RUN, STEPHEN, RUN:
Shoot First, Ask Questions Later

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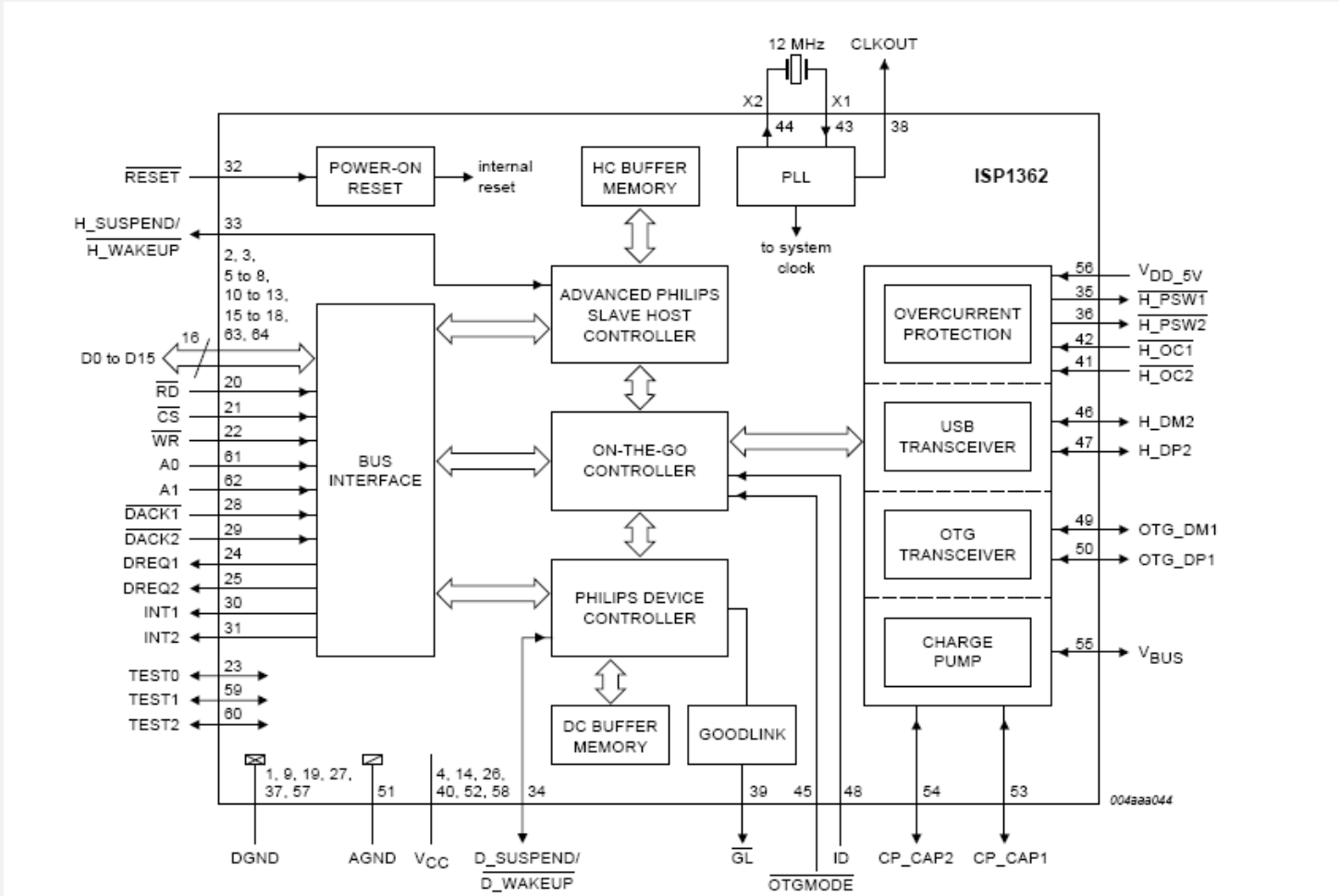
Goals:

- USB missile control
- RCA camera input
- Laser calibration and triangulation
- Laser targeting
- Ballistics determination
- VGA monitor view
- Termination

USB Control

Philips ISP1362 USB Controller



Commands by PC

Name	Value
0x01	Down
0x02	Up
0x04	Left
0x08	Right
0x10	Fire
0x40	Get Status
0x20	Stop
/	Reset

Responses by MCU

Byte	Byte 0							
bit	7	6	5	4	3	2	1	0
Meaning	/	/	/	Fired	Right Limit	Left Limit	Up Limit	Down Limit

USB Descriptor Information

Name	Value
Vendor ID	0x0A81
Product ID	0x0701
Manufacturer String	Rocket Baby
Product String	Rocket Baby
Version	1
Serial Number	/

Endpoint Descriptor

```
Bus 005 Device 002: ID 0a81:0701 Chesen Electronics Corp.
Device Descriptor:
 bLength                18
 bDescriptorType         1
 bcdUSB               1.10
 bDeviceClass            0 (Defined at Interface level)
 bDeviceSubClass         0
 bDeviceProtocol         0
 bMaxPacketSize0         8
 idVendor           0x0a81 Chesen Electronics Corp.
 idProduct          0x0701
 bcdDevice            0.01
 iManufacturer           1 Dream Link
 iProduct                2 USB Missile Launcher v1.0
 iSerial                 0
 bNumConfigurations      1
 Configuration Descriptor:
  bLength                9
  bDescriptorType        2
  wTotalLength          34
  bNumInterfaces         1
  bConfigurationValue    1
  iConfiguration         0
  bmAttributes        0xa0
    (Bus Powered)
    Remote Wakeup
MaxPower              100mA
  Interface Descriptor:
    bLength              9
    bDescriptorType      4
    bInterfaceNumber     0
    bAlternateSetting    0
    bNumEndpoints        1
    bInterfaceClass      3 Human Interface Device
    bInterfaceSubClass   0 No Subclass
    bInterfaceProtocol   0 None
    iInterface           0
      HID Device Descriptor:
        bLength             9
        bDescriptorType    33
        bcdHID           1.00
        bCountryCode        0 Not supported
        bNumDescriptors     1
        bDescriptorType    34 Report
        wDescriptorLength  52
        Report Descriptors:
          ** UNAVAILABLE **
      Endpoint Descriptor:
        bLength             7
        bDescriptorType
        bEndpointAddress    0x81  EP 1 IN
        bmAttributes        3
          Transfer Type          Interrupt
          Synch Type             None
          Usage Type             Data
        wMaxPacketSize     0x0001  1x 1 bytes
        bInterval           20
Device Status:     0x0000
 (Bus Powered)
```

