US011015902B2

(12) **United States Patent**
**Northrup**

(10) **Patent No.: US 11,015,902 B2**
(45) **Date of Patent: May 25, 2021**

(54) **SYSTEM AND METHOD FOR MARKSMANSHIP TRAINING**

(71) Applicant: **Shooting Simulator, LLC**, Dallas, TX (US)

(72) Inventor: **James L. Northrup**, Dallas, TX (US)

(73) Assignee: **Shooting Simulator, LLC**, Dallas, TX (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/814,860**

(22) Filed: **Mar. 10, 2020**

(65) **Prior Publication Data**

US 2020/0263957 A1 Aug. 20, 2020

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 16/397,983, filed on Apr. 29, 2019, now Pat. No. 10,584,940, which is a continuation-in-part of application No. 15/589,603, filed on May 8, 2017, now Pat. No. 10,274,287, which is a continuation-in-part of application No. 14/969,302, filed on Dec. 15, 2015, now Pat. No. 10,234,240, which is a continuation-in-part of application No. 14/686,398, filed on Apr. 14, 2015, now Pat. No. 10,030,937, which is a continuation-in-part of application No. 14/149,418, filed on Jan. 7, 2014, now Pat. No. 9,261,332, which is a continuation-in-part of application No. 13/890,997, filed on May 9, 2013, now Pat. No. 9,267,762.

(51) **Int. Cl.**
*F41G 3/26* (2006.01)

(52) **U.S. Cl.**
CPC .................................. ***F41G 3/2633*** (2013.01)

(58) **Field of Classification Search**
CPC ........ F41G 3/26; F41G 3/2655; F41G 3/2616; F41A 33/00; F41A 33/02; F41A 33/04; F41A 33/06; F41J 5/10; F41J 5/18
See application file for complete search history.

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* cited by examiner

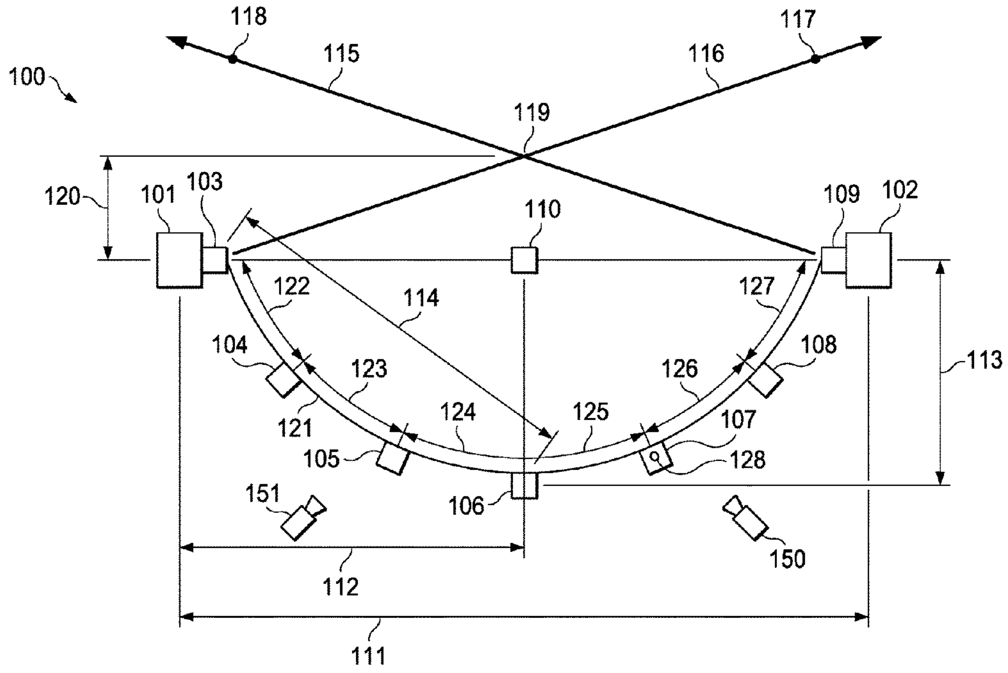
*Primary Examiner* — Timothy A Musselman

(74) *Attorney, Agent, or Firm* — Schultz & Associates, P.C.

(57) **ABSTRACT**

A system for and method of use of an augmented reality display is provided. The preferred system is implemented by one or more tactical units calculating a target path from a weapon position and a range. A lead is calculated. A phantom target is displayed at the lead. A virtual laser and virtual tracer are provided to assist in target tracking. A spotter unit is also provided to supplement target path and range data. A neural network is provided to learn from tracking and successful lead data and to predict lead in the tactical theatre.

**25 Claims, 85 Drawing Sheets**



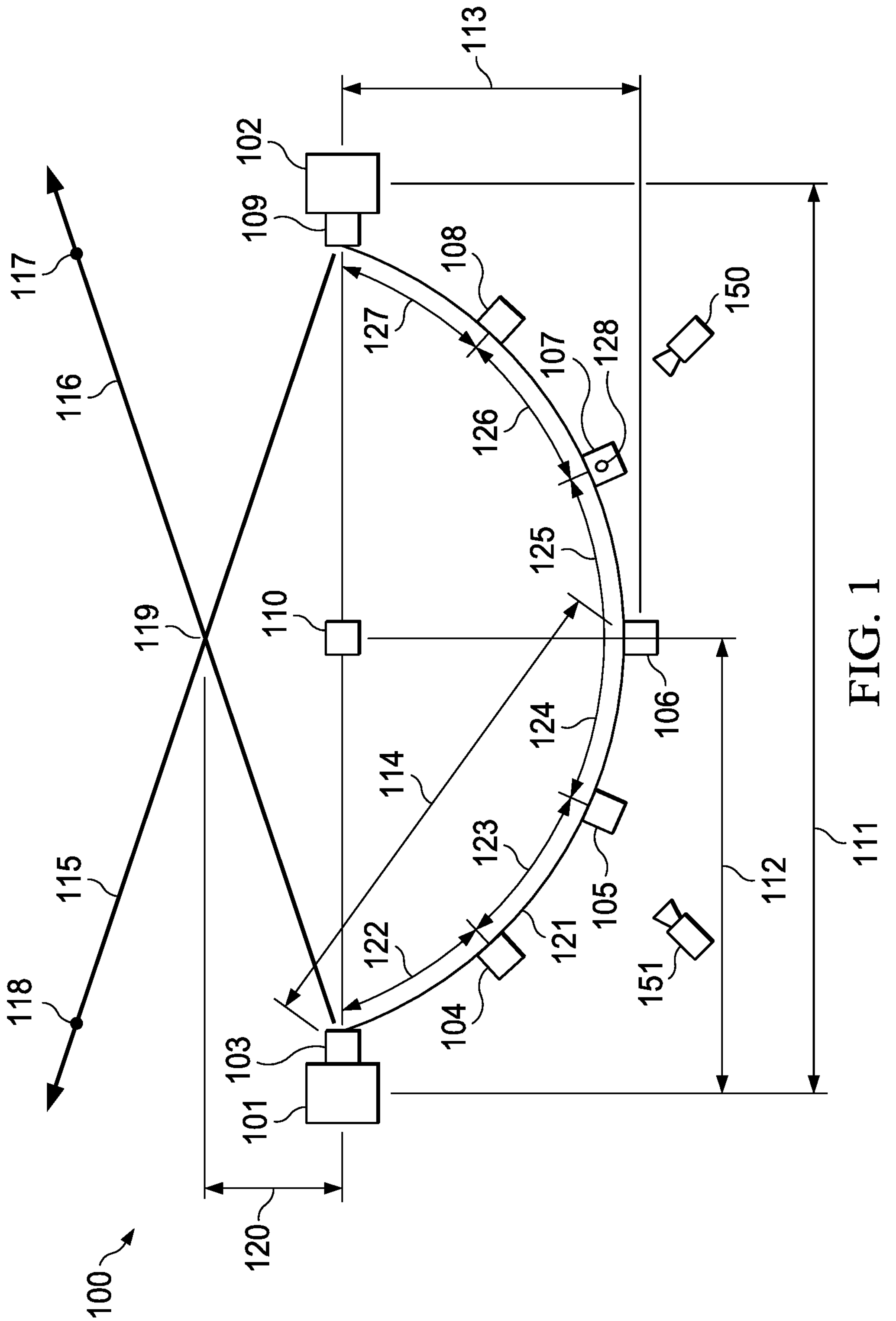

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FIG. 1

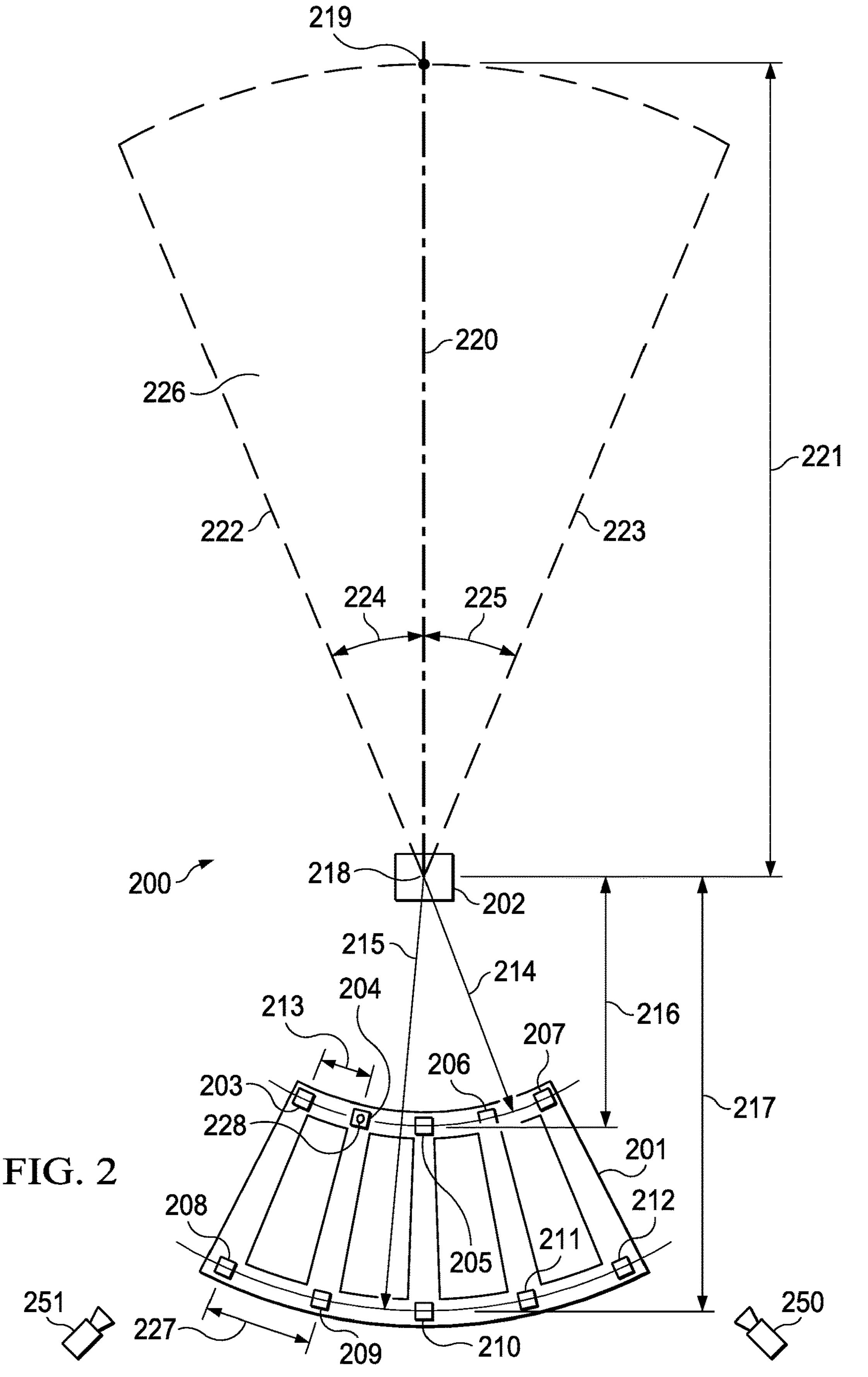
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FIG. 2

