctness

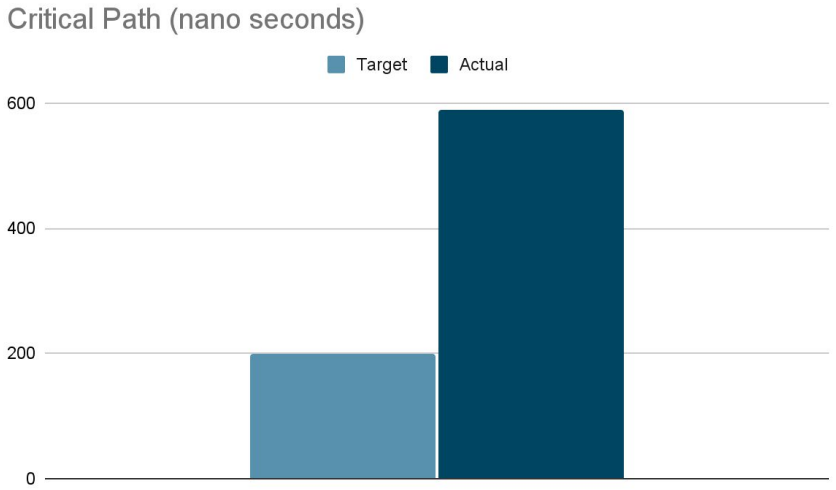


RTL Benchmark Verification

- 2271 < 110,000 lookup tables (LUT's)
- 590 > 200 nanoseconds
  - Did **not** meet constraint. Critical path was through the Altera generated RAM.
- .8095 >.5 Instructions per Cycle (IPC)





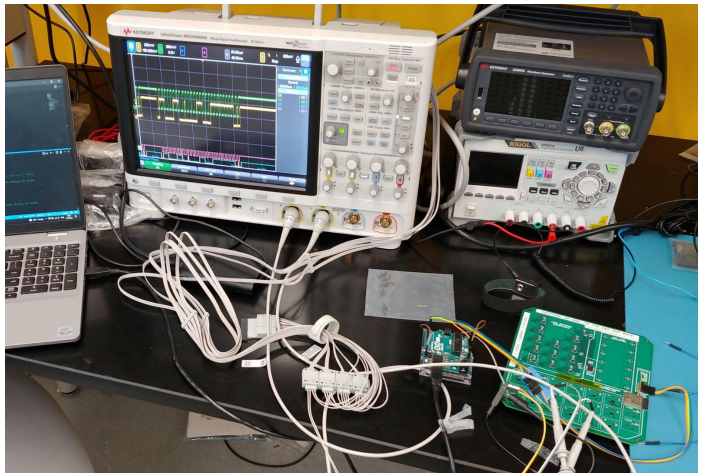


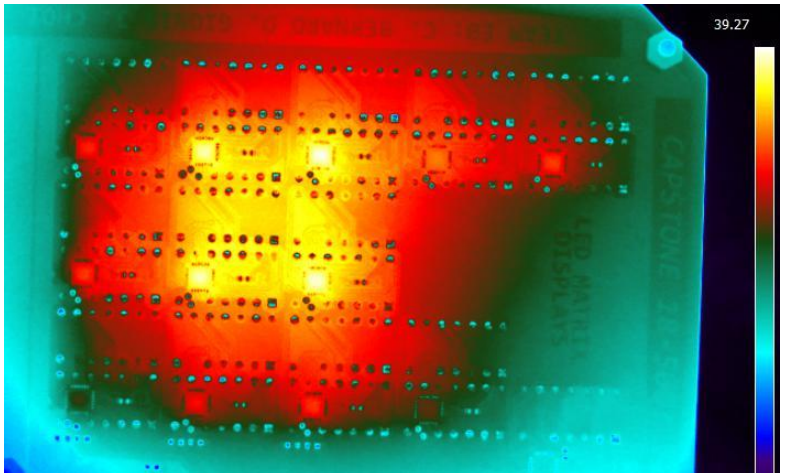
DSKY Verification

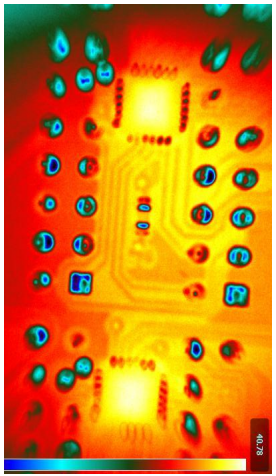
Max Temperature of around 40.8 degrees Celsius

I2C Bus Congestion: 31.8% Congestion (68.2% Idle) for 400kHz

UART Bus Congestion: 42.4% Congestion (56.6% Idle) for 115200 Baud







Software/Final Verification

Delta-V Calculation accuracy: Accurate to ± 0.001 m/s for normalized values

VERB	NOUN	Description
05	N/A	View mission time (05)
06	N/A	Test the displays (06) *- Default on Reset*
07	N/A	Clear the displays
39	PROG	Run Program Number # PROG (NOUN)

