STEAMVR™

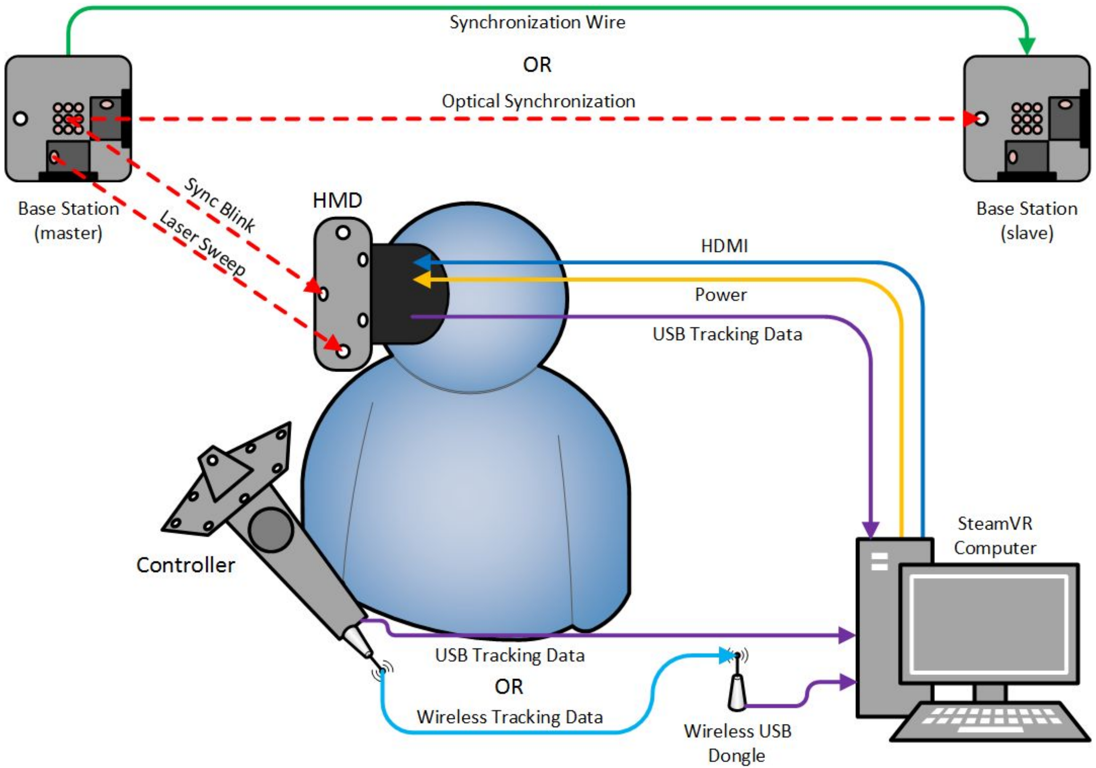
Tracking Training

STEAM®VR
Tracking Training

System Overview

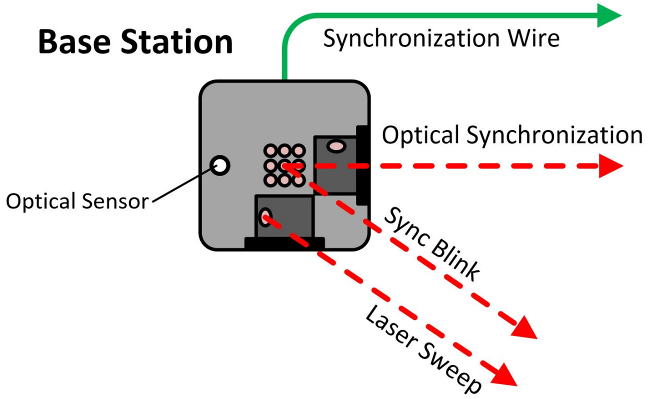
System Overview

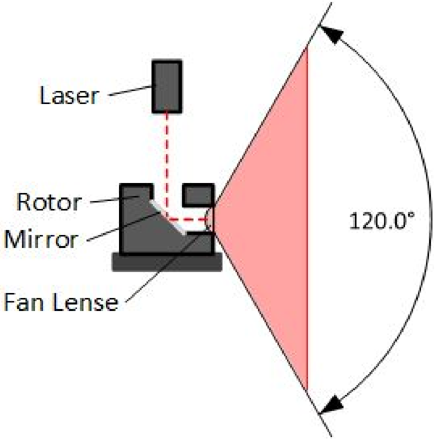
- Computer
- Base stations
- HMD
- Controller

