Proposal: Remote Escalation/De-escalation and Surveillance System (REDSS)

Team Pew^3 (Georgia Tech)

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Executive Summary

Military operations frequently target hostile personnel at night in otherwise neutral or friendly areas, dictating that soldiers positively announce their presence to any local inhabitants, a process which invariably reveals the soldier's position. The loss of concealment increases tension, endangering both the soldier and the local. REDSS will reduce this threat by removing the source of visual and audible cues from the soldier and placing it on a remotely located robot, and will increase combat effectiveness by serving as remote surveillance platform capable of detecting and confirming hostile intent. REDSS is a lightweight, cargo pocket portable stationary robot which will be thrown into position, and will deploy a white light to disorient targets designated by IR lasers, announce audible cues, and serve as a remote surveillance camera. Operators will control REDSS in an "Eyes Up" configuration by using rifle-mounted IR lasers and simple remotes for basic functions, and mobile apps for advanced control. The expected outcome of the project is a mechanically limited but electronically functional REDSS prototype. Construction cost is estimated at $275.

Team Pew^3

- Advisor : Dr. Mick West
- Sponsor : Mike McGonagle, Harris Corporation
- Team :
  - Mike Bossi (Team Leader)
  - Gyu Cheol Lim
  - Josh Dixon
  - Seong Ho Yeon
  - Satoshi Yuki

Objective

Increase safety and margin for error in combat environments for both unarmed civilians and armed military forces by providing a safe and effective means to escalate and de-escalate the use of force during military operations in neutral environments, without negatively impacting operator situational awareness.

Motivation

- Current handheld de-escalation tools, such as the GLARE MOUT laser, reveal the operator's position to potentially hostile forces and increase battlefield tension
- Airborne ISR systems with de-escalation tools are scarce, and cannot be fielded to many traditional units
- Traditional battlefield robots require "Eyes-Down" control

Background

- Currently available systems do not accomplish the objective, but verify feasibility of technological components
- Police body cameras prove SWaP (Size, Weight, and Power)
- SKYCOP, a remote surveillance product, proves market for deployable cameras
- Laser-guided research robots and weapons validate laser tracking as a means of control

Project Description

- REDSS (Remote Escalation/De-escalation and Surveillance System) is a cargo-pocket sized, stationary, throw-able robot

- REDSS reduces tension in escalation and de-escalation scenarios by being the source of visual and audio cues, allowing the assault force to remain behind cover and concealment when encountering unidentified personnel

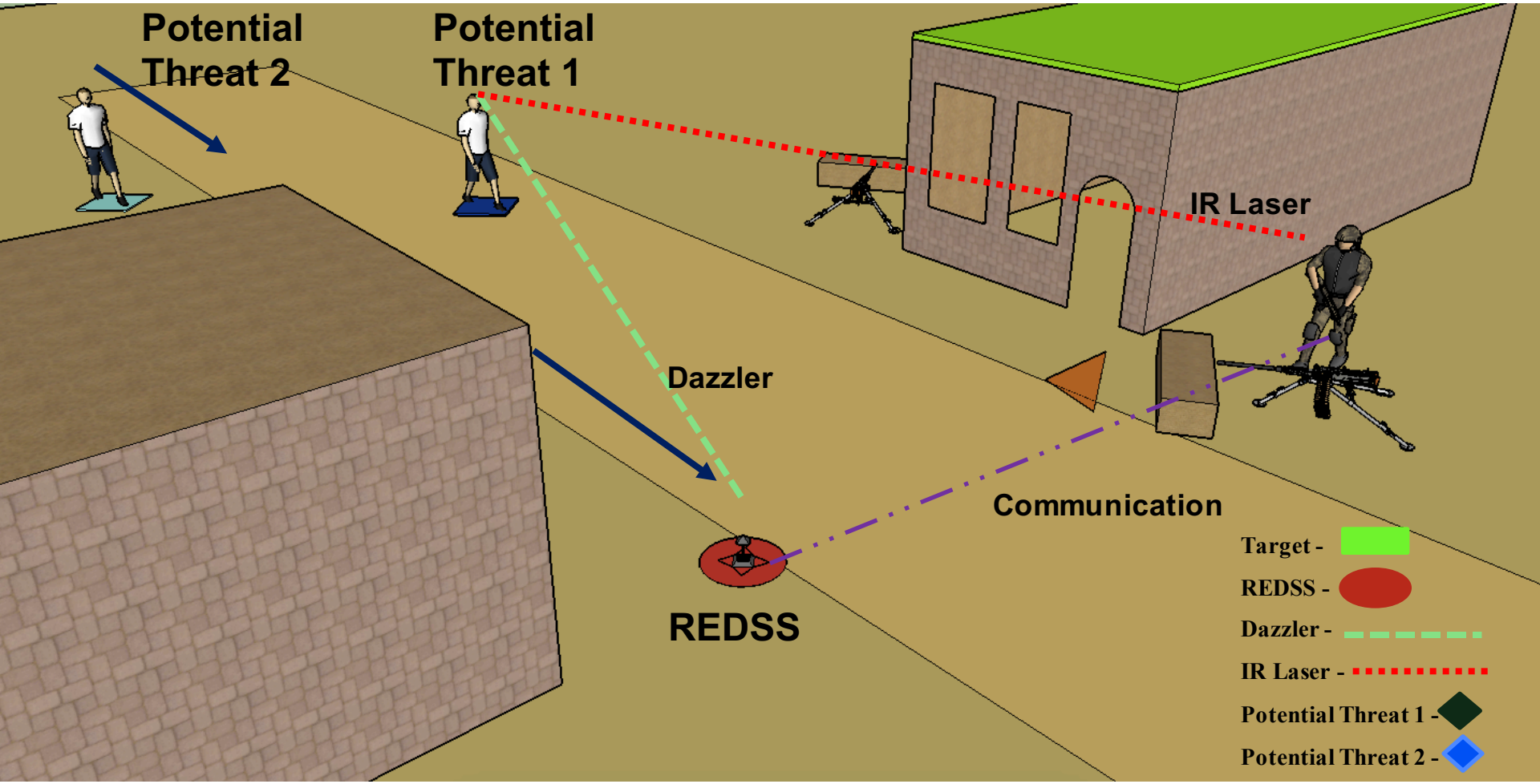
- REDSS will track IR lasers for an “Eyes-Up” control scheme, with advanced functionality provided through a mobile application