Lasers

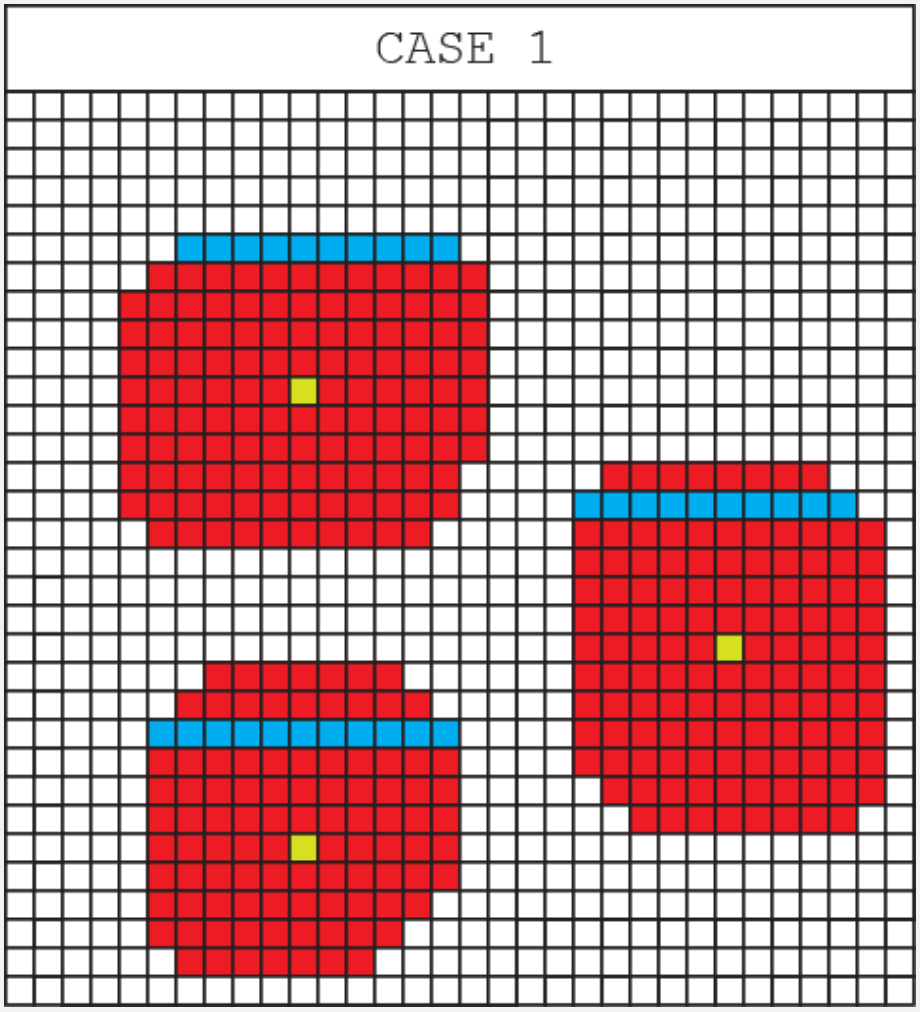
Laser Dot-Finding

- Must recognize multiple (3)

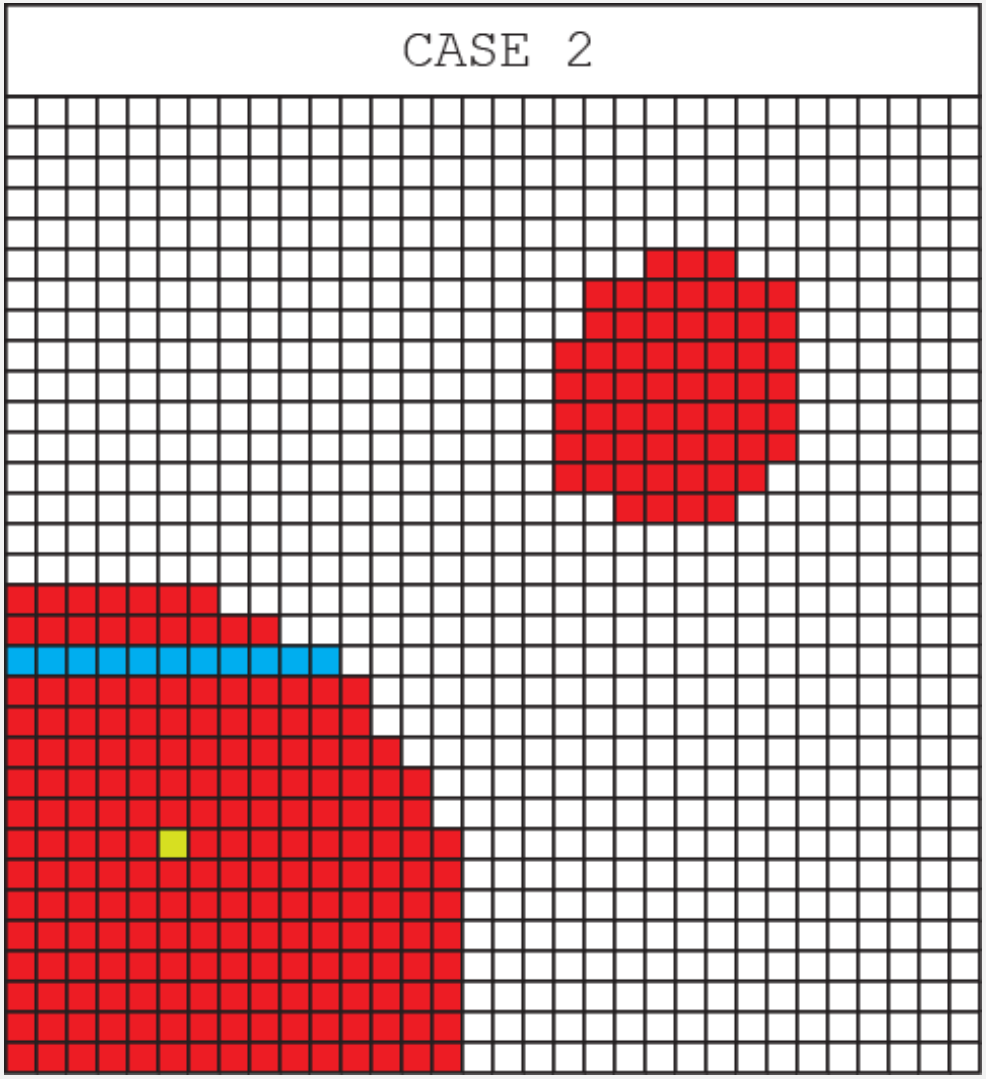
  laser dots
- Must ignore larger sources of light in the frame
- Must operate on a row by row basis

