

I PRO 324

**Enhancing the Functionality of Residential
Garage Door Operator Using CCD Camera Technology**

Industry Accident Statistics

1. Since 1990, an average of 20,000 people each year have been treated in hospital emergency rooms for injuries related to garage doors. (U.S. Consumer Products Safety Commission)
2. Sixty children under the age of 14 have been trapped and killed under automatic garage doors since March 1982. (U.S. Consumer Product Safety Commission)
3. Children accounted for approximately 15 percent of the total 22,431 garage door related injuries reported from January 1982 to December 1985. (U.S. Consumer Product Safety Commission)

Evolving UL Standards

- 1st Ed. (1973): 2 second reversal off 2” obstruction
- 2nd Ed. (1979): 30 second reversal off 2” compressible obstruction
- 3rd Ed. (1991): 30 second reversal off 1” compressible detection with external entrapment sensor

Purpose

- ❖ Chamberlain is investigating alternative sensors in an ongoing effort to improve their product line
- ❖ Chamberlain has commissioned us to investigate the feasibility of replacing their current infrared (IR) emitter detector pair with a ~~CCD~~ Camera sensor

CMOS

Methodology

- Verified goals with Chamberlain
- Developed two theories
- Investigated approaches for feasibility
- Implemented comparison testing

Existing IR System

- ❖ Infrared beam is only 1 pixel wide
- ❖ Single beam runs less than 6 inches above the ground
- ❖ Obstacles can remain undetected if they do not break the beam
- ❖ Existing design can be improved

Enhancing the Current Design

- ❖ Increase the active scope of sensors
- ❖ Increase the reliability of obstruction detection
- ❖ Reduce the probability of damage/injury

Current Standards and Regulations

- ❖ Door **MUST** reverse upon encountering an obstacle (50 cycles test)
- ❖ Local conditions set to most hostile
- ❖ Additional tests depending on complexity of garage door

Current Standards and Regulations

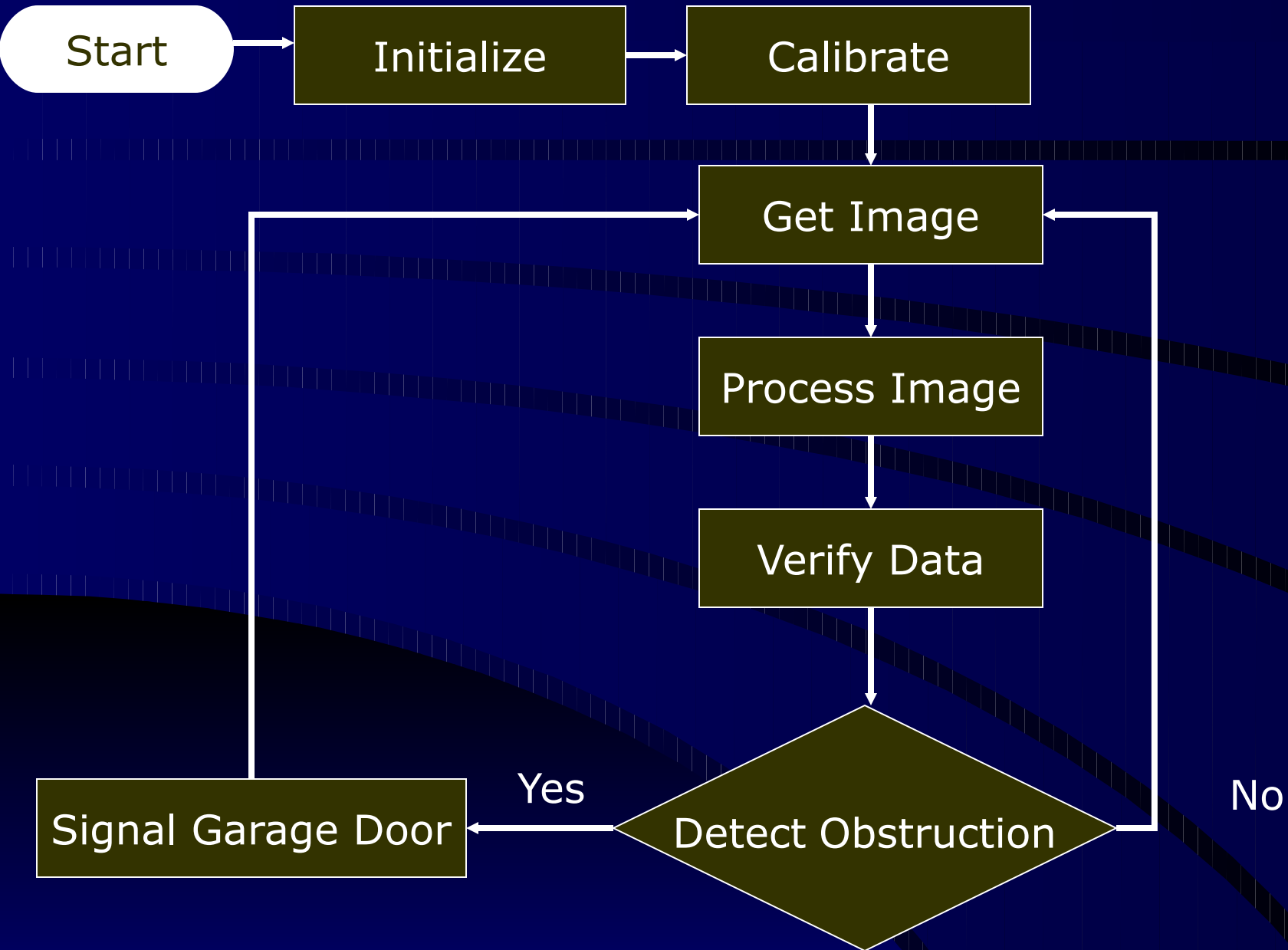
- ❖ Reversal of door
 - ❖ Must return to upper most location
 - ❖ Must stop

- ❖ Door movement monitored at increments no greater than 1 inch

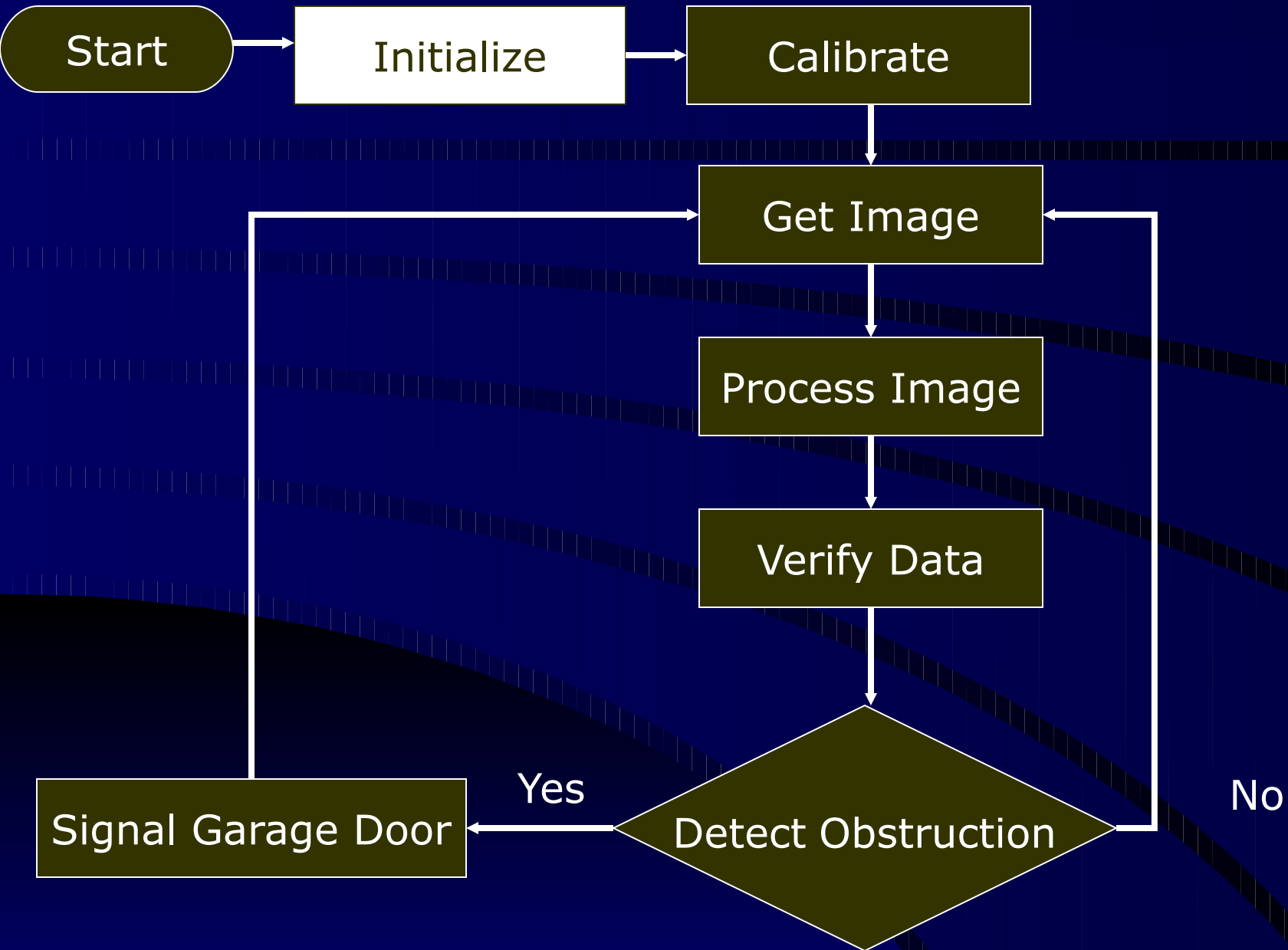
User Needs and Requirements

- ❖ Must be SAFE
- ❖ Must be affordable
- ❖ Must be easy to setup & maintain
- ❖ Must be reliable

