To the 60’s and Back

A modern take on the Apollo Guidance Computer (AGC)

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Use Case

The Customer requires a device to control and handle their rocket. They want:

- An *efficient*, *improved* flight computer to calculate the future spacecraft trajectory (basic Newtonian orbital mechanics).
- A computer that keeps track of spacecraft status and sensors, such as *mission time elapsed*, *battery power level*, *current power usage*, *warning*, etc.
- A compact reliable display and keyboard interface (**DSKY**) to interact with the computer
- To use an I/O focused ISA that is proven to have work for manned space travel

Areas covered: Hardware Systems, Software Systems

Use Case Requirements

- Given our mission time we should be able to calculate and write to the given I/O register for current battery level, distance from earth and moon within **1ms.** It should also be able to be accessed through DSKY.
- The DSKY will contain **compact LED displays** (capable of displaying seven segment) and **control lights** to display important information. A **tactile keypad** will be provided for input
- Improved **Frequency** 1.1Mhz->50Mhz. Condensed **ISA** 37->21 instructions, Decreased **Weight/size** 70lbs-> 3.5lbs.
- Each instruction we implement will pass a specialized test for that instruction in simulation

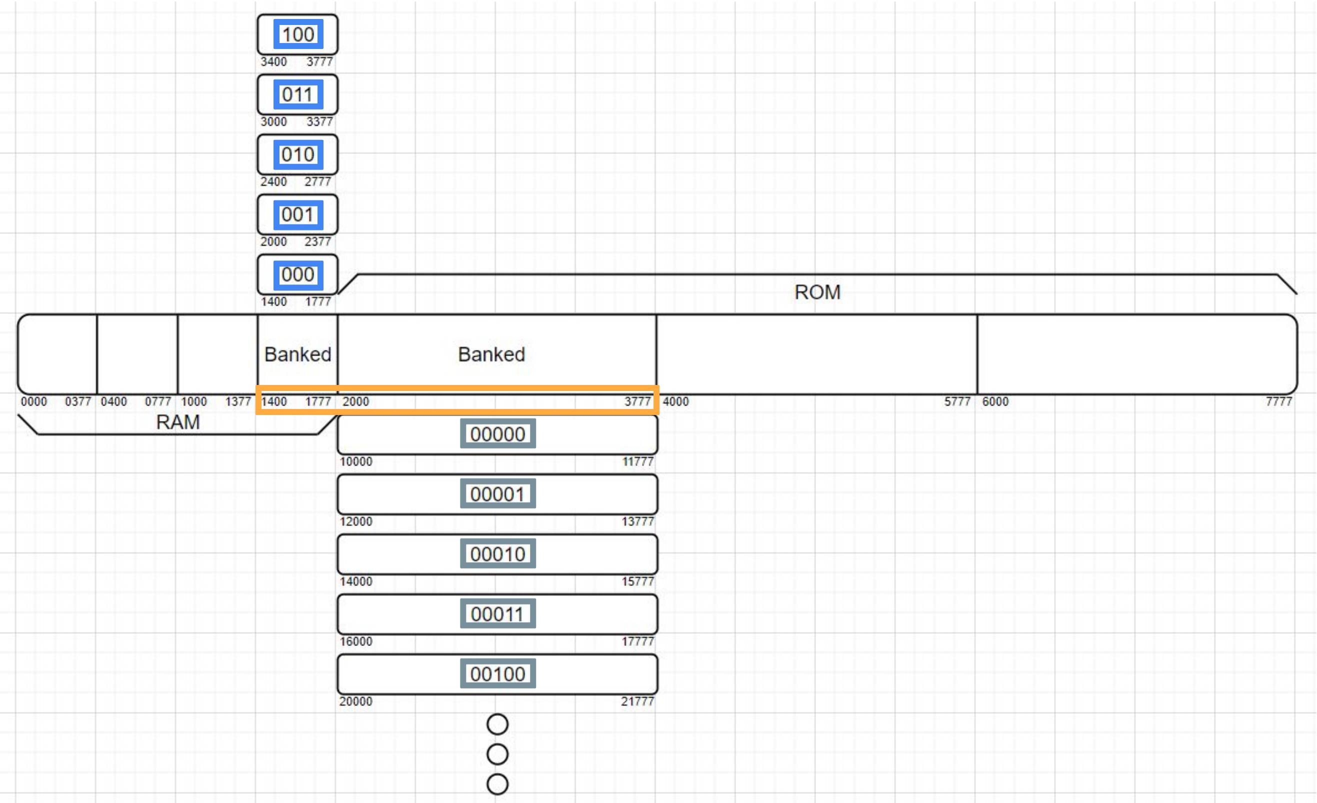
Technical Challenges: Verification, Assembler, Reduced ISA