Laser Dot-Finding

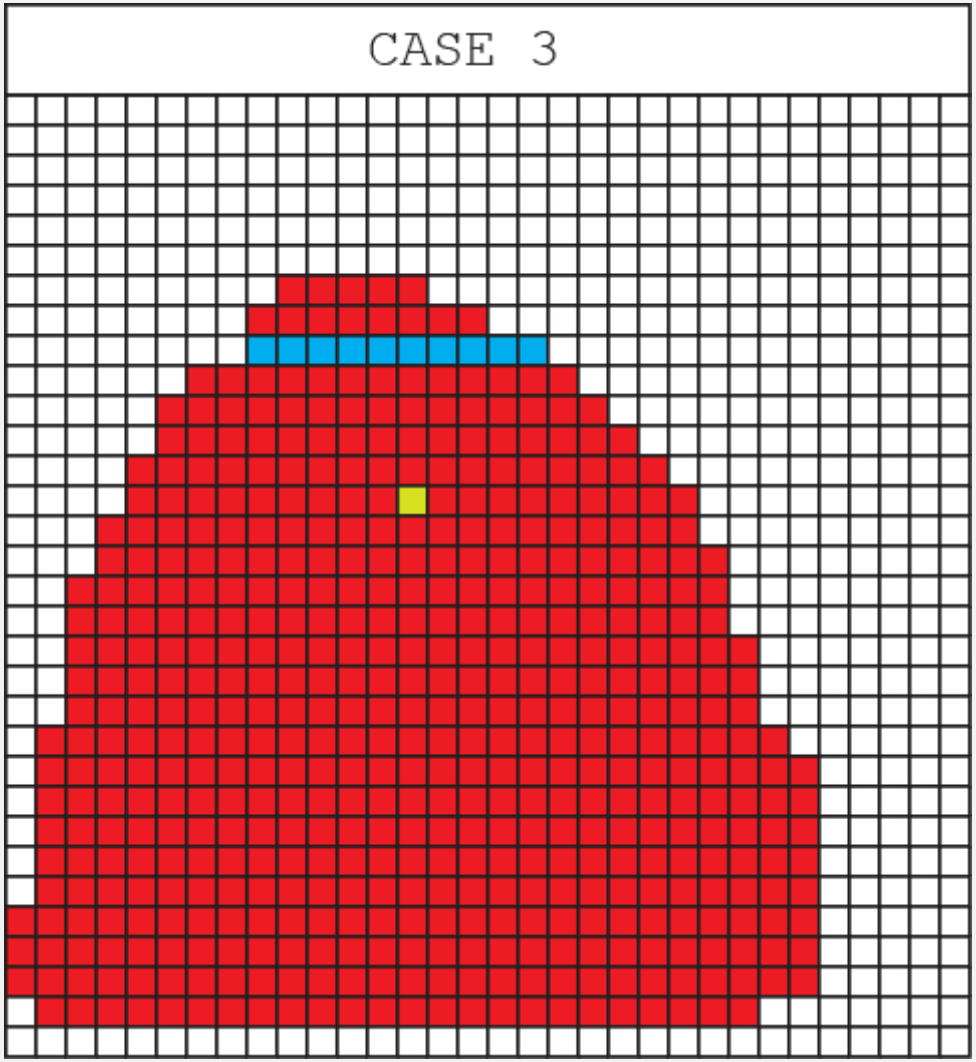
Case 1



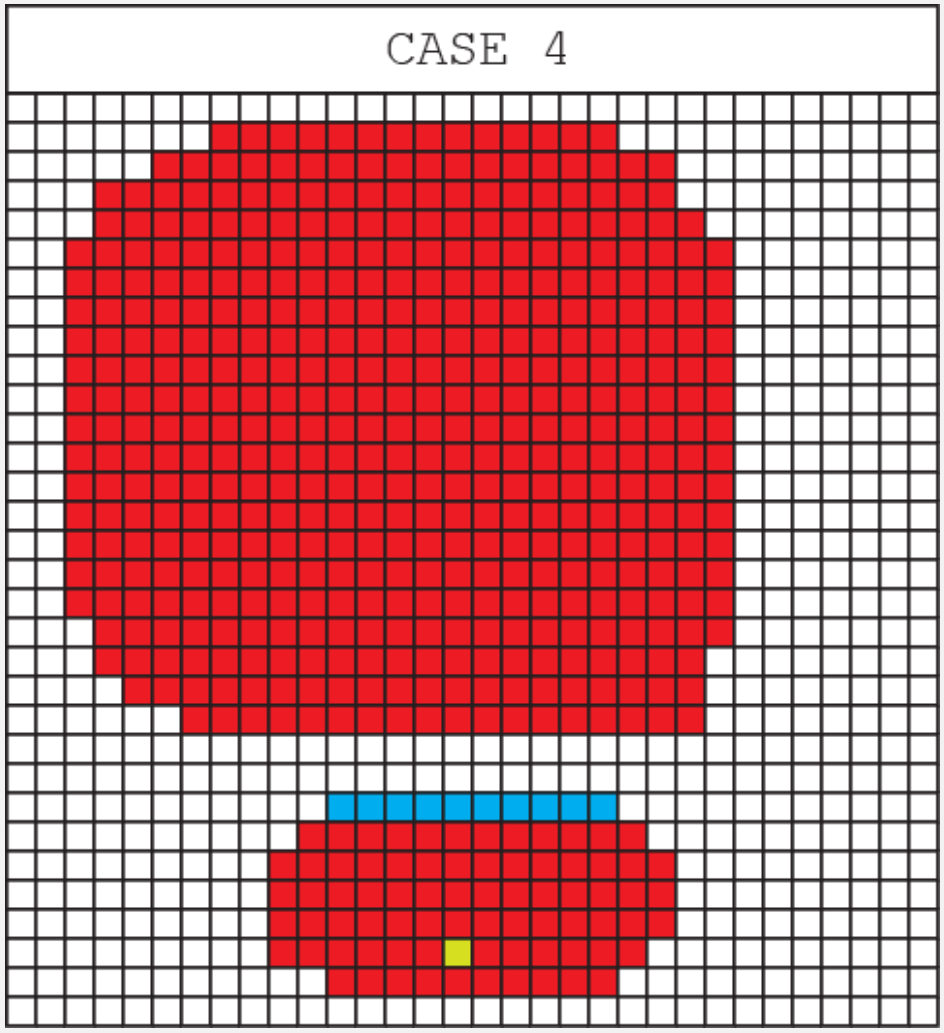
Case 2



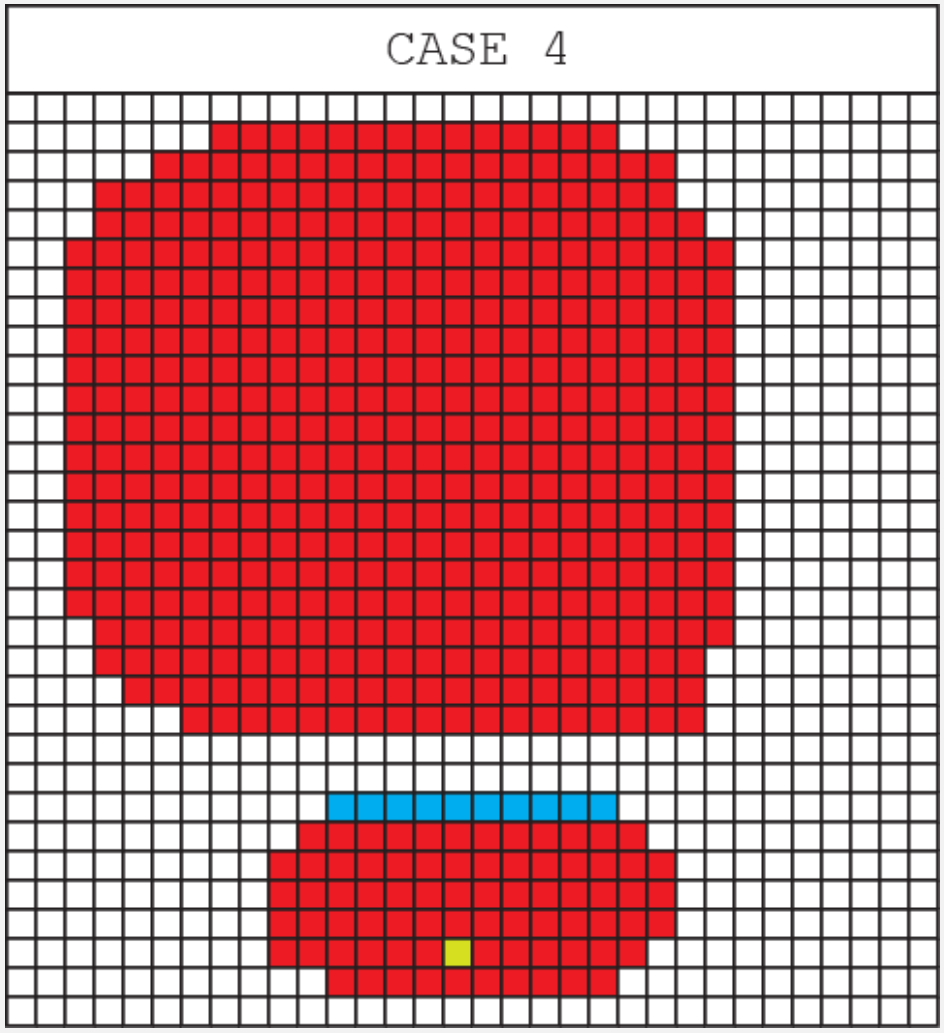
Case 3



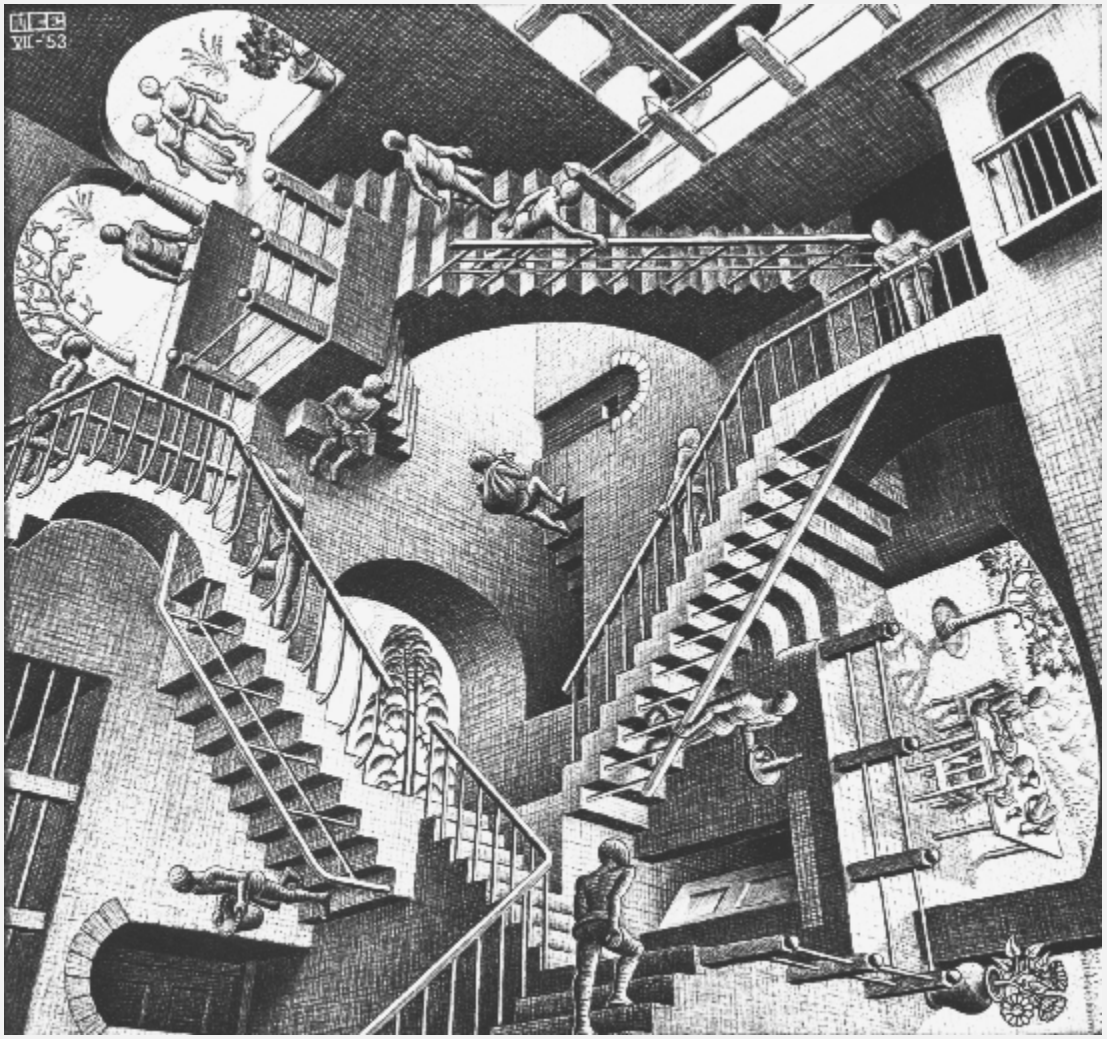
Case 4



Case 4



An Issue of Perspective - Rangefinding



