# Pegasus-21

## Midyear Design Review


**Senior Design Project**

**Fall 2016**

# Our Team

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**EE**

**Keith Miller**
**CSE**

**Trevor Berry**
**EE**

**Zlatan Aksamija**
**Advisor**

# Our Mission

We aim to create a turret-mounted system capable of transmitting audio in a directed beam that tracks the listener.

# Acoustic Directionality

-Directionality of sound correlates with the size of speaker compared to wavelength. The formula for far field directivity of a flat circular piston in an infinite baffle is

$$p(\theta) = \frac{p_0 J_1(k_a \sin\theta)}{k_a \sin\theta}$$

where...

$$k_a = \frac{2\pi a}{\lambda}$$

$p_0$ = pressure on axis

$a$ = piston radius

J1 = Bessel Function

$\theta$ = Angle off axis

-Piezoelectric transducers approximate the ideal acoustic piston

-Directionality is achieved by maximizing the piston radius and minimizing the wavelength

("Loudspeaker" n.d.)

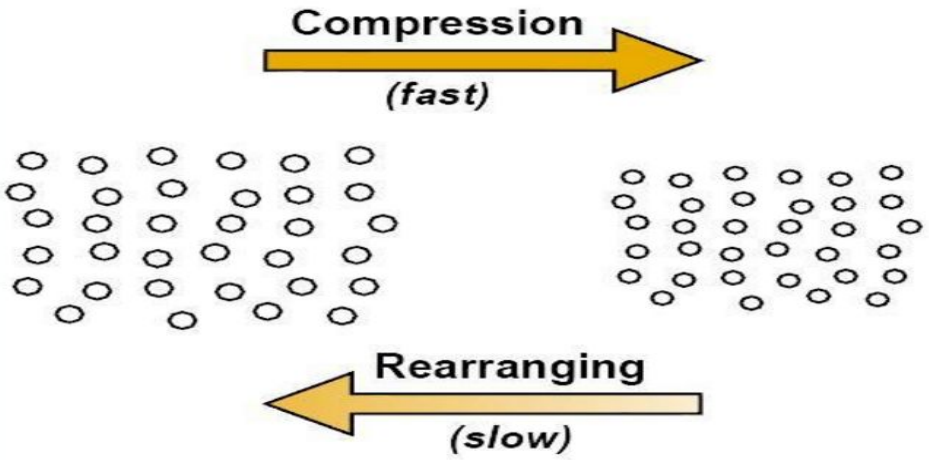
# Sound From Ultrasound

Technology to create directional, highly focused soundbeams:

-An array of transducers emits ultrasonic carrier waves in the direction of target

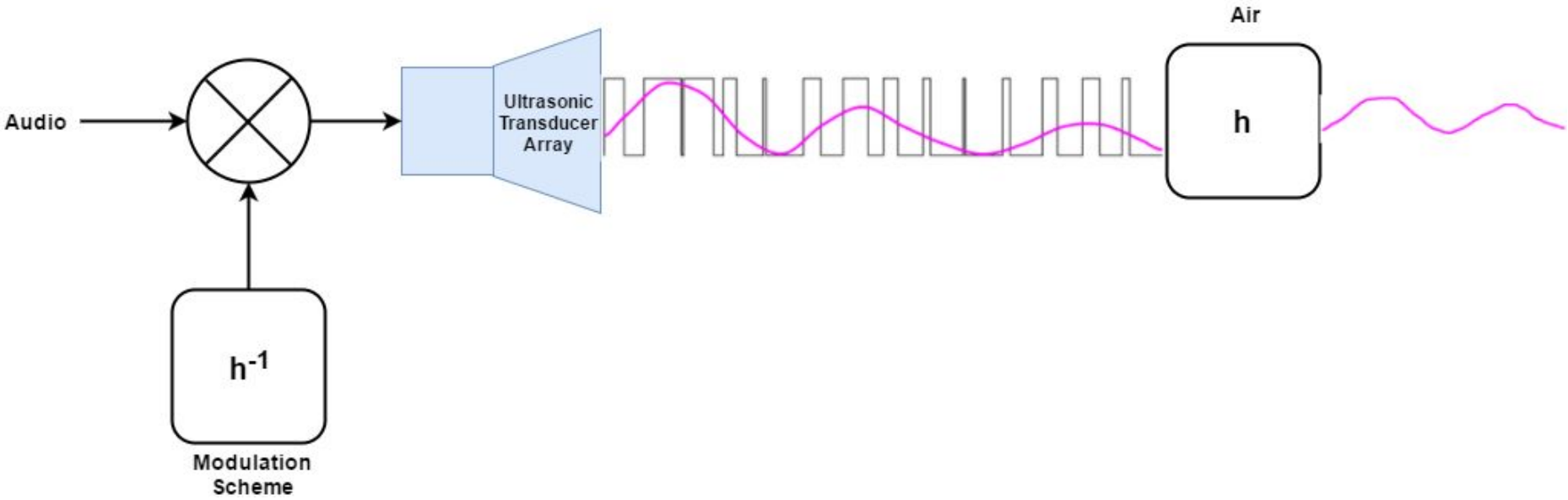
-Air, as a nonlinear medium, acts as a demodulator (no need for receiver)