- How will we **verify** that our processor meets the **requirements**?
- How will we set up an **infrastructure** that is capable of **testing** our processor?
- An **assembler** is needed to run **test/demo** programs.
- How can we **simplify** the original **ISA** while retaining its **defining features**?

Our ISA

Format	Operation	Format	Operation
ADD K	A = A + [K]	*BZF K*	If A = 0; PC = [K] Else PC = PC + 1
ADS K	[K] = A + [K] A = A + [K]	*BZMF K*	If A <= 0; PC = [K] Else PC = PC + 1
AUG K	If [K} >= +0; [K] = [K] + 1 Else; [K] = [K] - 1	*RETURN*	PC = Q
COM	A = ~A	*READ KC*	A = {KC}; Note {} means read from I/O channel
CS K	A = -[K]	*WRITE KC*	{KC} = A
DIM K	If [K} >= +0; [K] = [K] + 1 Else; [K] = [K] - 1	*NOOP*	Nothing
DOUBLE	A = A + A	*INDEX K*	Next instruction in memory is executed differently
INCR K	[K] = [K] + 1	*EXTEND*	Next instruction uses extra code to interpret
MASK K	A = A & [K]	*NOOP*	Nothing
SU K	A = A - [K]	*TS K*	[K] = A
		CA K	A = [K]

Memory Map



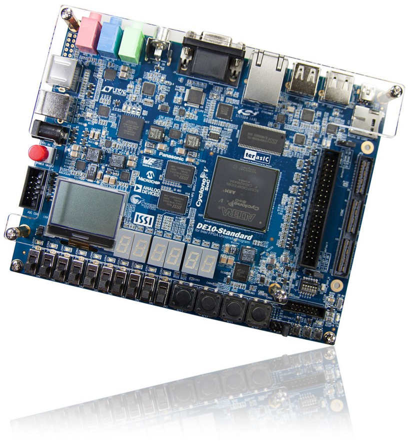
These addresses must be translated prior to memory access.