- REDSS will augment ISR coverage by serving as a deployable surveillance camera and host platform for intelligence collection equipment

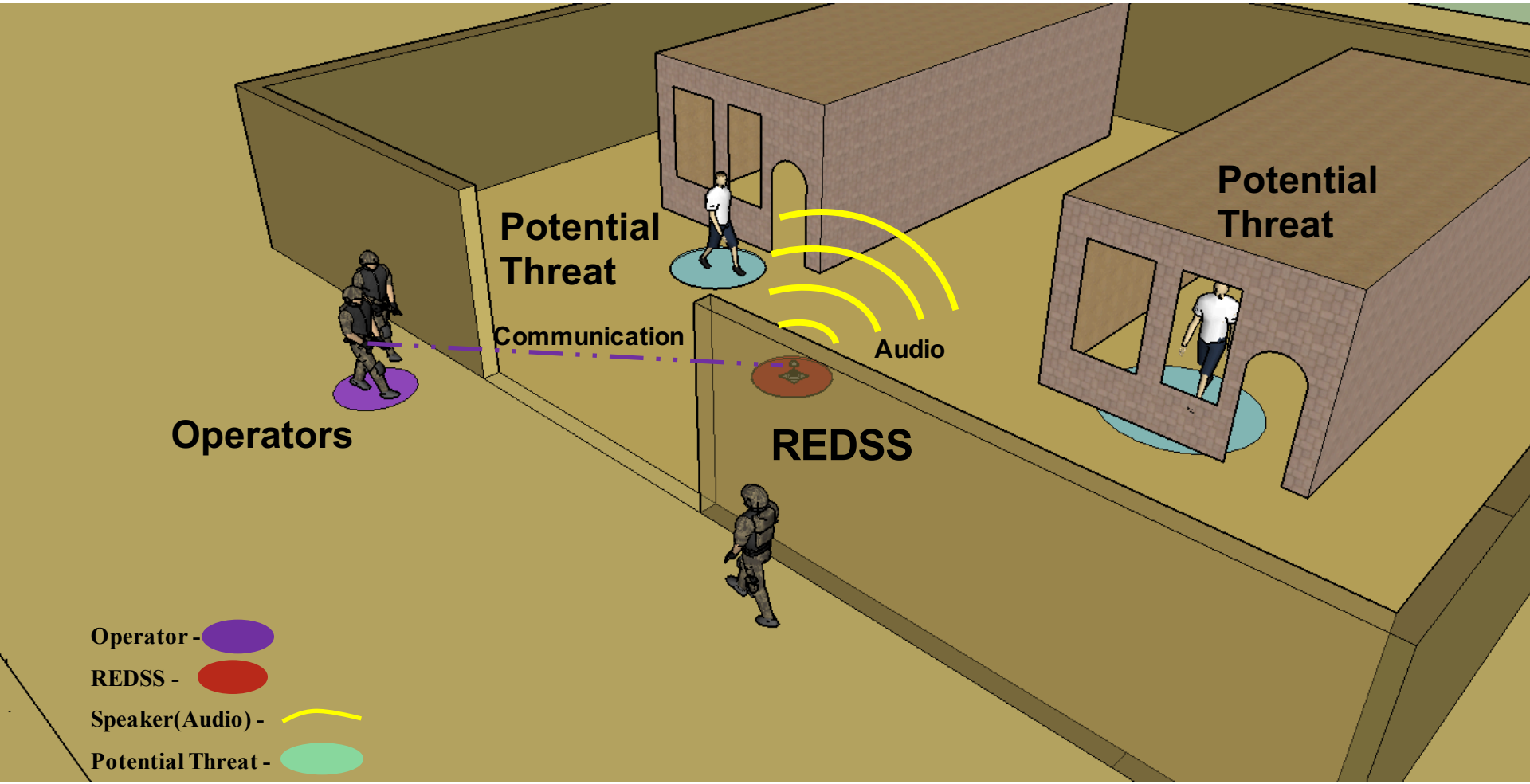
CONOPS and Use Scenarios

- De-Escalation Mode
  - At night, REDSS is thrown 12m away from a machine gun team. When an unidentified person (UIM) approaches the gun team, the gun team illuminates the UIM with an IR laser. REDSS tracks the laser, points a laser dazzler at the target, and on command deploys the visible laser to disorient the UIM
- Escalation Mode
  - REDSS is thrown over a 3m wall into a courtyard. Under remote control, REDSS gives audible instructions to any UIM's in the compound. REDSS provides video feed to an operator, and deploys laser dazzler as instructed
- Surveillance Mode
  - REDSS is placed in avenues of approach to the assault force. REDSS scans the area and functions in a surveillance alarm mode. If REDSS detects movement, it alerts the operator, provides a video feed, and transmits its location
- Remote Sensor
  - REDSS provides an API for modular sensor integration, supporting a radio direction finding sensor