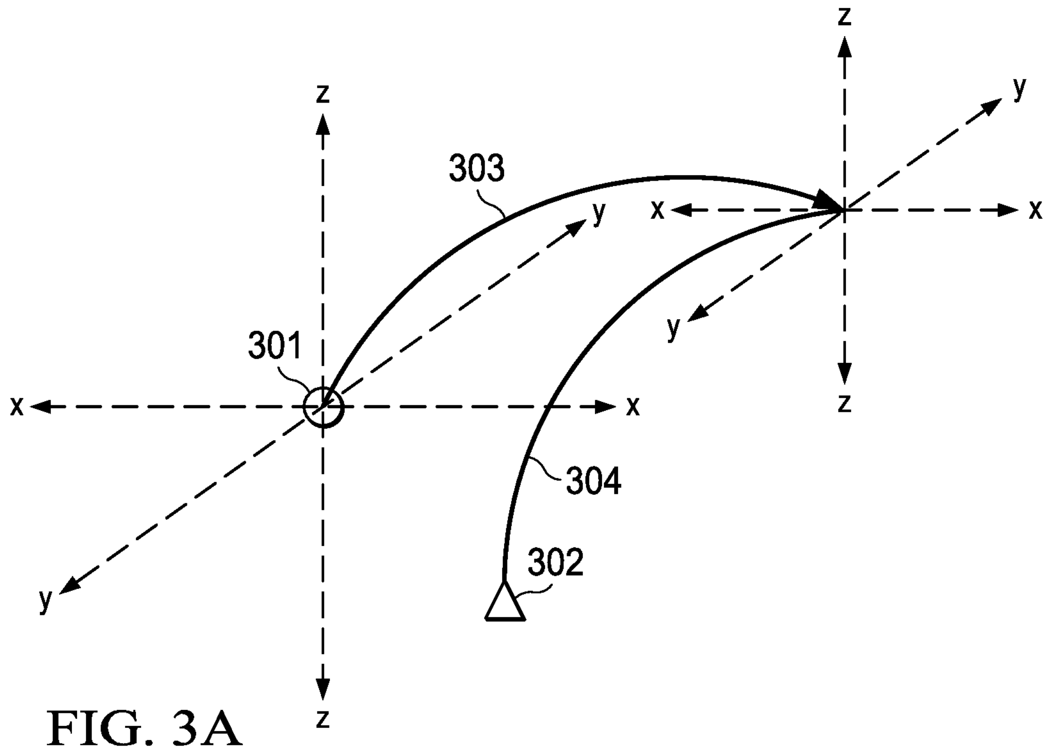


FIG. 3A

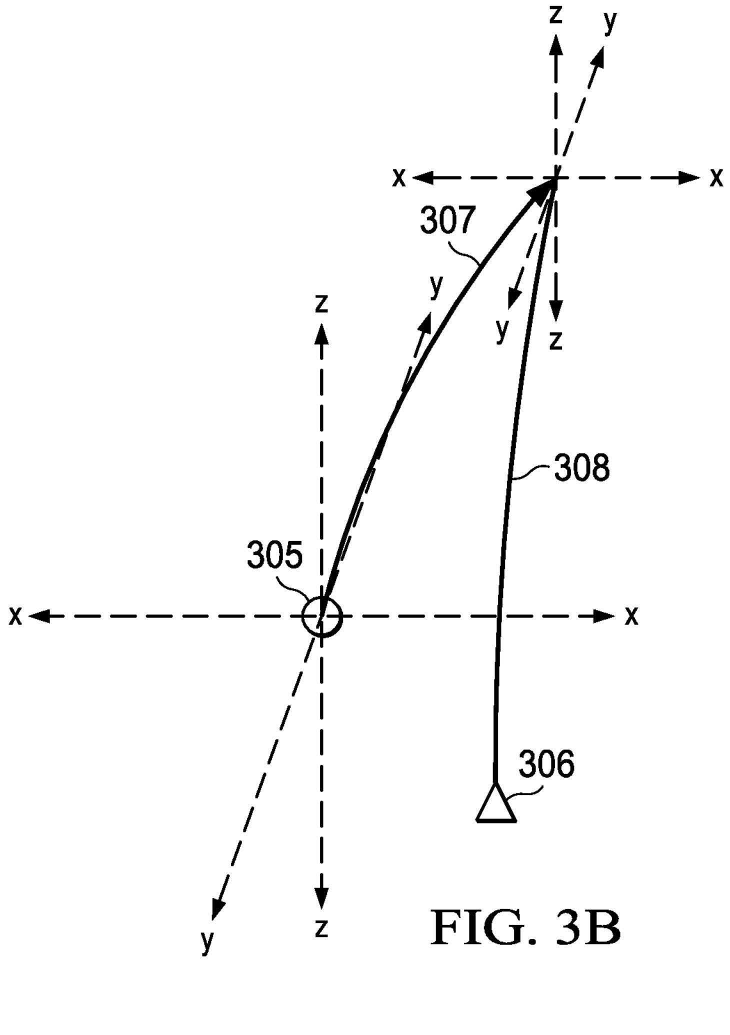


FIG. 3B

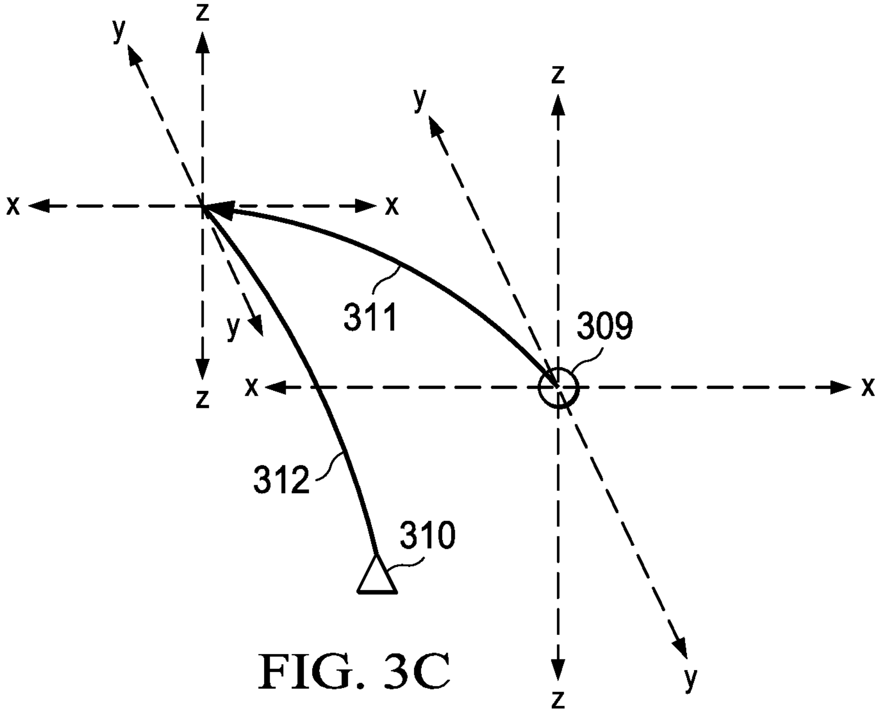


FIG. 3C

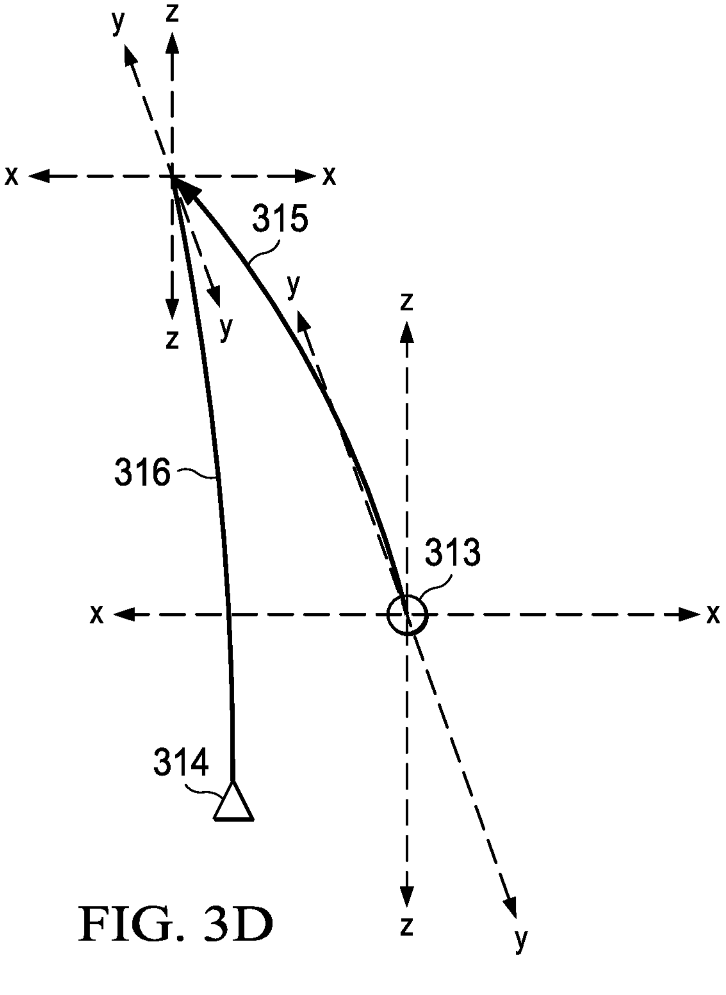


FIG. 3D

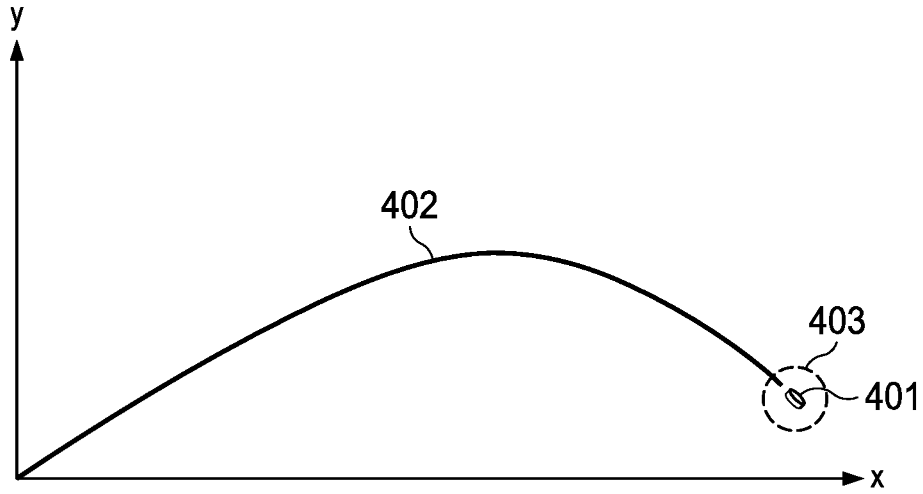


FIG. 4A

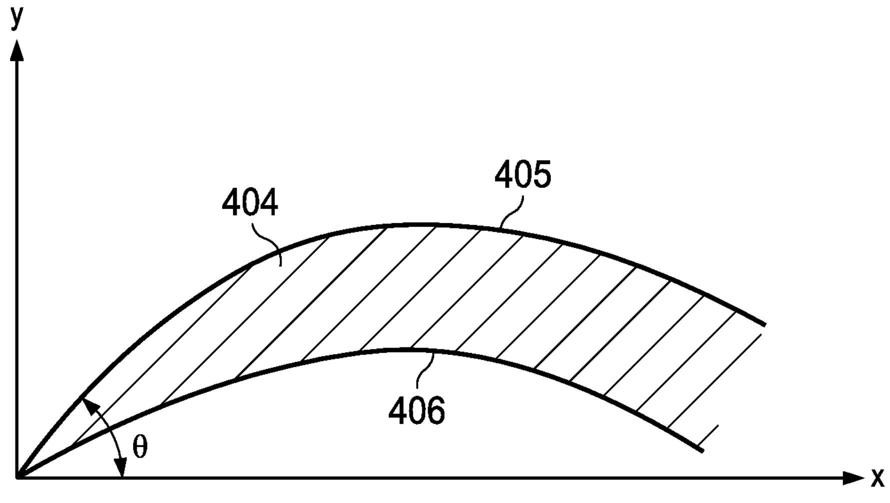


FIG. 4B

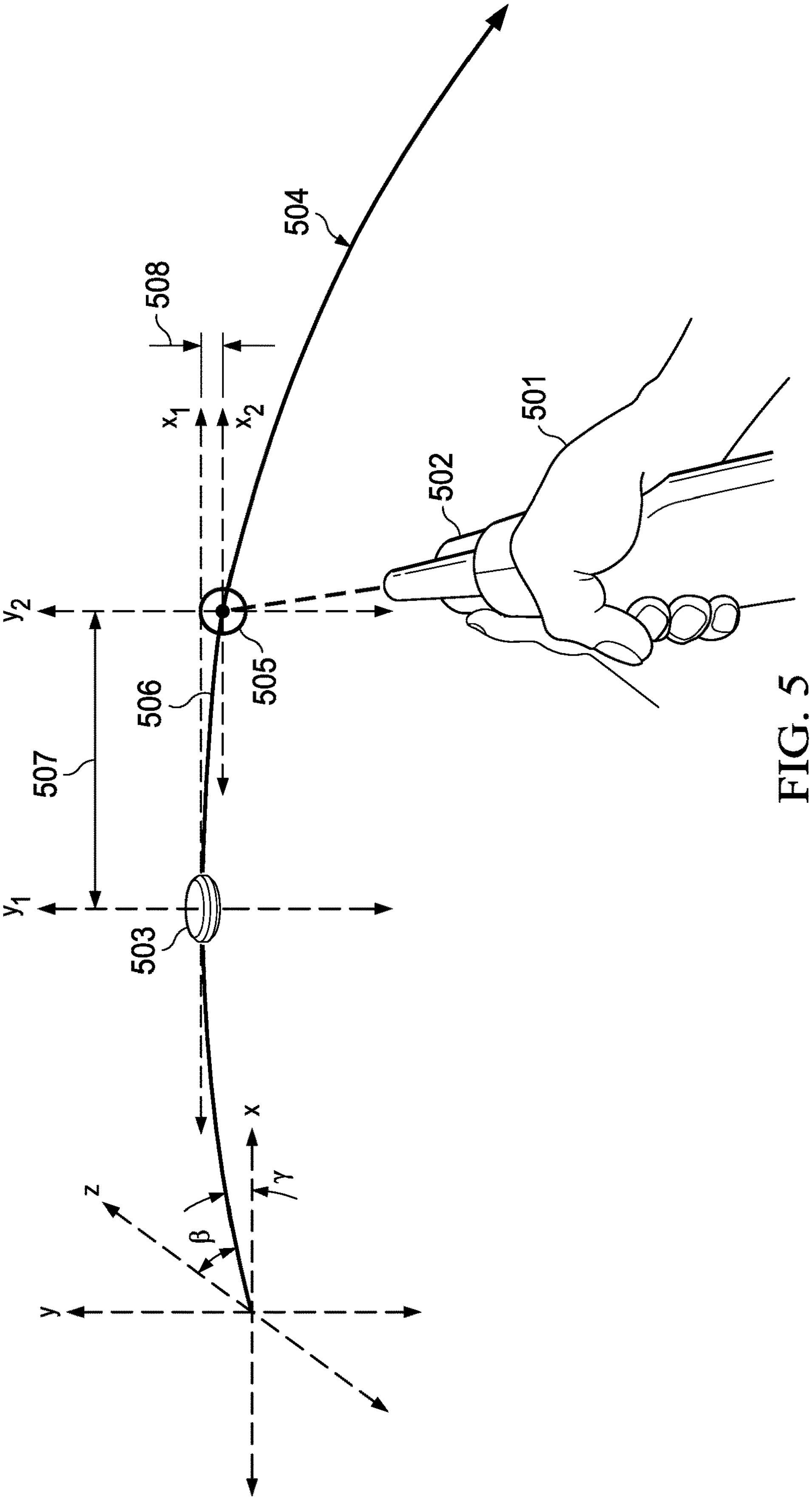


FIG. 5

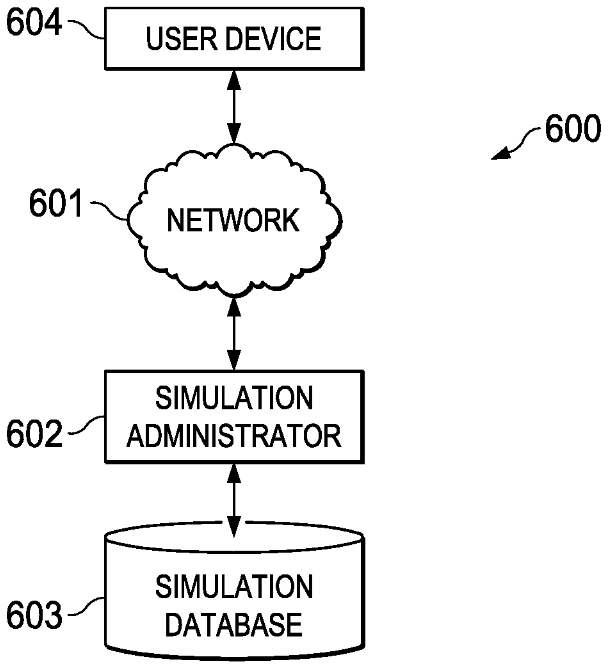

604