-When the modulated wave reaches a person the modulated sound becomes audible




( Nema, “Ultrasonic Directive Speaker”)

# Sound From Ultrasound



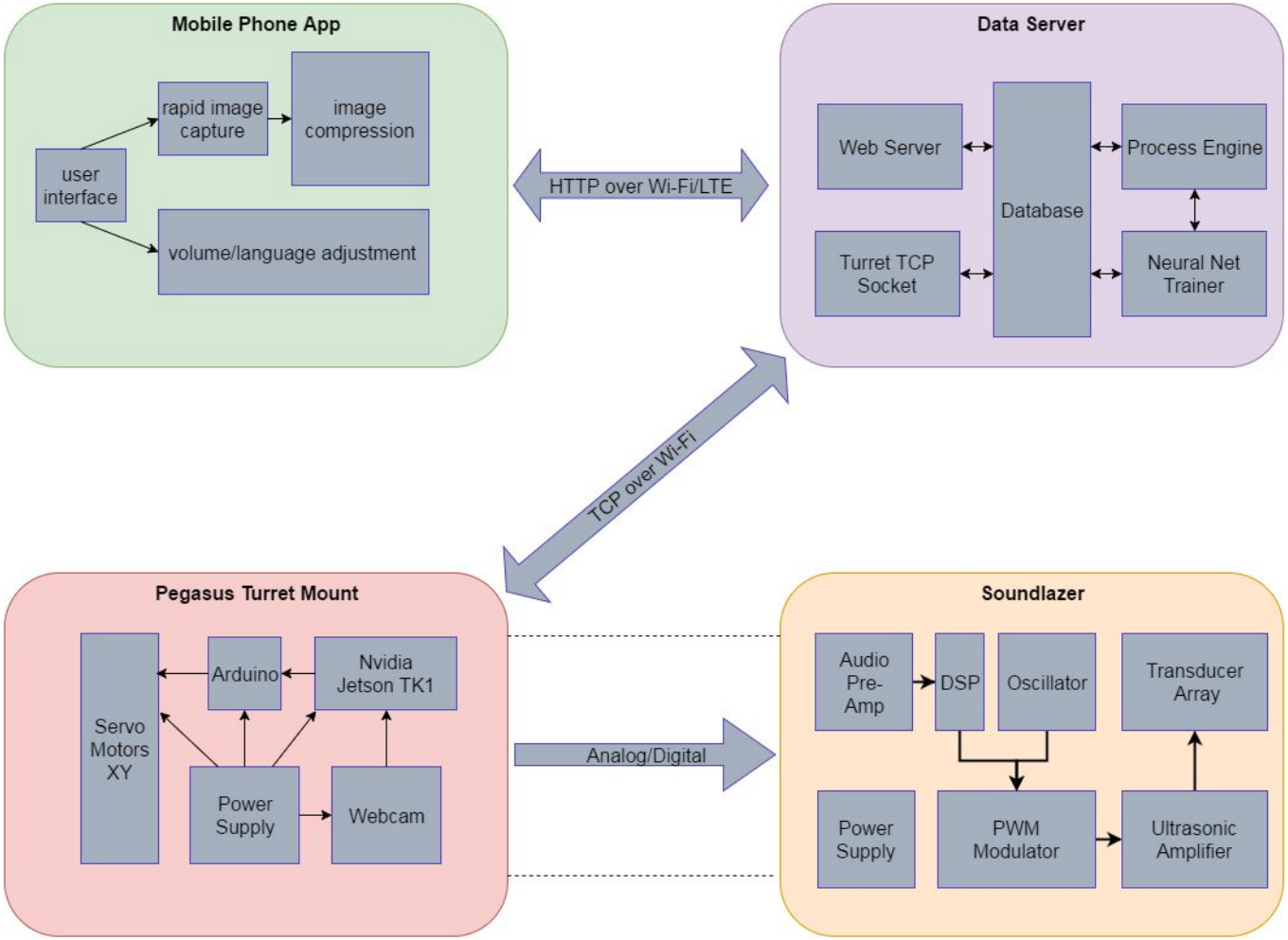

http://www.soundlazer.com/what-is-a-parametric-speaker/

# MDR Deliverables

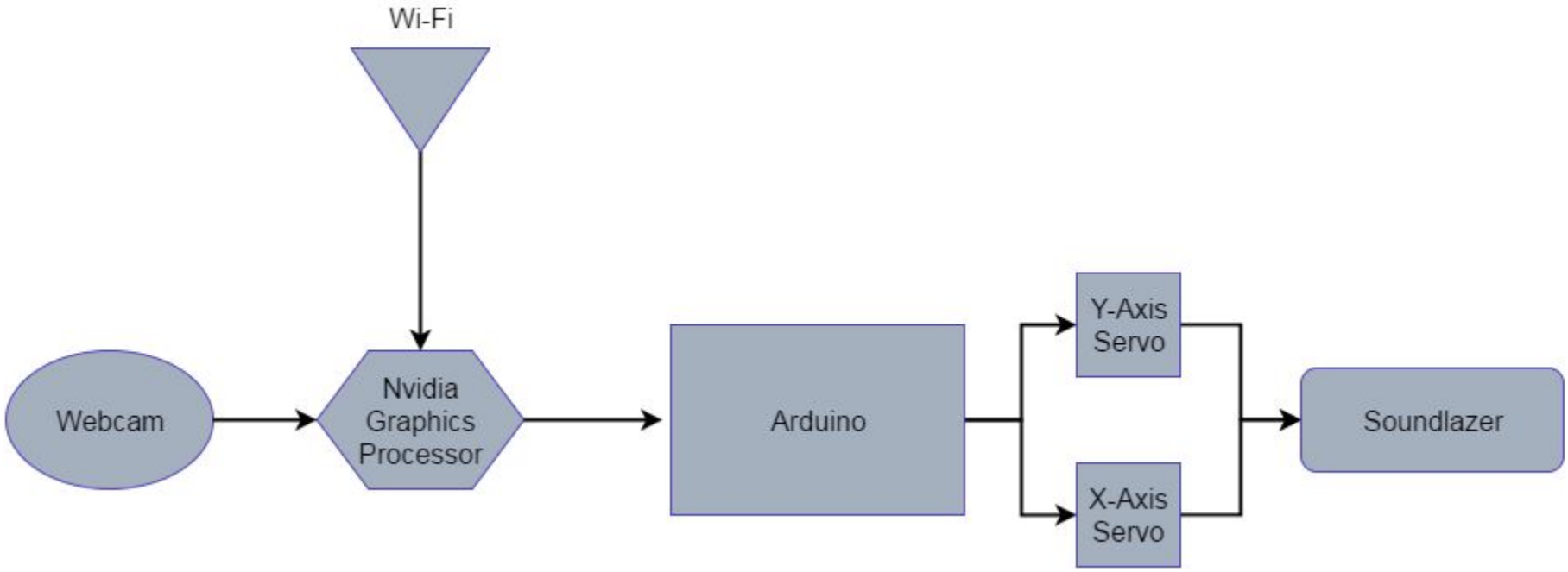
**Demonstrate the functionality of the individual stages**

- Range of motion in X and Y direction for Turret
- Directionality of piezo-array speaker
- Face detection and recognition

# System Block Diagram



# Pegasus Turret: Block Diagram



# Arduino

- Communicates with NVIDIA TEGRA TK1 over I2C
- Receives new position data from NVIDIA
- New data arrives every time an image is processed on the NVIDIA
- Turns the servos, controlling the turret to the desired position
- Upon request, sends back turret position to NVIDIA

# Hardware: Minor Components

**Servo Motors**

- Input Voltage: 6V
- Operating Speed: 0.15sec/60deg
- Stall Torque: 3.95 kg-cm

**Arduino Nano**

- Input Voltage: 7-12V
- Logic Level: 5V
- Clock Speed: 16MHz
- PWM Capable

**Webcam**

- 3.0 Megapixel
- 1280 x 720 pixels
- RightLight Technology

# Soundlazer


- 12VDC power input
- 120dB ultrasonic output
- Usable range indoors: 30.0 feet
- Beam size of around 3 feet
- 40 GHz Carrier Wave
- Pulse Width Modulation
- Digital Signal Processing
- 5 Watt Carrier Wave

