To the 60’s and Back

A modern take on the Apollo Guidance Computer (AGC)

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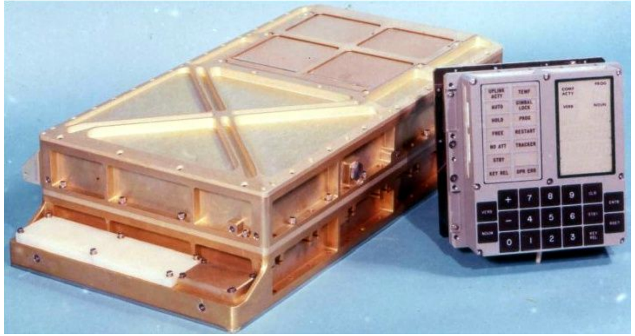
Use-Case/Applications

- Exhibition piece targeting museum displays, science exhibitions, classrooms
- Showcase Apollo Computer capabilities with an interactive DSKY
- Support space-related programs for demonstration
- Easily distributable for exhibitions, classrooms

Quantitative Use-Case Requirements

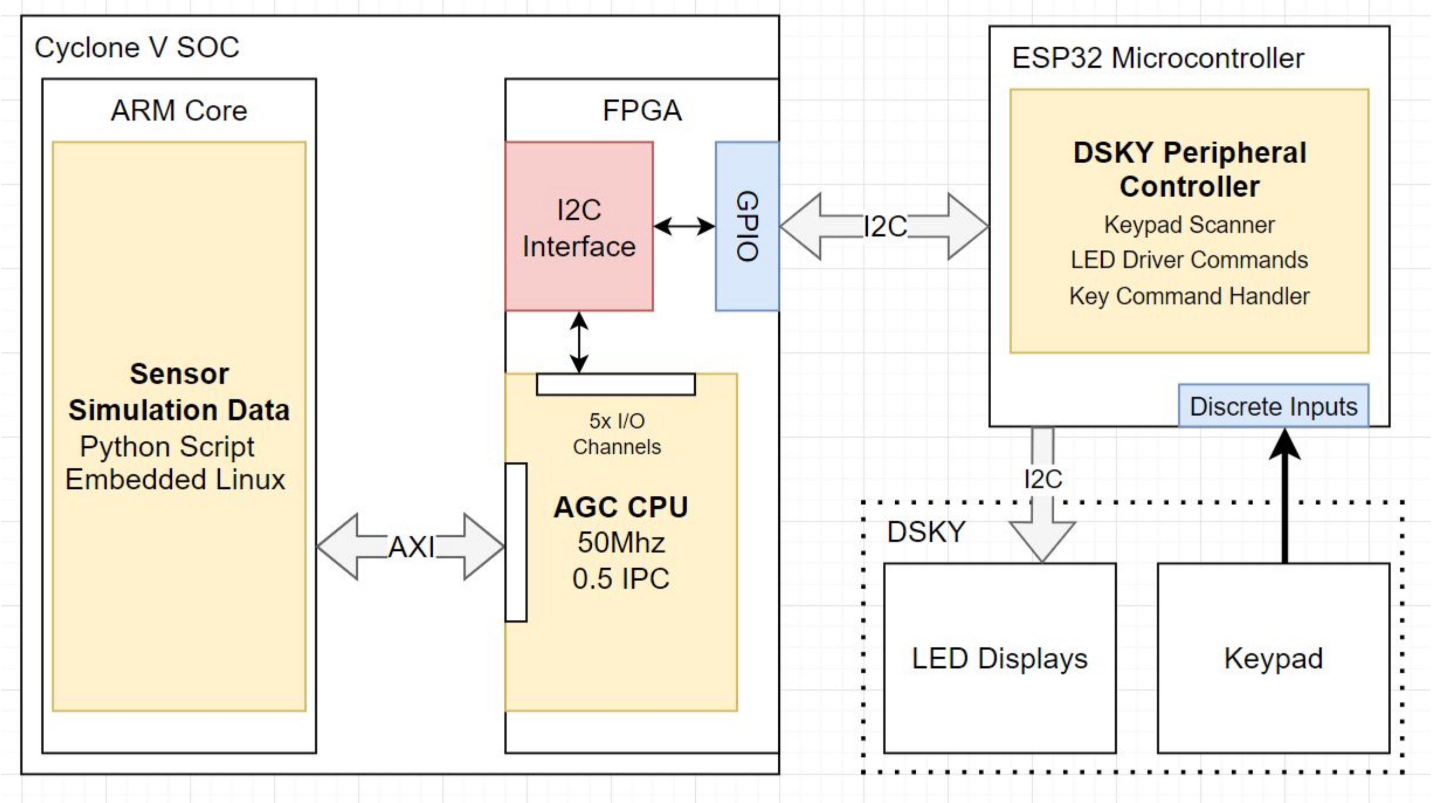
The AGC Architecture	50Mhz, 33 instructions, 5 I/O Channels
The Peripheral uC	Controller handles Key scans + LED updates at 50Hz
The DSKY PCB	14 LED Lamps, 25 Displays, 19 Key switches
Physical Dimensions	Compact weight/size of 1 by 2 foot and 5 pounds
Operating Conditions	Ambient temperature of 25°C. Protective Casing.