USER DEVICE
600
601
NETWORK
602
SIMULATION ADMINISTRATOR
603
SIMULATION DATABASE

FIG. 6

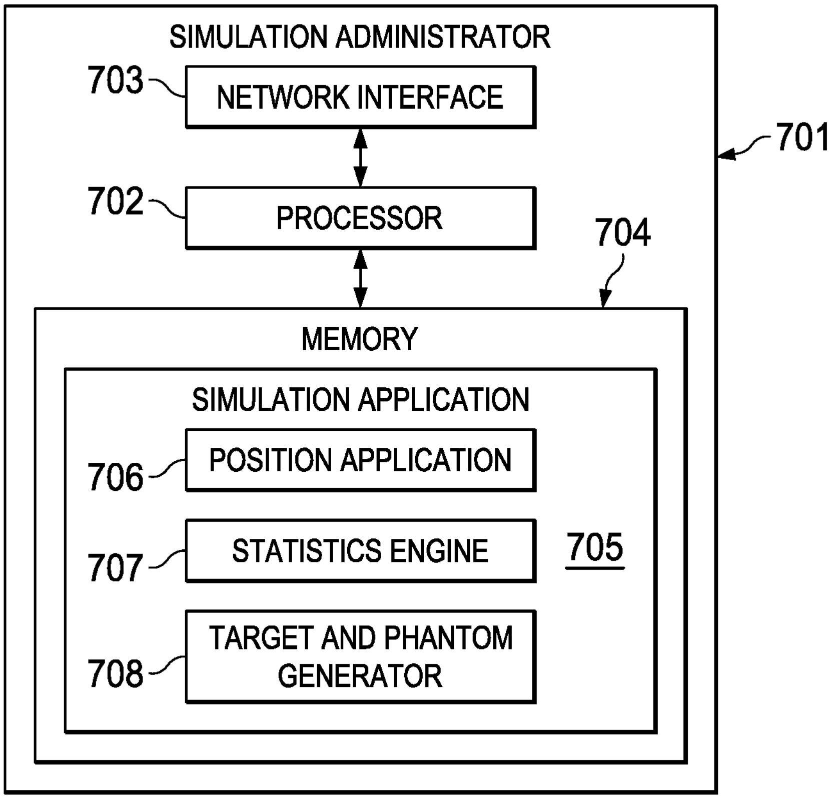

SIMULATION ADMINISTRATOR
703
NETWORK INTERFACE
701
702
PROCESSOR
704
MEMORY
SIMULATION APPLICATION
706
POSITION APPLICATION
707
STATISTICS ENGINE
705
708
TARGET AND PHANTOM GENERATOR

FIG. 7

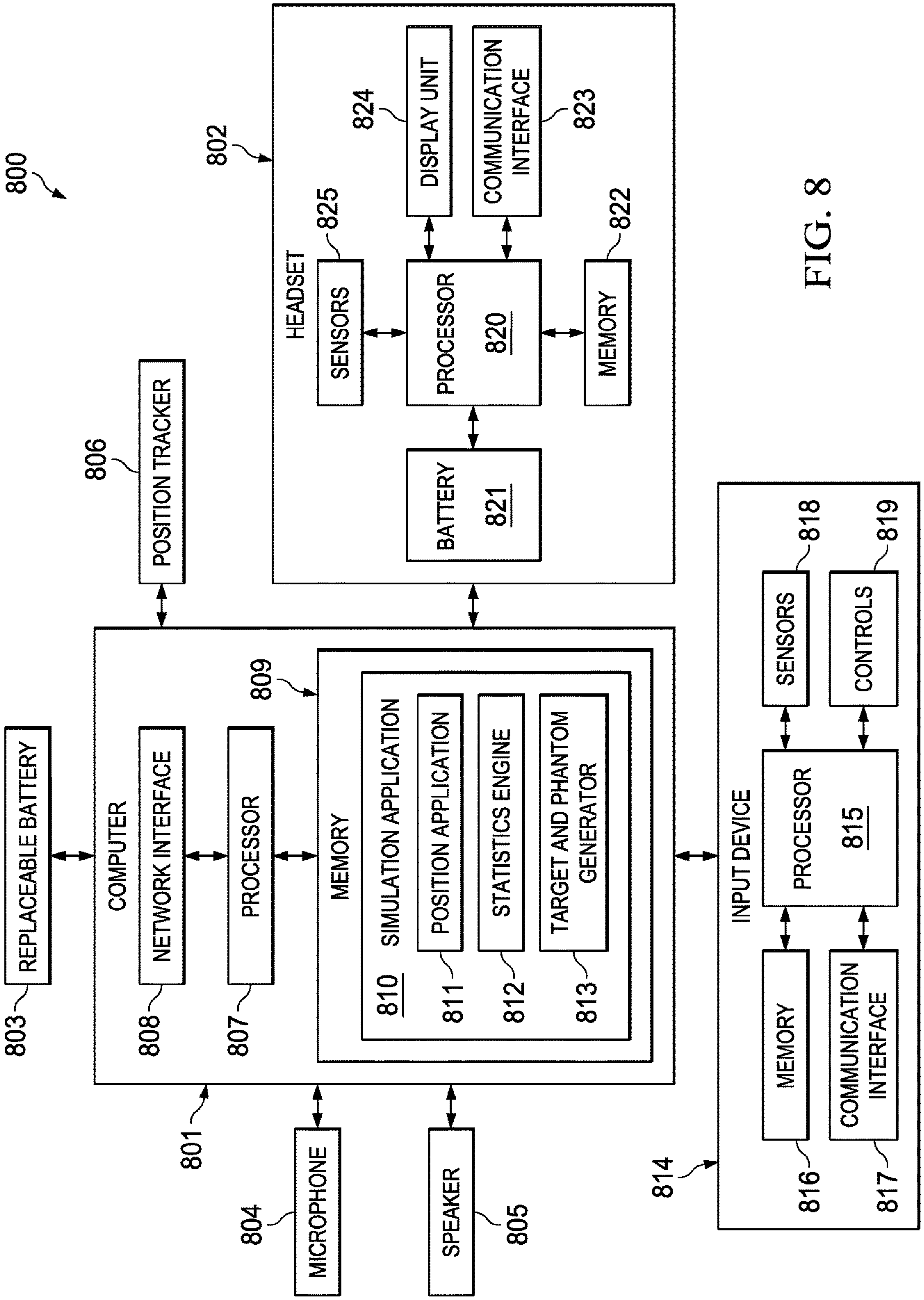
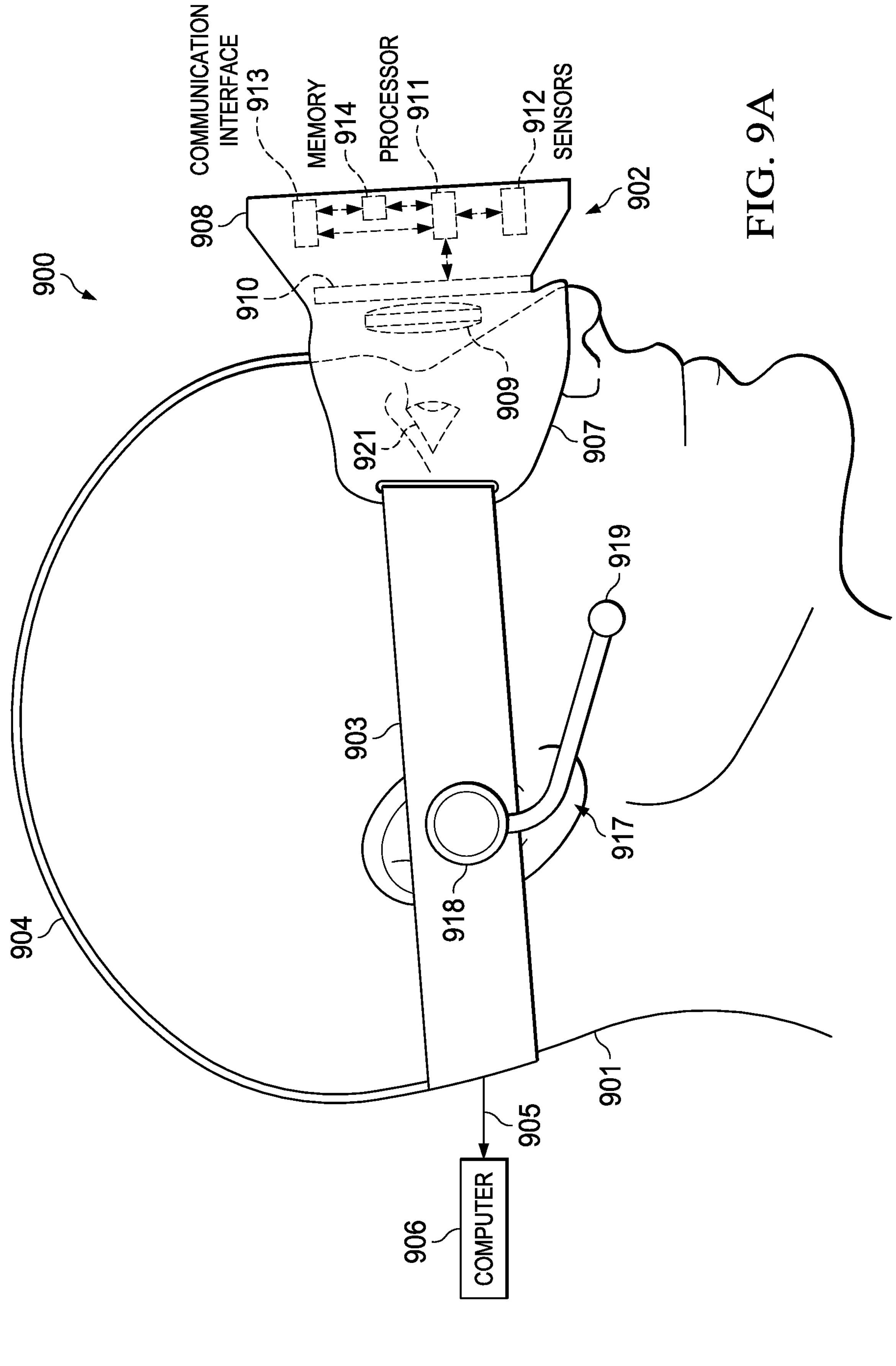