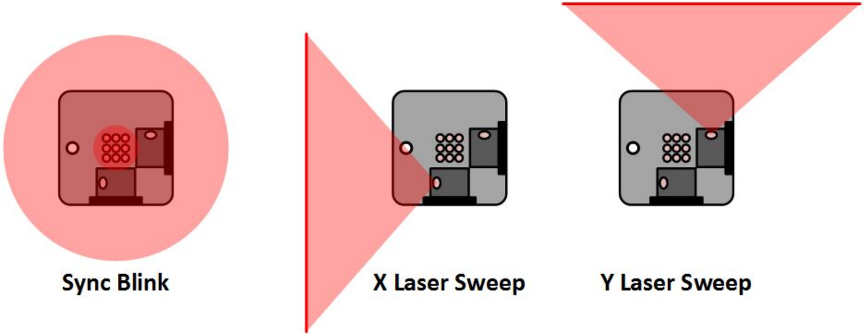


Base Station

- Sync Blinker (IR LEDs)
- X and Y (IR Lasers/Motors)
- Synchronization
  - Wired
  - Optical

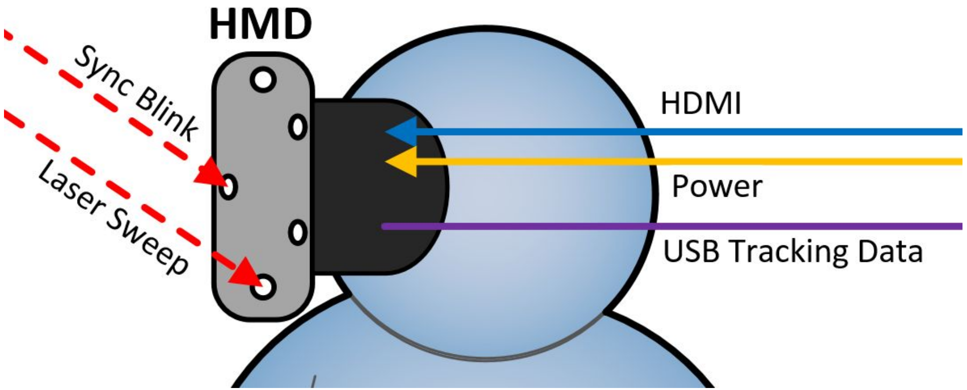






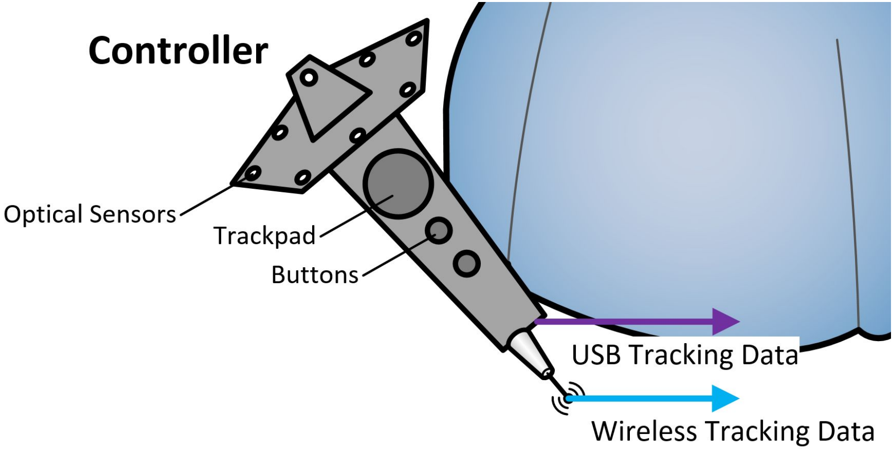
Head Mount Display (HMD)