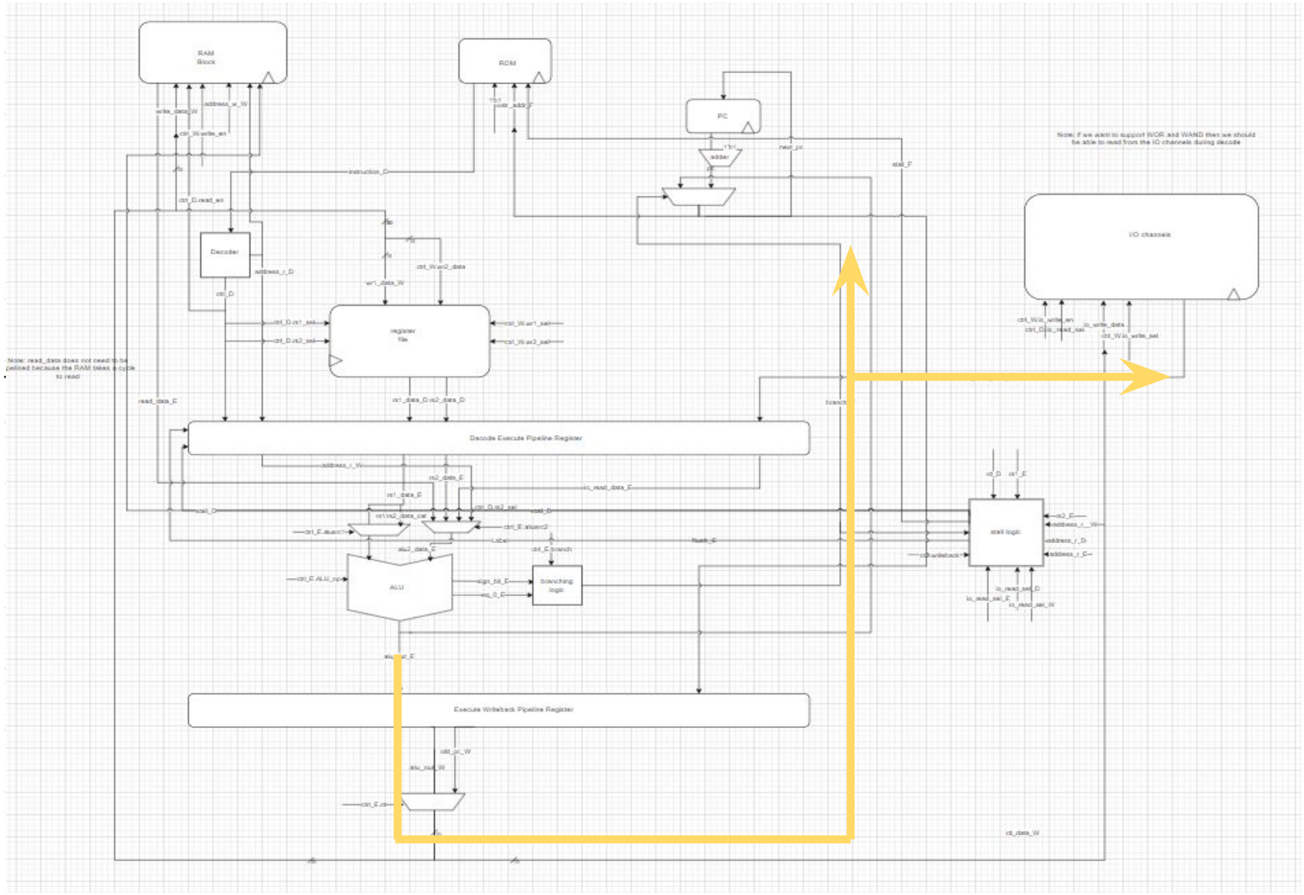
Solution Approach

- **Altera DE10-Standard Dev Board w/ Cyclone V SoC**
  - Readily available, efficient distribution
- **AGC CPU uArch Implementation**
  - Defined using SystemVerilog
  - Programmed via place-and-route to FPGA
- **Simulated sensor data fed to CPU input ports**
  - Python Script running on Linux OS on Cyclone V Core
- **User interface inspired by the original DSKY**
  - LED/Segment displays, Keypad on a custom PCB
  - Microcontroller as interface between FPGA and DSKY
- **I2C driver on FPGA**
  - To communicate between microcontroller and AGC core
- **Interactive, mission-oriented assembly programs**
  - A kernel that constantly polls the I/O and responds to commands from the DSKY
  - A python-script demo showcasing basic orbital mechanics and space missions.