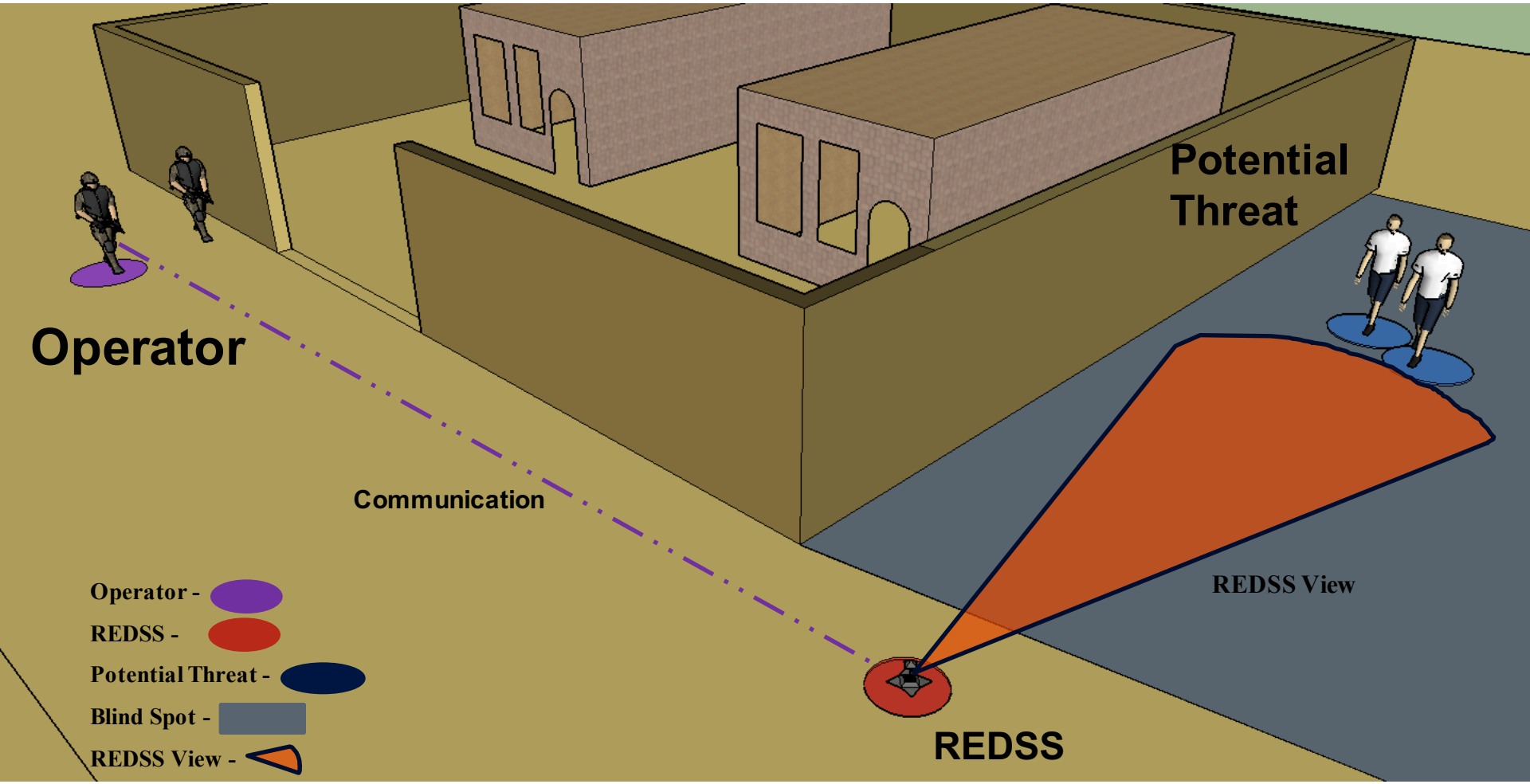
De-Escalation Mode (Laser Track)



Escalation Mode



Surveillance Mode



Critical Success Factors: Performance

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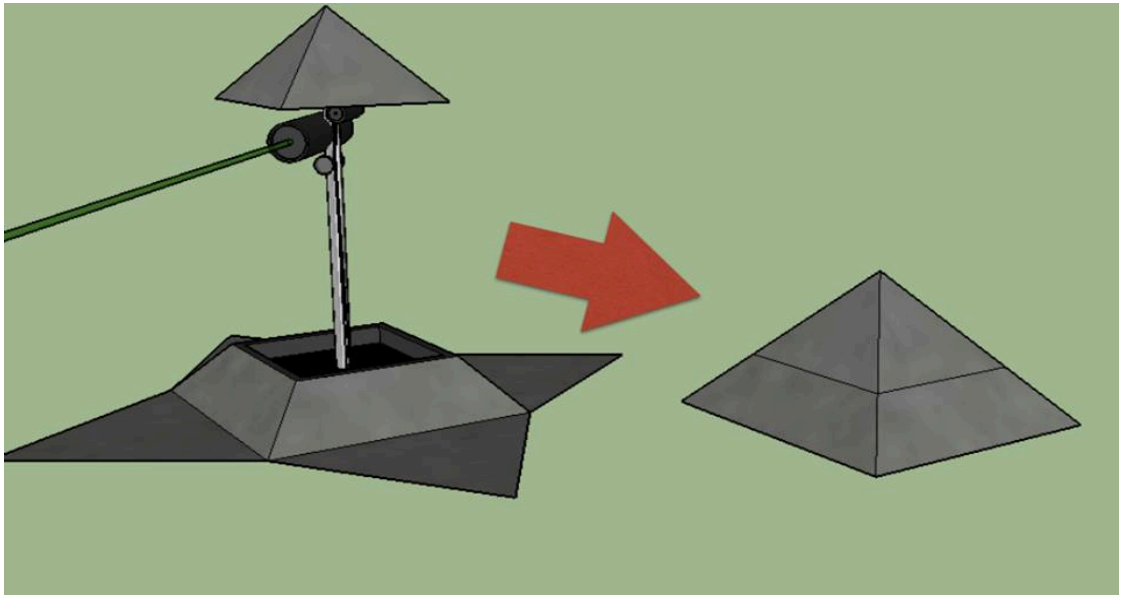
- Overall Success
  - Simple operation to permit a training time of less than one hour
  - Minimum impact on operator's situational awareness
- De-escalation Mode Success
  - Successful tracking of an IR laser to within 0.4 degrees of a target 50m away
  - Deploy an ultra-bright flashlight(dazzler) at the designated target with minimal operator workload
- Escalation Mode Success
  - Deploy the dazzler and announce audio instructions under remote command with a latency below 0.5 second at a range from the operator of 15m
- Surveillance Mode Success
  - Transmit an alarm signal when a man-sized object moves within 50m inside the REDSS visual coverage

