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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Guy	Bar-Nahum	San Francisco, CA
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Additional inventors are being named on the _____ separately numbered sheets attached hereto.		
TITLE OF THE INVENTION (500 characters max):		
Multimodal Sensor Empowered Awareness Engine for Target Recovery and Object Path Prediction		
Direct all correspondence to: CORRESPONDENCE ADDRESS		
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ENCLOSED APPLICATION PARTS (check all that apply)		
☐ Application Data Sheet. See 37 CFR 1.76. ☐ CD(s), Number of CDs _____		
☒ Drawing(s) <i>Number of Sheets</i> <u>11</u> ☐ Other (specify) _____		
☒ Specification (e.g., description of the invention) <i>Number of Pages</i> <u>14</u>		
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☒ Applicant asserts small entity status. See 37 CFR 1.27. 130		
☐ Applicant certifies micro entity status. See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent. TOTAL FEE AMOUNT (\$)		
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 2 of 2

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒

No.

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Yes, the invention was made by an agency of the U.S. Government. The U.S. Government agency name is: _____

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SIGNATURE /Saad S. Enam/ DATE 10/8/2016
 TYPED OR PRINTED NAME Saad S. Enam REGISTRATION NO. 69626
 (if appropriate)
 TELEPHONE 949.636.3126 DOCKET NUMBER AIR17

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AIR17 - Multimodal Sensor Empowered Awareness Engine for Target Recovery and Object Path Prediction

Cites AIR16 in its entirety.

Background

Autonomous robotic systems (ARS) tasked with detection and tracking of objects can often suffer from the lack of tracking if the target moves out of a sensor's field of view.

In one example, visual detection and tracking of moving targets suffers from target loss when the target leaves a camera's viewport due to the relative movement between the target and the camera. In such situations recovery from a full loss of target from visual data alone is very unlikely if not impossible without a wide area sweep of the ARS's surroundings. This is costly both in time and computational resources and thus very undesirable.

Thus there is a need for systems and methods that provide recovery of a target that are both speedy and not computationally intensive.

Solution

The present invention provides for a fast recovery of lost targets by empowering an ARS's awareness engine with multimodal sensors. This method is highly desirable for any system that tracks targets visually or by using any

Sensor Architecture

- System has a main tracking sensor (e.g. optical video) that feeds into a spatio-temporal engine on the ARS.
- Proximal sensors complement the main tra

Multimodal Sensors

- Using non visual, fast processing sensors that give rough directionality of the signal, allow for prioritization of the visual target scanning process.
- Such sensors include sound, RF, radar and proximity sensors that do not isolate the location of a possible target, but give general direction to be scanned first.

Figures and Descriptions

Figure 1: Concentric circles showing the range of sensors (optical in center, sound, rf, etc proximally situated)