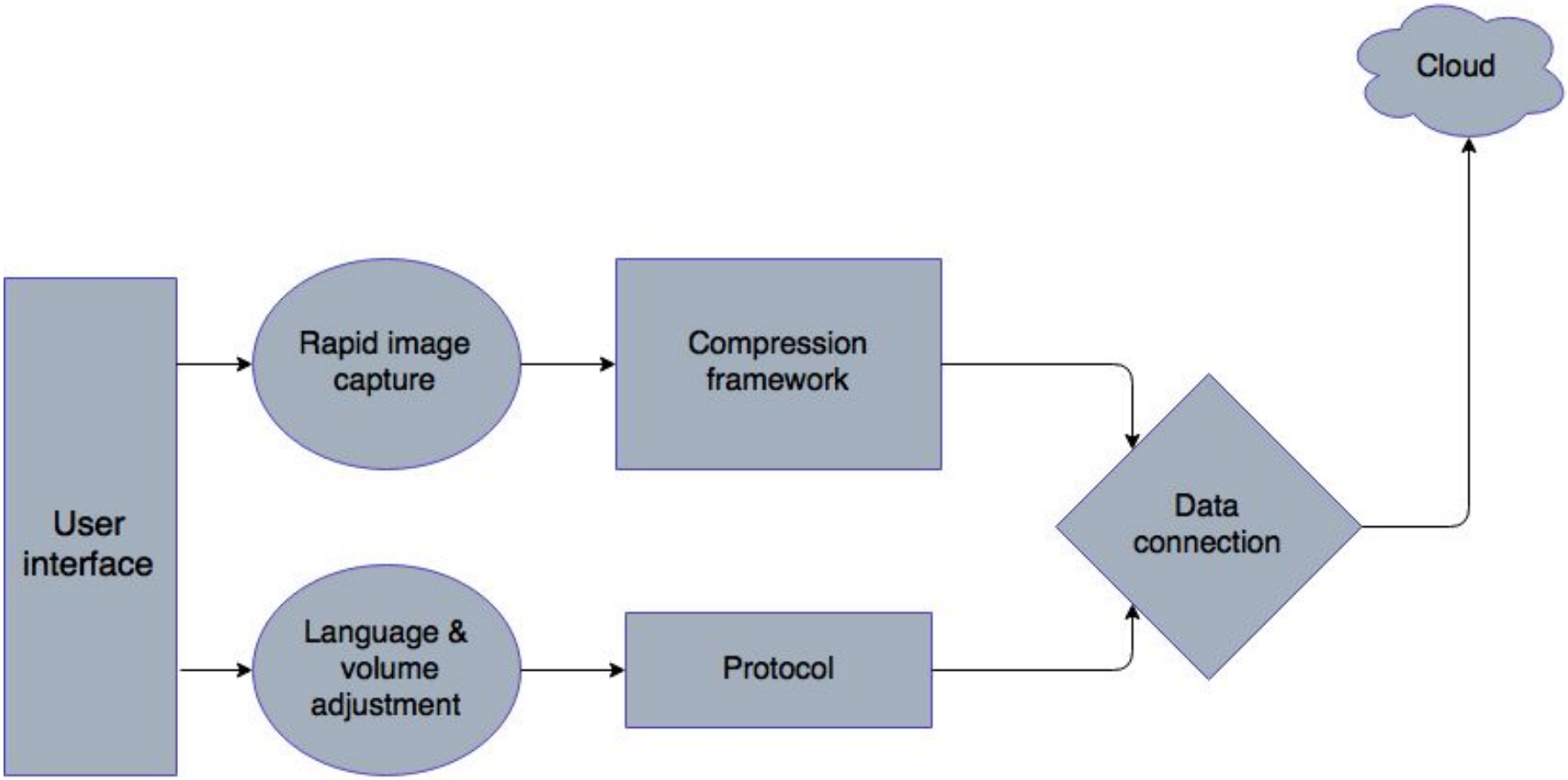
# NVIDIA Jetson TK1

- GPU: NVIDIA Kepler GK20a with 192 CUDA cores (326 GFLOP)
- CPU: Quad-Core Cortex-A15 32-bit ARM Processor
- DRAM: 2 GB DDR3
- Storage: 16GB fast eMMC 4.

# NVIDIA Jetson TX1

- GPU: NVIDIA Maxwell GPU  with 256 CUDA cores (1 TFLOP)
- CPU: Quad-Core Cortex-A57 64-bit ARM Processor
- DRAM: 4 GB DDR4
- Storage: 16GB fast eMMC 4.51
- Wi-Fi