800
802
HEADSET
824
DISPLAY UNIT
823
COMMUNICATION INTERFACE
825
SENSORS
PROCESSOR
820
MEMORY
822
BATTERY
821
806
POSITION TRACKER
803
REPLACEABLE BATTERY
801
COMPUTER
808
NETWORK INTERFACE
807
PROCESSOR
809
MEMORY
810
SIMULATION APPLICATION
811
POSITION APPLICATION
812
STATISTICS ENGINE
813
TARGET AND PHANTOM GENERATOR
804
MICROPHONE
805
SPEAKER
814
INPUT DEVICE
818
SENSORS
819
CONTROLS
PROCESSOR
815
816
MEMORY
817
COMMUNICATION INTERFACE

FIG. 8


COMMUNICATION INTERFACE
913
MEMORY
914
PROCESSOR
911
912
SENSORS
902
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906
COMPUTER

FIG. 9A

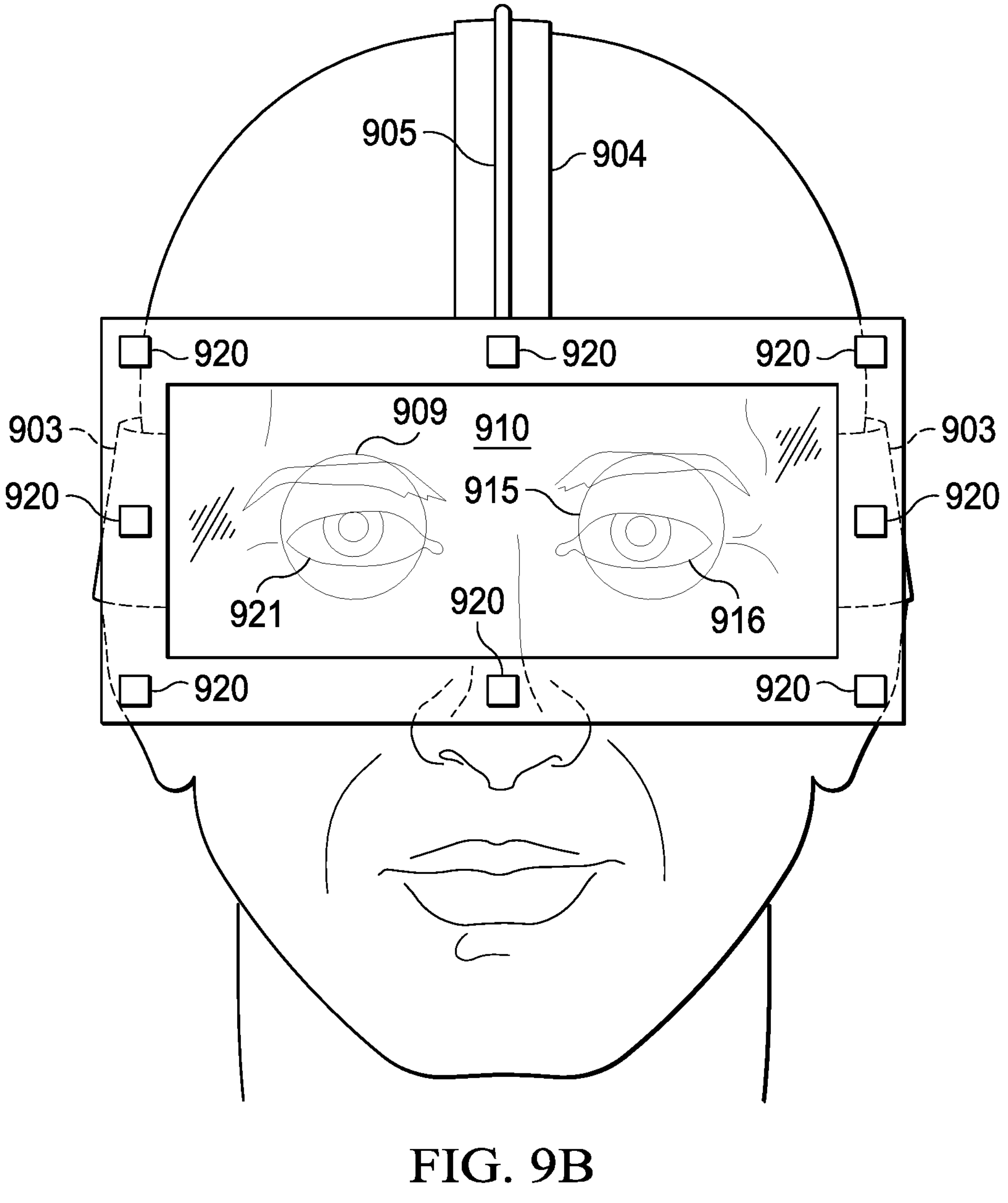
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FIG. 9B