Critical Success Factors: Prototype

- Functional robot in the “deployed” state
  - All operational modes are functional and demonstrated
- Non-functional “closed state” mockup robot



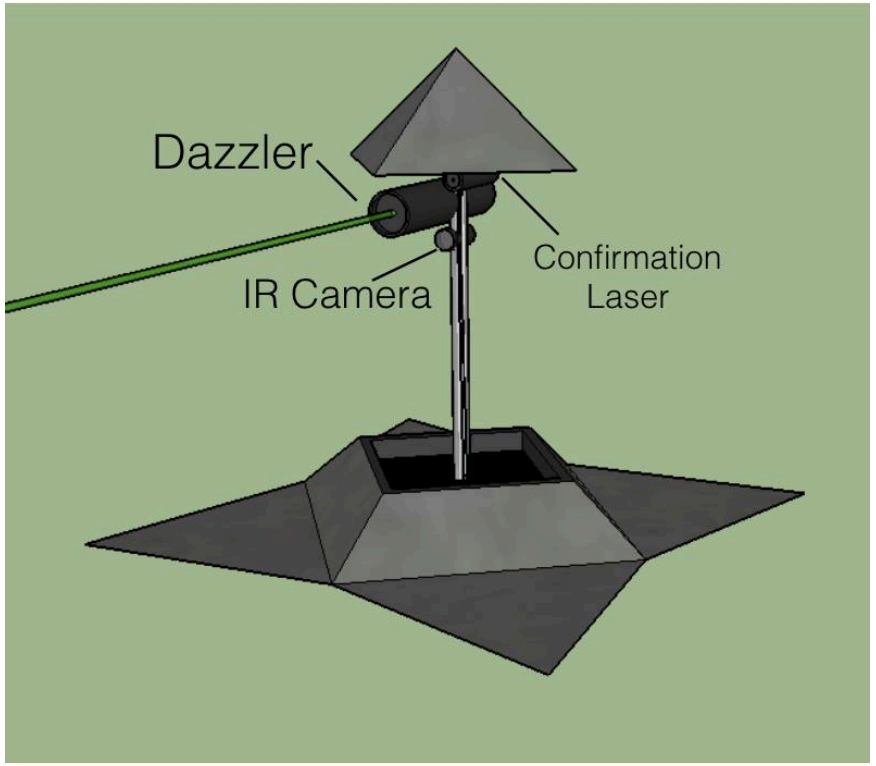
Overall System Specifications

Feature	Specification
Dimension	$< 17.8 \times 19 \times 10.1\ cm^3$ (Cargo pocket)
Weight	500 g - 1 kg
Operating Endurance	> 5 hours (Laser tracking mode) > 8hours (Surveillance mode)
Impact Endurance	> Survive drop from 3.2 m
Aiming Accuracy	< 0.5 Degrees
Target Distance	> 50 m
Rotational Speed	> 40 Degrees per Second
Speaker Range	> 25 m
Camera Height	> 16 cm
Interface	Hardware Remote and Android Mobile App with Video Stream