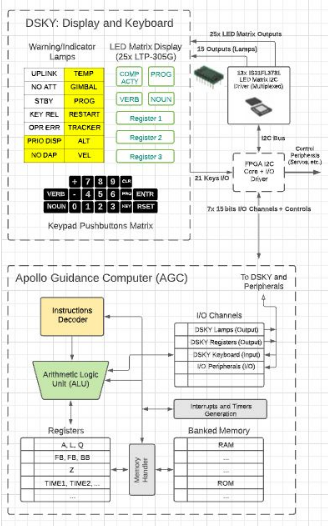
Translation based on…

3 Erasable Bank (EB) selection bits for banked RAM

5 Fixed Bank (FB) selection bits for banked ROM

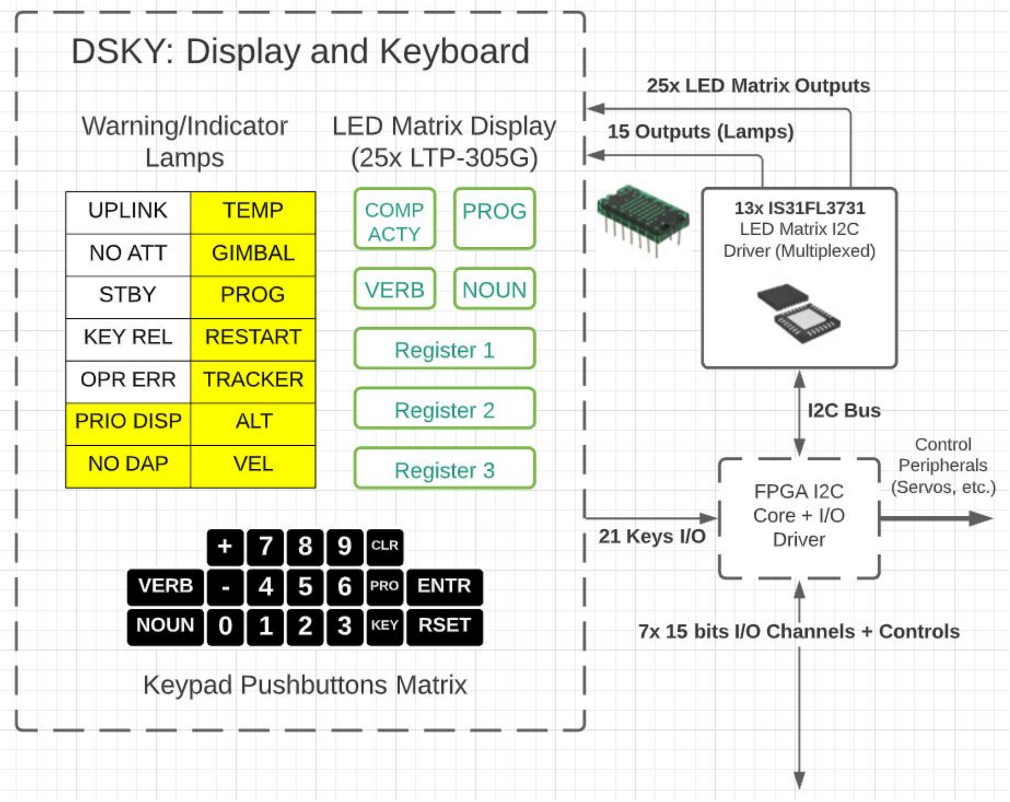
Technical Challenges Hardware Development & Integration





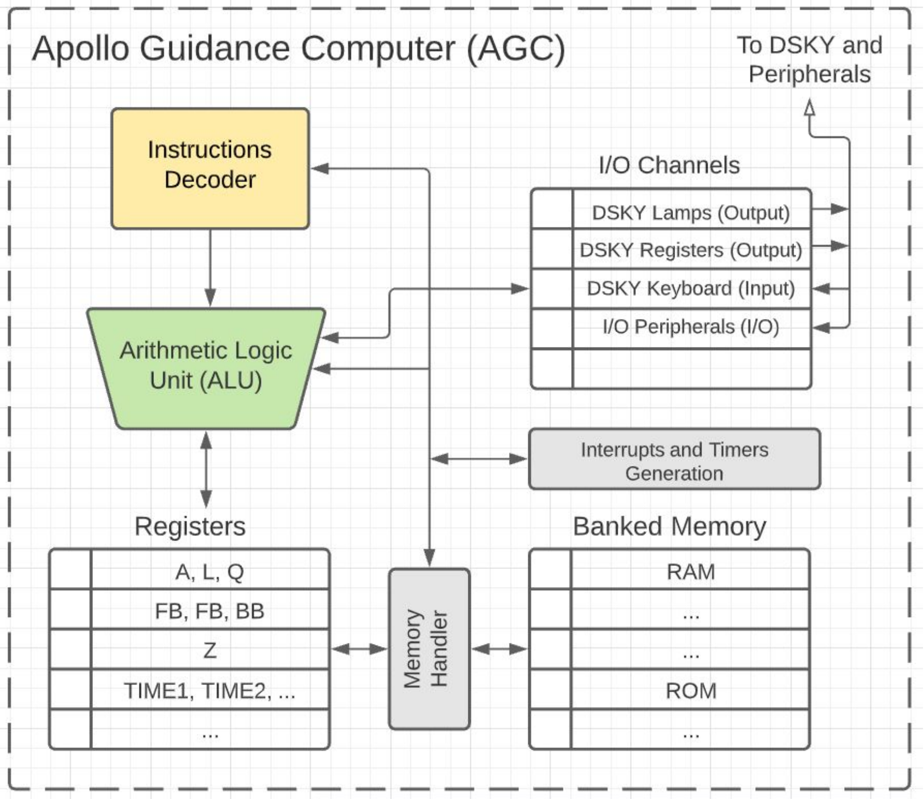
- How do we design a DSKY PCB to meet our requirements? Which components?
- Development of the DSKY interface will require a customized PCB: requires *component selection*, *schematic design*, *PCB layout*, and *PCB assembly.*
- Take into account component **shortage**, PCB board shipments, etc. to minimize **risk.**
- **Time allotment**: Hardware development, DE10 board setup will need to happen **parallel** with architecture development for time.