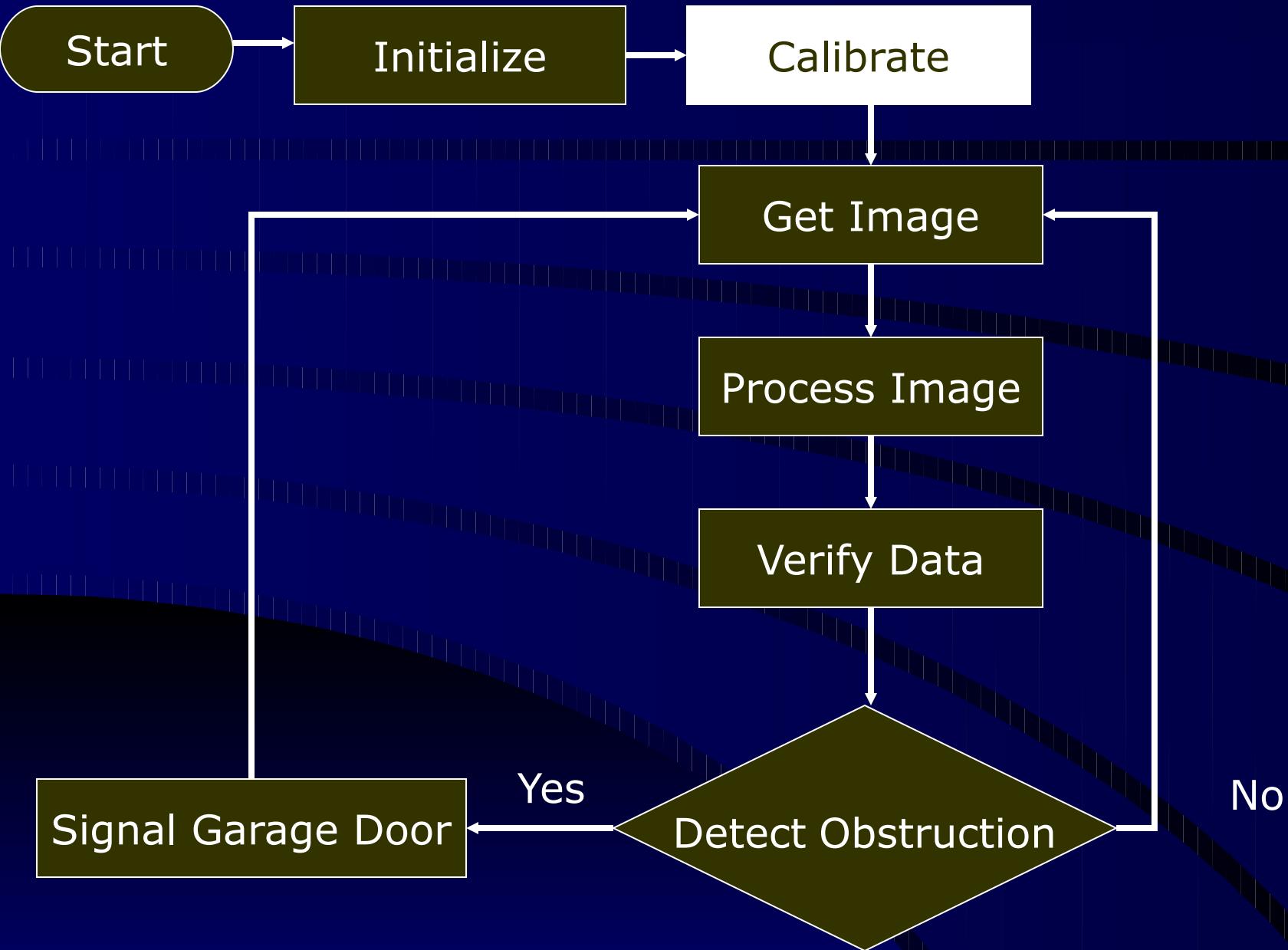
How it works



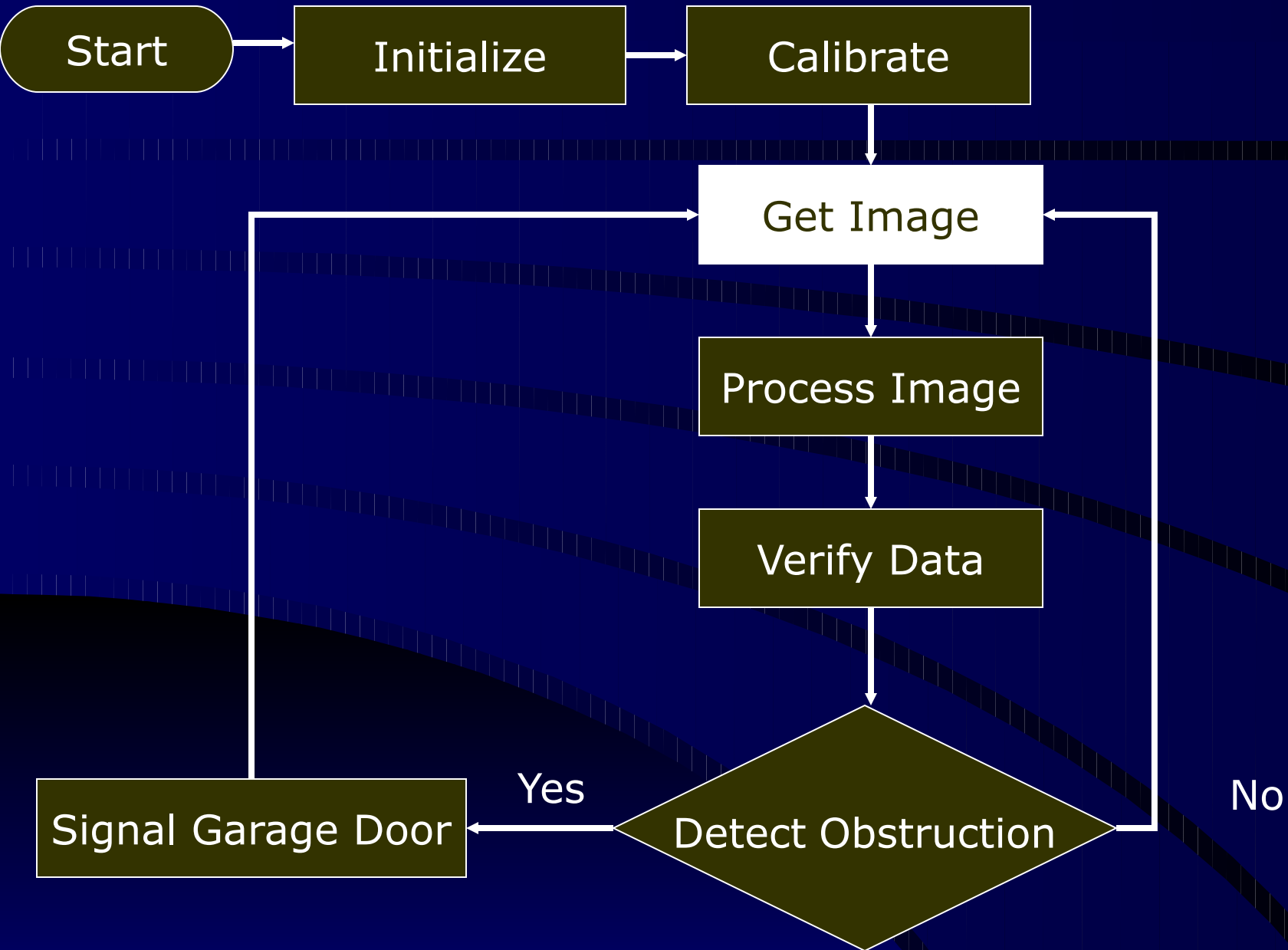
How it works



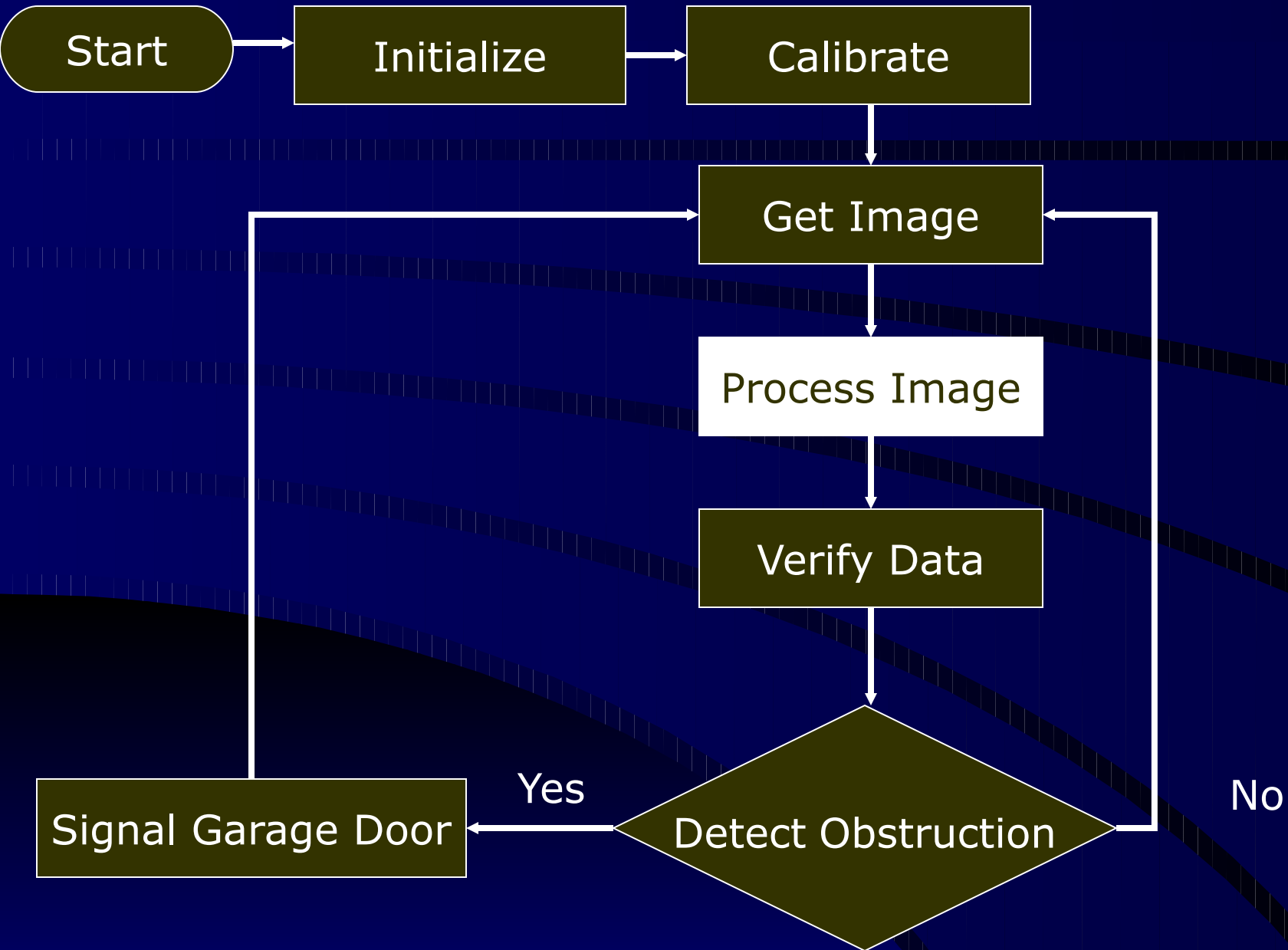
How it works