- Binocular Display
  - HDMI
- Optics
- Audio
  - HDMI for headphones
  - USB for microphone
- SteamVR Tracking
  - Optical sensors
  - Tracking core electronics



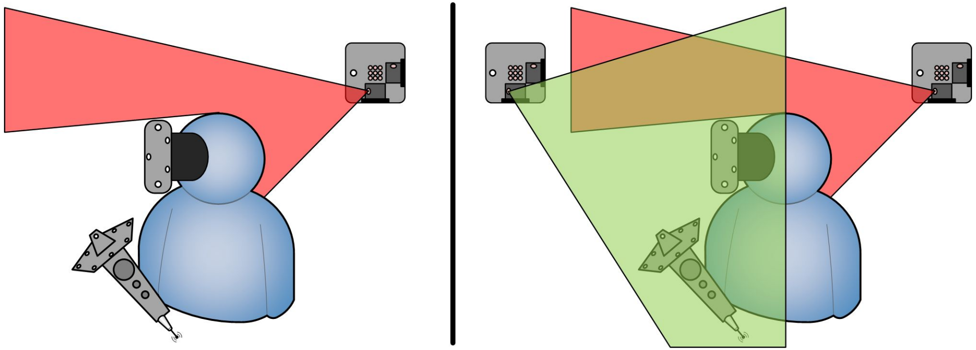
Controllers

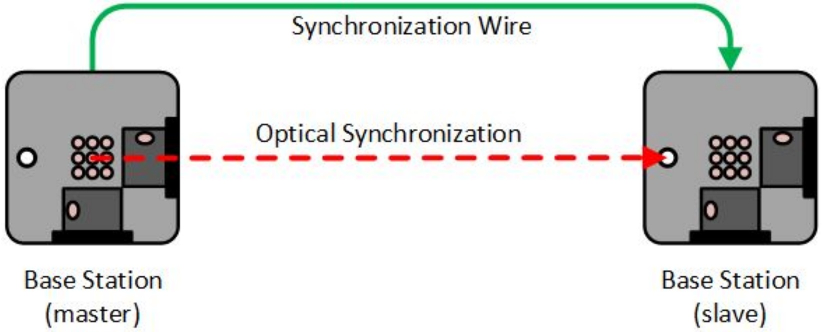
- Controls
  - Trackpad
  - Buttons
  - Haptic feedback
  - Analog trigger
- Connectivity
  - USB
  - Wireless
- SteamVR Tracking
  - Optical sensors
  - Tracking core electronics



Multiple Base Stations

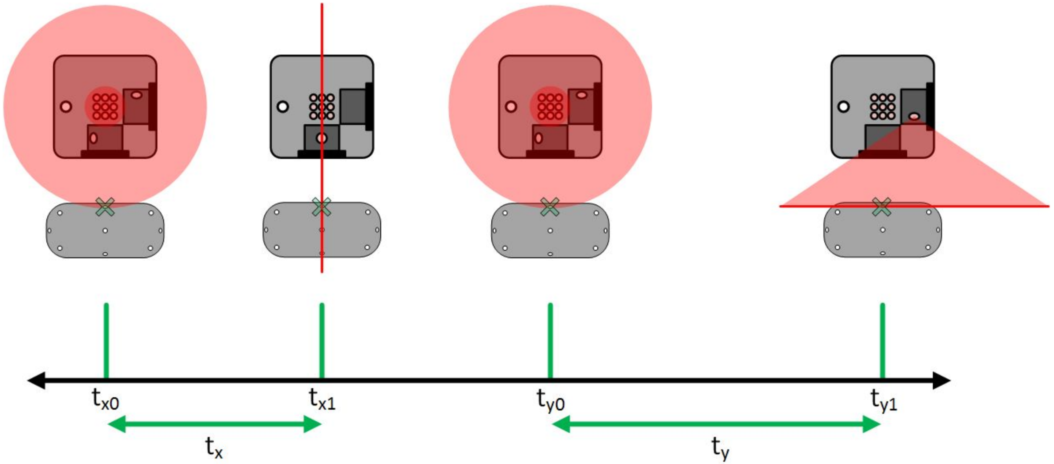
- Two base stations reduce shadows
- Requires synchronization
- Synchronization
  - Wired
    - 60 Hz clock from master
    - Balanced wired connection
    - Original method
  - Optical
    - Sync blink
    - Detected by optical receiver
    - Better user experience