# iphone App: Block Diagram



# iPhone App System Requirements

**Images**

- 720p image standard

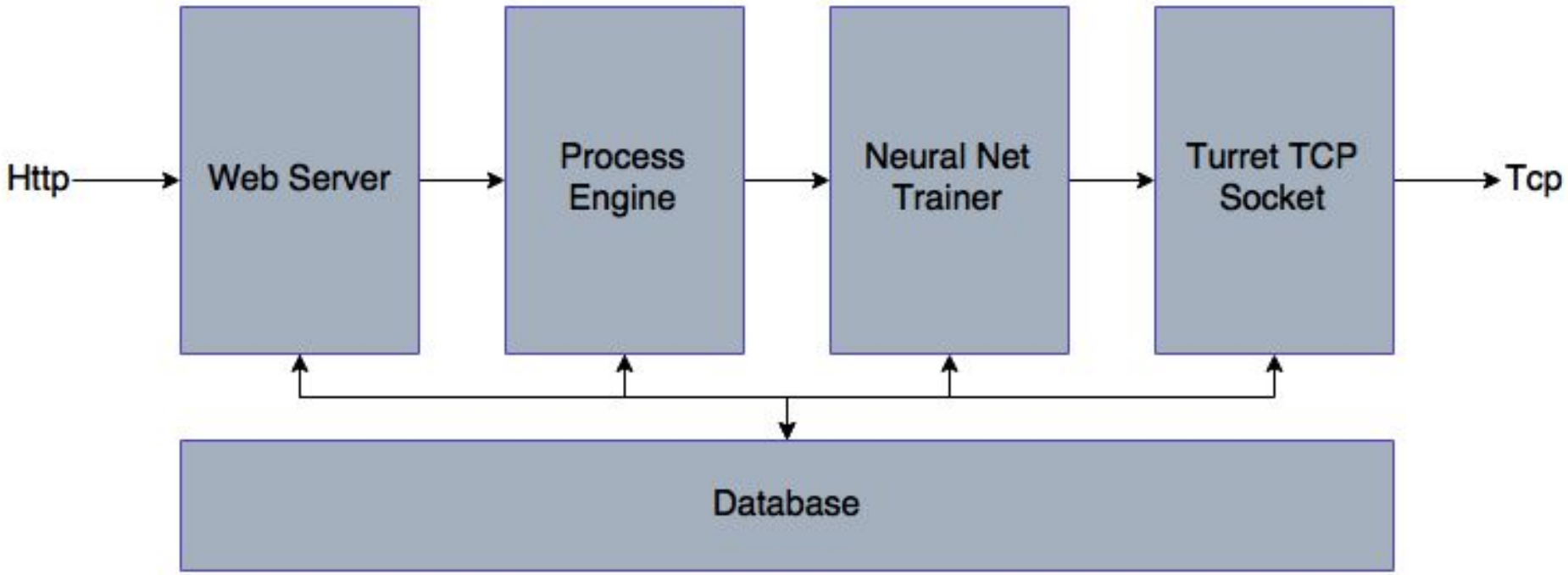
**Frameworks**

- RealmSwift
- .tar.gz compression
- sockets
- notifications

**Targeting**

- Override turret position
- Videofeed with aiming reticule

# Server: Block Diagram



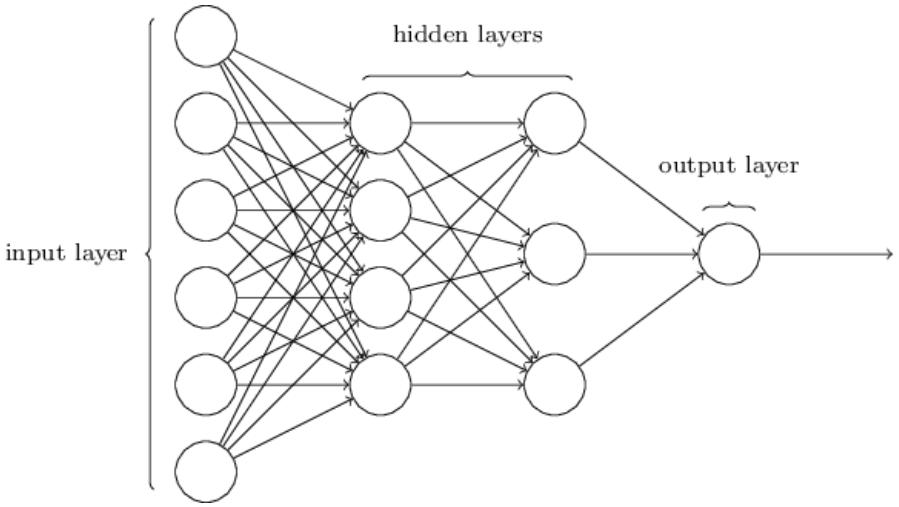
# Server System Specifications

**Database**

- SQLite will suffice for prototyping purposes

**Neural Net Training**

- Train 2-person neural net in under 5 minutes for demos
- Send push notification



# Tracking

**CAMShift + Kalman Filter**

- Currently utilizing a CAMShift algorithm for face tracking
- Next step to integrate Kalman Filter as described in *Improved CAMshift Algorithm Based on Kalman Filter*

("Advanced Science and Technology Letters." )