Solution Approach (System)



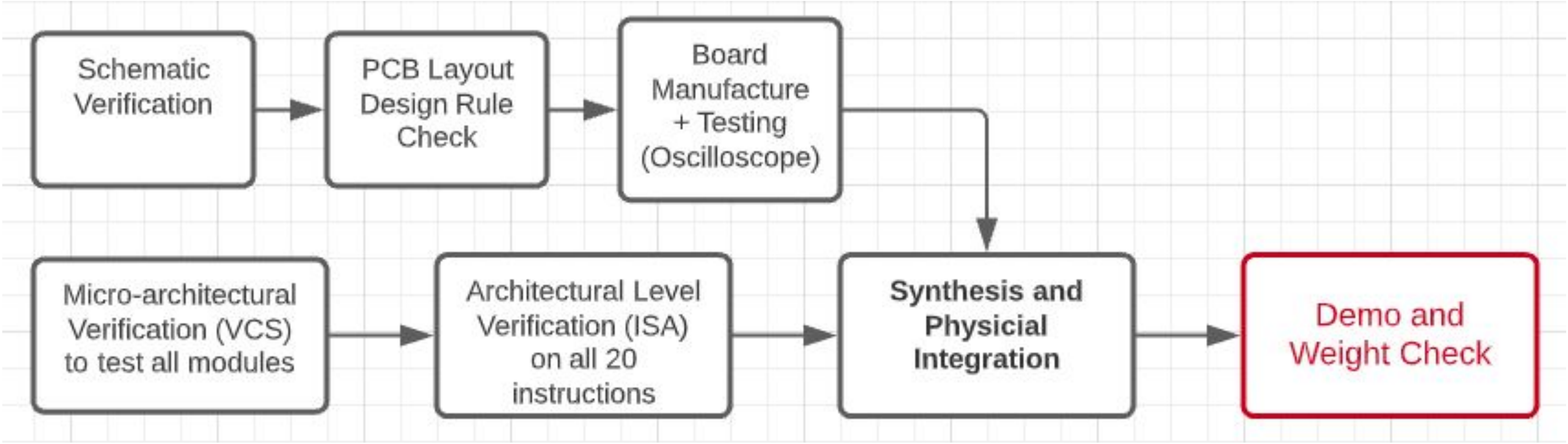
- DSKY is the primary user interface for the AGC
- Design a custom PCB containing LED indicators, LED matrix displays, and keypad
- FPGA will be interfacing the displays/indicators through an I2C bus for **minimal I/O usage**
- The board will be assembled manually using TechSpark equipment
- *All parts chosen are confirmed in stock in Digikey/Amazon (500+ stock)*

Solution Approach (CPU)