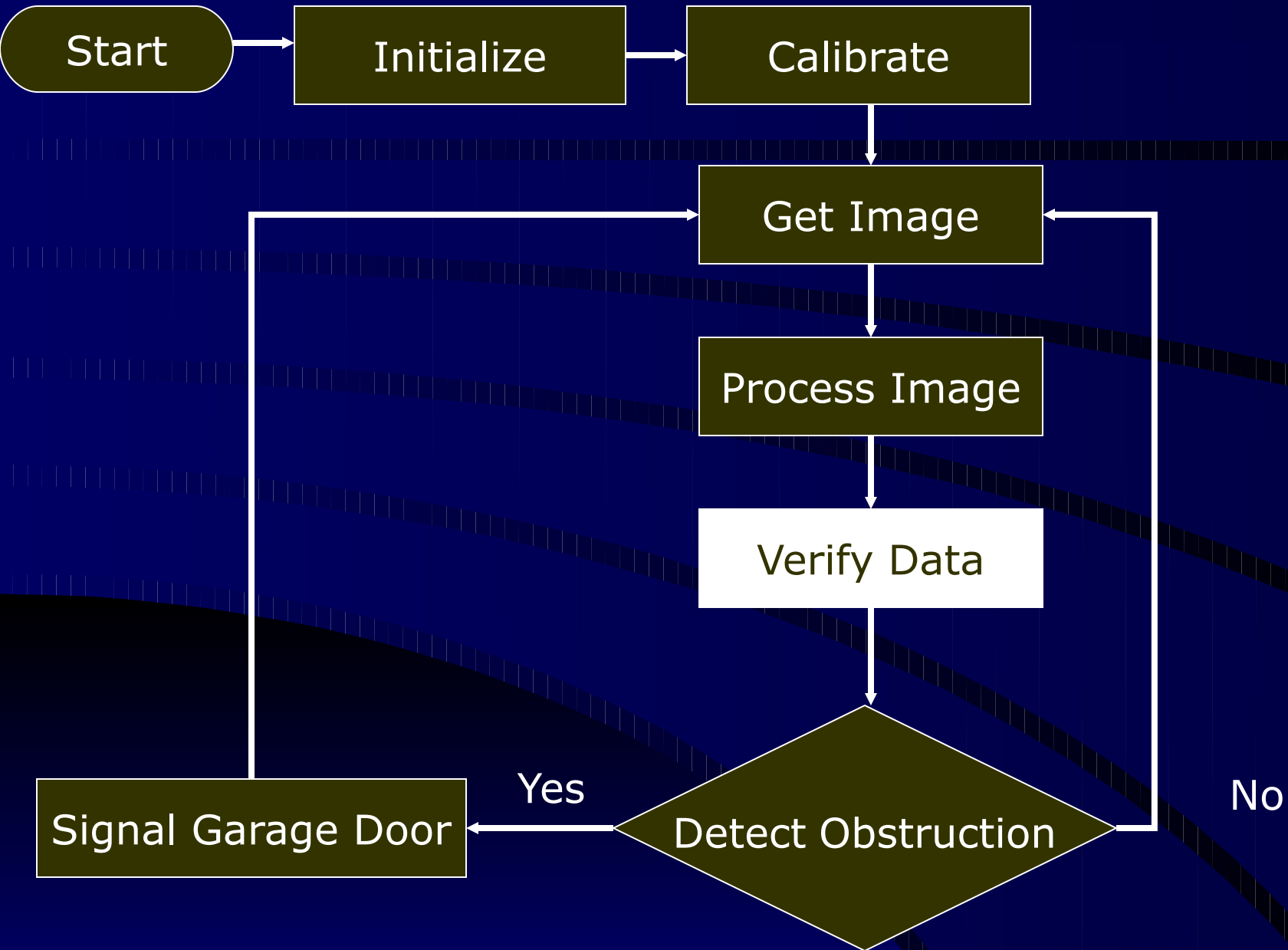
How it works



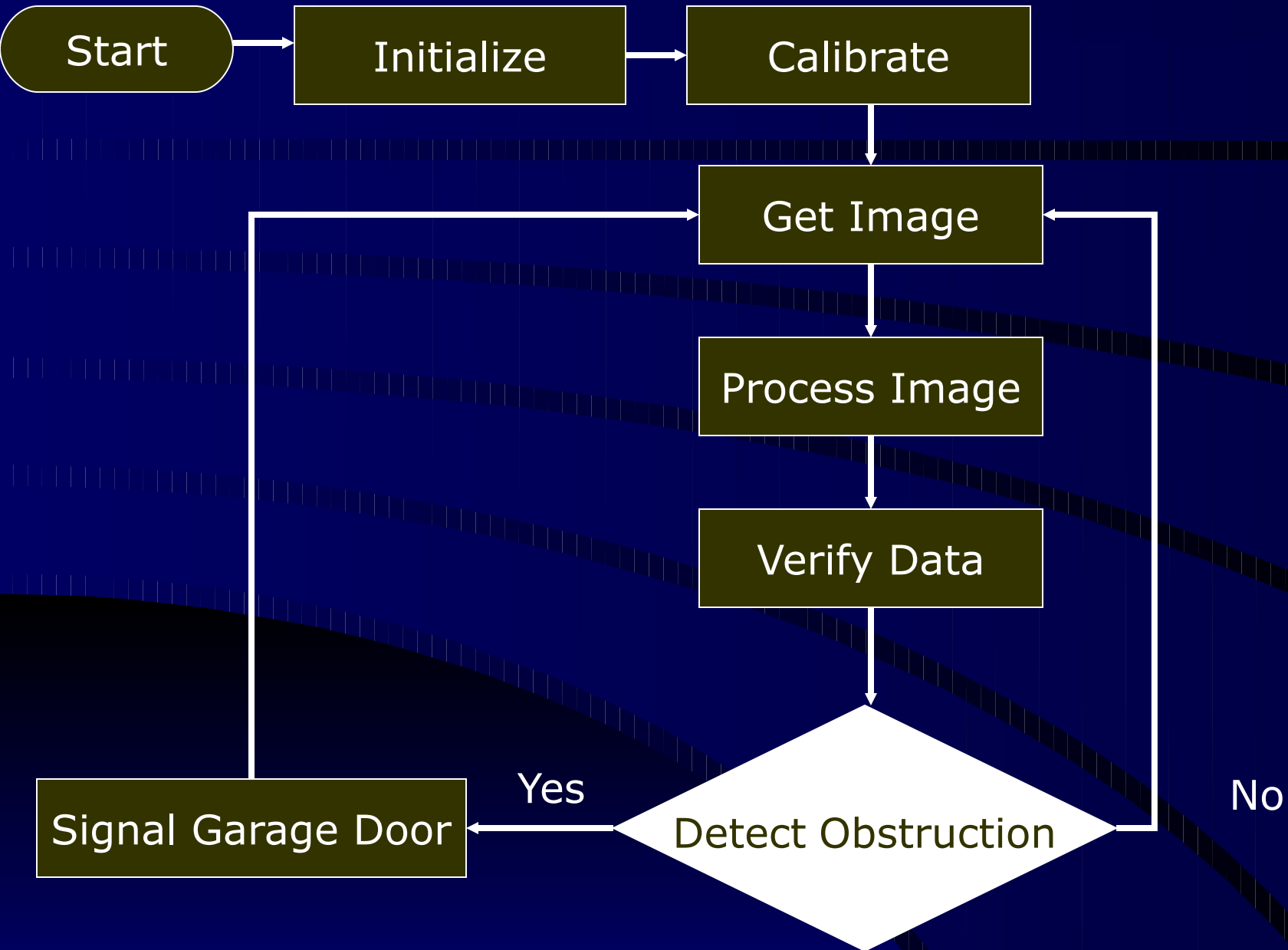
How it works



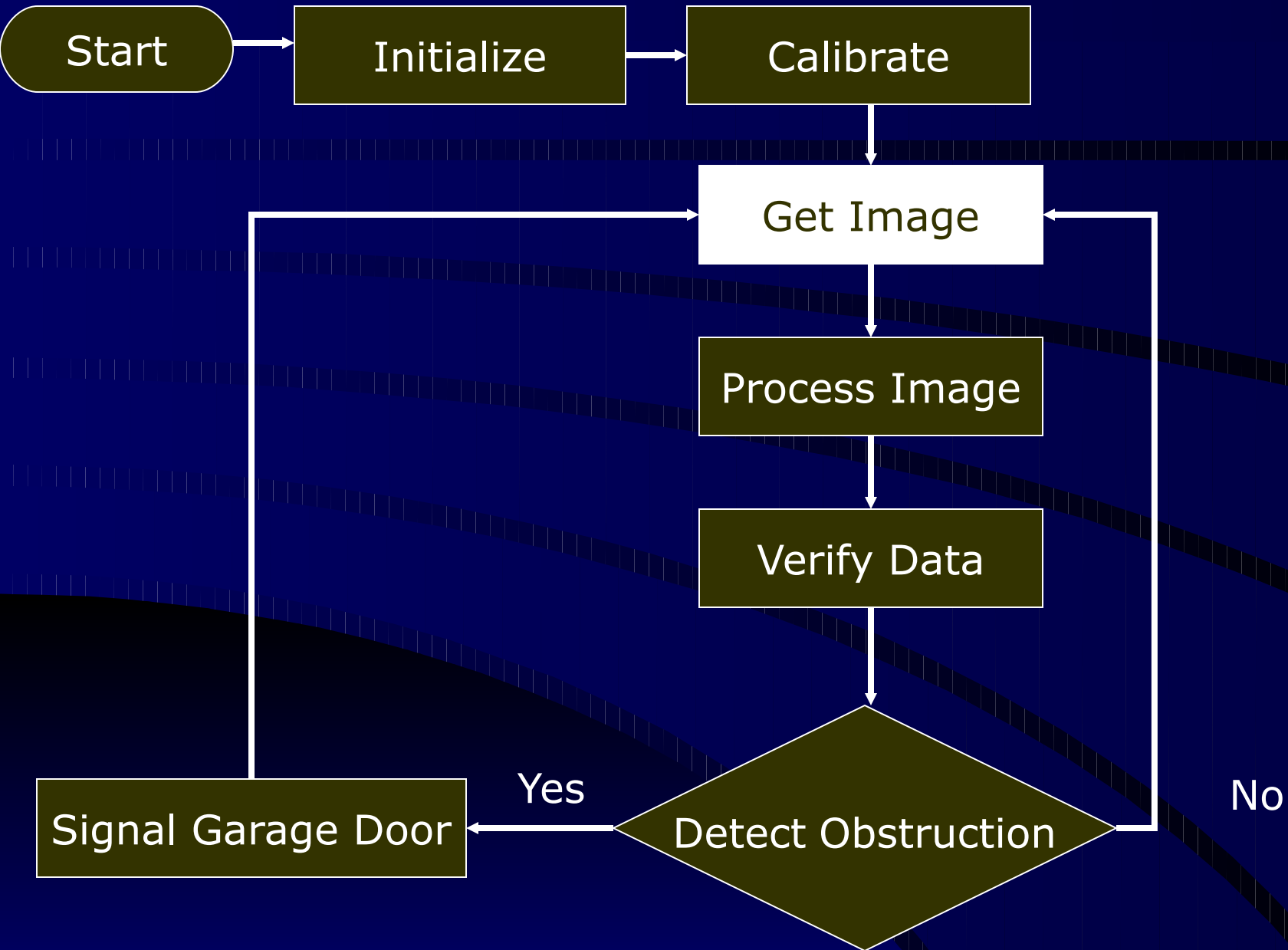