Reference Signaling

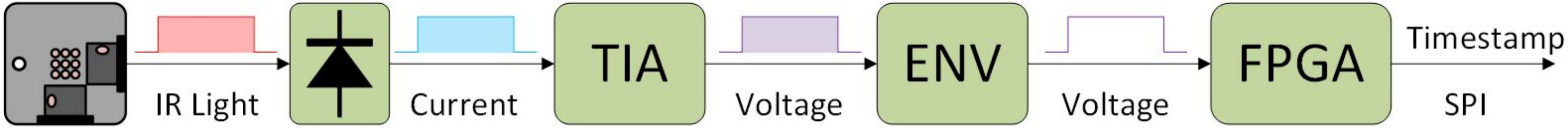
- Signal pattern
  - X Sync Blink
  - X Laser Hits
  - Y Sync Blink
  - Y Laser Hits



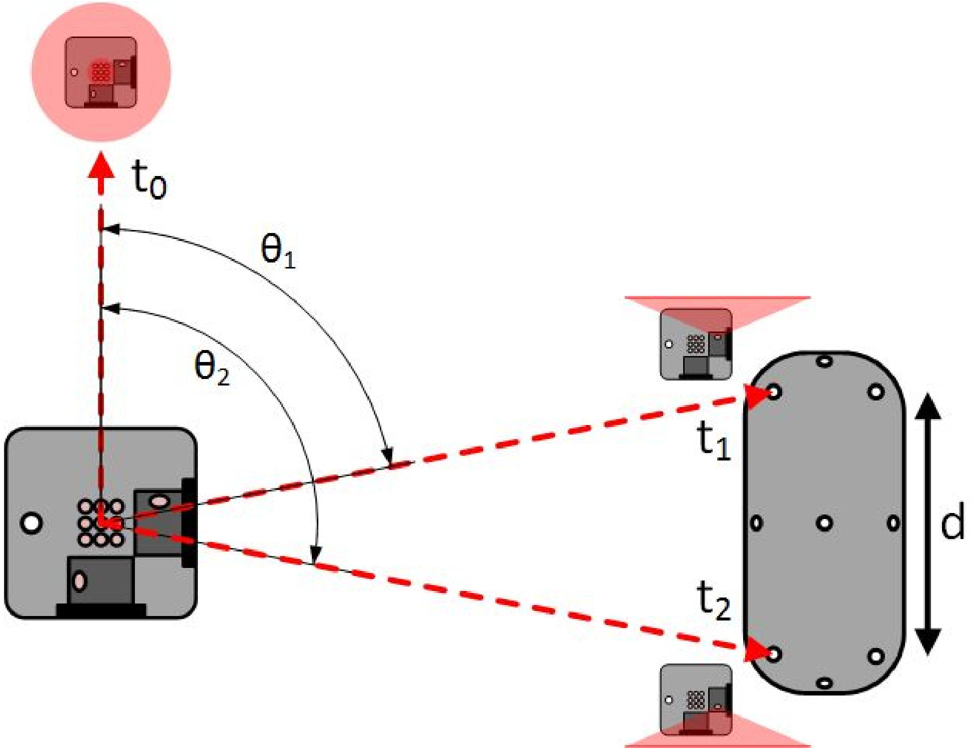
- Sync blinks and laser hits are timestamped by the tracked object
  - Motors spin at 60 Hz
  - IR signals modulated at 1.8 MHz
  - Timestamps occur at 48 MHz
- The difference between the sync blink and laser hit gives the angle

Optical Receivers

- Optical receivers detect the reference signals from the base station
- Photodiode converts IR light to current
- Transimpedance amplifier converts current to voltage
- Envelope detector remove the modulation frequency
- FPGA connects to all sensors to timestamp the arrival of reference signals