The problem

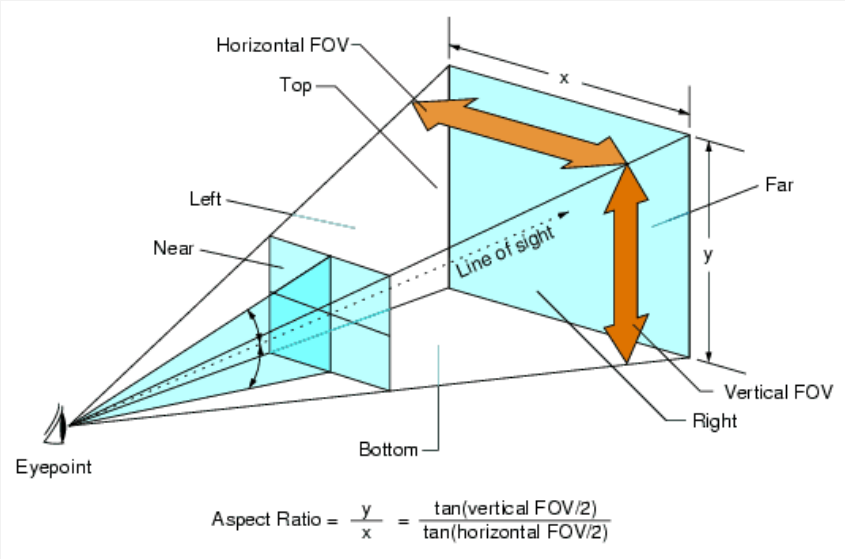
- The camera sees a 3D environment projected onto the CCD film plane
- Without any depth perception, how do we determine how far away the target is?
  - Catching a football with one eye closed

The solution

- Many options
  - Echolocation, stereoscopic vision, etc.
- Decided on a laser projection
  - Cheap to implement
  - Hardware has a more pronounced effect on the feasibility of the system compared to other alternatives
    - Threshold and RGB truncation/filtering