How it works



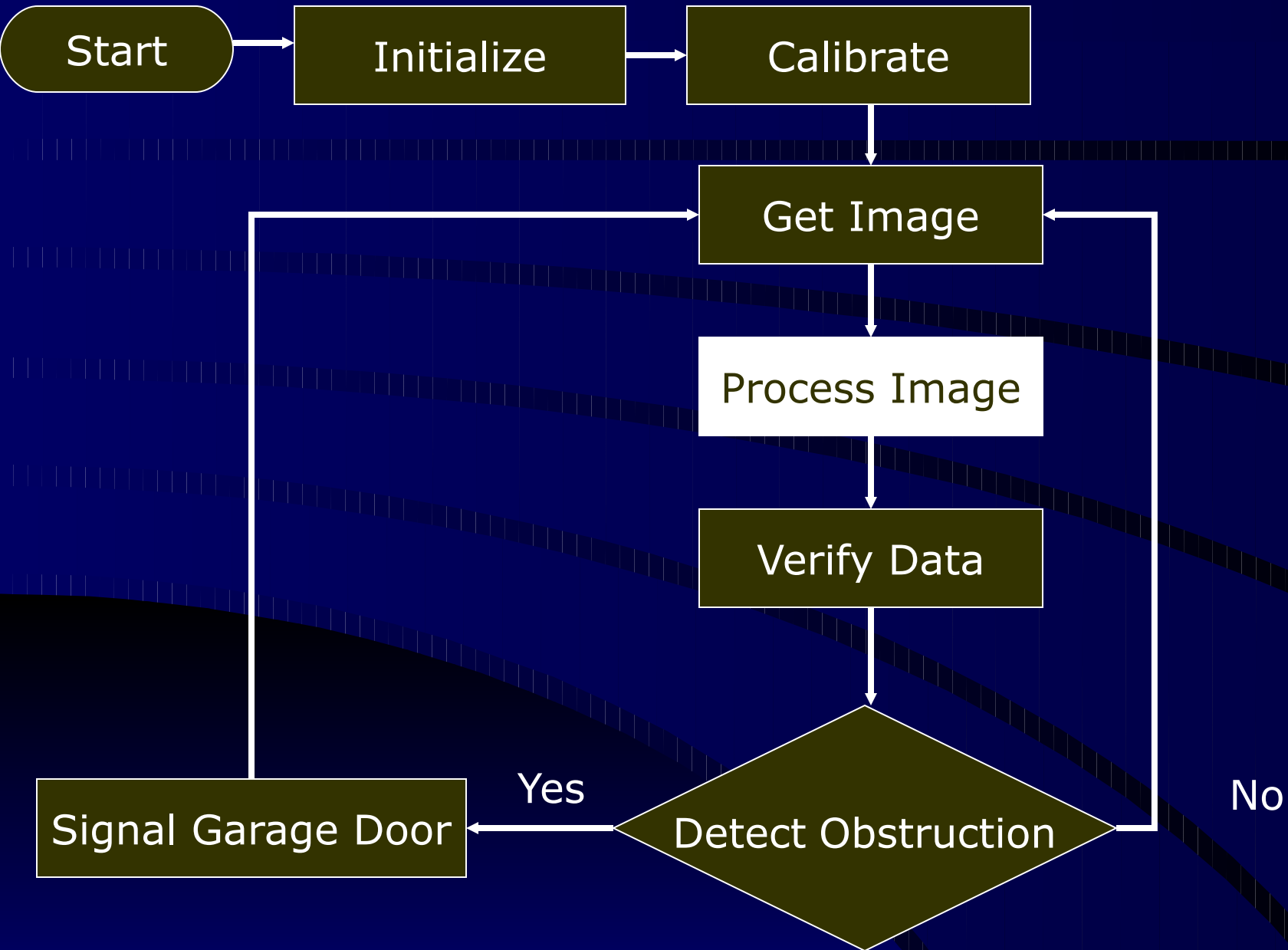
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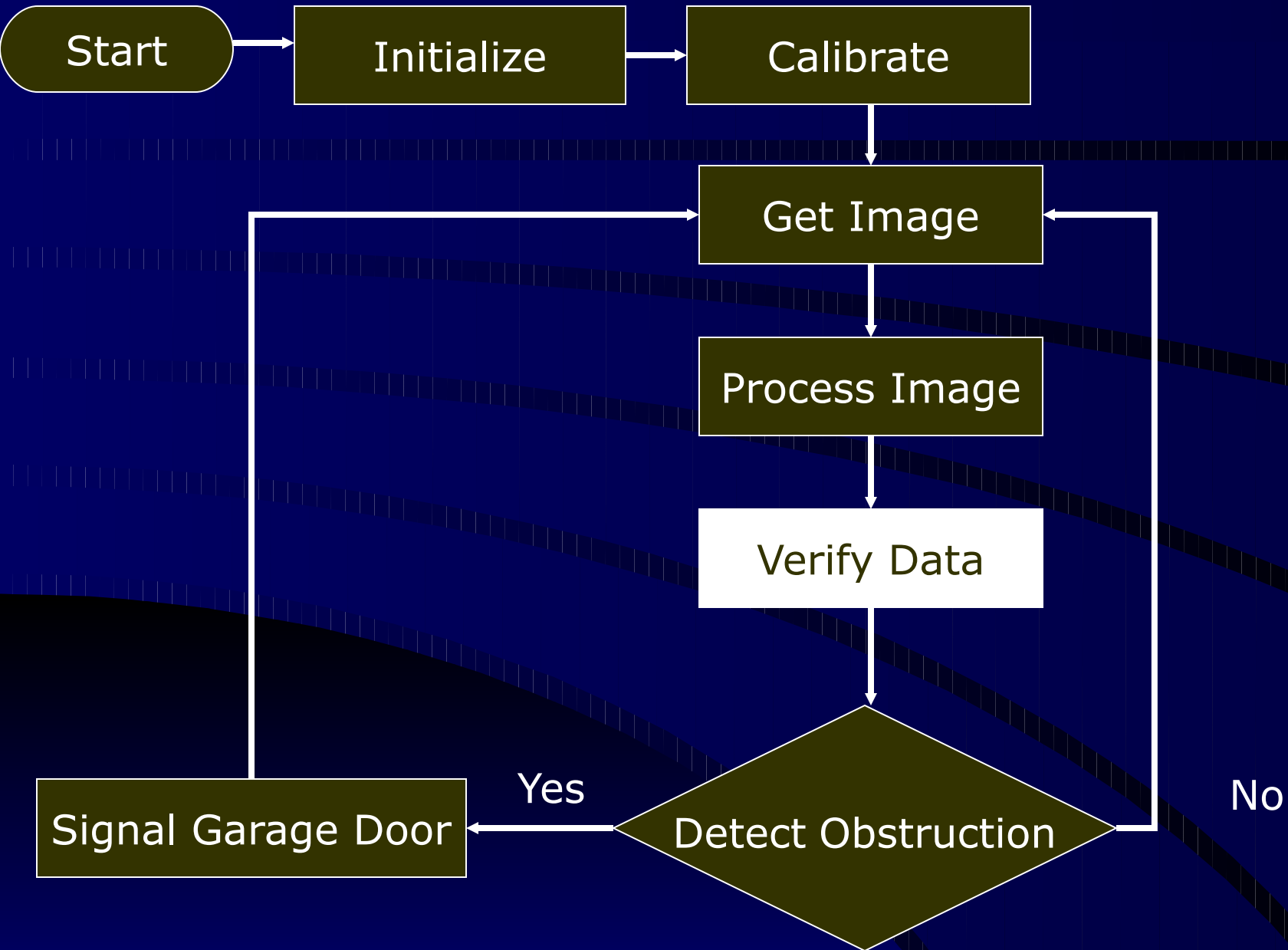
How it works