# System Performance Test

```
         18017 function calls (17888 primitive calls) in 6.485 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       15    0.774    0.052    0.774    0.052 :0(CascadeClassifier)
        2    0.000    0.000    0.000    0.000 :0(POINTER)
        1    0.089    0.089    0.089    0.089 :0(VideoCapture)
        2    0.000    0.000    0.000    0.000 :0(WEXITSTATUS)
        2    0.000    0.000    0.000    0.000 :0(WIFEXITED)
        2    0.000    0.000    0.000    0.000 :0(WIFSIGNALED)
        8    0.000    0.000    0.000    0.000 :0(__contains__)
      274    0.002    0.000    0.002    0.000 :0(__import__)
       17    0.001    0.000    0.001    0.000 :0(__new__)
       20    0.000    0.000    0.000    0.000 :0(__subclasses__)
       20    0.000    0.000    0.000    0.000 :0(__subclasshook__)
       82    0.000    0.000    0.000    0.000 :0(_getframe)
       67    0.000    0.000    0.000    0.000 :0(acquire)
      117    0.000    0.000    0.000    0.000 :0(add)
      271    0.001    0.000    0.001    0.000 :0(add_docstring)
        8    0.000    0.000    0.000    0.000 :0(all)
        6    0.000    0.000    0.000    0.000 :0(allocate_lock)
        3    0.000    0.000    0.000    0.000 :0(any)
     1481    0.005    0.000    0.005    0.000 :0(append)
       43    0.000    0.000    0.000    0.000 :0(array)
       18    0.000    0.000    0.000    0.000 :0(calcsize)
     1024    0.003    0.000    0.003    0.000 :0(chr)
        2    0.000    0.000    0.000    0.000 :0(clear)
       10    0.000    0.000    0.000    0.000 :0(close)
       14    0.000    0.000    0.000    0.000 :0(compile)
        3    0.000    0.000    0.000    0.000 :0(compress)
        1    0.000    0.000    0.000    0.000 :0(count)
       15    0.024    0.002    0.024    0.002 :0(cvtColor)
       15    4.232    0.282    4.232    0.282 :0(detectMultiScale)
```

```
         22341 function calls (22147 primitive calls) in 11.580 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       15    0.854    0.057    0.854    0.057 :0(CascadeClassifier)
        2    0.000    0.000    0.000    0.000 :0(POINTER)
        1    0.083    0.083    0.083    0.083 :0(VideoCapture)
       28    0.000    0.000    0.000    0.000 :0(WEXITSTATUS)
       28    0.000    0.000    0.000    0.000 :0(WIFEXITED)
       28    0.000    0.000    0.000    0.000 :0(WIFSIGNALED)
        8    0.000    0.000    0.000    0.000 :0(__contains__)
      274    0.002    0.000    0.002    0.000 :0(__import__)
       17    0.001    0.000    0.001    0.000 :0(__new__)
       20    0.000    0.000    0.000    0.000 :0(__subclasses__)
       20    0.000    0.000    0.000    0.000 :0(__subclasshook__)
       82    0.000    0.000    0.000    0.000 :0(_getframe)
       67    0.000    0.000    0.000    0.000 :0(acquire)
      117    0.000    0.000    0.000    0.000 :0(add)
      271    0.001    0.000    0.001    0.000 :0(add_docstring)
        8    0.000    0.000    0.000    0.000 :0(all)
        6    0.000    0.000    0.000    0.000 :0(allocate_lock)
       42    0.000    0.000    0.001    0.000 :0(any)
     1577    0.006    0.000    0.006    0.000 :0(append)
      108    0.000    0.000    0.000    0.000 :0(array)
       18    0.000    0.000    0.000    0.000 :0(calcsize)
     1024    0.003    0.000    0.003    0.000 :0(chr)
        2    0.000    0.000    0.000    0.000 :0(clear)
      140    0.002    0.000    0.002    0.000 :0(close)
       14    0.000    0.000    0.000    0.000 :0(compile)
       42    0.001    0.000    0.001    0.000 :0(compress)
       14    0.000    0.000    0.000    0.000 :0(count)
       15    0.025    0.002    0.025    0.002 :0(cvtColor)
       15    5.277    0.352    5.277    0.352 :0(detectMultiScale)
```

# Looking Forward

- 3D Print an acoustic horn Array to increase speaker directionality
- 3D Print turret chassis and casing
- Implement algorithms on NVIDIA TX1
- Build App
- Full Integration of subsystems

http://www.thingiverse.com/thing:45649/apps/#apps

# CDR Deliverables

**Keith:**

- Fully working software pipeline for tracking, interfaced with the turret

**Trevor:**

- Design and 3D print acoustic horn and turret chassis
- Design universal power supply

**Istvan:**

- Build iPhone application skeleton
- PCB for power supply

# References

"Advanced Science and Technology Letters." *Improved CAMshift Algorithm Based on Kalman Filter* (2016): n. pag. Web. Cam-Shift Info

Haberkern, Richard. "What Is a Parametric Speaker? - Soundlazer." *Soundlazer*. N.p., n.d. Web. 06 Dec. 2016. Soundlazer abstract

Haberkern, Richard. "#SL-01 Open Source Parametric Speaker - Soundlazer." *Soundlazer*. N.p., n.d. Web. 06 Dec. 2016. #SL-01 Technical Specifications

"Loudspeaker Facts - Directivity as a Design Issue." *Loudspeaker Facts - Directivity as a Design Issue*. Mc Squared System Design Group, Inc, n.d. Web. 07 Dec. 2016. Principles of speaker directionality