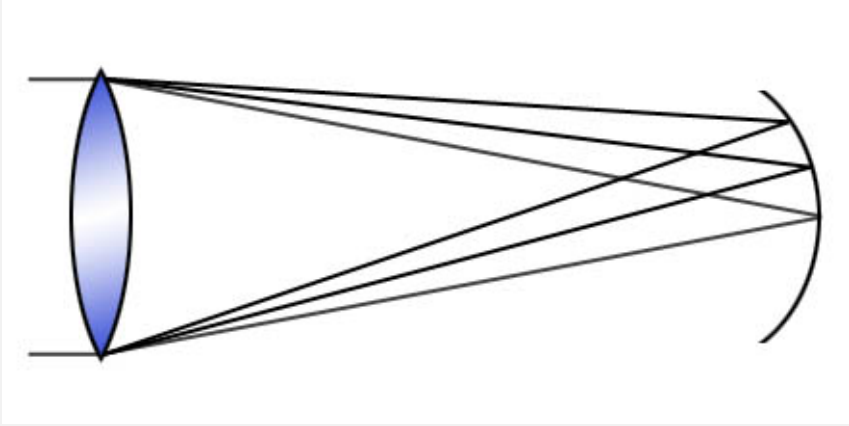
The concrete solution

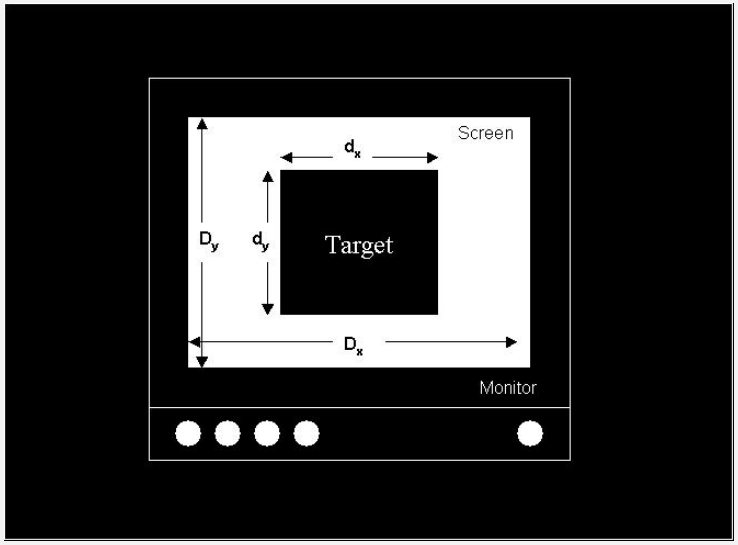
- Take two lasers, *a known distance apart*, and project onto a wall
  - The perceived distance decreases as the camera is moved to and from the wall
- In fancier terms, the angle subtended by the line formed by the laser points scales depending on the **length** and **Field of View (FOV)**

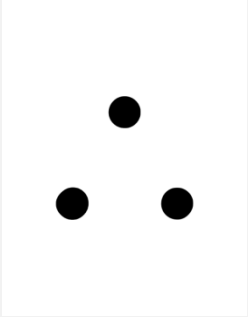


Assumptions

- Ignores the effect of field curvature
  - Increased error near the edges of the image
- There is **linear scaling** between the object's angle and the **distance subtended in pixel space**
- The FOV only encapsulates the flat wall
- **The camera line of sight and the laser beams are all perpendicular**







- Calculate the ratio of the horizontal pixel distance between the dots over the entire CCD width; this is proportional to the angle subtended

$$\frac{d_x}{W_{CCD}} = \frac{\beta}{FOV}$$

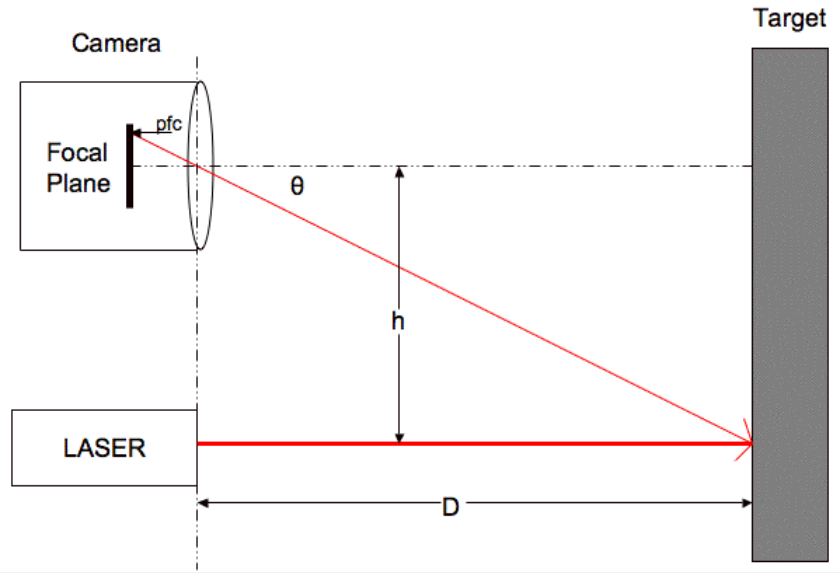
- This angle relates the **known length** of the dots in real-world measurements to the real distance **from the camera**

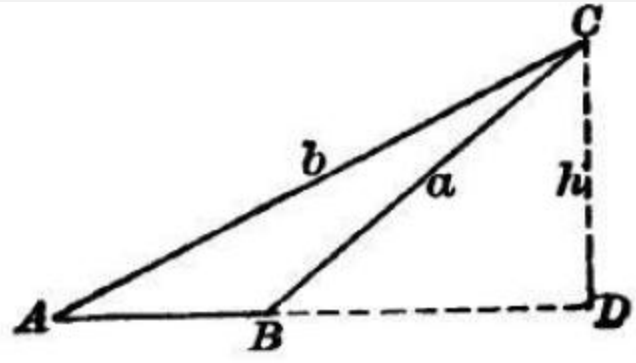
$$\frac{L_{laser}}{2D_{wall}} = \tan\frac{\beta}{2}$$

Robustness

- Notice that the final equation involves β/2, implying that **only one off-center (from the camera LOS) laser is required**