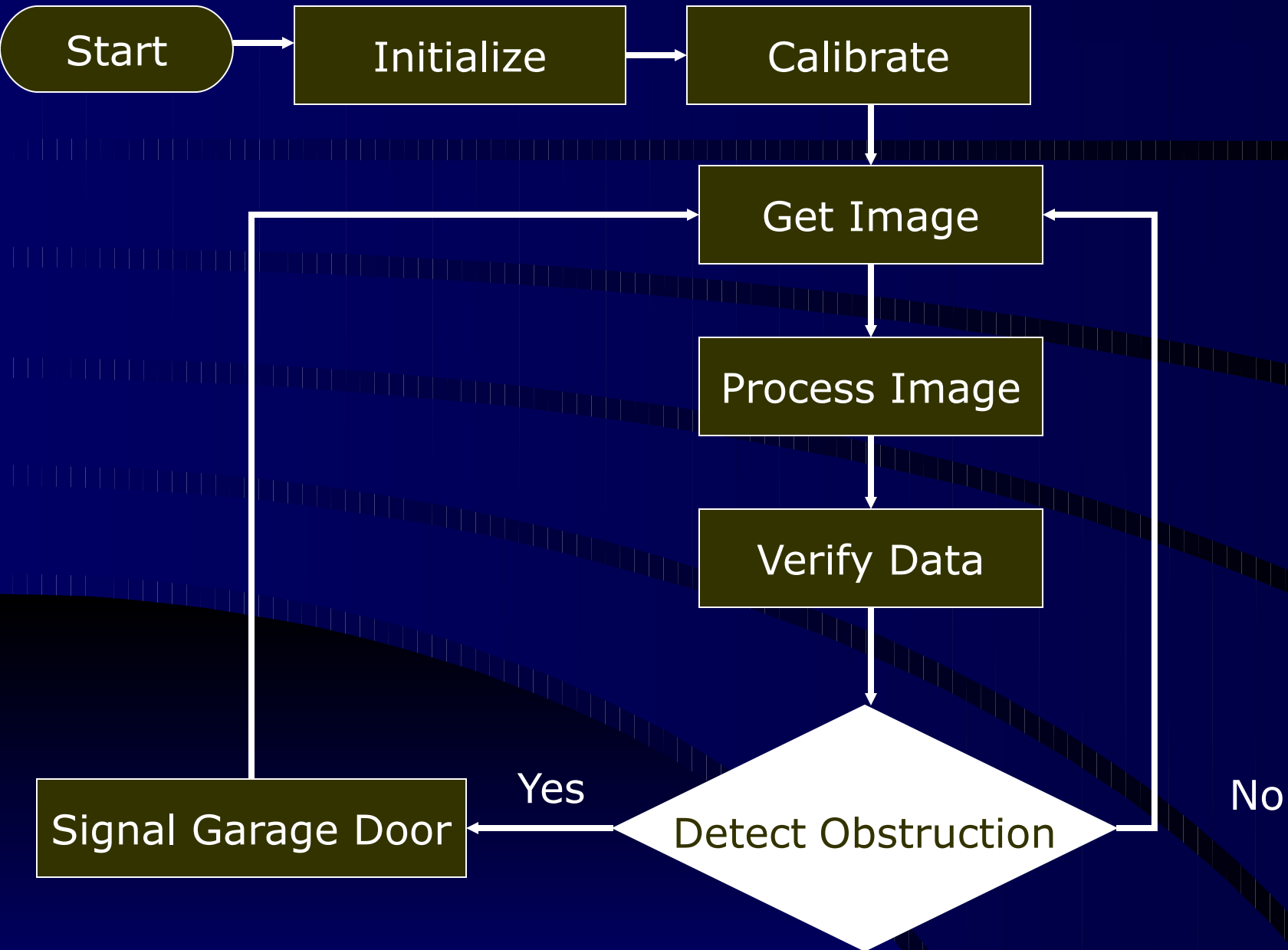
How it works



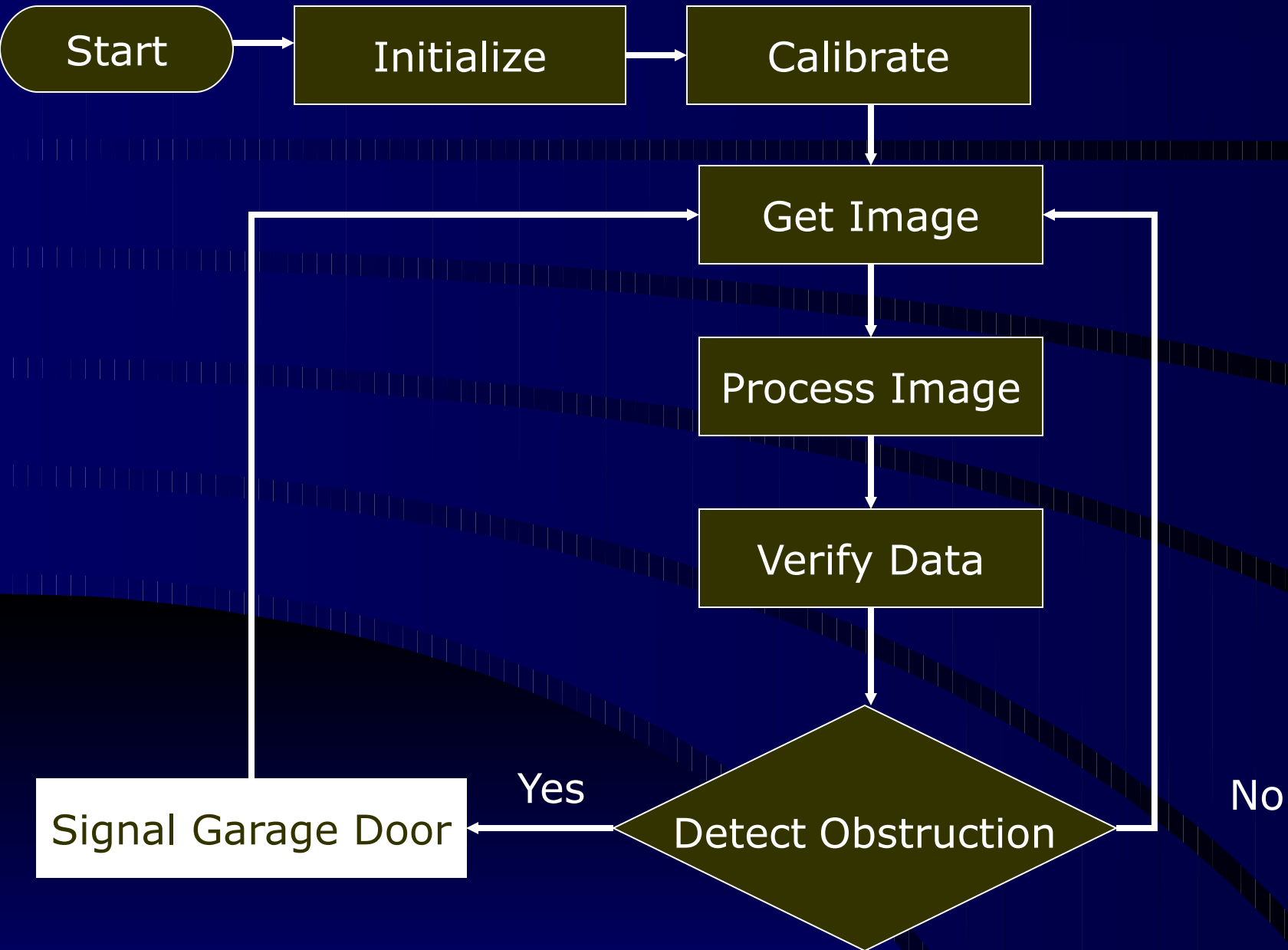
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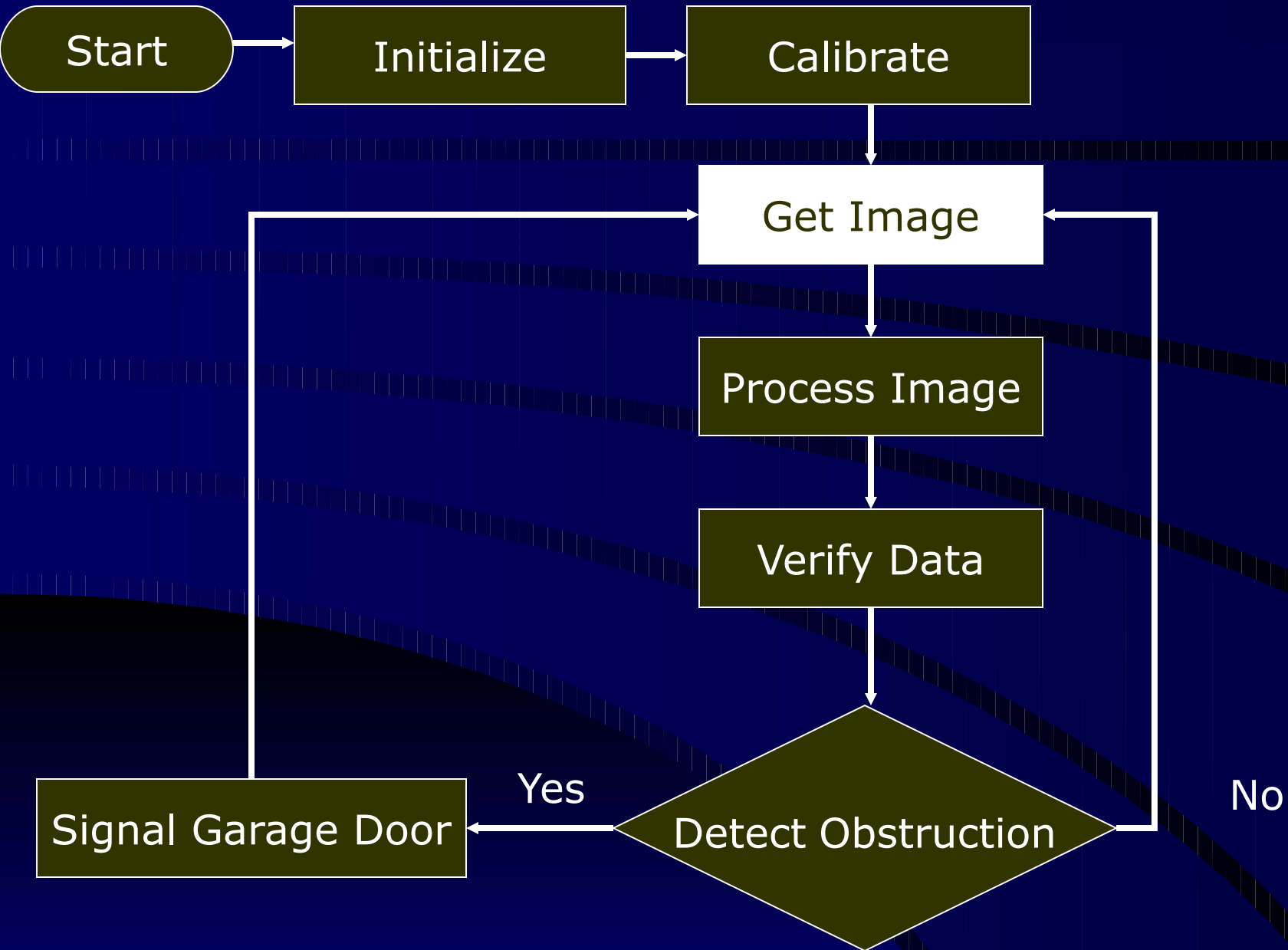
How it works