REDSS Design

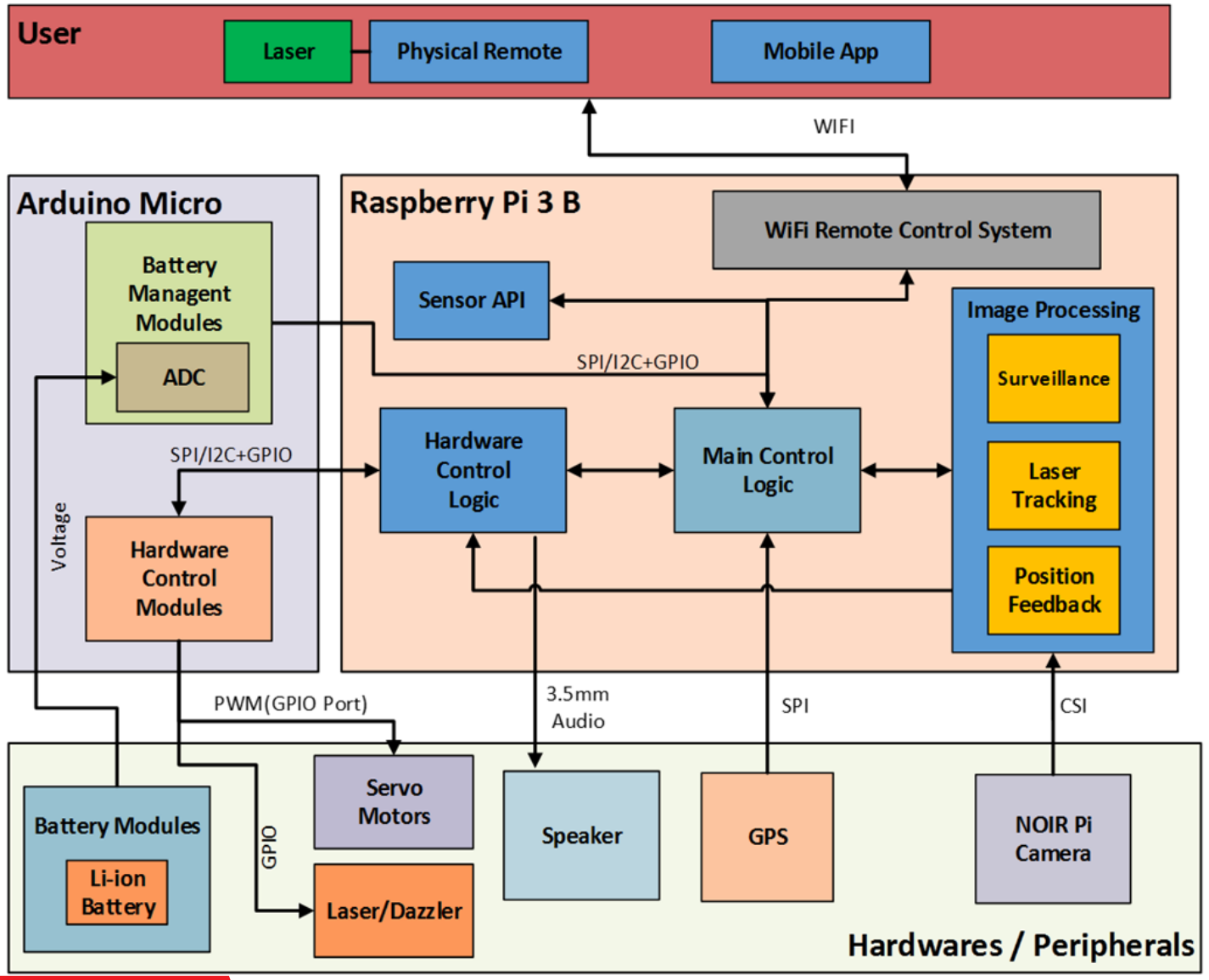
- The REDSS Robot will contain:
  1. White light dazzler to disorient personnel
  2. Visible/IR camera to track IR lasers and provide video feeds
  3. IR Confirmation laser to confirm aim
  4. Red laser to discreetly warn personnel*
  5. IR floodlight for night vision*
  6. Field-replaceable batteries*
  7. Computing units
  8. Wireless communications
  9. Speaker
  10. GPS

*Customer Request



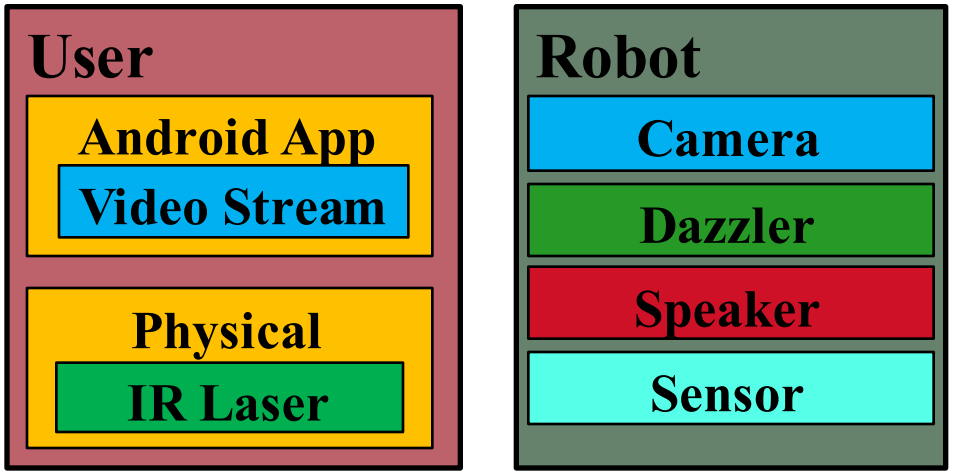
- The REDSS User Segment will contain:
  1. Rifle-mounted hardware remote for basic functionality
  2. Mobile application for advanced control