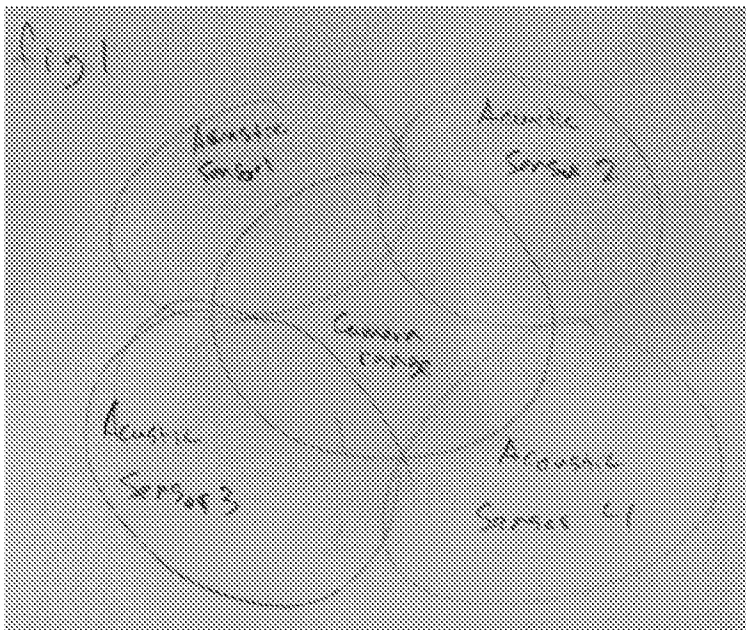


Figure 2: Flowchart of target loss and subsequent recovery

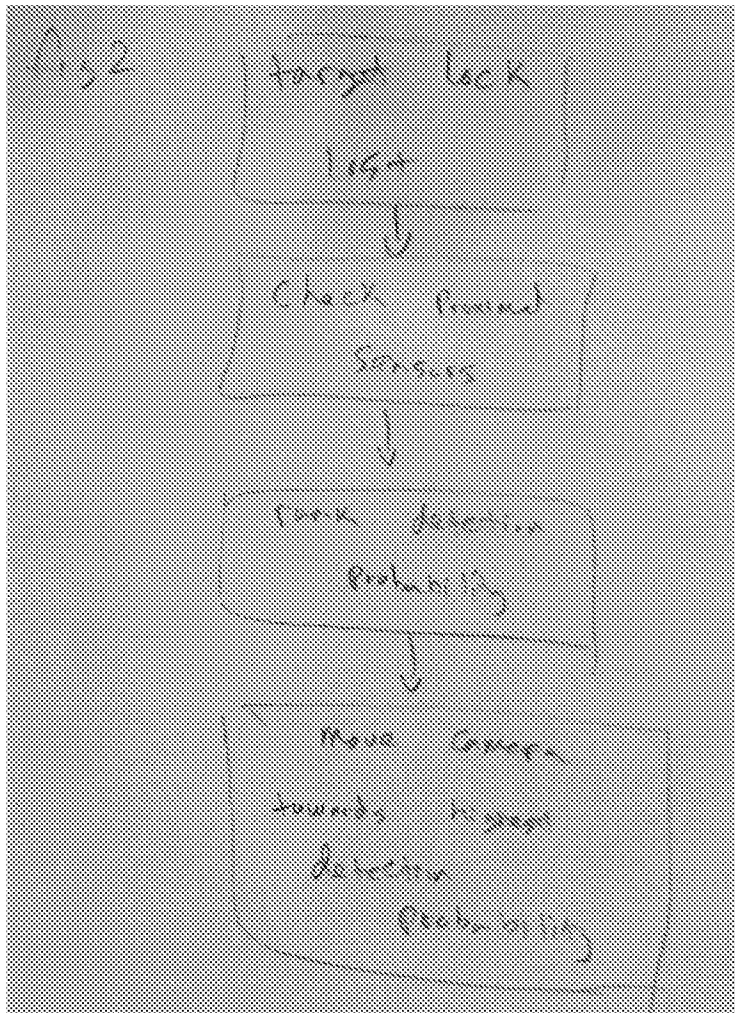
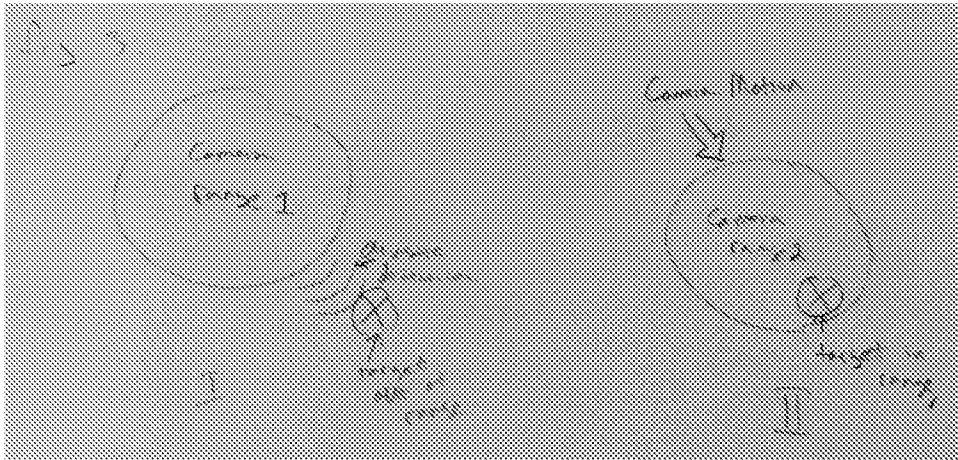


Figure 3: Proximal sensor directionally cueing the main sensor



Appendix: Airspace ML Technology Overview and Disclosures

1. Topic 1: ML around object identification / targeting, field view depth sensing, etc.

a. Problem

- i. Conventional radar and airspace monitoring technologies are designed to detect objects that are large, moving at high speeds, and fly in low clutter environments (i.e. airplanes, missiles, etc.). However drones present unique challenges because they are small, move relatively slower, and fly in densely surrounded areas.

b. Technological Solution

- i. We employ state of the art machine vision algorithms in combination with an array of commercially available off the shelf cameras/lidar sensors to blanket the sky with 'eyes.'
- ii. This implementation allows us to take advantage of the increasing affordability of sensors/cameras technology in order to cost effectively scale our area of coverage.
- iii. Drone based cameras offer further triangulation and coordination for closing in on a given target.

c. Related Airspace IP

- i. AIR14 - System for sUAS Interception and Interdiction Utilizing Multimodal Fusion and COTS Sensors
- ii. AIR15 - Camera Based sUAS Triangulation and Targeting System

- iii. AIR16 - Spatio-temporal Awareness Engine for Priority Tree Based Region Selection Across Multiple Input Cameras
- iv. AIR18 - Recognition and Validation of Object of Interest Using Deep Learning and Offline Ensemble Classifier Based Model Training.

2. Topic 2: DNN / Tracker + Flight path predictor (for foreign drone object)

a. Problem

- i. Drones are very small, very agile, and quick moving objects, which can have unpredictable trajectories. Targeting drones thus requires high sampling rate so that they may be continuously monitored and tracked.
- ii. Current state of the art machine vision algorithms are optimized for high performance and power intensive hardware (i.e. data centers, autonomous cars, etc.). However light weight and high-speed drones have limited power supplies and thus cannot devote a lot of power for vision processing.

b. Technological Solution

- i. Our innovation is around the optimization of limited resources available on a drone.
 - 1. High Power: Deep Neural Networks are run to periodically to detect objects and distinguish targets.