System Specification



Implementation Plan: AGC CPU Pipeline



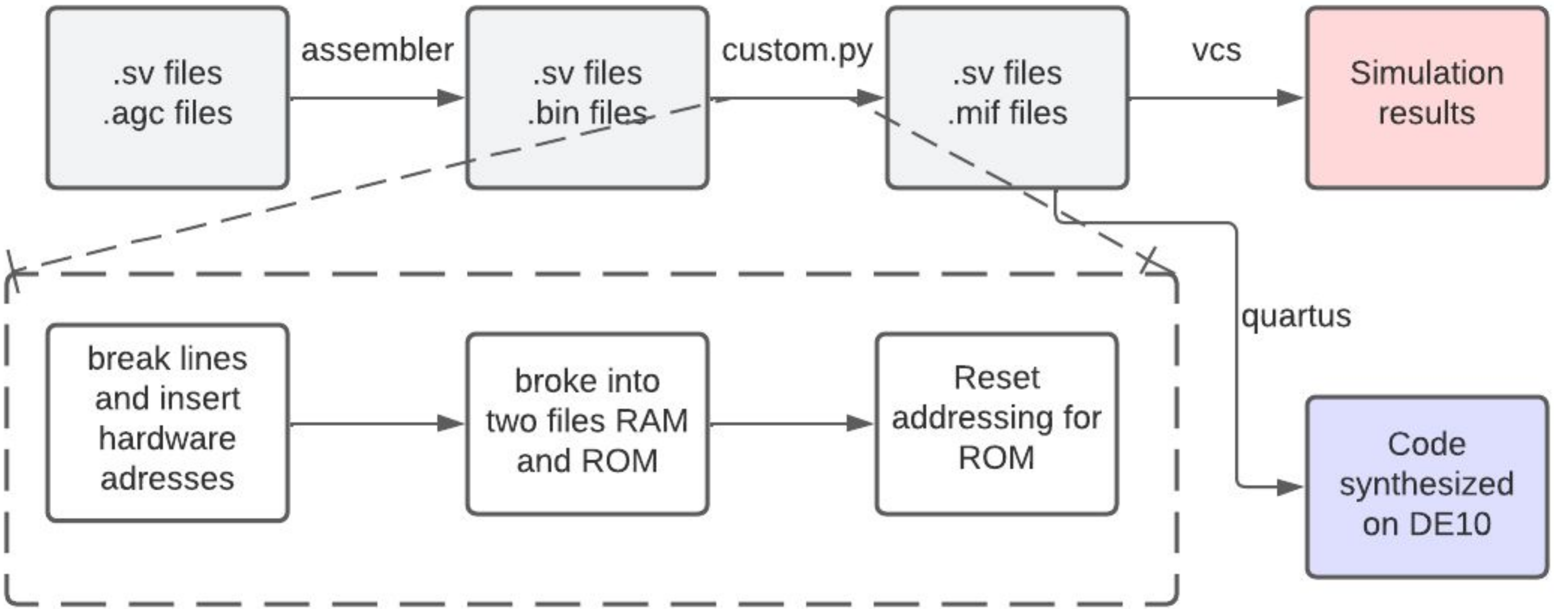
Fetch

Decode

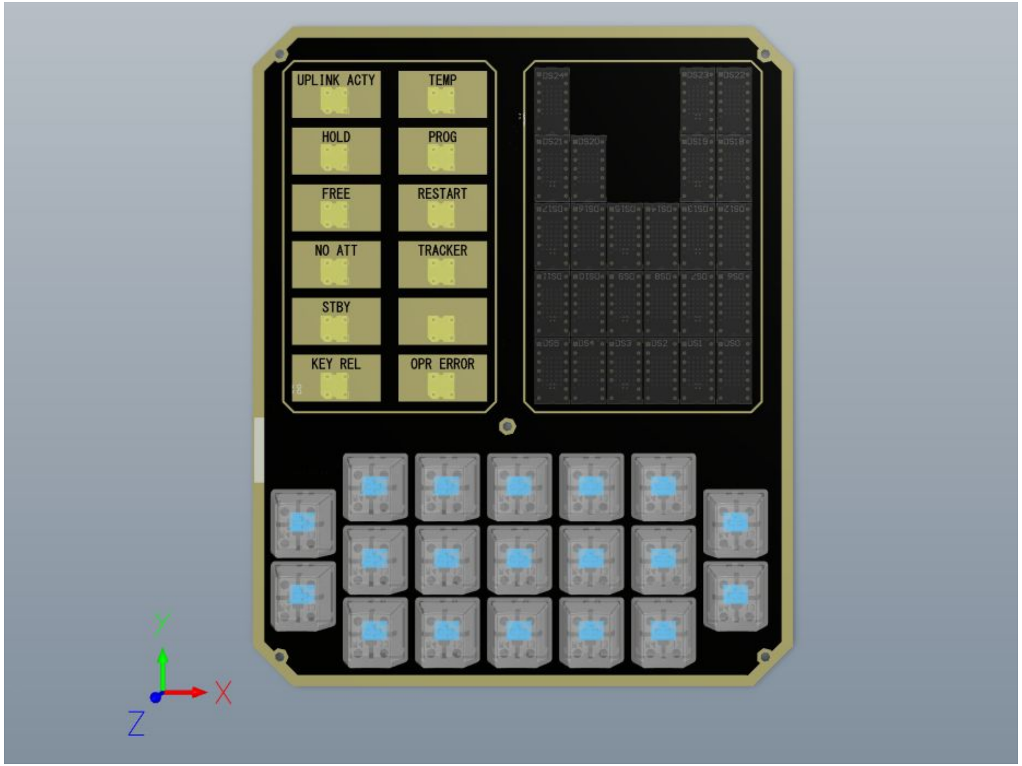
Execute

Writeback

Implementation Plan: Simulation/Synthesis Toolchain



Implementation Plan: DSKY



Goal: DSKY will be implemented on a single PCB board (15 cm by 20 cm)