How it works



How it works



Obstruction Detection

Two Approaches

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graph TD; A[Two Approaches] --> B[Comparison Testing]; A --> C[Object Recognition];
```

Comparison Testing

Object Recognition

Comparison vs. Recognition

	Comparison	Recognition
Code Complexity	Simple	Very Complex
Feasibility	Relatively little development time	Large R&D effort
Cost	Moderate cost	High Cost
Reliability	More Reliable	Less Reliable

Cross Correlation

Original Image



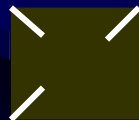
Scale of Correlation



0.125



0.25



0.375



0.5



0.625



0.75



0.875



1.0

Sum of the Squared Differences

0	20	128	55
255	32	233	109
33	16	64	255
16	8	48	16

Target strip pixels

2	21	129	55
255	30	233	109
32	16	60	254
17	8	48	16

Captured image pixels

$$SSD = \sum (\text{target-captured})^2$$

Sum of the Squared Differences

0	20	128	55
255	32	233	109
33	16	64	255
16	8	48	16

Target strip pixels

2	21	129	55
255	30	233	109
32	16	60	254
17	8	48	16

Captured image pixels

$$SSD = \sum (\text{target-captured})^2$$

$$SSD = 4$$

Sum of the Squared Differences

0	20	128	55
255	32	233	109
33	16	64	255
16	8	48	16

Target strip pixels

2	21	129	55
255	30	233	109
32	16	60	254
17	8	48	16

Captured image pixels

$$SSD = \sum (\text{target-captured})^2$$

$$SSD = 1$$

Sum of the Squared Differences

0	20	128	55
255	32	233	109
33	16	64	255
16	8	48	16

Target strip pixels

2	21	129	55
255	30	233	109
32	16	60	254
17	8	48	16

Captured image pixels