2. Low Power: Once an object is detected (i.e. using DNN or manual input) a tracker algorithm takes over and maintains lock on the target.
- ii. This optimization allows us to use the latest advances in machine vision algorithms while also allowing us to develop specialized algorithms in-house.
- iii. Flight path prediction: The combination of DNN/tracker algorithm has the added benefit of anticipating how a detected object will move.

c. Related Airspace IP

- i. AIR8 - Region of Interest Selection in Machine Vision Systems for Aerial Object Tracking
- ii. AIR16 - Spatio-temporal Awareness Engine for Priority Tree Based Region Selection Across Multiple Input Cameras
- iii. AIR17 - Multimodal Sensor Empowered Awareness Engine for Target Recovery and Object Path Prediction

3. Topic 3: Flight Mission / Trajectory (for Airspace drone)

a. Problem

- i. In order to be readily deployable and effective interceptor drones must be designed to be fully autonomous with minimal pilot intervention.
- ii. Traditional flight control/mission solutions (i.e. Pixhawk) have limited functionality and are not suitable for high speed guidance and interdiction.

b. Technological Solution

- i. Custom drone guidance system that is directly tied to the onboard machine vision system.
- ii. User is able to program mission application logic based upon human understandable tasks (i.e. track and follow, interdict and tow, etc.)

c. Related Airspace IP

- i. AIR6 - High Speed Guidance System for Autonomous Drone Systems
Incorporating Sensor Feedback
- ii. AIR21 - Path Planning and Prediction Techniques for Autonomous Pursuit
Drone Systems
- iii. AIR22 – System for the Implementation of Mission Application Logic in
Autonomous Vehicle Systems

4. Topic 4: Flight Pilot (for Airspace drone)

a. Problem

- i. An effective counter drone system is one that is easy to operate and readily usable with minimal set up and training.
- ii. In addition a user must be able to execute commands using a mobile phone/device.

b. Technological Solution

- i. “Point and Communicate”: Wifi + LED enabled secured communication between observer and drone pilot/owner.

- ii. “Point and Capture”: Mobile phone/device camera based target lock and interceptor deployment system.

c. Related Airspace IP

- i. AIR7 - System and Methods for Establishing Communication with a Drone Owner
- ii. AIR10 – Object Detection and Target Cuing System Utilizing a Mobile Device
- iii. AIR19 - Encryption for Low Altitude Aircraft Identification Systems

Disclosure Technical Details

Machine Learning

2. Drone ROI detection CNN

Problem:

Ability to detect drones in the air, with different types of backdrops (fields, sky, city etc).

Solution:

ROI detection is a technology that employs an Airspace proprietary deep neural network trained not only to identify the presence of a drone but also the position of that drone in the camera frame in real time. The technology employs our private drone data set trained with a DNN designed to do high speed inference in low power devices. The training is augmented offline with newly collected relevant data for a particular deployment.

Our technology is an advancement on latest developments in deep learning academia/industry work like Faster-RCNN/SSD/YOLO along with a combination of LSTM and Bayesian inference model.

Vision + ML

3. Spatio-Temporal Awareness Engine

Problem:

Airspace interceptor drones need a spatial and temporal awareness to effectively detect and track a target drone. It provides the ability to avoid other flying objects, re-detect lost target and contribute to optimal path planning.

Solution:

Airspace Spatio-Temporal awareness engine uses multi-camera view which is processed in parallel by a cascade of noise removal and super pixel feature consolidation and isolation algorithms to bring them to lower resolution images. These images are processed continuously using proprietary anomaly detection and populated in a probability distribution based priority quadtree/octree maps for further processing by the main high resolution tracking engine. Our anomaly detection uses a combination of traditional edge and contour based features in combination with a temporal prediction filter.

The main high resolution tracking engine runs high speed feature based tracking based on disparity of similarity features with live adaptation, main engine in addition employs color features and model predictions (Kalman/Particle filters etc.) to rule out pixel domain inconsistencies. The advantage of this two-tier architecture is the ability to reject and give prioritized areas for heavier compute algorithms.

On a fixed compute budget there is a negative relation between robustness of the algorithm and the cost or latency of the algorithm per frame. Tight restrictions on available compute cycles limits the responsiveness of the system.

By using different tracking algorithms and DNN based detections of target in video frame the main tracking engine has high robustness but also has high compute cost. A simple background tracker can incrementally predict the location of a target in the frame with low compute cost average robustness.

By combining the multiple algorithms in a way that achieves high combined frame rate with higher quality prediction we attempt to get the best of all worlds.

Vision + ML

4. Multimodal Visual Target Recovery

Problem:

Recovery of a full loss of tracking target from visual data.

Visual detection and tracking of moving targets suffers from target loss when the target leaving the camera viewport due to the relative movement between the target and the camera.

Solution:

Fast recovery of lost targets is highly desirable for any system that tracks targets visually.

Using non visual, fast processing sensors that give rough directionality of the signal, allow for prioritization of the visual target scanning process. Such sensors include sound, RF, radar and proximity sensors that do not isolate the location of a possible target, but give general direction to be scanned first.

Autopilot

5. High Speed Trajectory and Flight Path Estimation

Problem:

Trajectory estimations in high speed scenarios with high background clutter becomes extremely challenging because of the temporary loss or lag in visual tracking.

Solution:

The trajectory estimation engines have a dynamic vector update rate to control the flight path.

The vectors continuously correct the flight path, effectively controlling the trajectory of the interdiction drone. The dynamic vector rate allows the flight path to be independent of the vision tracking rate. The dynamic rate of flight path is done through trajectory predictions.

Prediction of trajectory employs a collection of estimated flight vectors, estimated flight vectors is based on flight vectors generated by tracking engine, the predictions done by EKF based model in combinations with two possible trajectory alterations. The trajectory alteration vector is a linear combination of high confidence probabilities candidates from spatio-temporal engine and from the visual target location recovery subsystem.