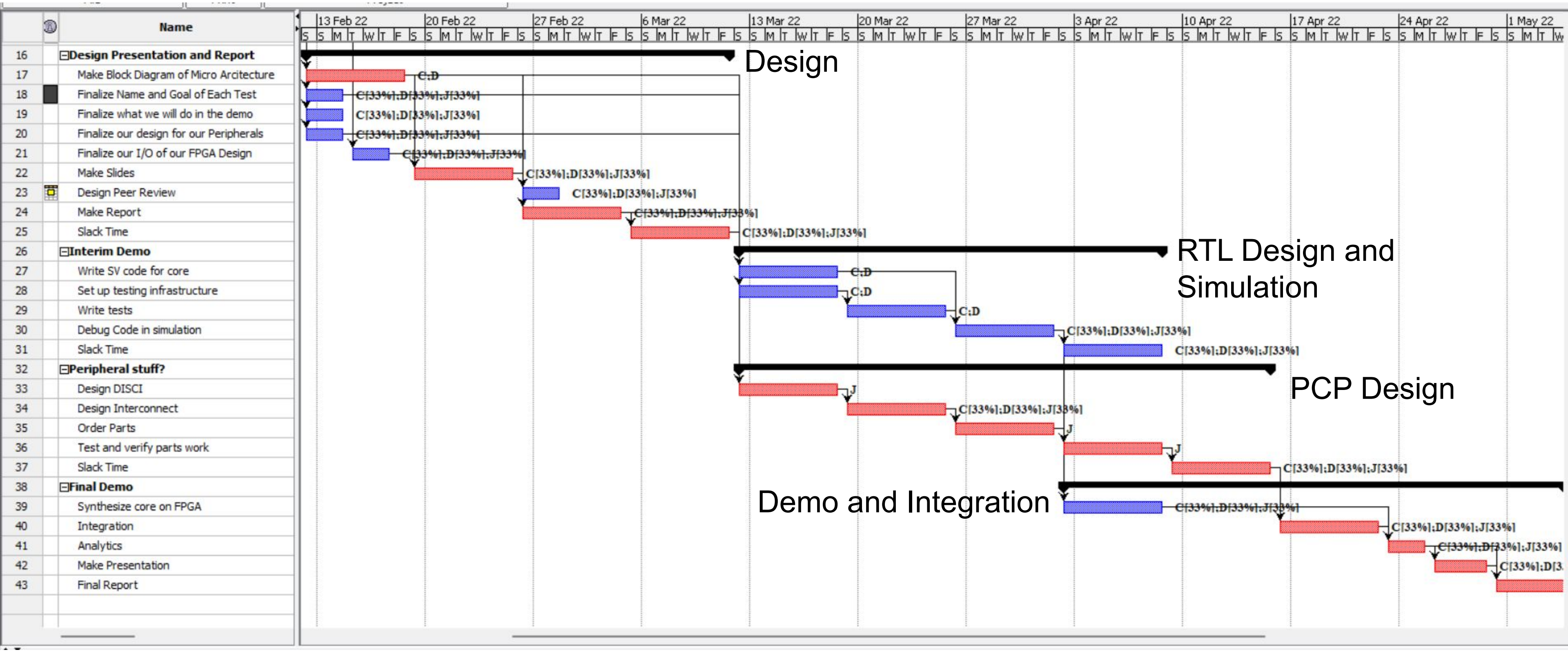


- The AGC architecture will be implemented with Intel (Altera) FPGA in SystemVerilog. Current candidate is **DE10 with SoC**.
- With the help of SoC, the AGC will have accessed to simulated mission data
- Custom AGC assembly routines based on **Apollo Luminary 99 programs** will be written and run on our hardware to demo functionality

Testing and Verification Metrics



Schedule and Division of Labour



Conclusion

- AGC Architecture
    - Purpose-built for **space travel**
- Modern Redesign
    - Use **EDA**, **synthesis** tools, **miniaturized** IC form factor
    - Vastly **smaller** package, **faster** performance
- Target Commercial Space Travel
    - Recent **surge** in national interest
    - Efforts to reach **Mars**