REDSS Block Diagram



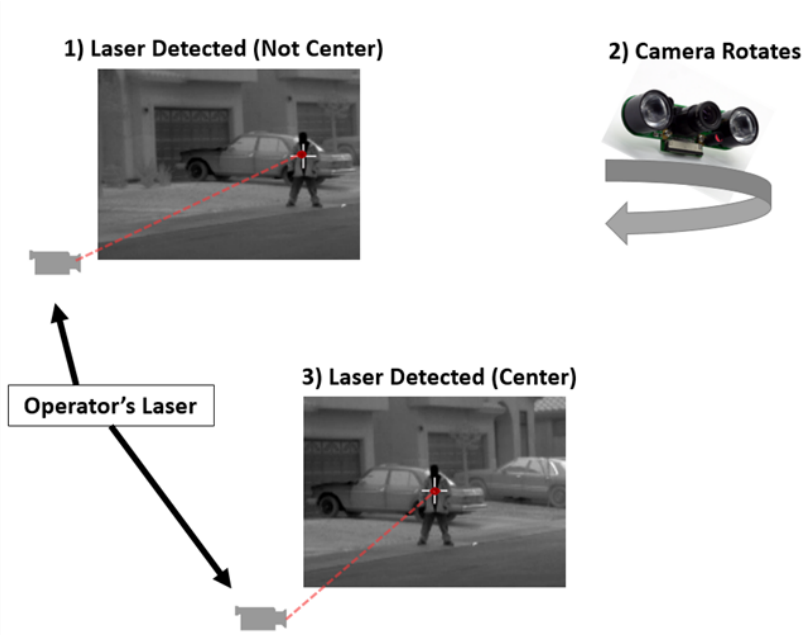
User Perspective: Block Diagram

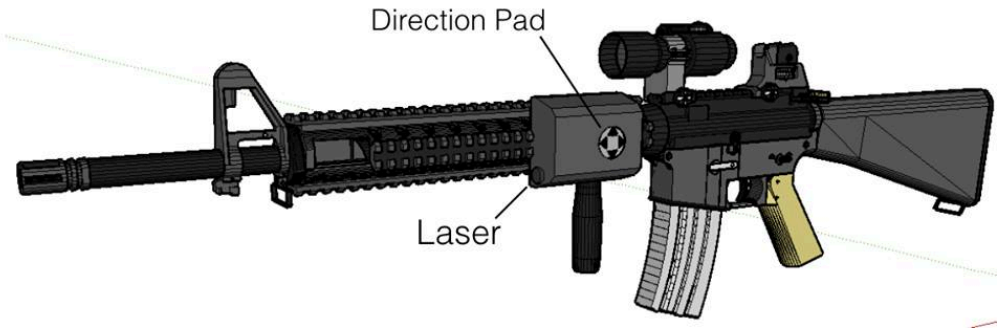
- User-side Subsystem
  - Rifle-mounted remote with IR laser
  - Android mobile app with advanced functionality
- Robot-side Subsystem
  - Interacts with targets via the dazzler and speaker
  - Supports generic sensor payload



User Perspective: Physical Interface

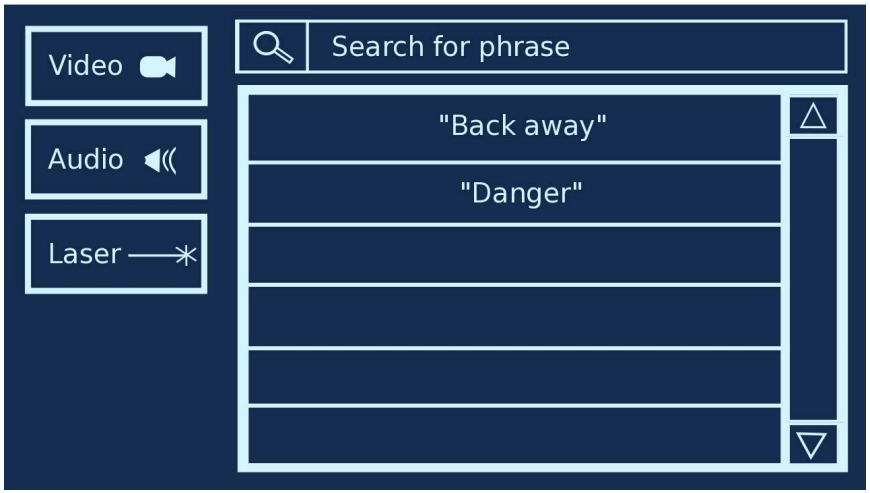
- Rifle-mounted remote control with physical buttons and IR laser
  - "Eyes up" control when de-escalating with approaching personnel
  - Small aiming corrections and dazzler control provided by direction pad





User Perspective: Graphic Interface

- Detailed control of the system
  - Selection between escalation, de-escalation, and surveillance modes
- Audio instruction broadcast
  - Plays recorded commands in local languages
- Continuous video stream
- Alarm on motion detection
  - Reduces operator workload, conserves battery



Sensor Integration

- REDSS will integrate with modular sensors using an Application Program Interface (API)
- REDSS will provide GPS and timing data, memory access, and communications to attached sensors
- Prototype REDSS will target radio direction finding sensors

Overall Computing System

- Off-the-shelf commercial components
- Backseat/Frontseat Architecture
- Backseat
  - High-speed processor for complex operations
  - Camera interface
  - Audio interface
  - Video processing capability
- Frontseat
  - Hardware control (Actuator, Laser, Dazzler)
  - Sensor extensions (ADC, SPI, I2C, UART, GPIO, ….)
  - Routine operations

Significant Tradeoffs

- Cost vs. Capability
  - REDSS must be inexpensive enough to leave behind when reacting to contact. An emplaced REDSS is an IED opportunity, and tactical considerations may prevent retrieval
  - System is inherently inexpensive due to COTS equipment. Manufactured systems will include self-destruct mechanisms
- Battery Life vs. Weight
  - System endurance has been calculated and is within design goals. Li-ion batteries ensure a low system weight
- Aiming Accuracy vs. Processor Demand
  - Higher resolution video permits more accurate aiming, but necessitates a more powerful processor
  - Manual controls allow operator to fine tune accuracy, and eliminates need for advanced autonomous feedback
- Prototyping Speed vs. Physical Capabilities
  - Drop tolerant physical construction is beyond team's capabilities, military-rated hardware is not readily available at the consumer level
  - Prototyping ease has priority over physical design factors

Primary Computing Unit

- Backseat processor
- Camera Interface & Video Processing
- Raspberry Pi
  - On board GPU, Camera Serial Interface, Open source SW compatibility
  - Raspberry Pi 3B : Mitigates processing risks related to computer vision

Features	RPi 1A+	RPi 1B+	RPi 2B	RPi 3B
Power Consumption	4 (1W)	3 (3W)	1 (4W)	2 (4W w/ 2.5W Idle)
Processor Speed Margin	1 (700MHz)	1 (700MHz)	3 (900MHz)	4 (1.2GHz)
GPU Capability	2 (400MHz)	2 (400MHz)	2 (400MHz)	2 (400MHz)
Memory Size	1 (256MB)	2 (512MB)	4 (1024MB)	4 (1024MB)
Price	4 ($20)	3 ($25)	2 ($35)	3 ($35 w/ On-Board BT and WiFi)
Total	11	10	11	17

Peripheral Control Unit

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- Frontseat microcontroller
  - Raspberry Pi is not well suited for peripheral control
  - Microcontrollers compensate for Raspberry Pi deficiency
- Interface with peripherals
  - Provides more precise HW control signal
  - Sensor extensions for feedback control
- Arduino Micro
  - Size and user community support are priority factors and are heavily weighted in the decision process