$$SSD = \sum (\text{target-captured})^2$$

$$SSD = 1$$

Sum of the Squared Differences

0	20	128	55
255	32	233	109
33	16	64	255
16	8	48	16

Target strip pixels

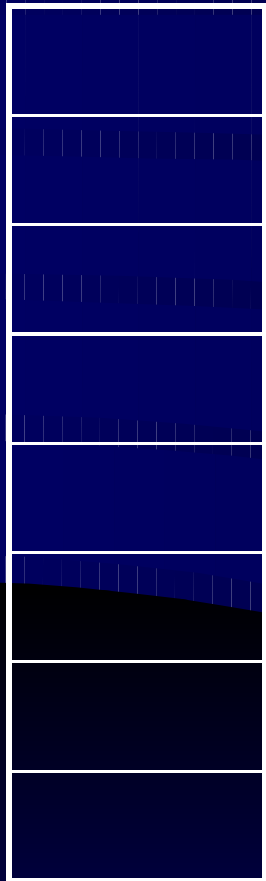
2	21	129	55
255	30	233	109
32	16	60	254
17	8	48	16

Captured image pixels

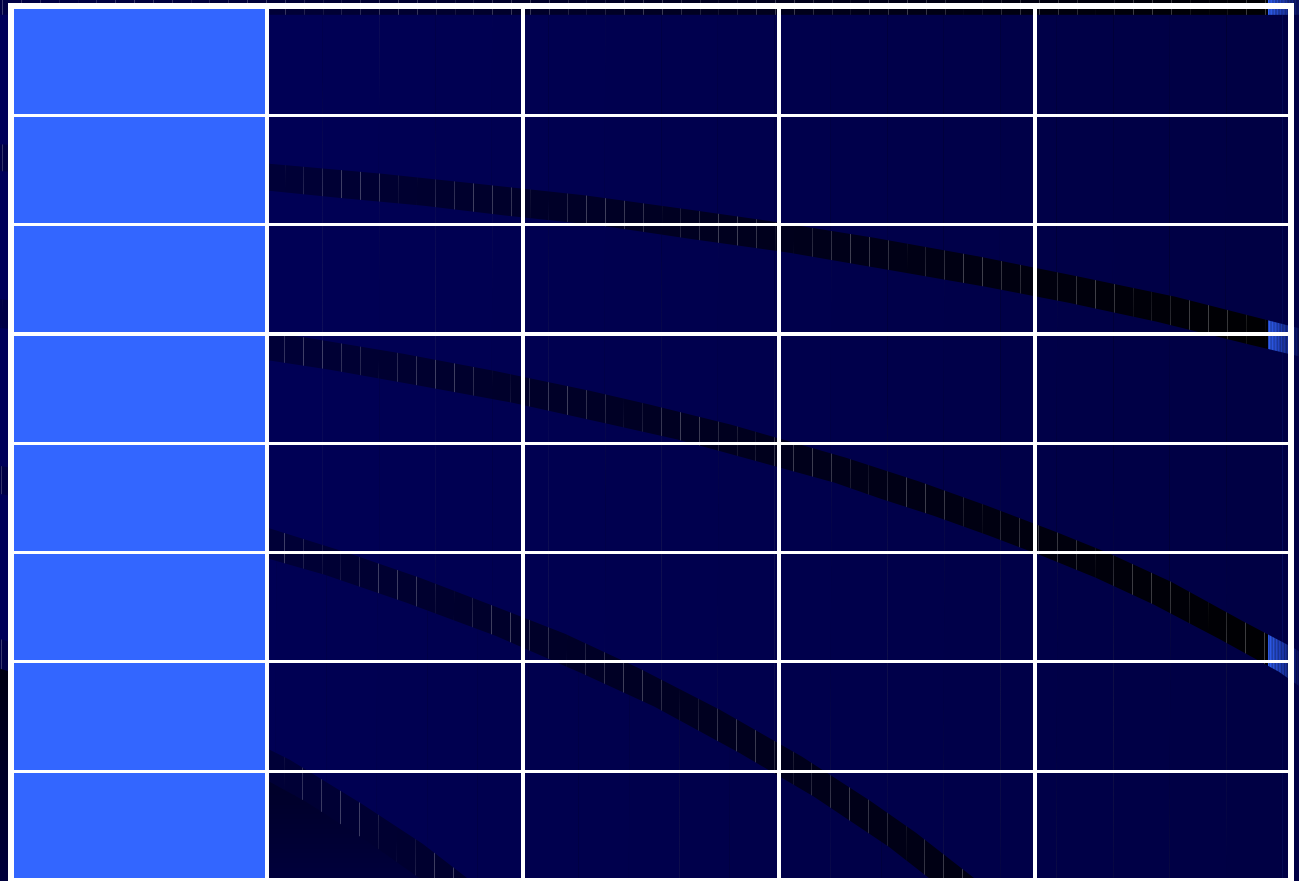
$$SSD = \sum (\text{target-captured})^2$$

$$\text{Total SSD} = 29$$

Calibration



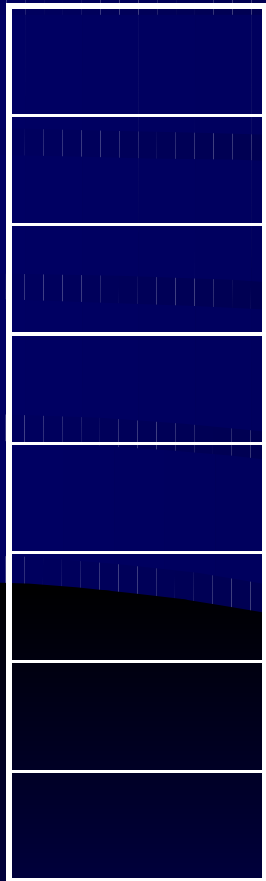
Target



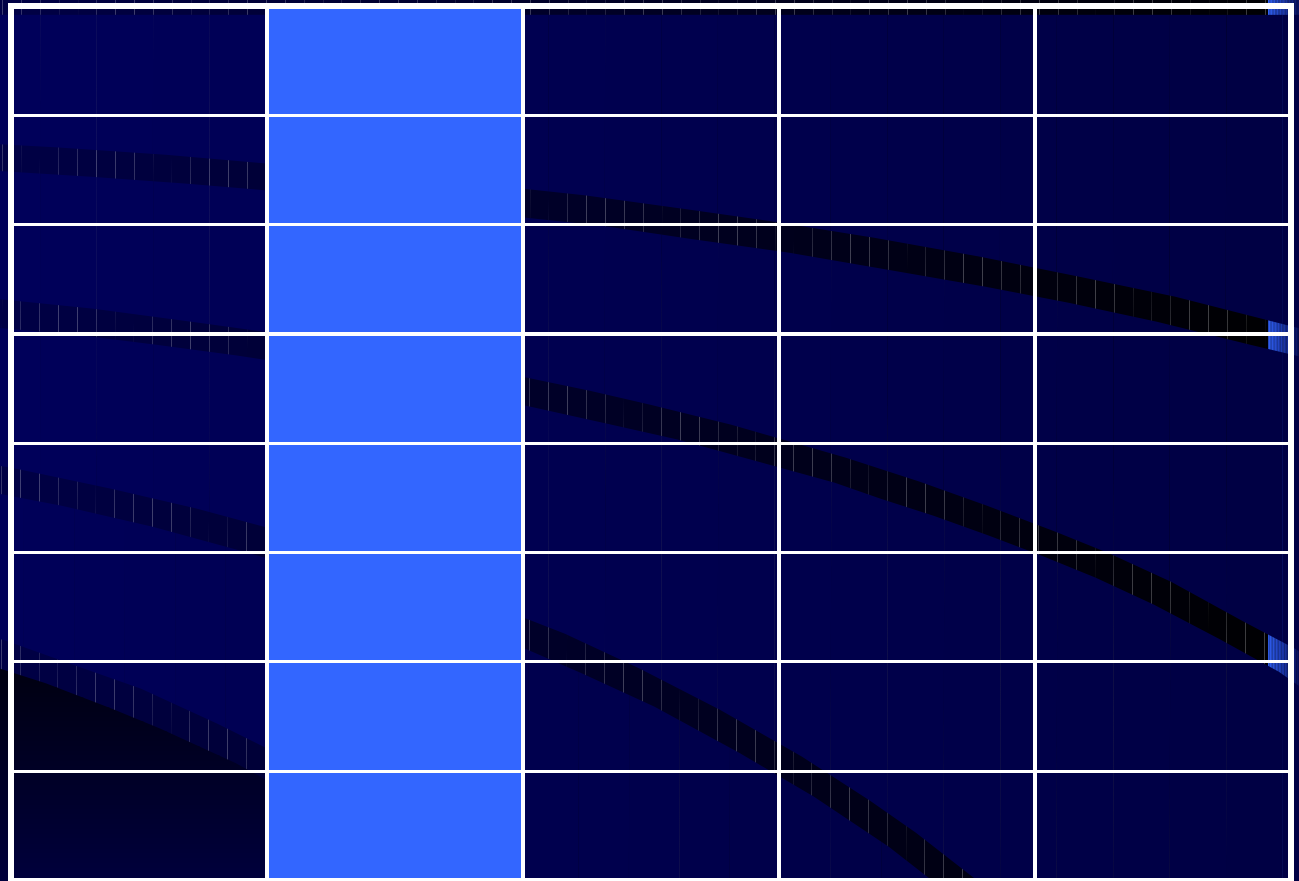
Captured

SSD = 104

Calibration



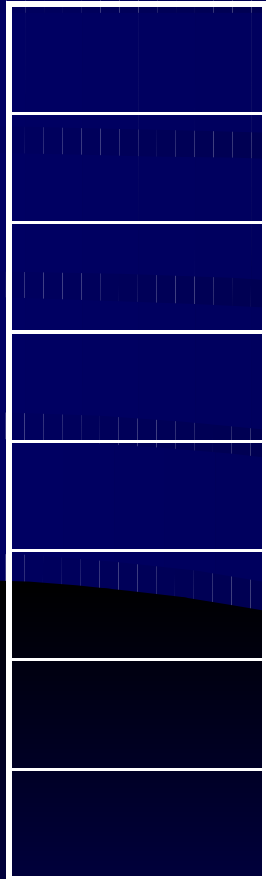
Target



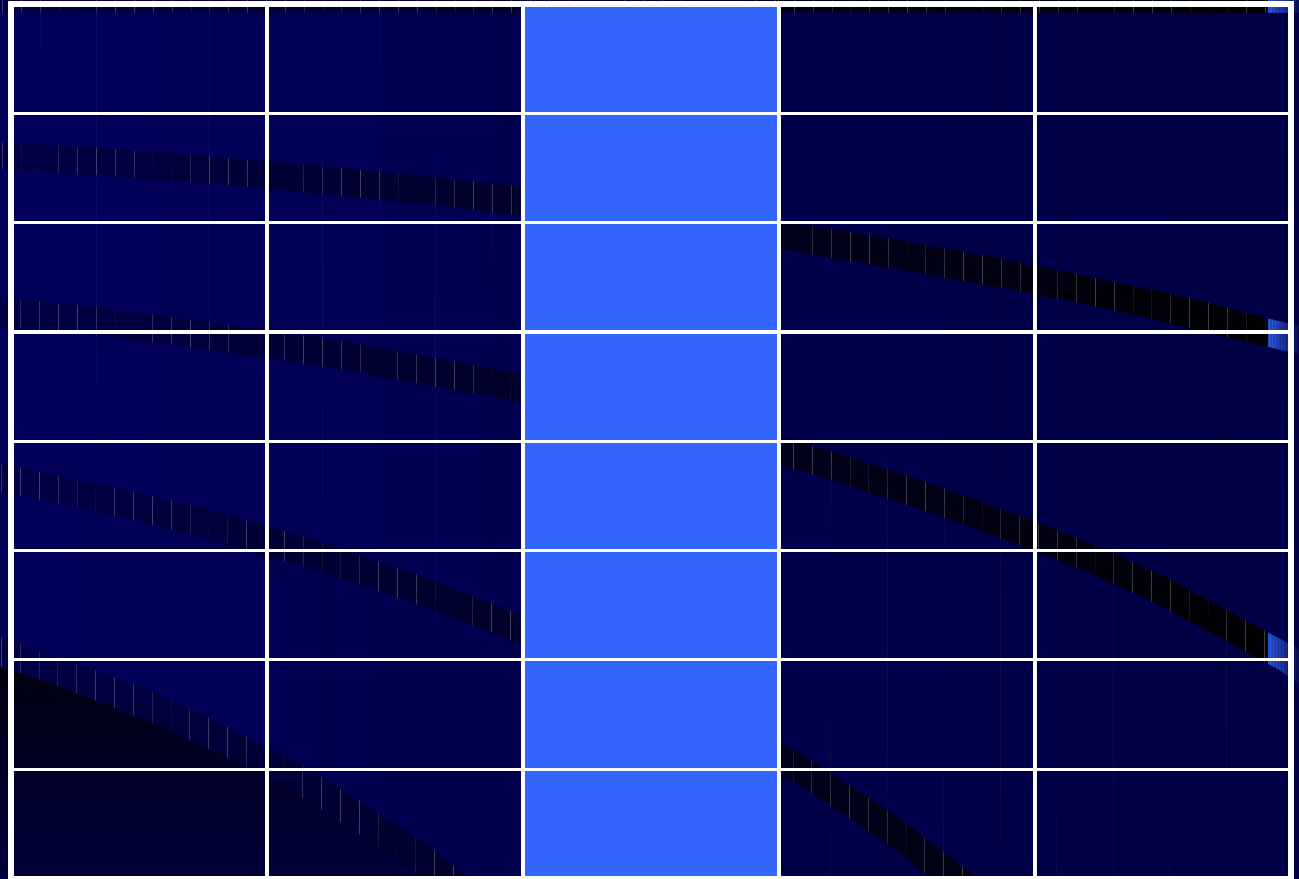
Captured

SSD = 230

Calibration



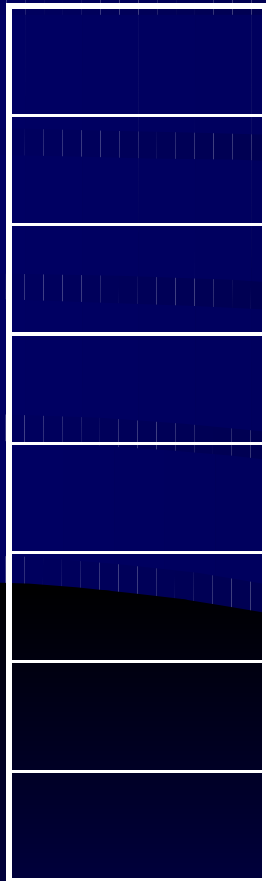
Target



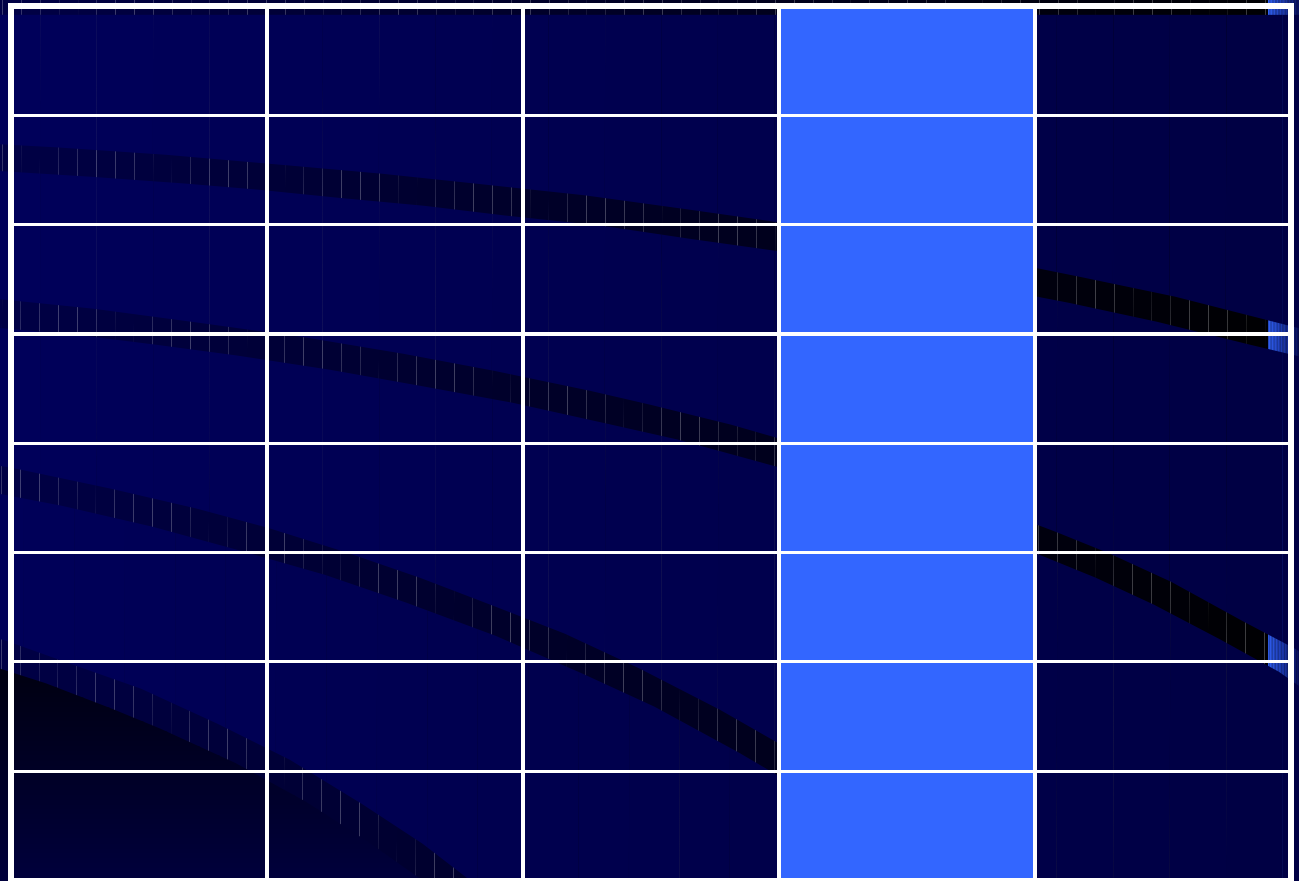
Captured

SSD = 100

Calibration



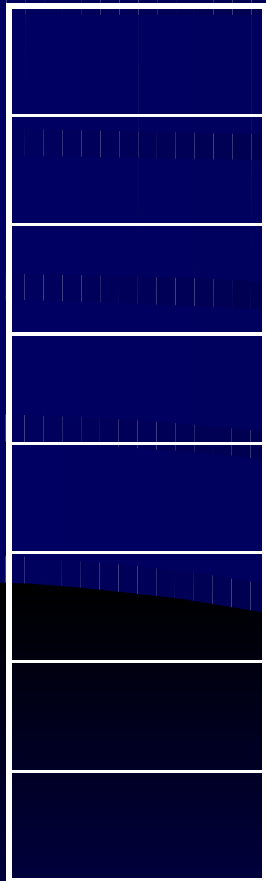
Target



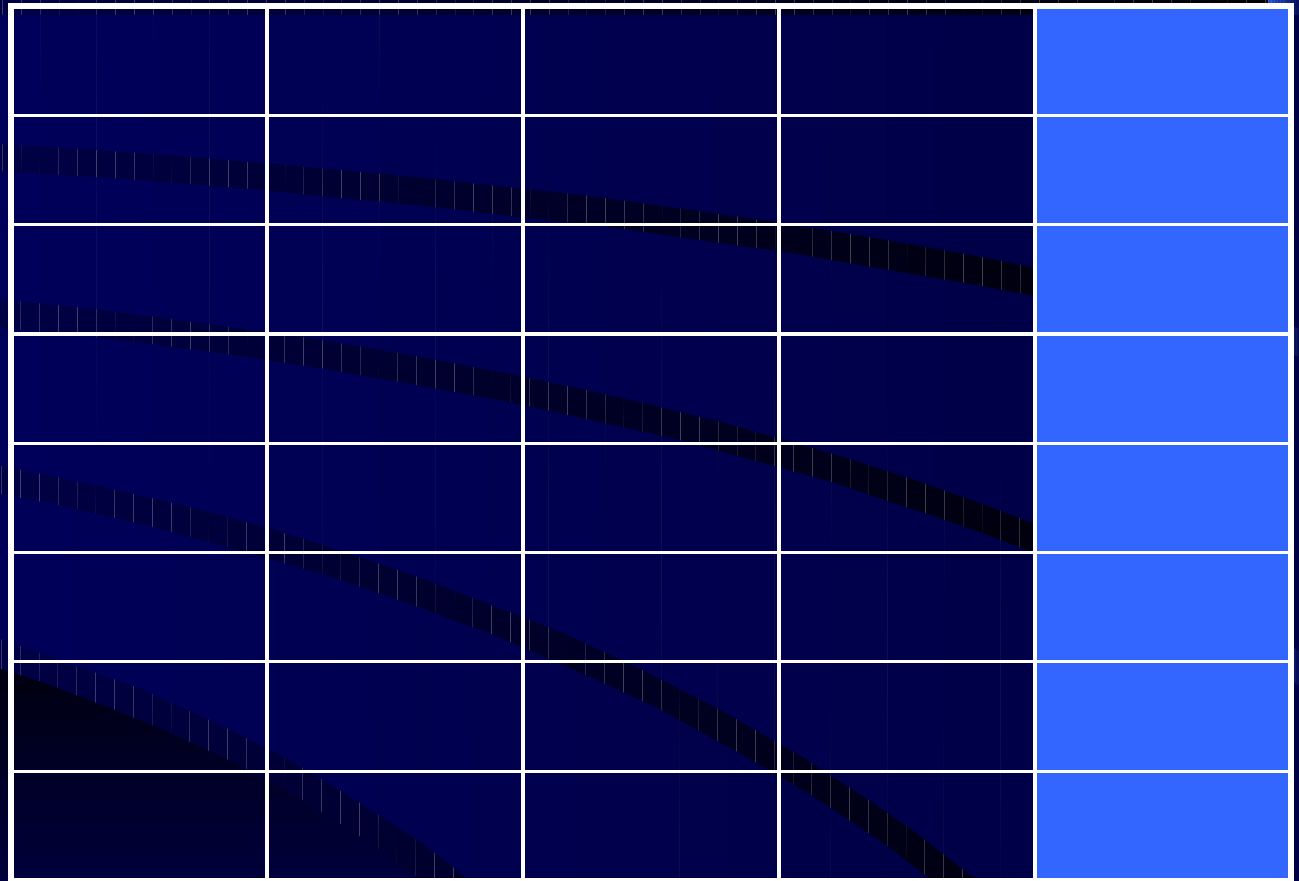
Captured

SSD = 7

Calibration



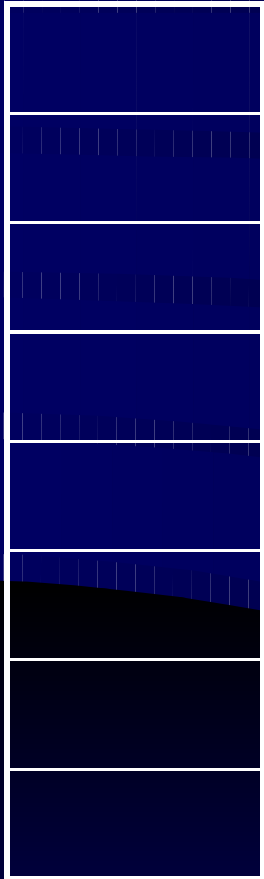
Target



Captured

SSD = 345

Calibration



Target



Target Found

Minimum SSD = 7

Captured

Demonstration

The image features a dark blue background with a subtle grid pattern. At the top center, the word "Demonstration" is written in a gold, serif font. Below the text, there are four thick, black, curved lines that sweep from the left side towards the right, creating a sense of motion or a sequence of steps. The lines are positioned at approximately one-quarter, one-third, two-thirds, and three-quarters of the way down the page.