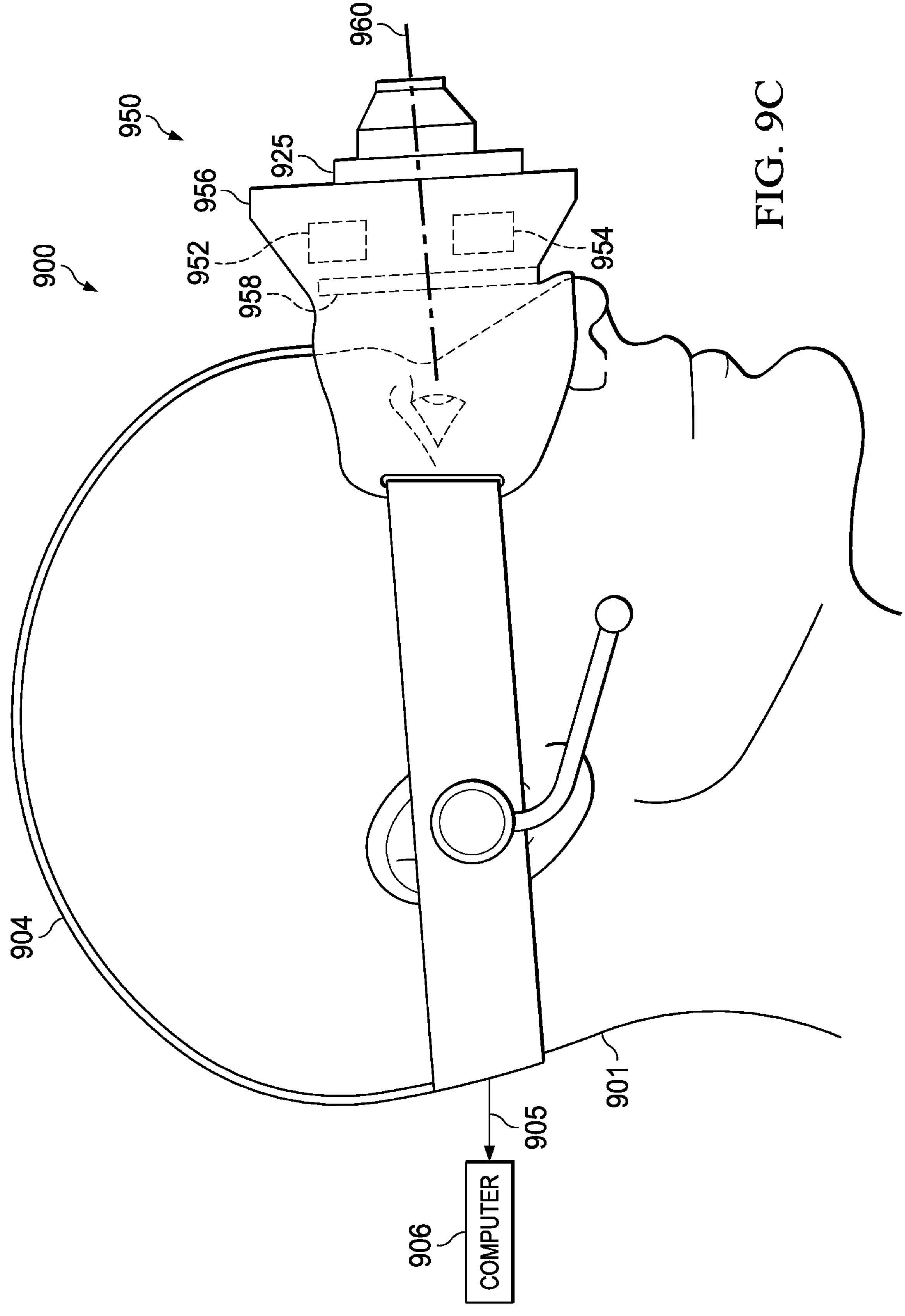

FIG. 9C

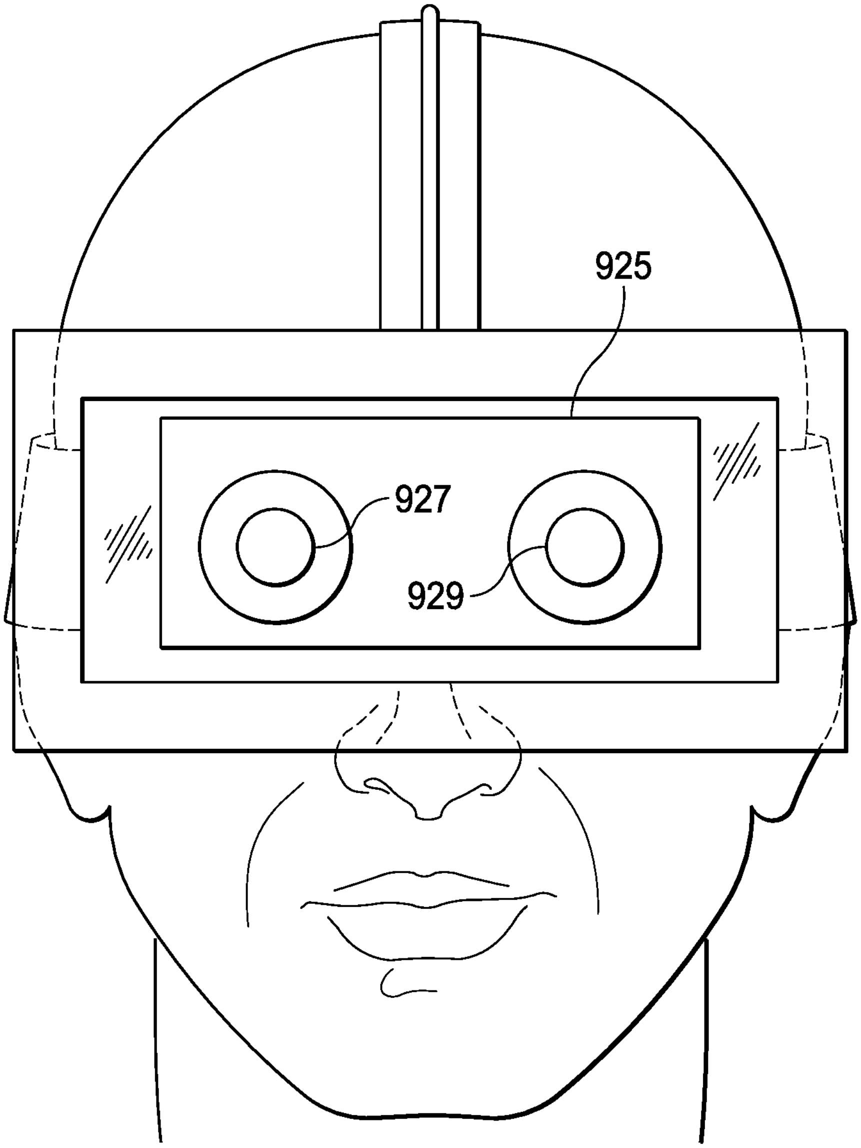

FIG. 9D

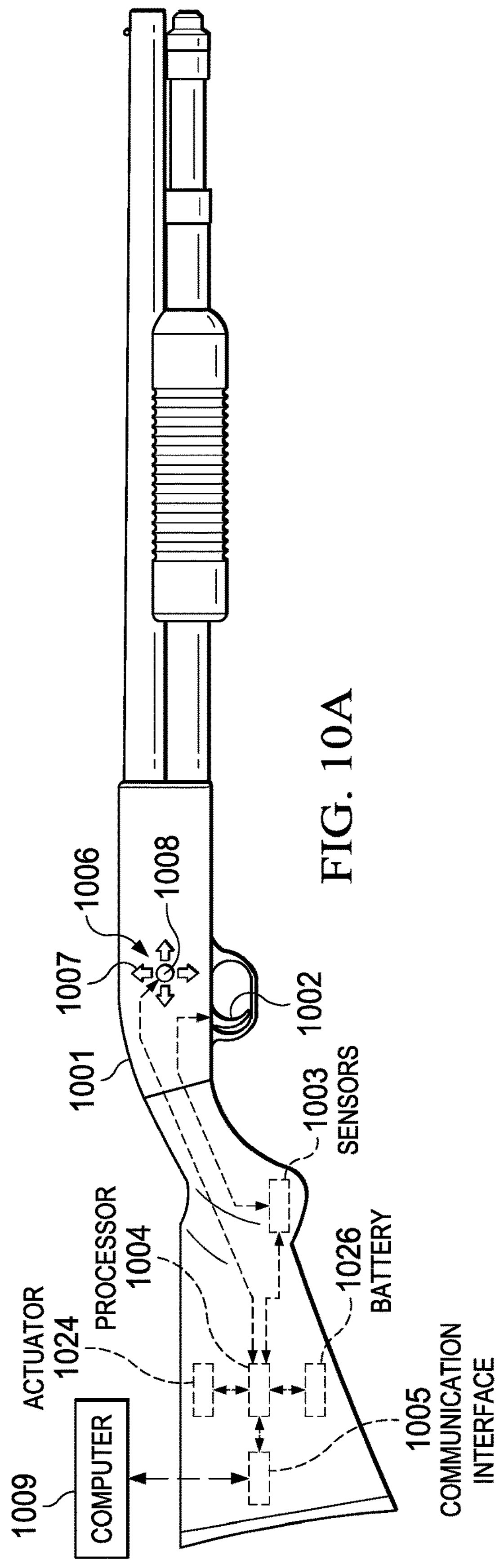

FIG. 10A

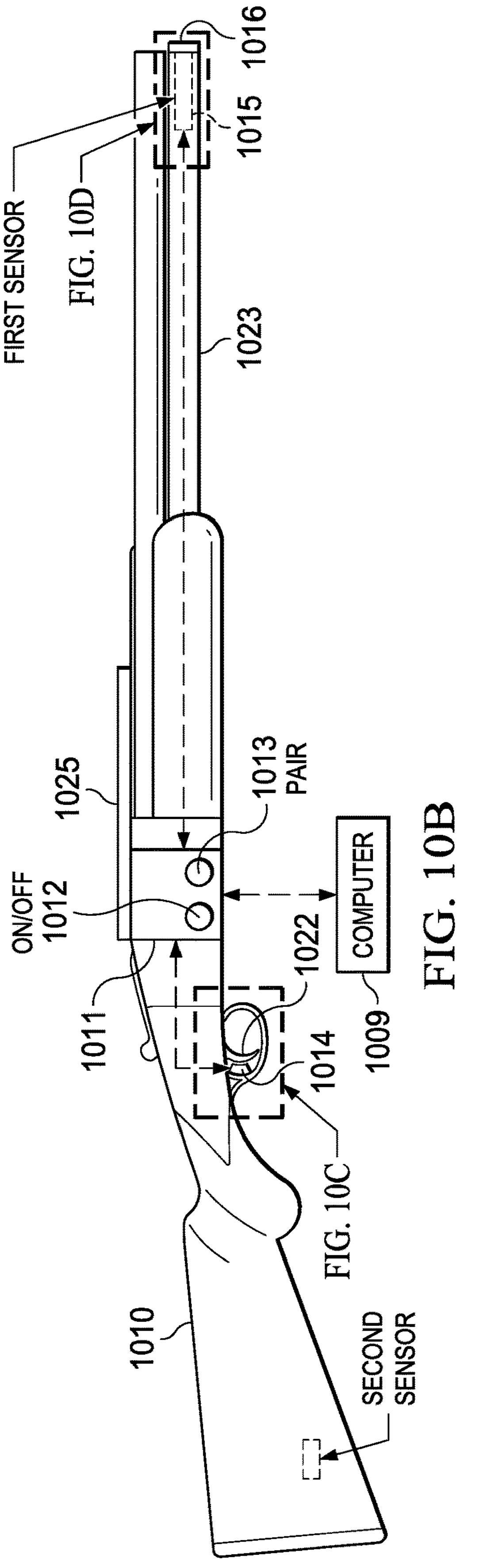

FIG. 10B

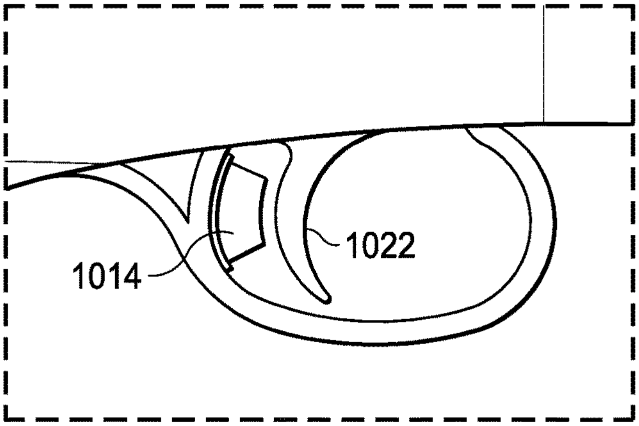

FIG. 10C