Features	Arduino Micro	Arduino UNO	MBED	TI MSP430 Launchpad
Power Consumption	3 (~20 mA)	3 (~20 mA)	1 (~138 mA)	4 (~10 mA)
Size*	8	4	6	4
User Community Support	6	6	2	4
Price	3	2	1	4
Total	20	15	10	16

Standard Interfaces

- Remote Control
  - WiFi: IEEE 802.11n
  - Bluetooth : Bluetooth 4.0 BLE
  - IR Laser: ~ 850nm
- Camera
  - Camera Serial Interface (CSI): Mobile Industry Processor Interface Alliance
- Sensor Integrations
  - Inter-Integrated Circuit (I2C): NXP Semiconductor
  - Serial Peripheral Interface (SPI): No specifying authority
- RPi - Arduino
  - Universal Serial Bus (USB): USB Implementers Forum

Part Specifications: Processor

Feature	Specification
Calculation of motor angle	< 15 ms
Communication	WIFI (802.11n)
Image Refresh Rate	> 60 fps
Image resolution	480p – 1080p
Audio Capability	Required
Location	GPS

Part Specifications: Peripherals

Peripherals	Feature	Specification
Camera	Angular Resolution	< 0.4 degrees
	Detectable wavelength	Visible light, Infrared light
Pan Motor	Angular velocity	60 - 120 degrees/sec
	Active range	0 - 360 degrees
Tilt Motor	Angular velocity	20 - 60 degrees/sec
	Active range	10 - 170 degrees
Pan/Tilt Module	Maximum payload weight	300 g
IR Laser	Wavelength	850 – 900 nm
	Power	< 5 mW
	Weight	< 50 g
Dazzler	Diameter	5 – 10 cm
	Intensity	500 lumen
	Weight	< 100 g

System Performance Estimation

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- Microcomputer is sufficient for many computer vision tasks
  - Verified by RPi user community
- Laser tracking at 10FPS has been accomplished with a single core 700Mhz processor
  - RPi 3B will be able to track the laser using the GPU and the quad-core 1.2GHz processor
- Battery life requirement of 5+ hours in laser tracking mode, and 8+ hours in surveillance mode
  - Initial estimation shown in next slides

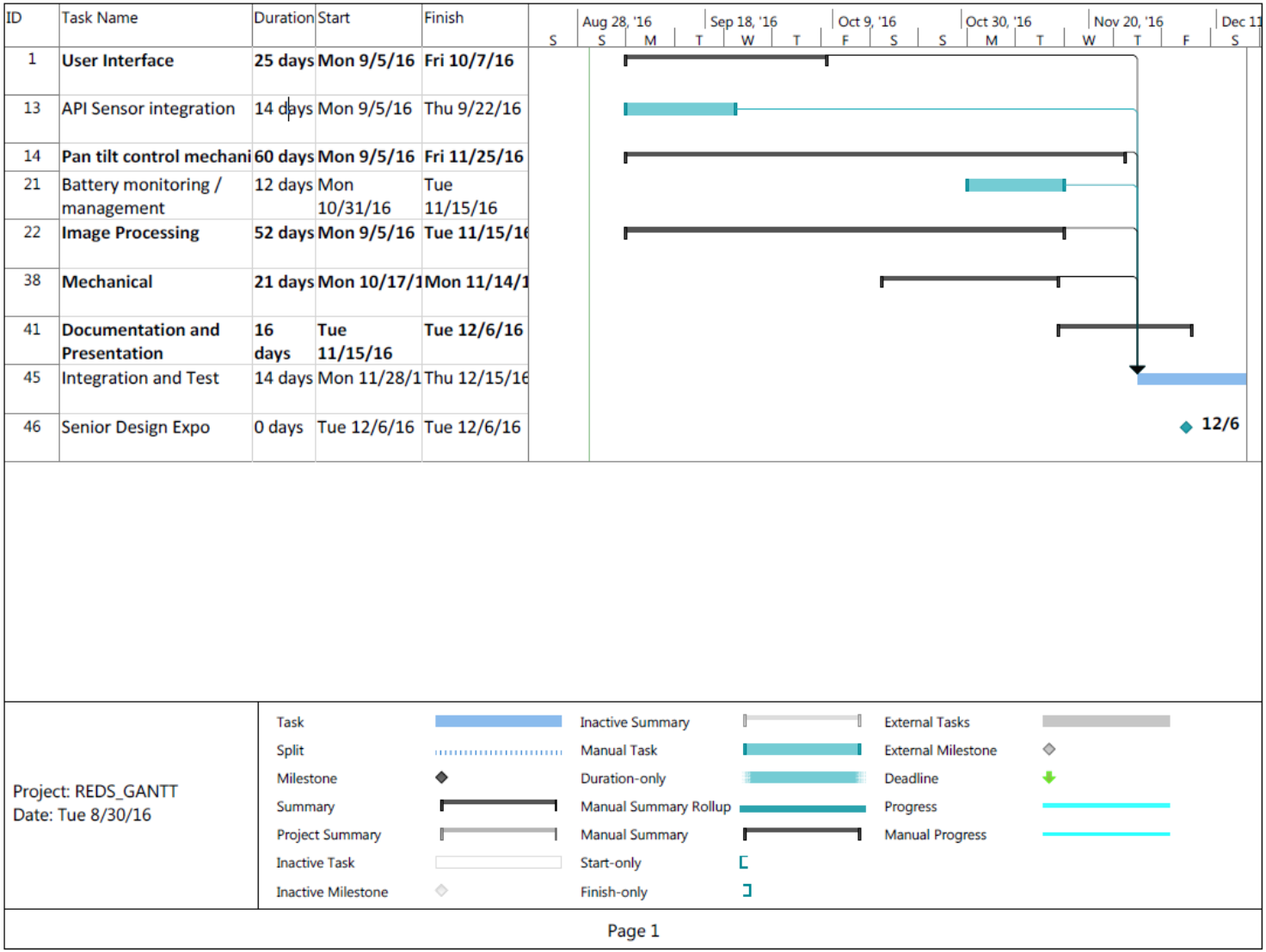
Battery Life Estimation

- Battery capacity modeled on the Harris Falcon III radio battery (~60 Wh)

