APOLLO Timing/Control Scheme

Zeroth Order
• Measure round trip travel time of photon bouncing off moon (reflector).

First Order
• Use APDs to generate temporally reliable detection events.
• Place corner-cube in exit beam to generate “departure” signal.
• Measure time interval between departure and return signals
  • Combination of counting clock pulses and fractional interval
    \[ 0.35 + \frac{1}{4} = 7 \rightarrow \text{pulse count} \]
    In this example, \( \Delta T = 7 \times 0.35 - 0.91 = 6.44 \text{ clock periods} \)

Second Order
• Know time of laser fire to \( \pm 3 \text{ms} \) UTC (via GPS clock)
• Compute distance to moon for each pulse launched
• Adjust mirror rate to put arrival departure & return signals ~ 180° out of phase \( \rightarrow \) maximum breathing room (720 ms)
• Use computed moon distance to tell 100 ns APD gate when to open
• Employ many-bit counters to keep track of important time intervals;
  • Fiducial Times:
    - FOD pulse STOP clock pulse : PINST
    - Calibration gate ON clock pulse : CALON
    - Calibration gate OFF clock pulse : CALOFF
    - Lunar gate ON clock pulse : LUNON
    - Lunar gate OFF clock pulse : LUNOFF

Counters:
- PPS (Pulse per second) counter : reset by GPS clock, latched on CALON, LUNOFF
  \( \rightarrow \) where within second did gate \( \text{OFF} \) occur?
- CPS (counts per second) counter : reset by GPS PPS, latched by GPS PPS
  \( \rightarrow \) sanity check: how many clock pulses per second?
- FRC (free-running counter) : never reset, latched by CALOFF, LUNOFF
  \( \rightarrow \) provides uninterrupted continuity; “basis” language for lunar delay (LINON)
- GWC (gate width counter) : reset by CALON, LUNON; controls gate duration
- CAL (calibrator) gate delay : reset by fast photodiode; controls CALON
- PIN (PIN photodiode) : reset by photodiode, latched by CALOFF, LUNOFF
  \( \rightarrow \) keeps track of laser fire-to-departure signal clock pulses
Second Order (cont.) - TDCs (Time-to-Digital Converters) precisely measure short intervals (<100ns) to 25 ps resolution. TDCs measure time between photon signal and fiducial clock pulse. Phillips Scientific 7186H has 16 TDC channels.

- Computer retrieves TDC data (via CAMAC) and latched counter values every ~25 ms.

- Counter/Comparator/Latch configuration programmed into Ibm/10,000 Programmable Logic Device.

- Fast photodiode in laser housing serves as high signal-to-noise alert of the beginning of the cycle. The CFD (constant fraction discriminator) - triggered leading edge is timed relative to the master clock by a TDC channel.

Discussion on:

- General scheme/approach
- Implementation
- Test version for lab work
- Data I/O