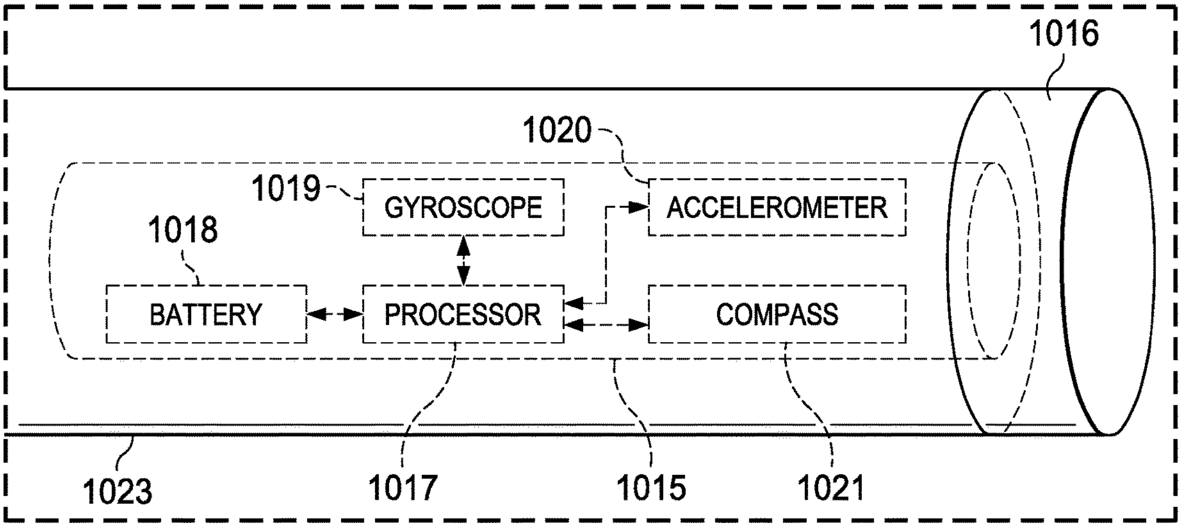

FIG. 10D

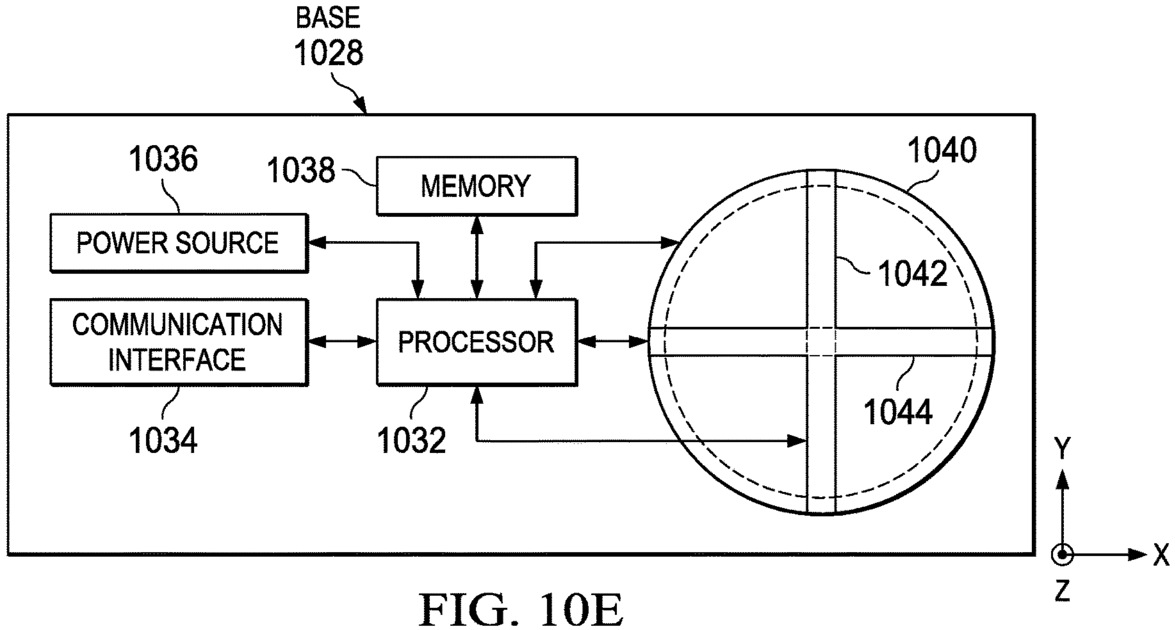

FIG. 10E

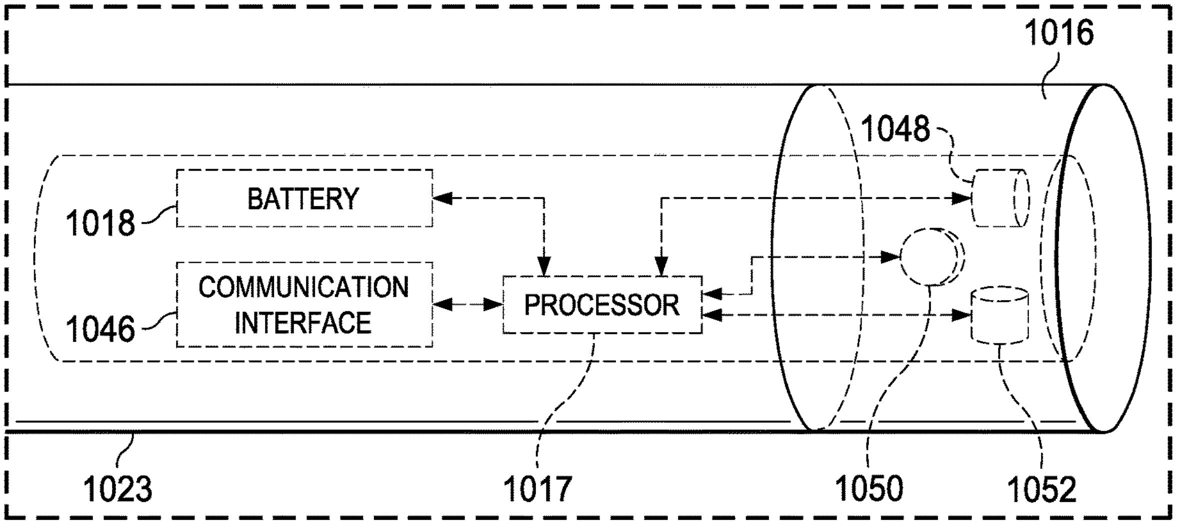

FIG. 10F

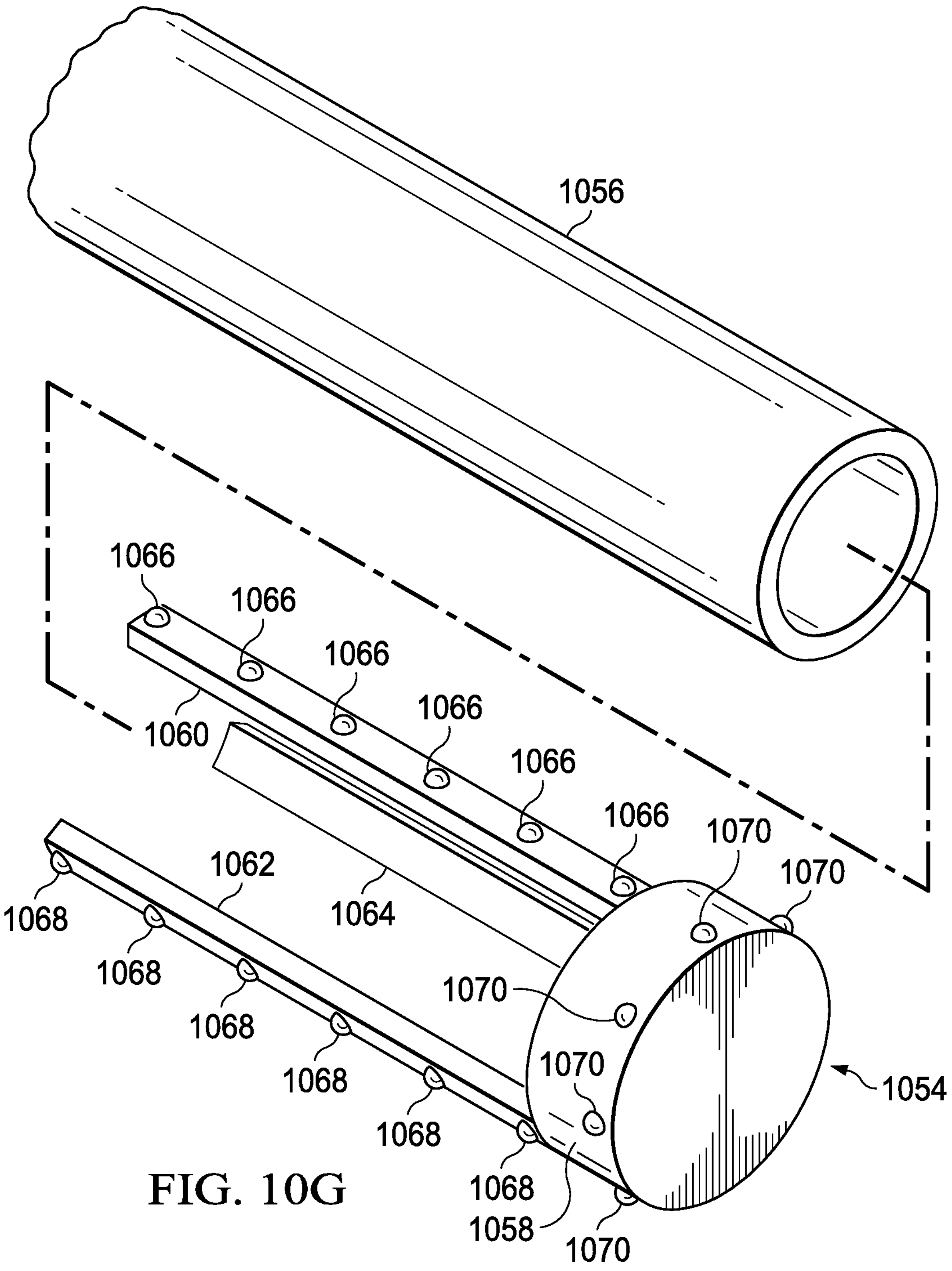
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FIG. 10G