Interdiction

6. Automatic Interdiction Trigger

Problem :

Timing and relative position are key in successful automated deployment of interdiction measures. Deployment of interdiction measure that capture targets in mid-flight allows for a system that captures a drone in mid-flight.

Solution :

A directional proximity sensor that auto triggers the interdiction measure is pre-calibrated to ensure a successful capture of the target. The system software arms this mechanism in the last phase of the flight once the target drone is close, to avoid false positives. Once armed the proximity sensor will sense objects in a range that is operational and synchronize with the effective range of the interdiction measure.

The flight system needs to position itself in the right range and the automatic interdiction would be triggered.

System

7.System for drone interdiction

Problem:

Drone visual sensors / cameras have limited range that restrict the range of the system in tracking and flying visually toward a target.

It is desirable to have a system that captures and removes drones from an airspace that has long range capabilities. It is not enough to disable or damage a drone, as a disabled drone may cause more harm.

Solution :

By combining long range ground sensors, a control network and short range visual flight, the interceptor drone can perform long range missions against anomalies in the airspace.

An interceptor drone is in standby in a special compartment and is in fast takeoff state with detachable tethered power and gps lock.

The drone is listening to a network for instructions from a control server. Once a sensor package has detected an anomaly in the airspace, it's location is communicated to the appropriate interceptor drone by the control server. The interceptor drone takes off and flying to the location of the anomaly by gps, getting updates while flying from the network.

Once it is in visual range (depending on the interceptor drone optics) it will scan the approximate location of the target anomaly and attempt to detect it using its machine vision classifiers. It will then accept or reject the anomaly as a valid target (SCAN mode)

If it is a valid target, the interceptor drone will track it and fly toward it, positioning itself in a predefined relative position to the target, it will then arm its interdiction measures and wait for an automated interdiction to occur.

(In case of lost tracking it will go back to SCAN mode)

(In case of failure to interdict it will arm the next interdiction measure)

(In case of no interdiction measures it will abort and go home)

On successful interdiction the drone will tow the target drone into a pre-defined location to be prepared for the next mission.

Drawing Descriptions

- Drawing 1: Overview Architecture
 - a. Overview of system including
 - i. Sensor Resources: short range and long range
 - ii. Sensor Control Systems
 - iii. Detection/Localization Engine (Spatio-Temporal Awareness)
 - iv. Pixel to Vector Pipeline
 - v. Mitigation Resources
- Drawing 2: Sensor Resources
 - a. Long Range: Includes video feeds, radar, lidar
 - b. Short Range: Includes cameras, gps
- Drawing 3: Control System
 - a. Sensors are controlled by manufacturer SDKs
 - b. Translates camera control signals
- Drawing 4: Spatio-Temporal Awareness
 - a. Includes prediction engine
 - b. Longterm Path planning
- Drawing 5: Mitigation System
 - a. Recieves XYZ GPS coordinates and triggers interdiction
- Drawing 6: Pixel to Vector Pipeline 1
- Drawing 7: Pixel to Vector Pipeline 2
- Drawing 9: Quadtree Structure (Example of a quadtree division of a visual field)

Sensor Resources

Long Range

Video, multiple body
catrac
- triangulation
- gyroscope
LiDAR

Short Range

Cameras - 4K
GPS

Control System

Manichaeus
F. 1000 - 500 B.C.

Control

Group 10 of 100
 10's Group
 10's Group

100

Approved by the Board of Directors

Print - Working

Pro's in System - for Germany

803 12/1 - 4/1

Don't know what

February 23rd

Thompson, John G. & Co.