# References (cont.)

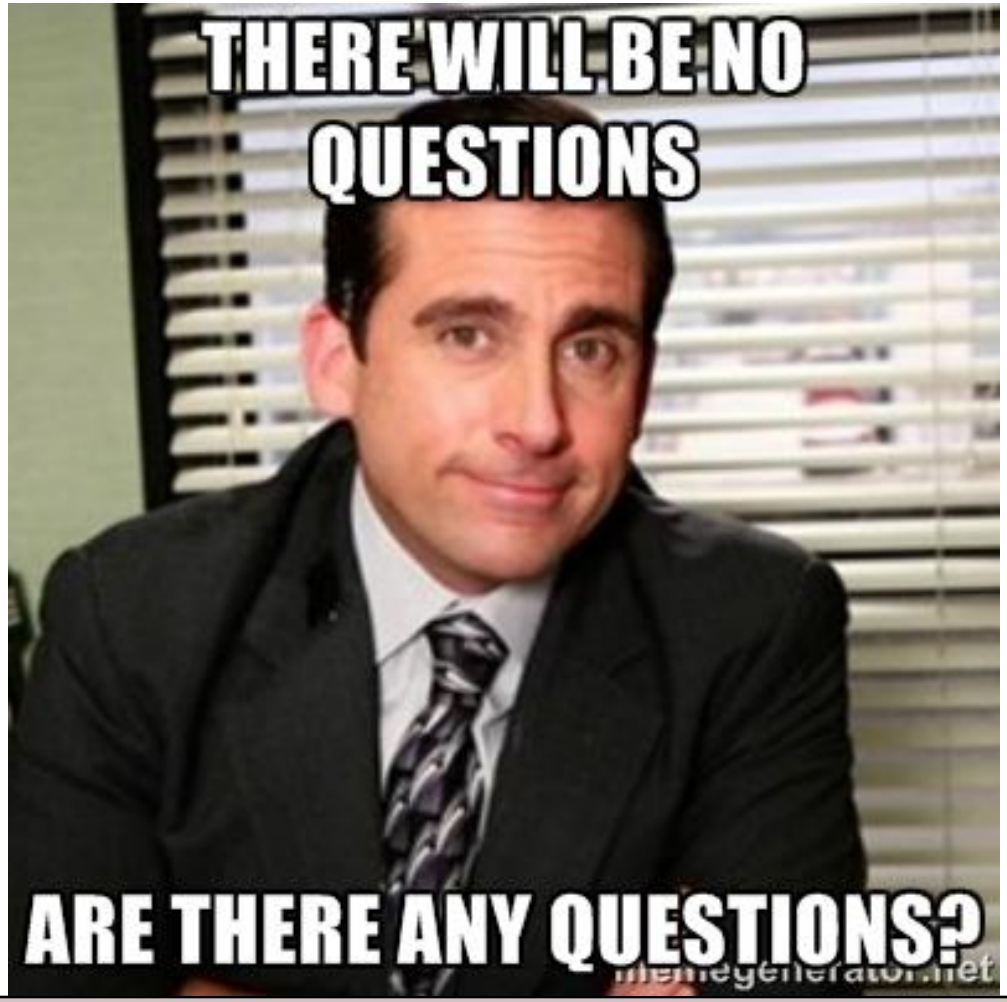
"Loudspeaker." *Wikipedia*. Wikimedia Foundation, n.d. Web. 07 Dec. 2016. Equations of directionality and acoustic impedance

Nema, Nakul. "Ultrasonic Directive Speaker." *Scribd*. Scribd, 14 Apr. 2012. Web. 06 Dec. 2016. Detailed article explaining the science and technology behind ultrasonic directional speakers

"PRODUCTS." *Audio Spotlight Directional Sound Speaker Technology - Holosonics*. N.p., n.d. Web. 04 Dec. 2016.