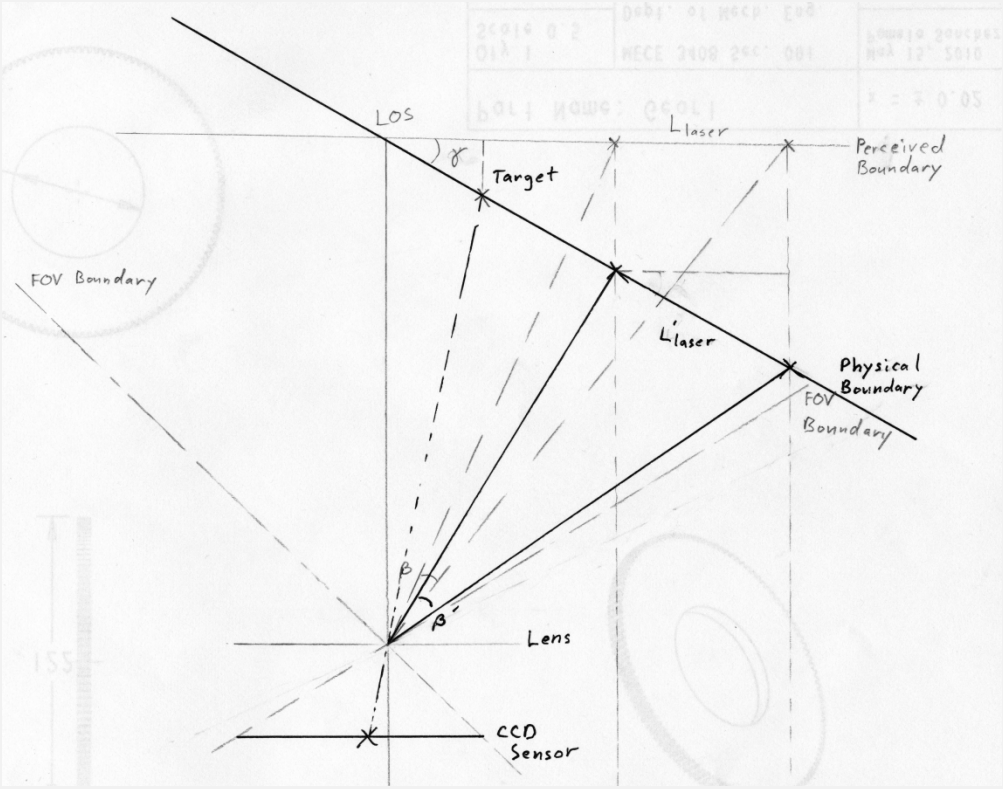
- In fact, for any horizontal displacement of the camera or launcher (adhering to prior assumptions) , using two points is redundant
- Discovered trying to determine the height of the FOV independent of the width





Complicating the Problem - Angular Displacement

- Simplify the problem by superimposing an physical boundary on top of the existing coordinate system
  - Can be viewed as a rotation of the coordinate system (formed by the depth and length) by an angle γ
  - Assumed valid given that the vision is from the perspective of the camera
- The new projection of the length is scaled by sec(γ)