Spatio-Temporal Awareness

Detection / Localization
Engine

Prediction
Engine Location
 Path Planning

Predict

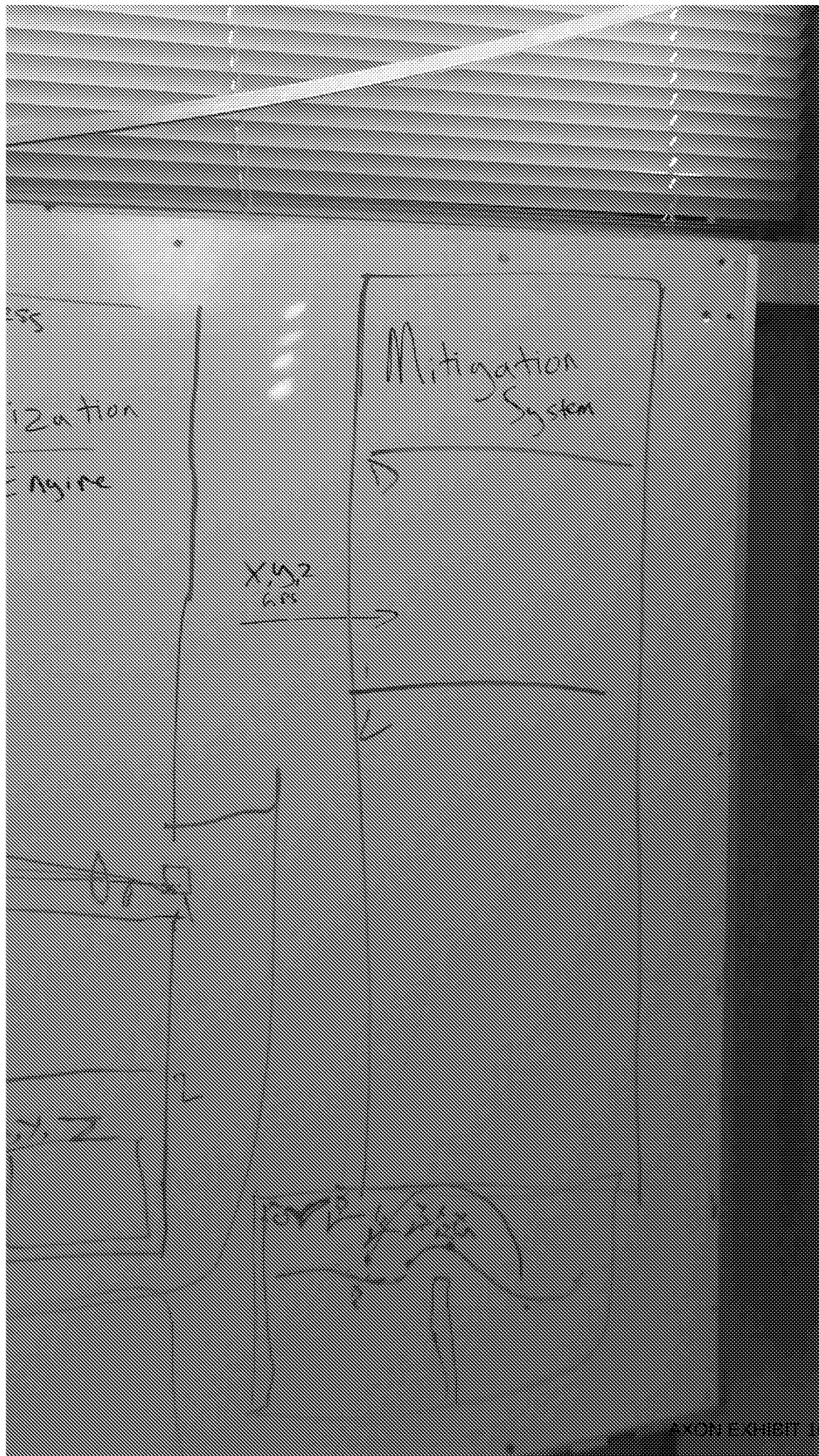
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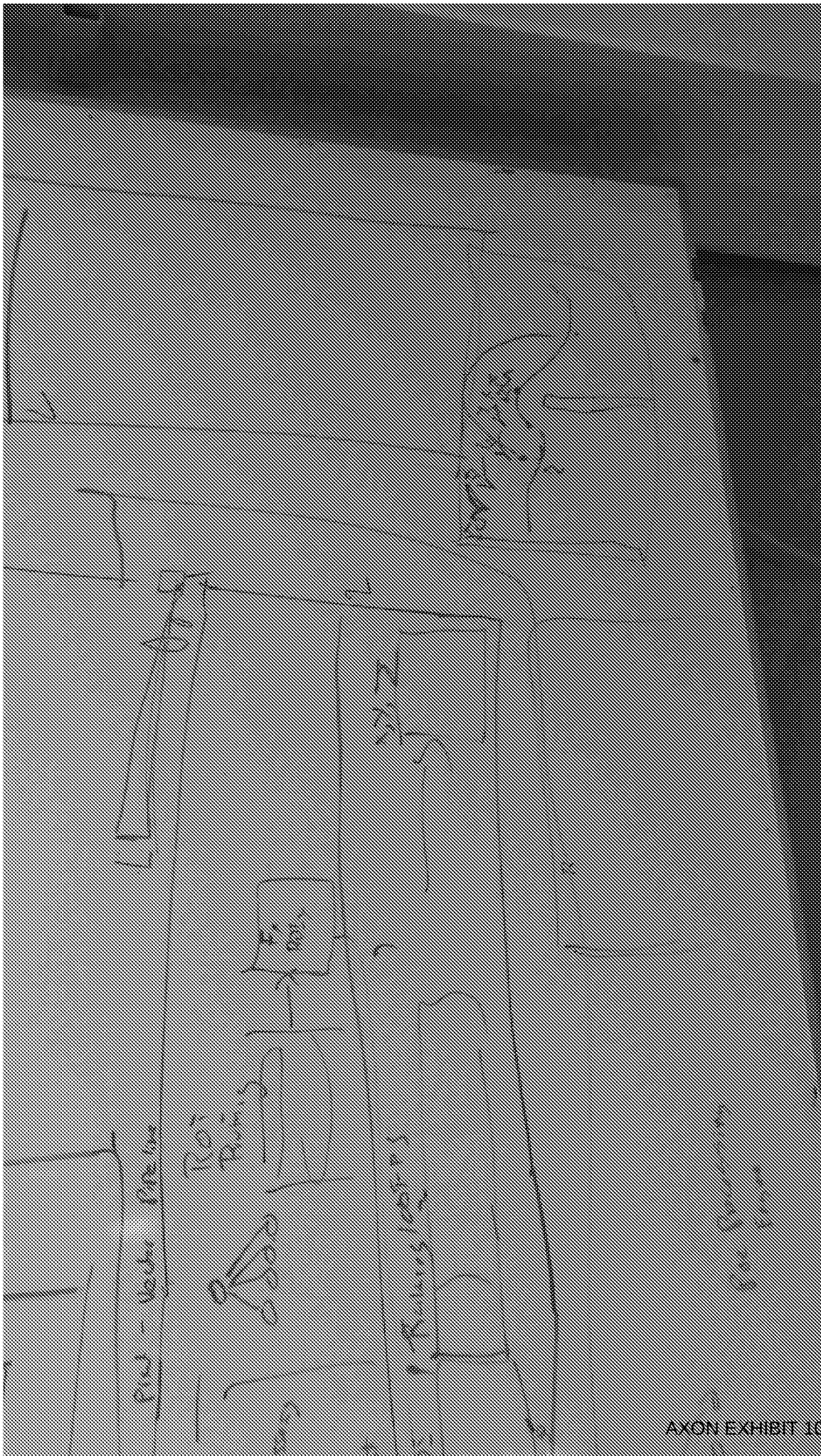