Openface Issues, Github.com, https://github.com/cmusatyalab/openface/issues/157

# Questions



# Backup Slides

# Mathematics of Secondary Waves

$$\nabla^2 p_s - \frac{1}{c_0^2}\frac{\partial^2 p_s}{\partial t^2} = -\rho\frac{\partial q}{\partial t}$$

$\rho$ : density of fluid, $T_{ij}$: stress tensor,

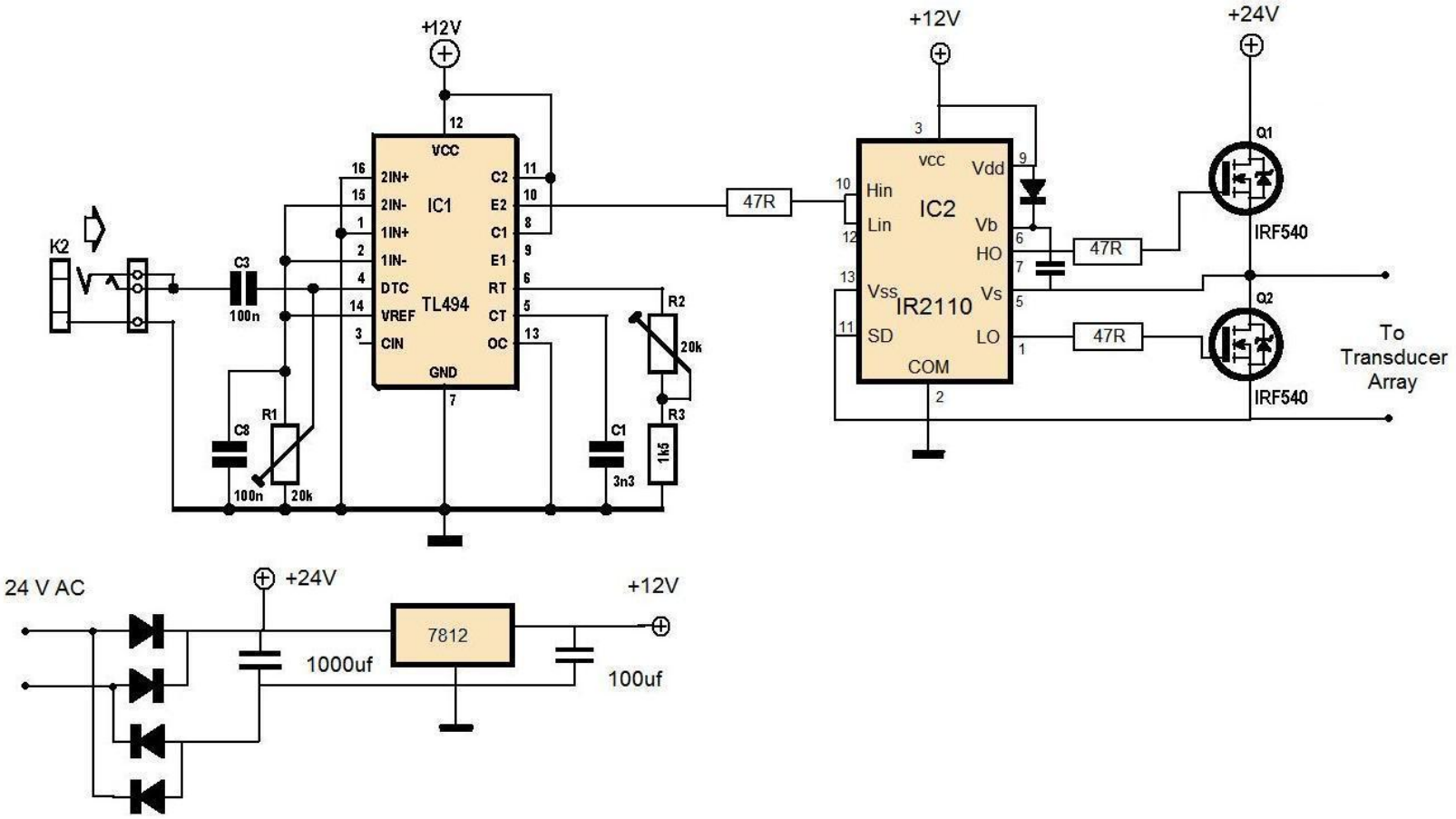
$p_s$ is the secondary wave sound pressure, $p_1$ is the primary wave sound pressure, $\beta$ is the nonlinear fluid parameter, and $c_o$ is the small signal sound velocity.