Triangulation



$$\theta = t \times T_{counter} \times \omega_{motor}$$

$$t = t_1 - t_0 \ ticks$$

$$f_{counter} = \frac{48 \times 10^6 \ ticks}{1 \ s}$$

$$T_{counter} = \frac{1 \ s}{48 \times 10^6 \ ticks}$$

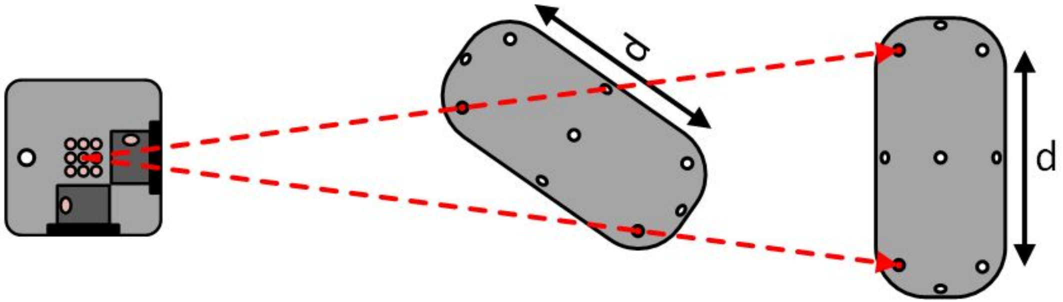
$$\omega_{motor} = \frac{2\pi \ rad}{1 \ cycle} \times \frac{60 \ cycles}{1 \ s} = \frac{120\pi \ rad}{1 \ s}$$

$$\theta = t \ ticks \times \frac{1 \ s}{48 \times 10^6 \ ticks} \times \frac{120\pi \ rad}{1 \ s}$$

$$\theta = t \times \frac{\pi}{400{,}000} \ rad$$

Solving the System

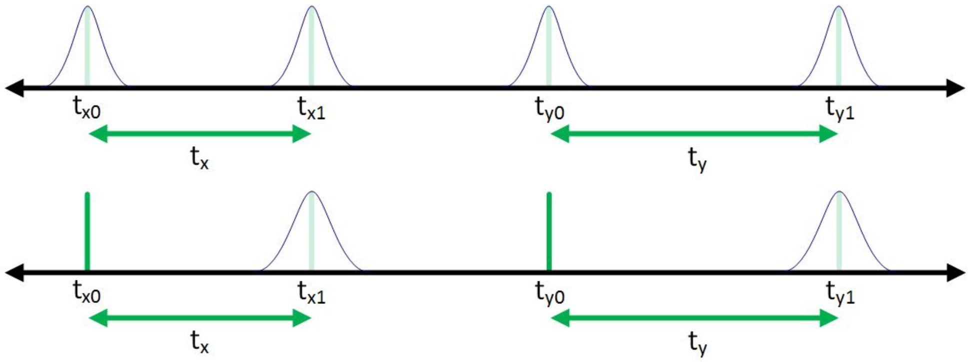
- The angle to all sensors creates a solution set for the position of the object
- SteamVR™ matches the measured angles to the known object geometry
- There must only be one solution to the problem!