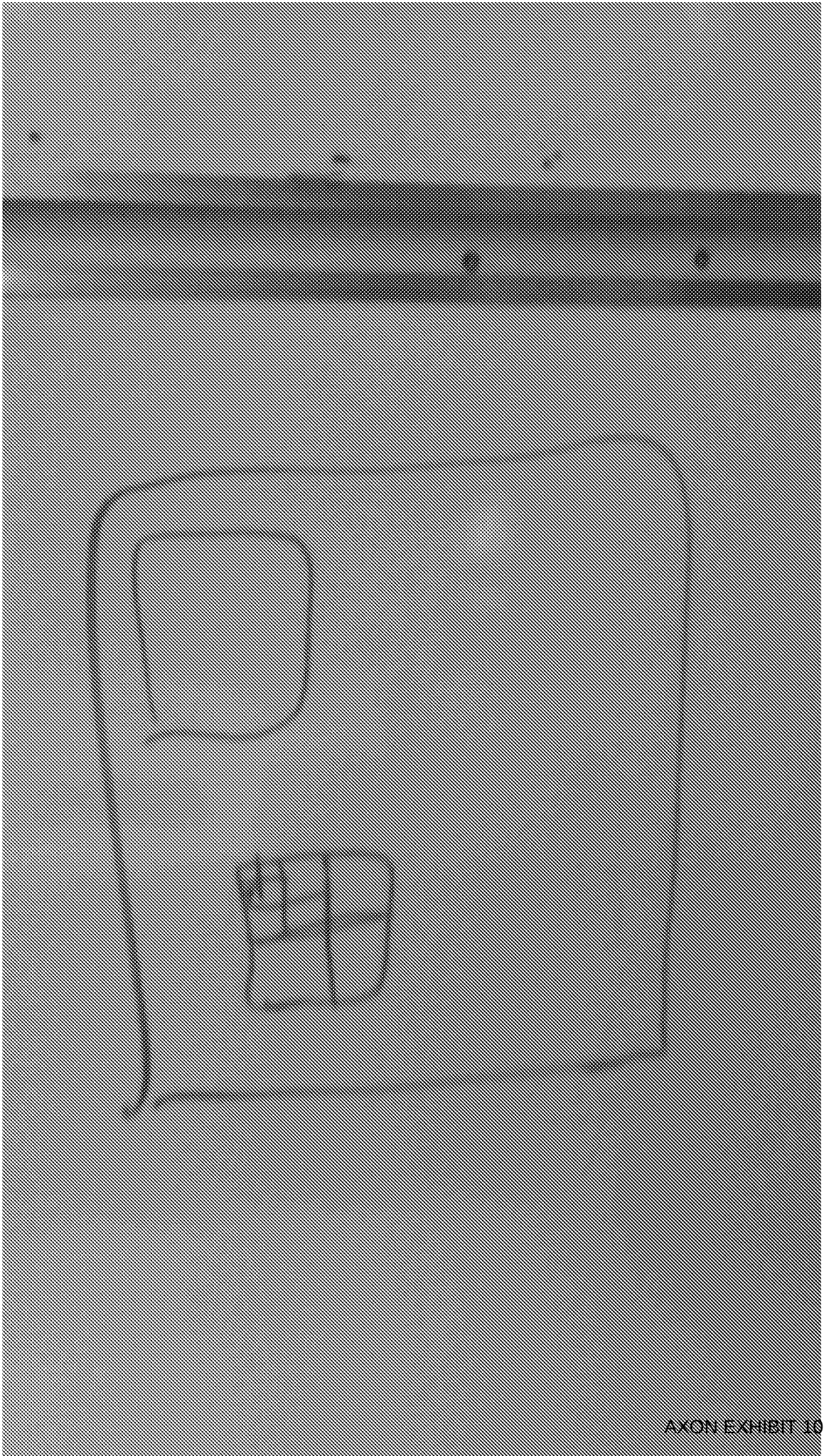
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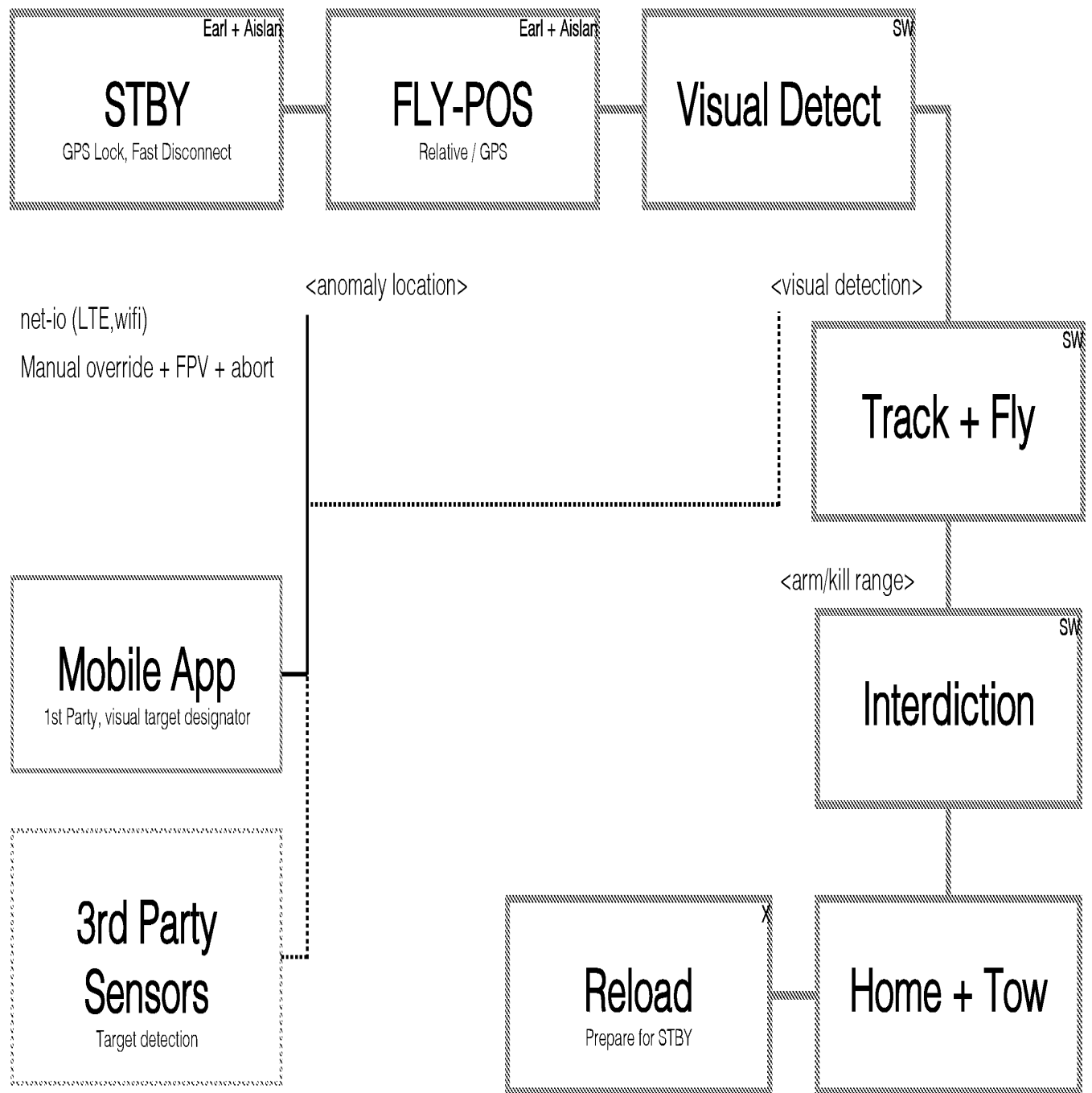