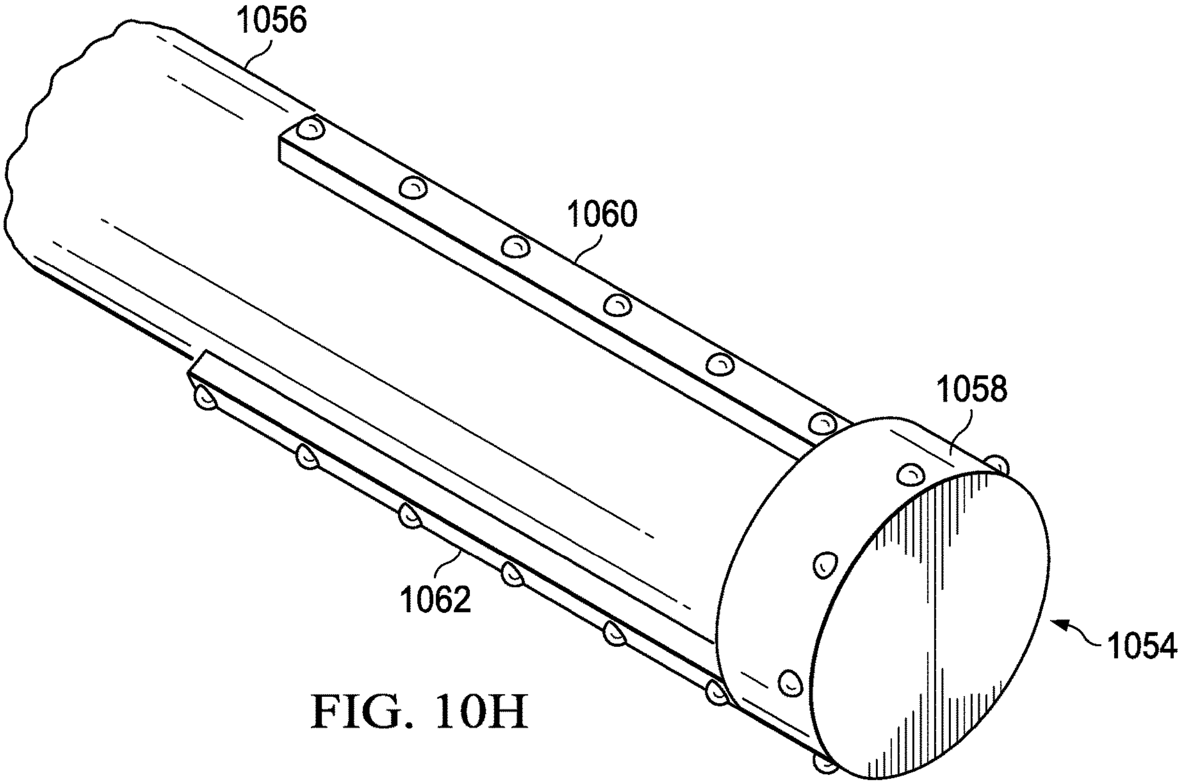

FIG. 10H

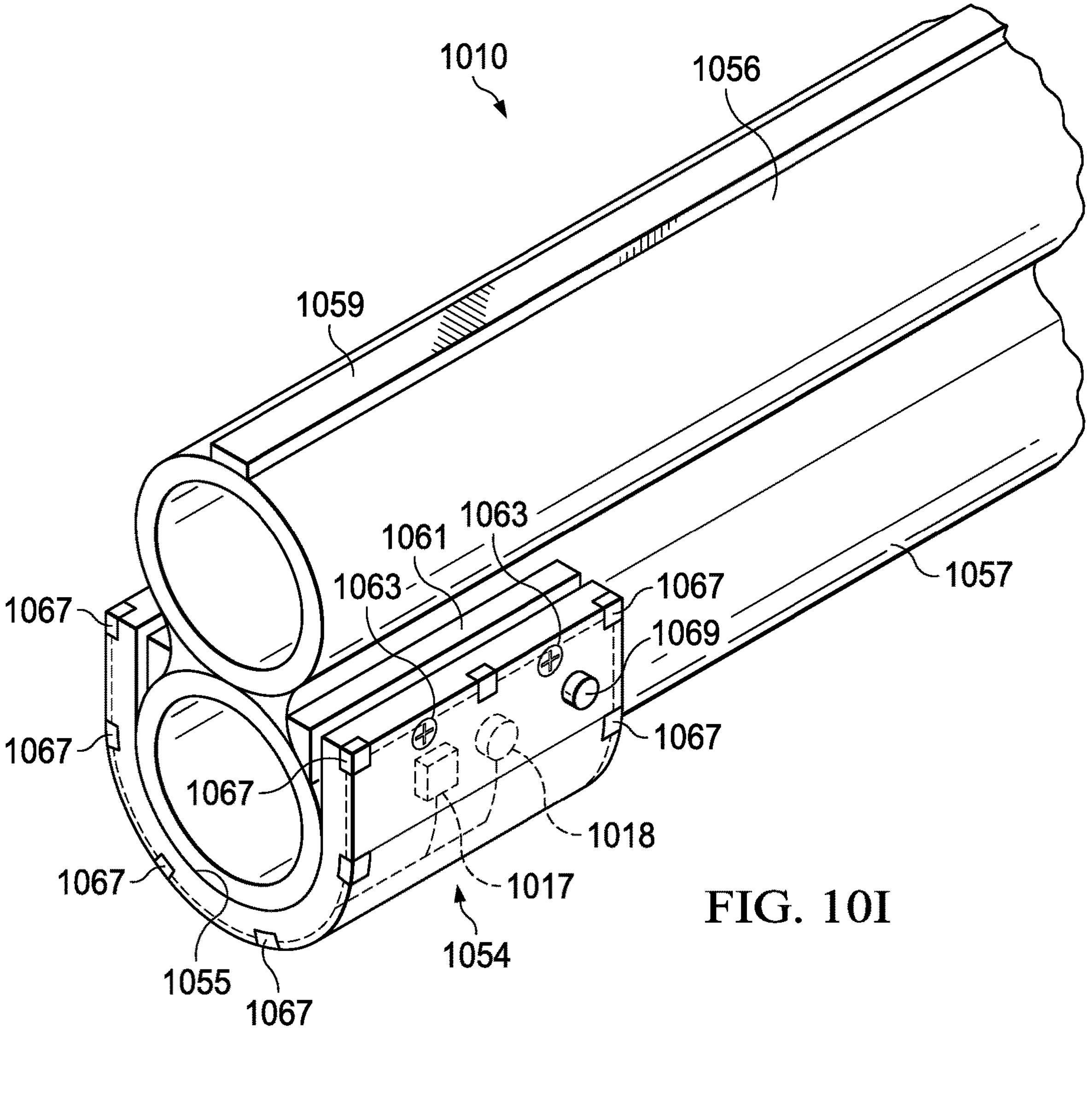
1010
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FIG. 10I

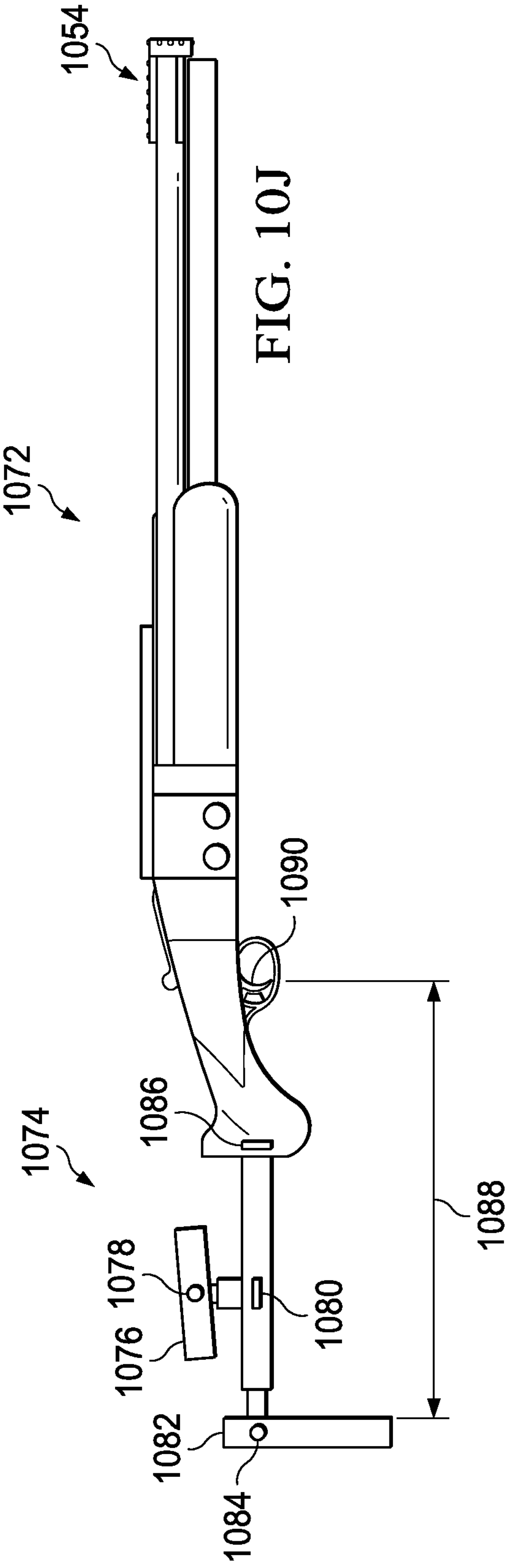
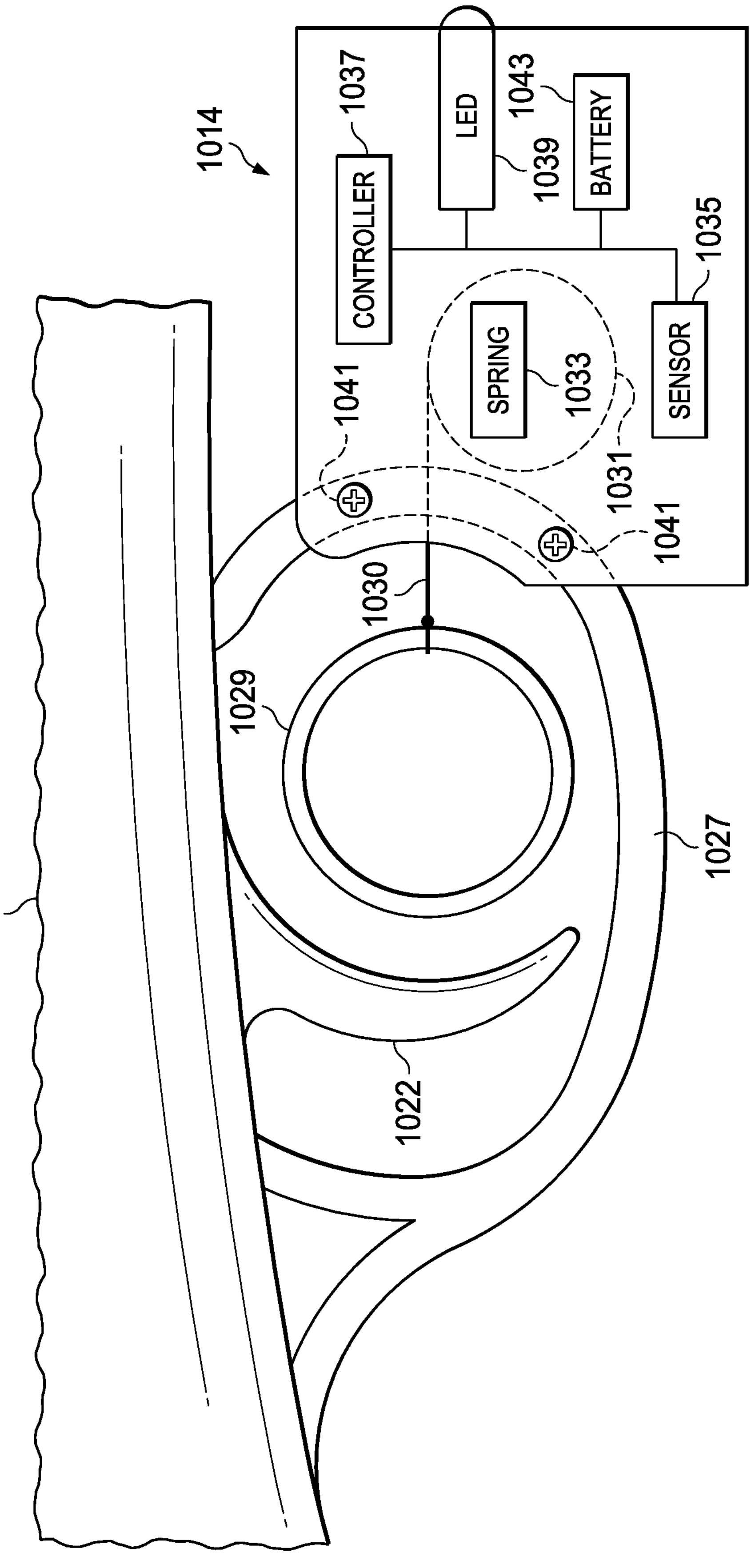


FIG. 10J


1014
1037
CONTROLLER
LED
1039
1043
BATTERY
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SENSOR
SPRING
1033
1041
1031
1041
1030
1029
1010
1027
1022