- **How many sensors are required to constrain the system?**

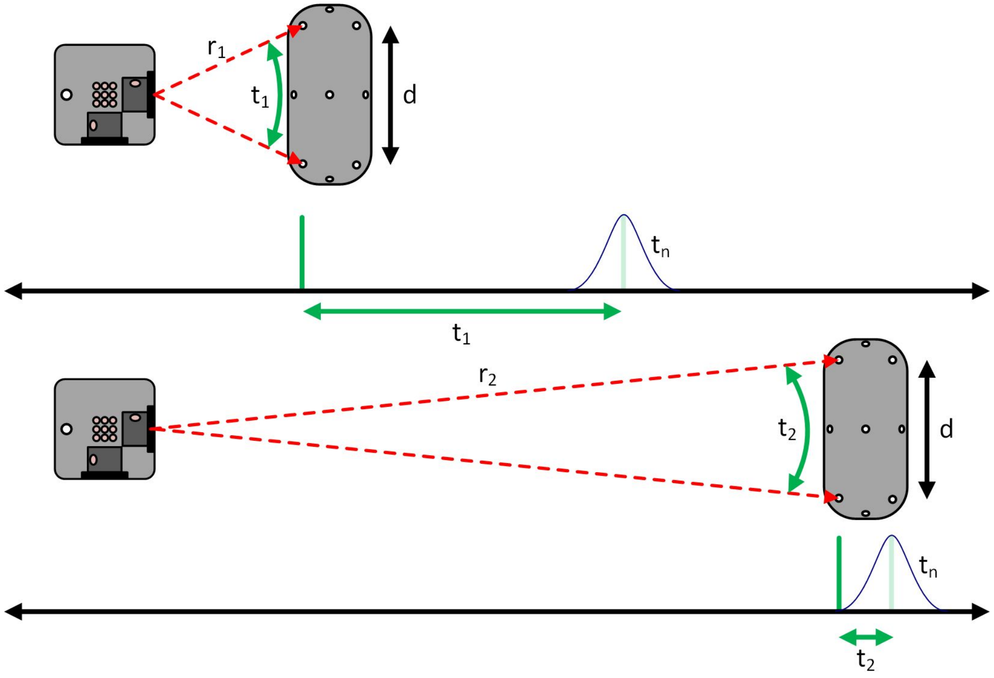
Sources of Error

- Sensor covering
  - Refraction through coverings
  - Cannot be calibrated out
- Sensor placement
  - Variation in placement
  - Can be calibrated out
- Reference signal jitter
  - Timestamp quantization
  - Motor jitter
  - Minimized by design
- Sources of error place requirements on object design



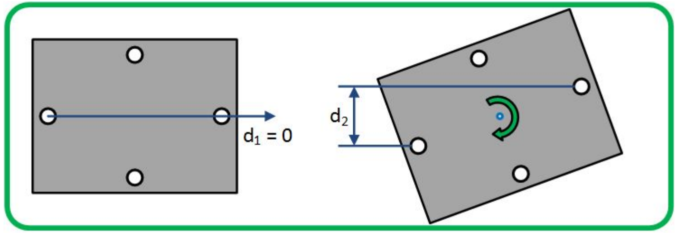
Consequences of Error

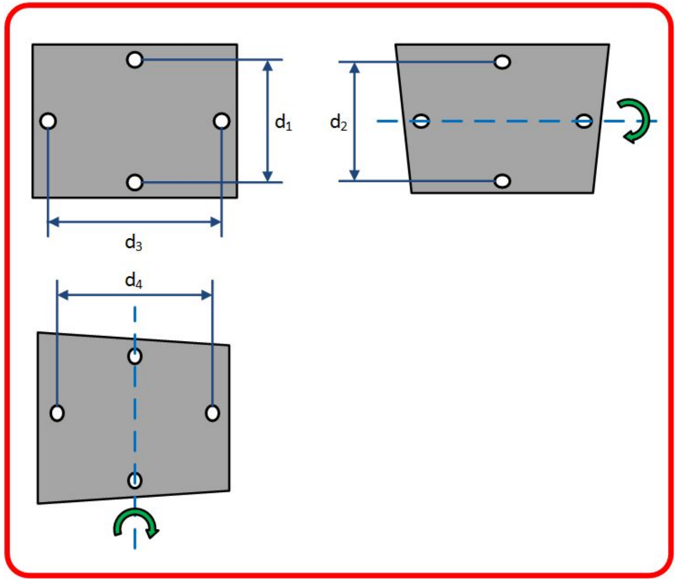
- **Translation Error**
- As distance increases
- Tangential velocity increases
- Time between sensors decreases
- Error begins to dominate
- Limits the maximum radius from the base station
- **How could we reduce this error?**



Consequences of Error

- **Rotation Error**
- Rotation orthogonal to a plane yields significant displacement
- Rotation in the plane yields much smaller displacement per degree rotation
- Error dominates the small change in distance
- **How could we reduce this error?**





Summary

- System comprised of base stations, HMDs, controllers, computer
- HMDs and controllers are examples of tracked objects
- Base stations emit IR reference signals, timestamped by tracked objects
- Timestamps are used to triangulate position
- Four visible sensors are required to constrain the object in space
- Sensor covering, sensor placement, and system jitter are sources of error
  - Follow sensor covering best practices
  - Calibrate away errors in sensor placement
  - Design for sufficient baseline between sensors in all three axes to reduce translation and rotation error