Marketing Strategy

- Target Market - Who are the customers?

Marketing Strategy

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Since the CCD camera is only meant to enhance or replace the IR transmitter-receiver, the target market currently used by Chamberlain should not change.

Marketing Strategy

- How much will our selected market spend on our product?

Marketing Strategy

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**Price range is from \$129 - \$249
depending on Drive system:**

- 1. Belt Drive**
- 2. Chain Drive**
- 3. Screw Drive**

Marketing Strategy

- Competition – Who are the competitors with similar products?

Marketing Strategy

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Genie, Wayne-Dalton, and many other smaller companies, however, Genie is the largest company competing with Chamberlain.

Product Specifications

- Architectural Specs & NEMA Standards
- UL (Underwriters Laboratory)
- FCC (Federal Communications Commission)
- NEC (National Electrical Code)

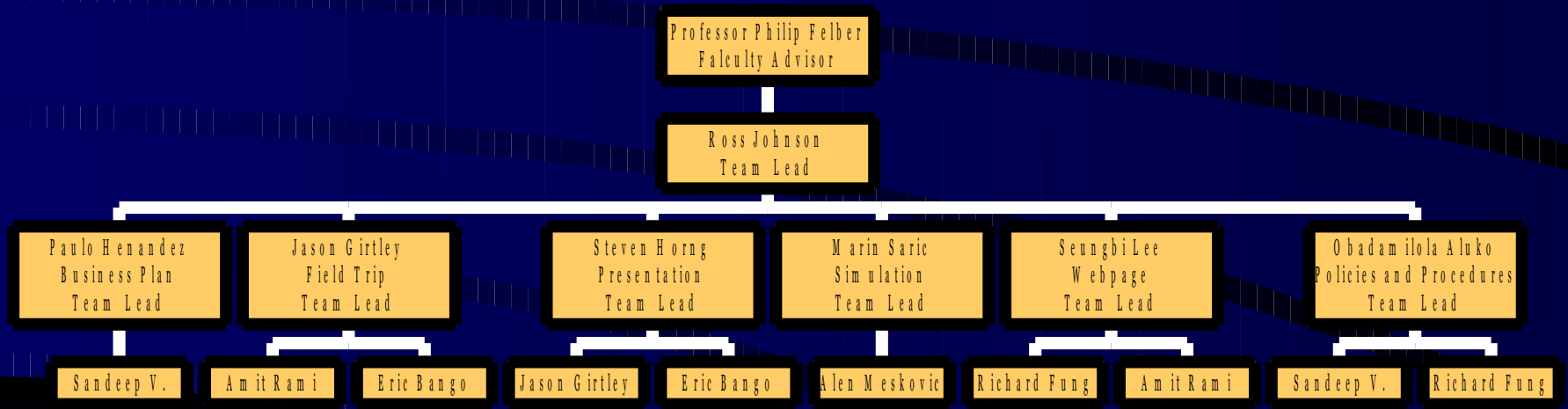
Comparison to IR System

- ❖ More Costly
- ❖ Slower response time (Unnoticeable to human perception)
- ❖ Larger scope of obstruction detection
- ❖ New

Future Plans

- ❖ Continue research by building a working prototype
- ❖ The prototype should:
 - ❖ Function in varying lighting conditions
 - ❖ Pass current UL standards
 - ❖ Support an additional camera to eliminate any blind spots
 - ❖ Run as an embedded application

Team Members



Questions