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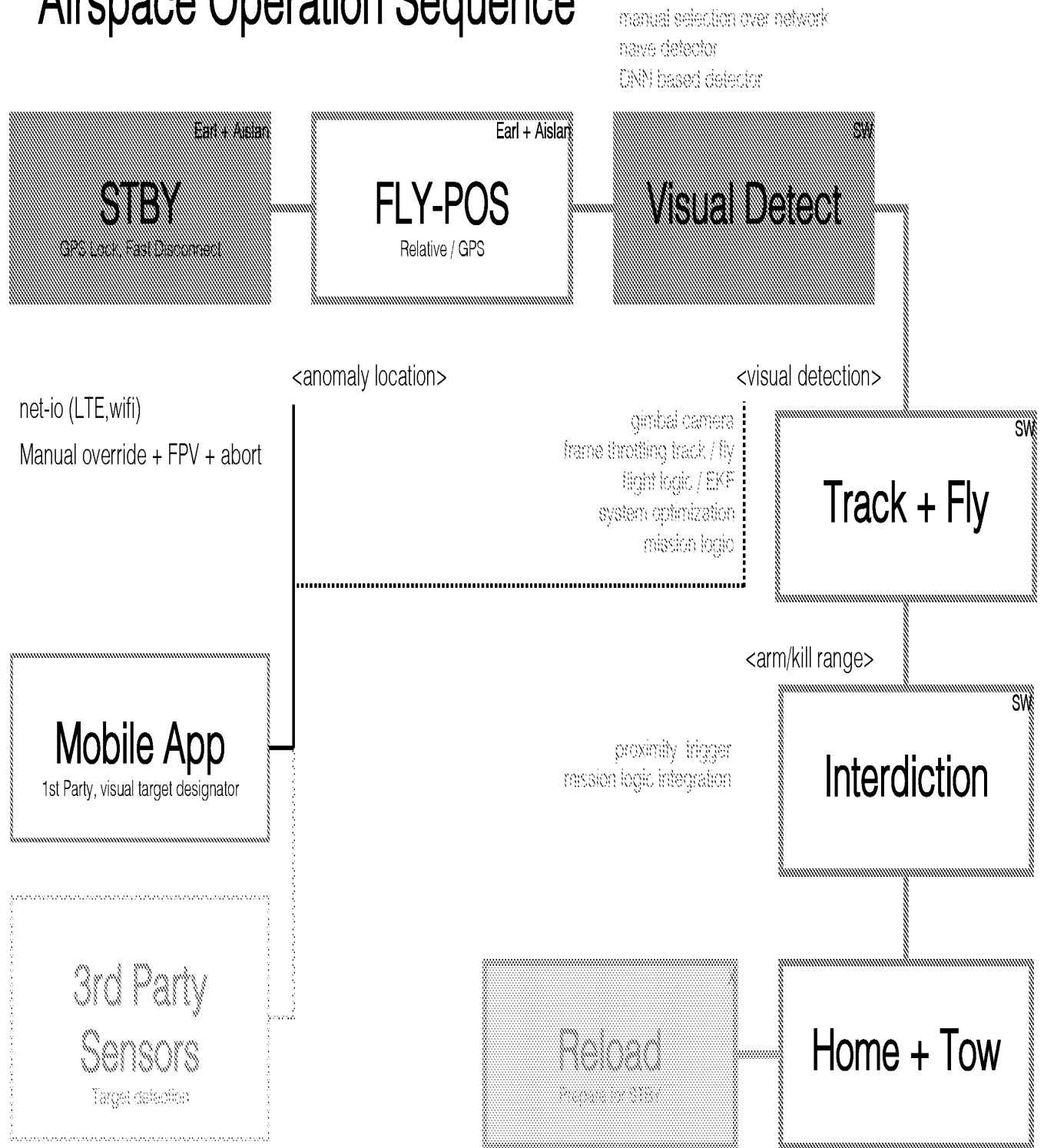