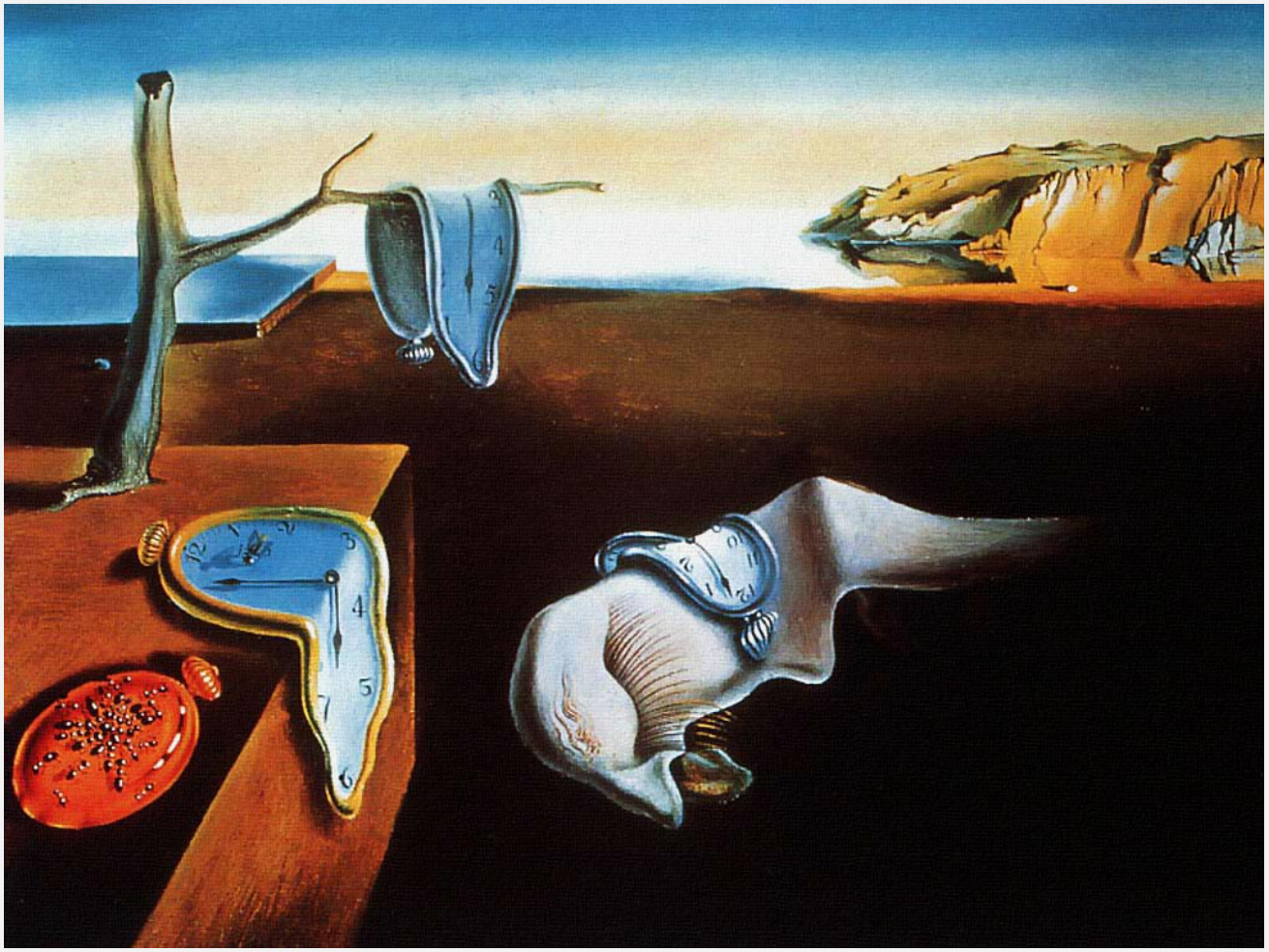
Angular Displacement - Consequences

- Can implement correction factor with **prior knowledge of γ** (not feasible in practice
- The length now varies across the field, and must be corrected

$$\begin{pmatrix} \cos\gamma & -\sin\gamma \\ \sin\gamma & \cos\gamma \end{pmatrix} \begin{pmatrix} W \\ D \end{pmatrix} = \begin{pmatrix} W_{corr} \\ D_{corr} \end{pmatrix}$$

- The field curvature becomes warped and the approximated linear β-L_{laser} relationship breaks down
- In short: without the “anchor” of knowing the real distance between the laser dots in pixel space, the problem becomes unconstrained

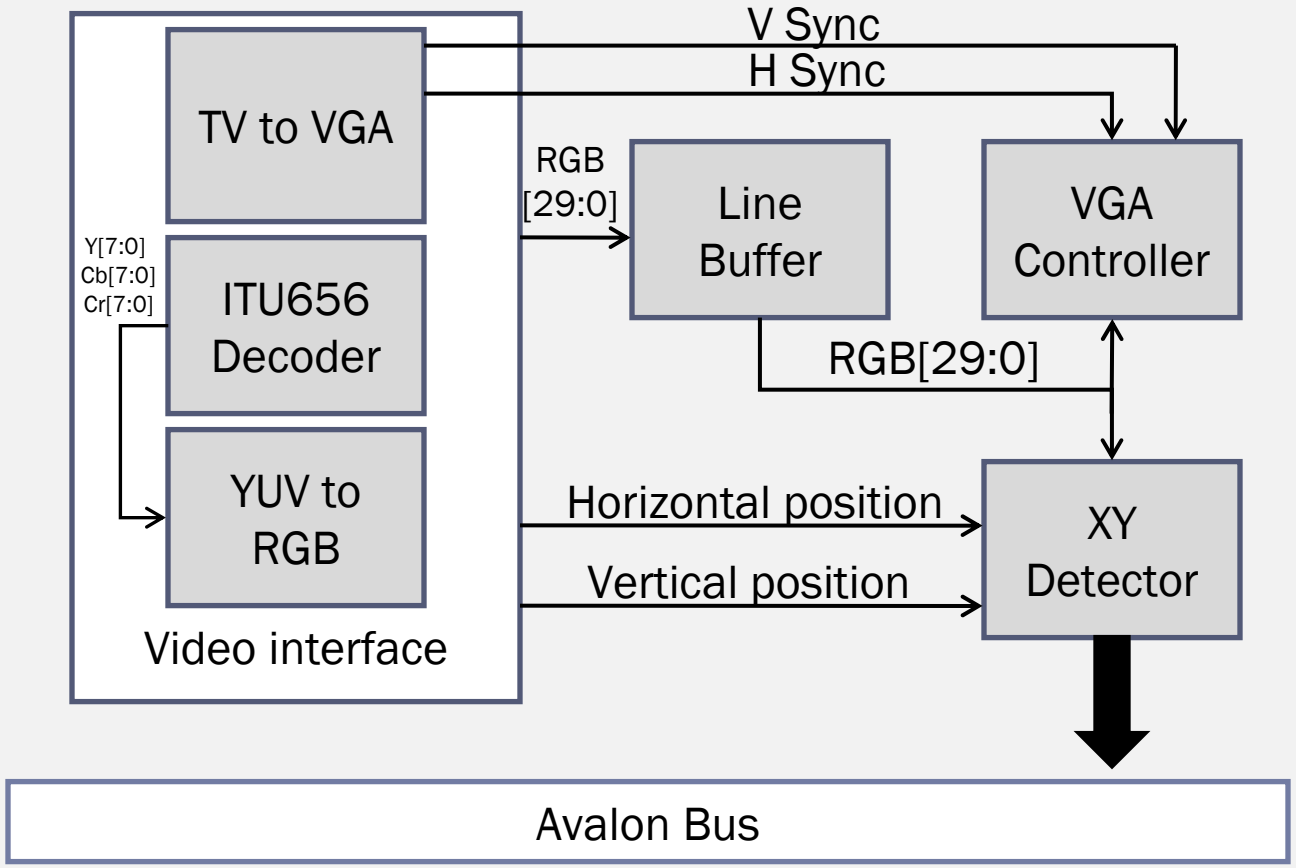
The Persistence of Vision



Video Input

Spec	VGA	NTSC
Horizontal Refresh Rate	31.469 kHz	15.75kHz
Vertical Refresh Rate	59.94 Hz	60 Hz

Video Module Block Diagram



Lessons Learned:

- When inconsistently manufactured projectiles are used, each must have a unique set of projectile constants and expectations.
- Lasers are an excellent distinguishing feature in a frame of otherwise ambient light.
- Code from outside projects is not a reliable source.
- Buy extras when structuring a project around plastic toys.
- Proprietary USB protocols are difficult to reverse engineer.