The solution for Eq. (2.2) may be expressed by the superposition integral of the Green's function and the virtual second source [right side of Eq. (2.2)] as shown in Eq. (2.4).

$$p_s = \frac{\rho}{4\pi}\iiint_v \frac{1}{|r-r'|}\frac{\partial}{\partial t} q\left(rt - \frac{|r-r'|}{c_0}\right) dr'$$

Where r is the observation point position vector, r' is the source position vector and v is the nonlinear interaction space.

# Ultrasonic Directional Speaker Circuit



# MDR Deliverables

**Sound Spear:**

- Functioning amplifier and signal generator prototype capable of driving an ultrasonic waveform through a piezoelectric transducer

**Pegasus Turret:**

- Functioning turret with transducer array mounted

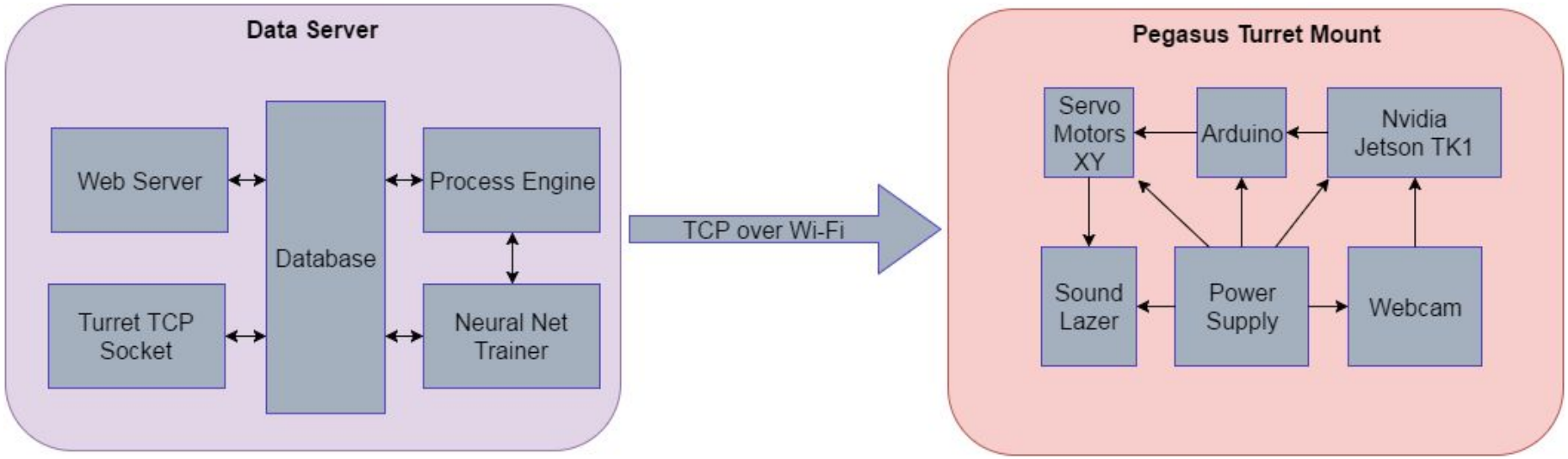
**iPhone App:**

- Version b.1.0
- Successfully sends pictures and preferences to the server

**Server Cluster:**

- Trains the neural net
- Protocols created to communicate with the app and turret

# Compacted System Overview



# How can it be done?

**Pegasus-21**