Utilize previously used and verified designs and components:

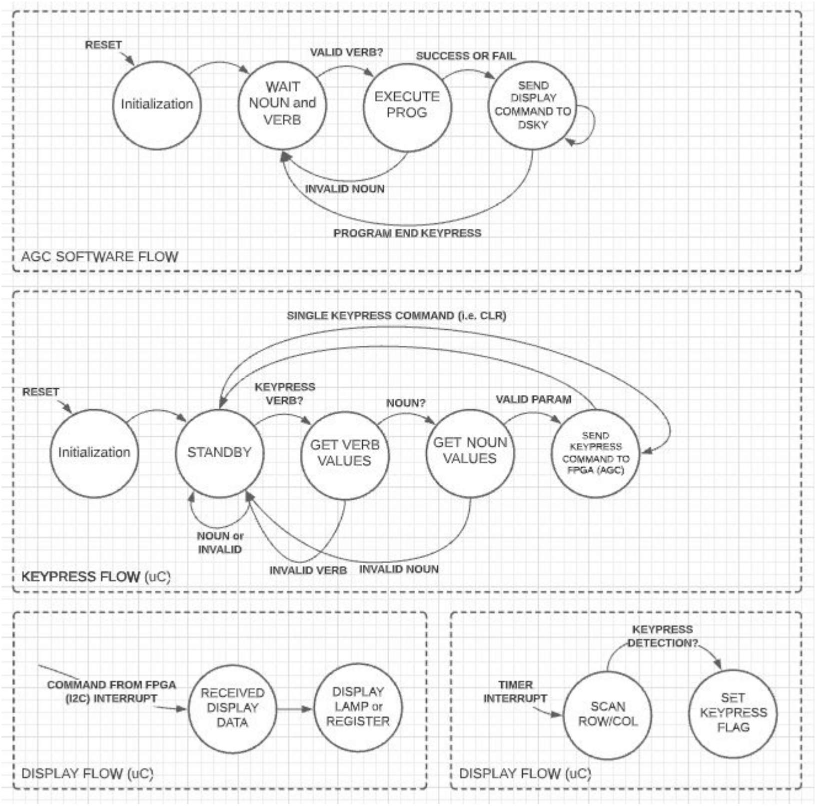
- LTP-305 Display with IS31FL3730 I2C Driver
- ESP32 Microcontroller
- Cherry MX Switches

Suppliers are PCBWay and Digikey: *Stock confirmed and budget for 2.5 units < 500 USD*

Assembly: SMD using reflow oven and a solder stencil. By hand for through hole components at Techspark.