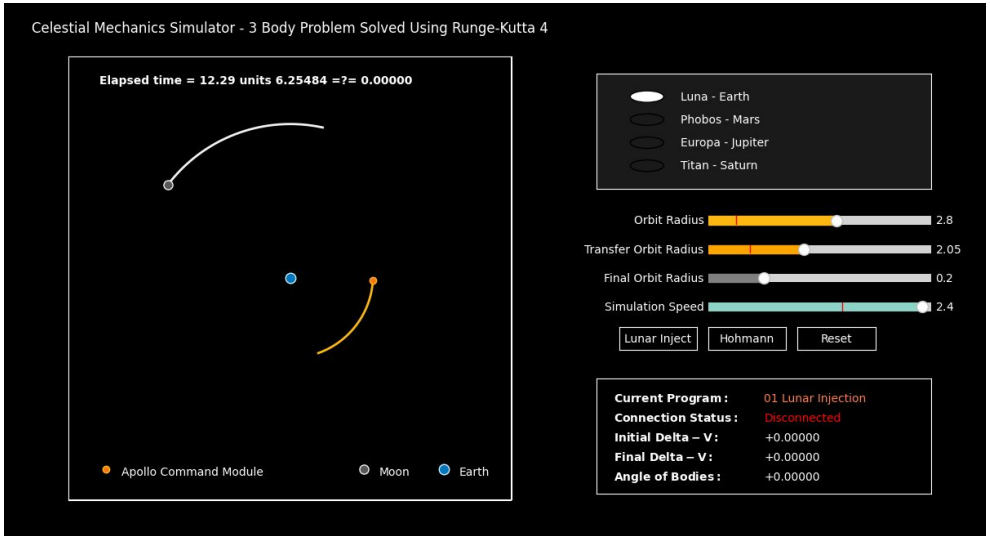
VERB	NOUN	Description
39	00	Escape Velocity Calculation (00)
39	01	Hohmann/Orbital Transfer Calculation (01)
39	02	Translunar Injection Initial Change in Velocity Calculation (02)
39	03	Translunar Injection Final Change in Velocity Calculation (03)
39	04	Translunar Injection Angle Calculation (04)
39	05	Orbital Plane Change Calculation

Software/Final Verification

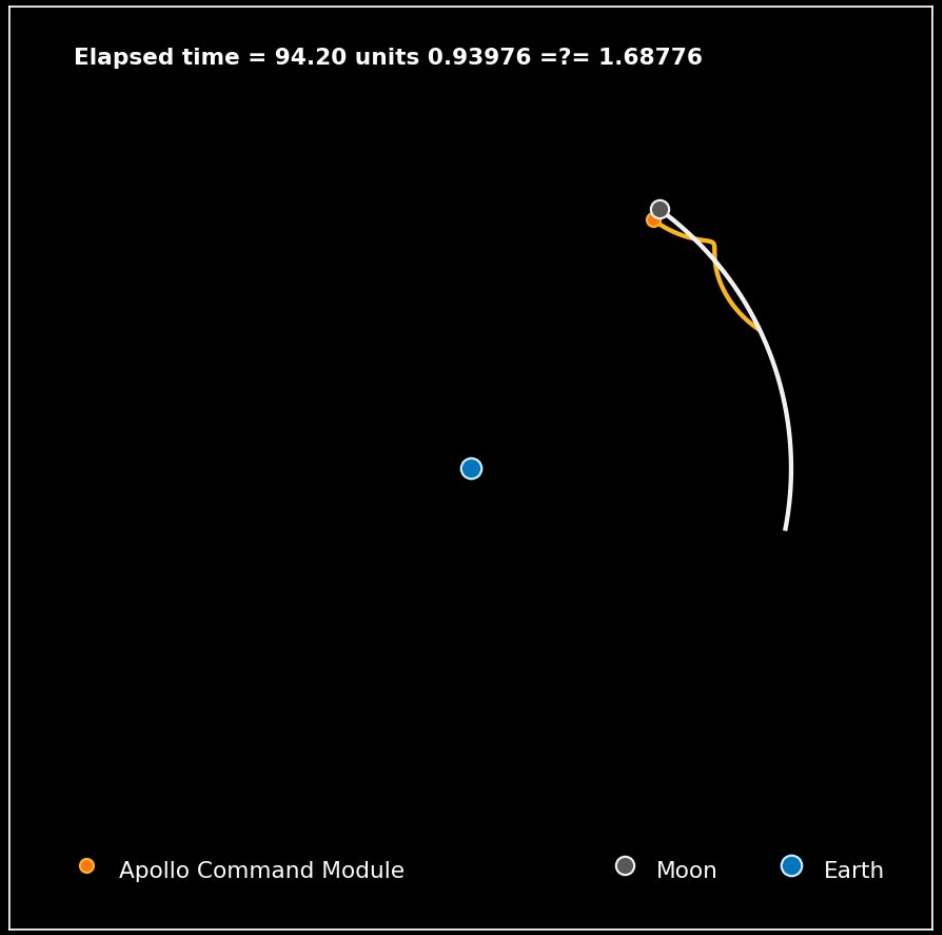
Delta-V Calculation accuracy: Accurate to ± 0.001 m/s for normalized values