Airspace Operation Sequence



Airspace Operation Sequence

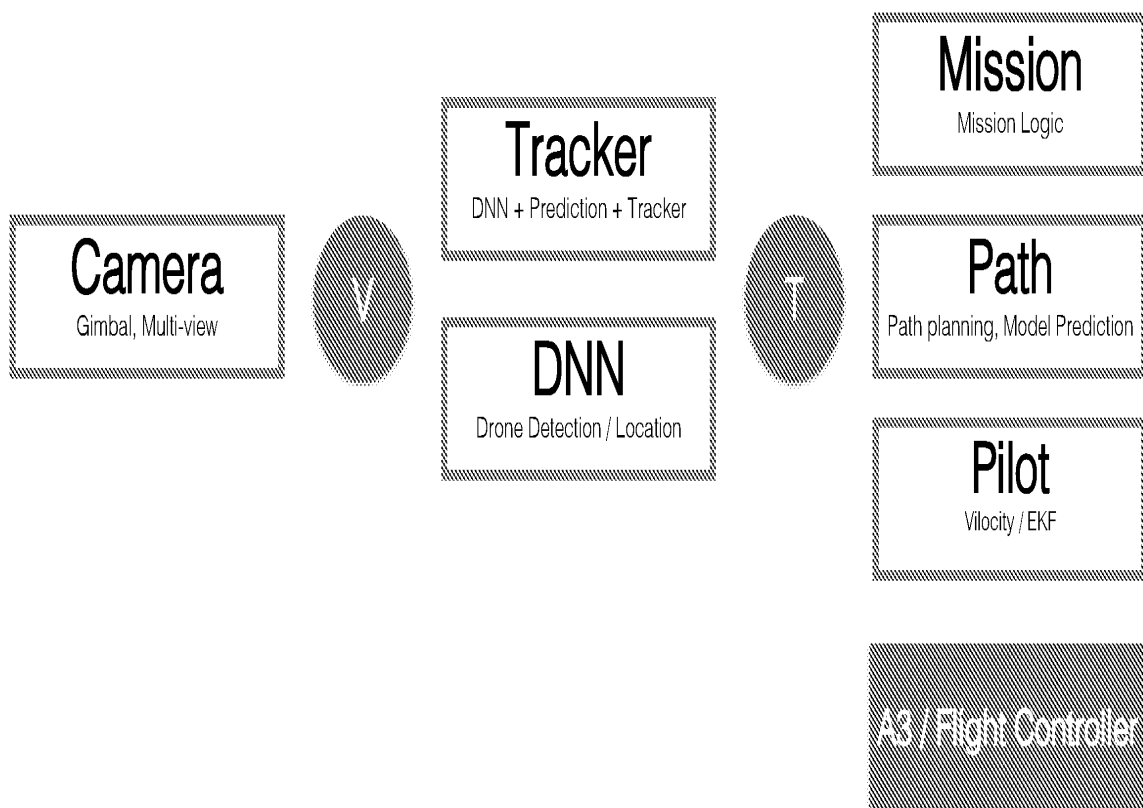


Airspace Vision / Flight Architecture

GoldenEye

HAL

TopGun



video fps

tracker fps

<

flight fps

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		Multimodal Sensor Empowered Awareness Engine for Target Recovery and Object Path Prediction		
First Named Inventor/Applicant Name:		Guy Bar-Nahum		
Filer:		Saad Syed Enam		
Attorney Docket Number:		AIR17P		
Filed as Small Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
PROVISIONAL APPLICATION FILING FEE	2005	1	130	130
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
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Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				130

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EFS ID:	27162269
Application Number:	62405972
International Application Number:	
Confirmation Number:	5896
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First Named Inventor/Applicant Name:	Guy Bar-Nahum
Customer Number:	117915
Filer:	Saad Syed Enam
Filer Authorized By:	
Attorney Docket Number:	AIR17P
Receipt Date:	09-OCT-2016
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Application Type:	Provisional

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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
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