Laser cut Acrylic for final housing

Implementation Plan: Software



Microcontroller: Handle scan of keypad matrix, update lamps and numeric displays

AGC: Specific program per given Verb/Noun.
Basic initialization and single-precision subroutines will be reused from Aurora 12 and Commanche055

The SoC Linux will show basic Python plots to demonstrate orbital mechanics.

VERB	**NOUN**	**Description**
00	**N/A**	Idle
69	**N/A**	Restart
35	**N/A**	Test Lights
37	**XY**	Jump to mission program #XY
50	**N/A**	Get Position rel. to Earth

Test, Verification and Validation

The AGC Architecture

- The registers state of our ISA must match a simulated AGC for all **33** instruction specific tests
- Code < **110,000 LUT's**
- Critical Path < **200 microsecond**
- **0.5 Instructions per Cycle (IPC)**

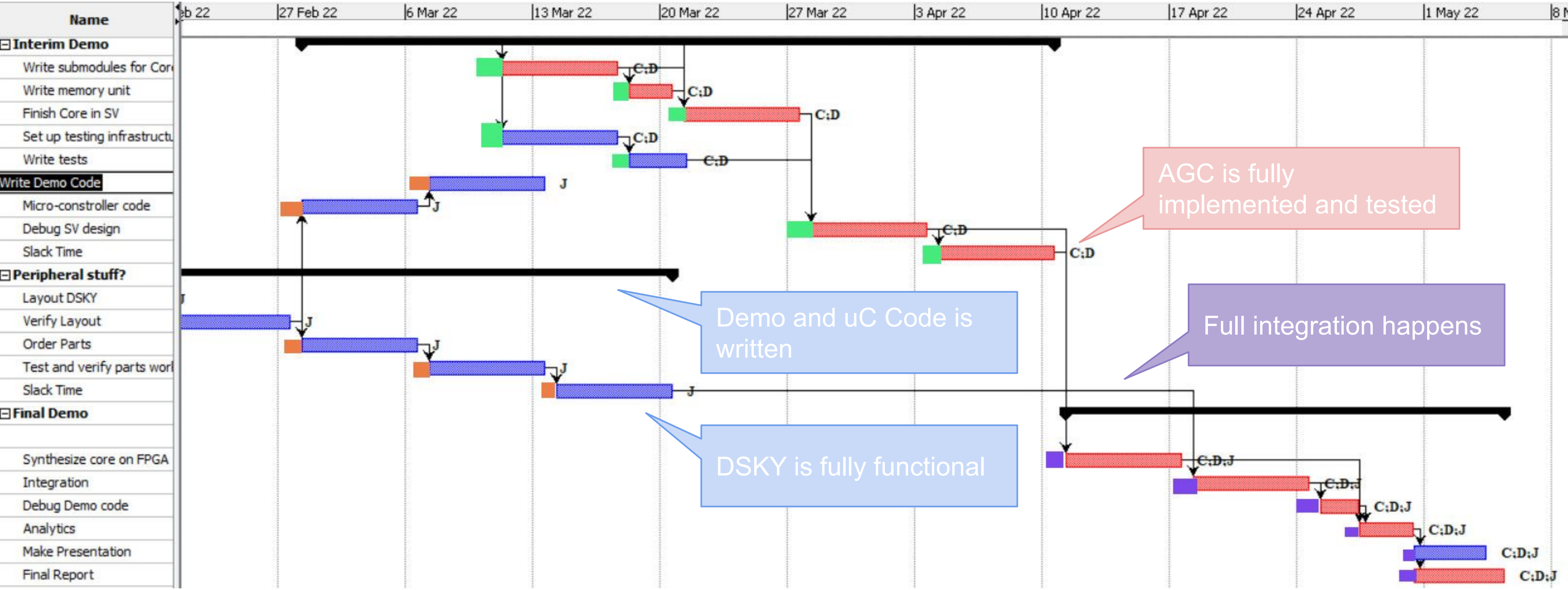
The Software

- **< 0.01%** error of math functions SQRT, SIN, COS (from **Aurora12** and **Comanche055**)
- **< 0.1%** error of orbital mechanics functions (Orbital Plane Transfer, Translunar Injection, …)

The Hardware

- ΔTemperature **< 25 °C**. 3V3 Voltage Rail **> 3.0V**
- Verification through Microscope inspection and TruView X-ray Analyzer (Techspark)
- I2C Bus Analysis and Bandwidth (**< 400kHz**) check using a protocol analyzer.

Project Management



Conclusion

- Apollo's **influence** still seen to this day
- An architectural and manufacturing **trailblazer**
- **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**
    - I2C, FPGA, PCB, HDL