** Using 15-bit single precision fixed point numbers*

Calculation results in correct Orbital transfers and Translunar injections in the 3-body simulation (Runge-Kutta 4th order ODE solver) for step-size (dt) of 0.01



Celestial Mechanics Simulator - 3 Body Problem Solved Using Runge-Kutta 4



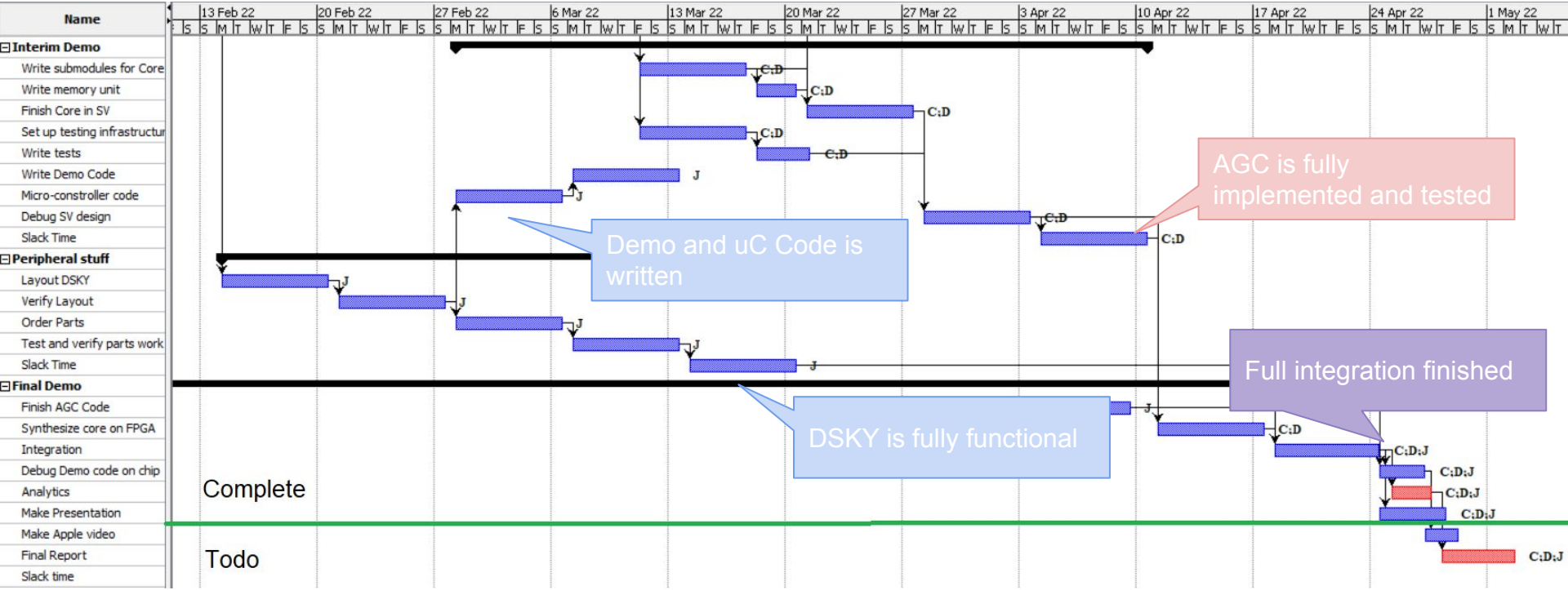
Luna - Earth
Phobos - Mars
Europa - Jupiter
Titan - Saturn

Orbit Radius 1.0
Transfer Orbit Radius 1.0
Final Orbit Radius 0.2
Simulation Speed 2.4

Lunar Inject | Hohmann | Reset

Current Program : 01 Lunar Injection
Connection Status : Connected
Initial Delta – V : +0.00000
Final Delta – V : +0.00000
Angle of Bodies : +0.00000

Project Management



Conclusion

Educational opportunities

- **Demonstrate historic applications on modern equipment**
  - Contrast with original AGC: **How far** we've come
- **Interactivity appeals to young audience**
  - Excitement about history and innovation
- **Working examples of post-AGC innovation**
  - UART, FPGA, PCB, HDL