Components	Surveillance Mode Power Consumption	Laser Tracking Mode Power Consumption
Raspberry Pi 3B	2.75 W	3.3 W
Pan Servo Motor	1.125 W	1.25 W
Tilt Servo Motor	1.125 W	1.5 W
Camera	1.2 W	1.2 W
Total	6.2 W	7.25 W

Battery	Surveillance Mode Operation Hours	Laser Tracking Mode Operation Hours
55Wh Li-ion Battery	8.9 hours	7.6 hours

GANTT Chart



ID	Task Name	Duration	Start	Finish
1	**User Interface**	**25 days**	**Mon 9/5/16**	**Fri 10/7/16**
13	API Sensor integration	14 days	Mon 9/5/16	Thu 9/22/16
14	**Pan tilt control mechani**	**60 days**	**Mon 9/5/16**	**Fri 11/25/16**
21	Battery monitoring / management	12 days	Mon 10/31/16	Tue 11/15/16
22	**Image Processing**	**52 days**	**Mon 9/5/16**	**Tue 11/15/16**
38	**Mechanical**	**21 days**	**Mon 10/17/1**	**Mon 11/14/1**
41	**Documentation and Presentation**	**16 days**	**Tue 11/15/16**	**Tue 12/6/16**
45	Integration and Test	14 days	Mon 11/28/1	Thu 12/15/16
46	Senior Design Expo	0 days	Tue 12/6/16	Tue 12/6/16

Project: REDS_GANTT
Date: Tue 8/30/16

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress

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Division of Labor

Task Name	Task Lead	Risk Level
Documentation and Presentations	All (Lead by Mike)	Low
User Interface Design/Implementation	Josh	High
Hardware Integration	Gyucheol, Mike, Satoshi, Seong Ho	Medium
API Software Integration	Josh, Mike	Medium
Image Processing	Gyucheol, Mike	Highest
Peripherals (Motors, Laser, Dazzler) Controls	Satoshi, Seong Ho	Medium
GPS Processing	Mike, Seong Ho	Low

Risks

- Unable to map OpenCV into RPi GPU, forcing CPU to handle image processing
  - Mitigation: Use Rpi 3, which should have processor margin
- Safety issue of IR laser diode
  - Mitigation: Laser safety glasses and use of resistors to ensure <5mW, 1mW preferred
- Late/Damaged parts
  - Mitigation: Simulate using available analogs and test equipment

Immediate Plans

- Establish software structure and specifications
- Determine major functions within each design block
- Experiment with OpenCV
- Build test benches
- Begin work on the Critical Design Review

Demonstration Plan

- If the demo environment is conducive to laser tracking, REDSS will track an eye-safe IR laser on a notional target and deploy its dazzler

- REDSS will rotate and deploy its dazzler as commanded by the mobile application, and provide a video feed to the mobile device

- Audible warnings will be played in English, Korean, and Japanese

Market Analysis

- The target market is the government, specifically for military personnel in combat environments

- No single comparable system exists, but remote surveillance systems provide an acceptable comparison

- Residential-grade stationary camera systems with recording and communication capabilities cost at least $500, while deployable surveillance trailers start at roughly $42,000

Prototype Equipment Cost

Part	Number	Cost Each	Cost Total
Raspberry Pi 3	1	$39.95	$39.95
Arduino Micro	2*	$24.95	$49.90
Pan tilt system	1	$45.99	$45.99
Sailwinch Servo (SW5513-4MA)	1	$12.20	$12.20
Servo (HS-485HB)	1	$16.99	$16.99
NOIR Camera	1	$29.95	$29.95
Li-ion Battery (5.2 AH)	2*	$34.80	$69.60
1/8" x 12" x 12" aluminum sheet metal	1	$28.56	$28.56
Surface Mount Hinge	8	$4.83	$38.64
Stainless Steel Hex Nut pack 100	1	$3.83	$3.83
Stainless Steel Flat Head Phillips Machine Screw	1	$5.80	$5.80
IR Laser Diode	2*	$36.12	$72.24
RED Laser Diode	2*	$5.95	$11.90
LED Torch	1	$35.00	$35.00
5v regulator (2.5A)	1	$10.00	$10.00
GPS Shield	1	$44.95	$44.95
Parts Total Without Spares			$413.68
Parts Total With Spares			$515.50

*Asterisk indicates extra spare part.

Prototype Labor Cost

- Assumes typical starting engineer salary of ~56k annually

Project Component	Labor Hours	Labor cost
User interface	160	$4,800.00
Pan tilt control mechanism	144	$4,320.00
Battery monitoring	40	$1,200.00
Image processing	128	$3,840.00
Mechanical construction	56	$1,680.00
Documentation	48	$1,440.00
Labor Total	576	$17,280.00
Parts Total		$272.03
Grand Total		$17,552.03

Mass Production Cost

- Assumes an order of 5k units

- MIL-SPEC parts could increase part costs by 300%, increasing end unit cost to $1,000

Parts 20% discount	$1,088,120.00
Labor	$17,280.00
Fringe	$5,184.00
Subtotal	$1,110,584.00
Overhead	$1,443,759.20
Production Total	$2,554,343.20
Sales	$76,630.30
Amortized Development Costs	$5,000.00
Profit	175000
Total Production, Sales and Profit	$2,810,973.50
Selling Price	$562.19

Thank You!

- Questions?