FIG. 10K

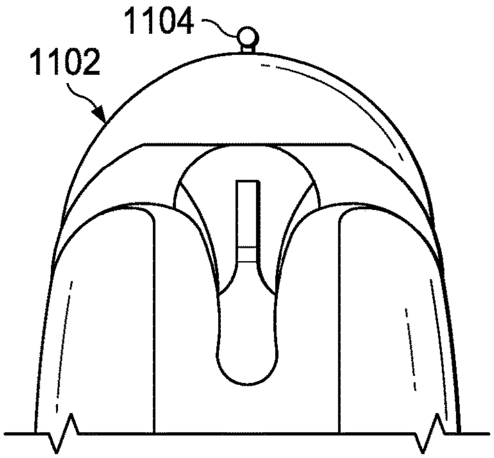


FIG. 11A

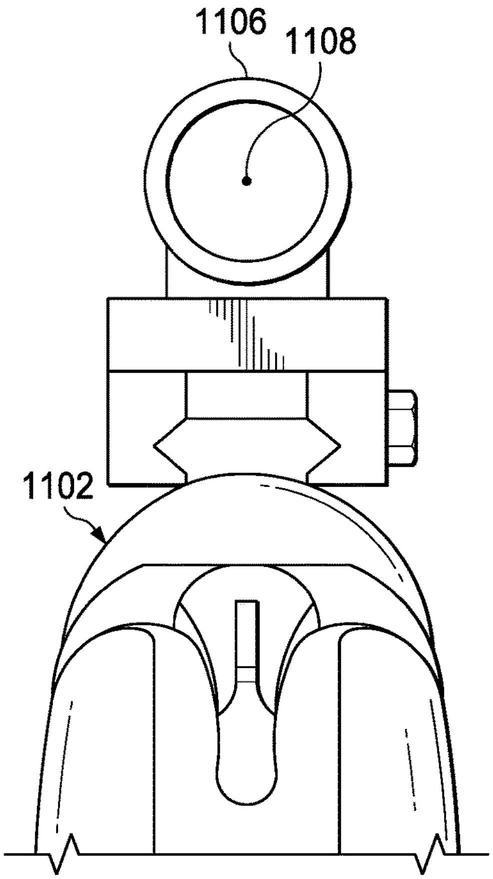


FIG. 11B

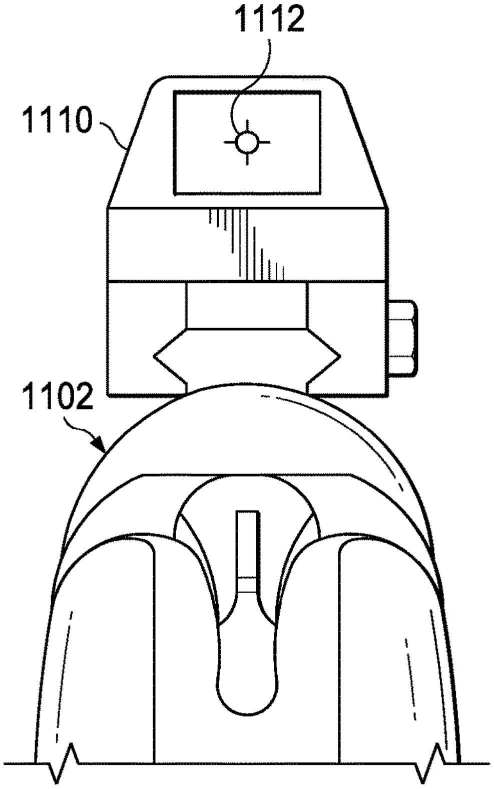


FIG. 11C

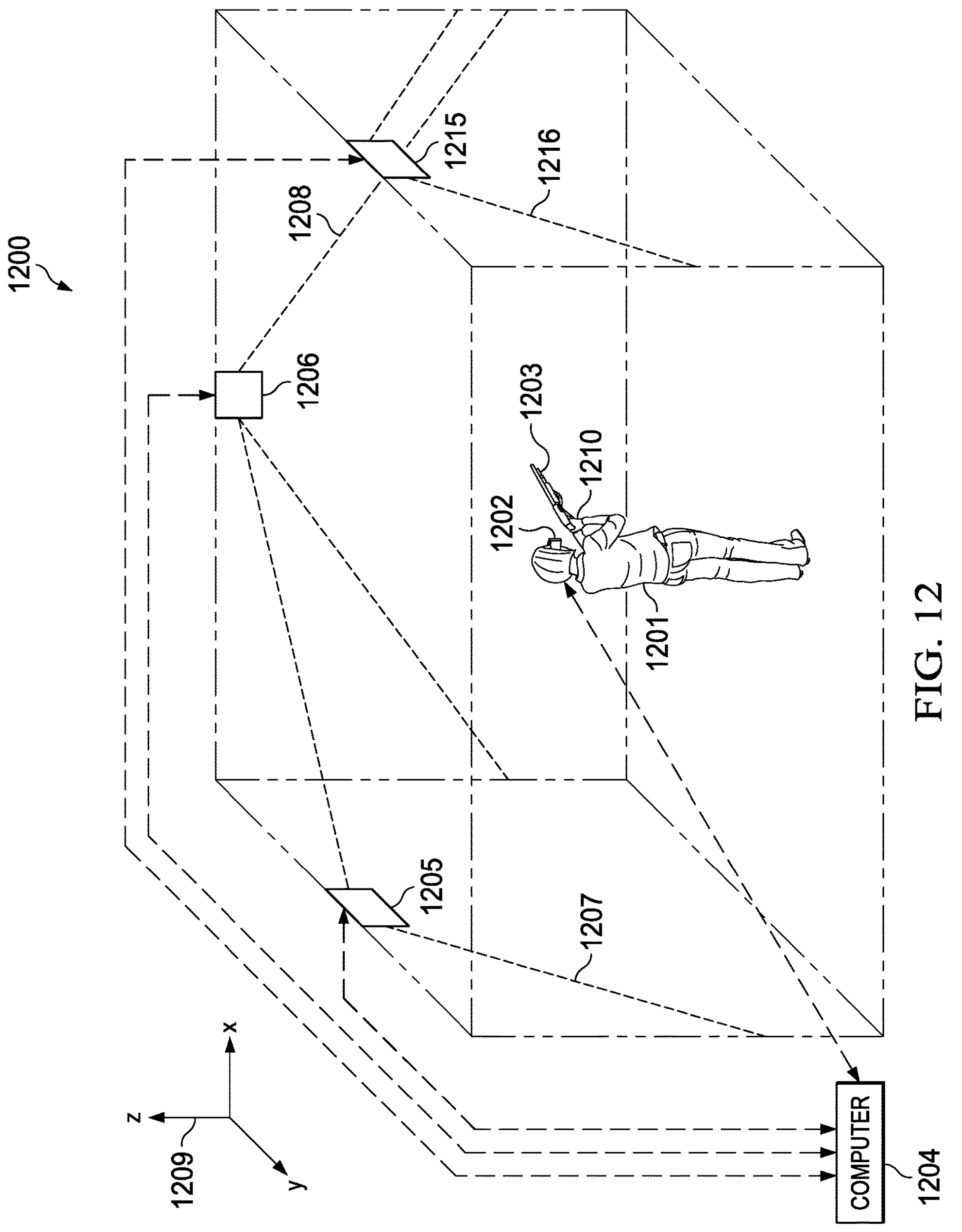

1200
1215
1216
1208
1206
1203
1210
1202
1201
1205
1207
x
z
y
1209
COMPUTER
1204

FIG. 12

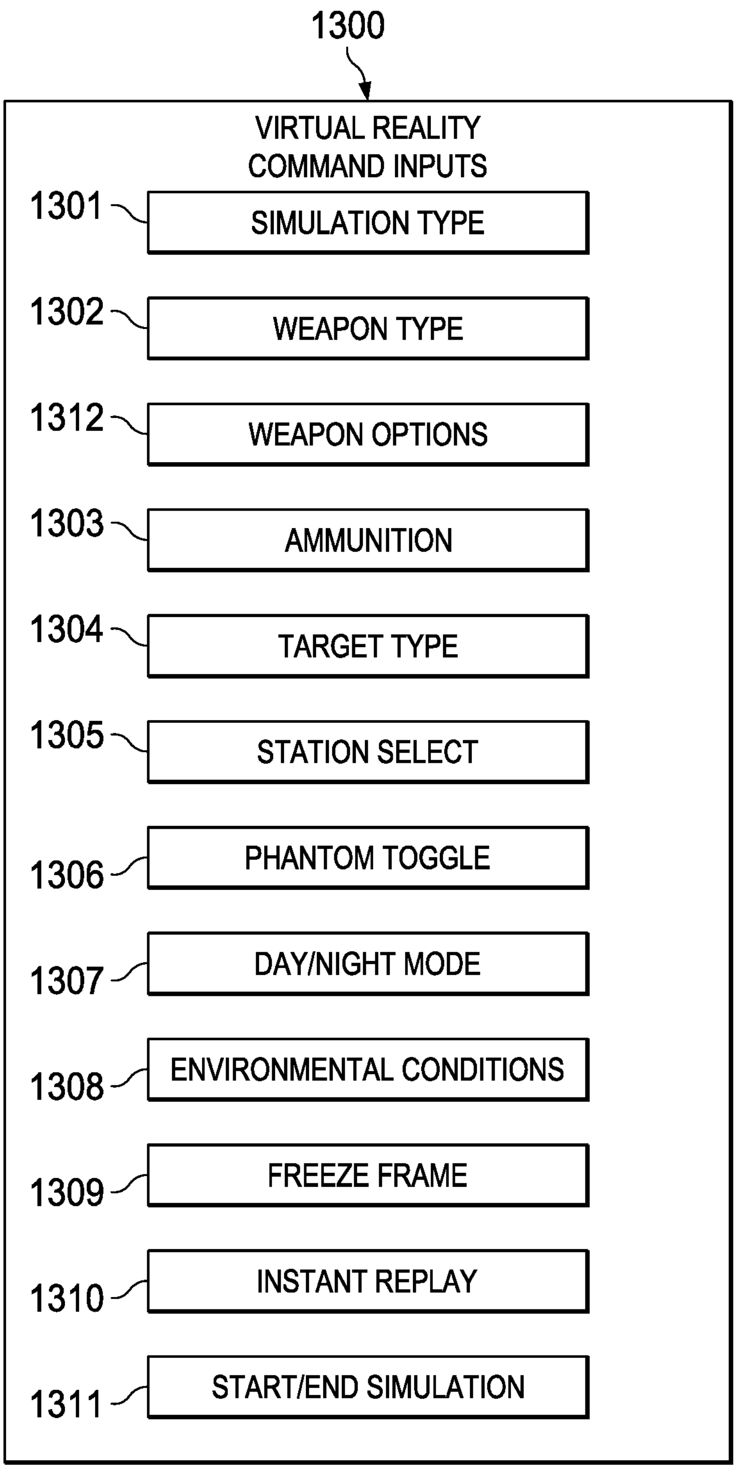

1300
VIRTUAL REALITY COMMAND INPUTS
1301
SIMULATION TYPE
1302
WEAPON TYPE
1312
WEAPON OPTIONS
1303
AMMUNITION
1304
TARGET TYPE
1305
STATION SELECT
1306
PHANTOM TOGGLE
1307
DAY/NIGHT MODE
1308
ENVIRONMENTAL CONDITIONS
1309
FREEZE FRAME
1310
INSTANT REPLAY
1311
START/END SIMULATION

FIG. 13

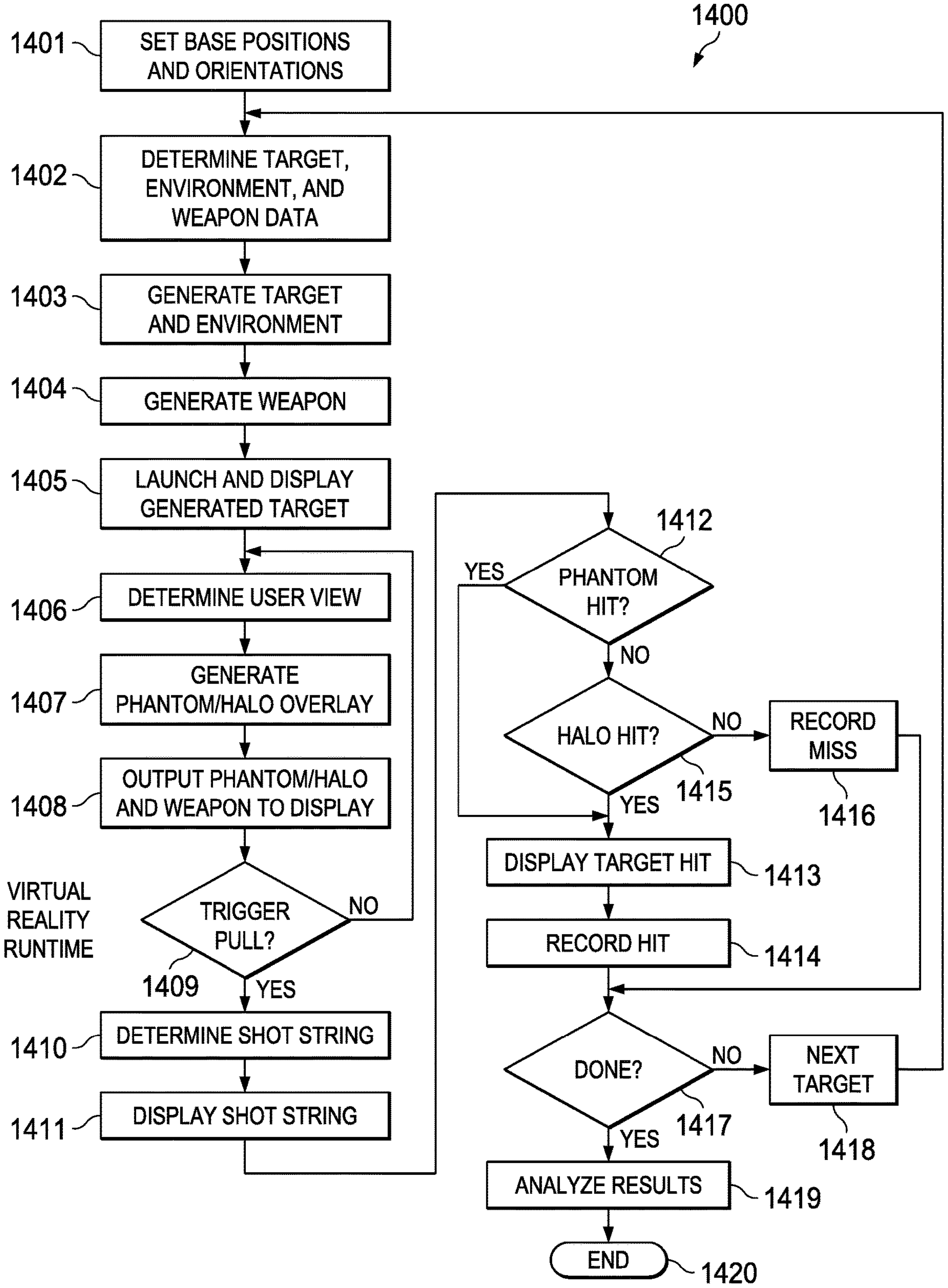
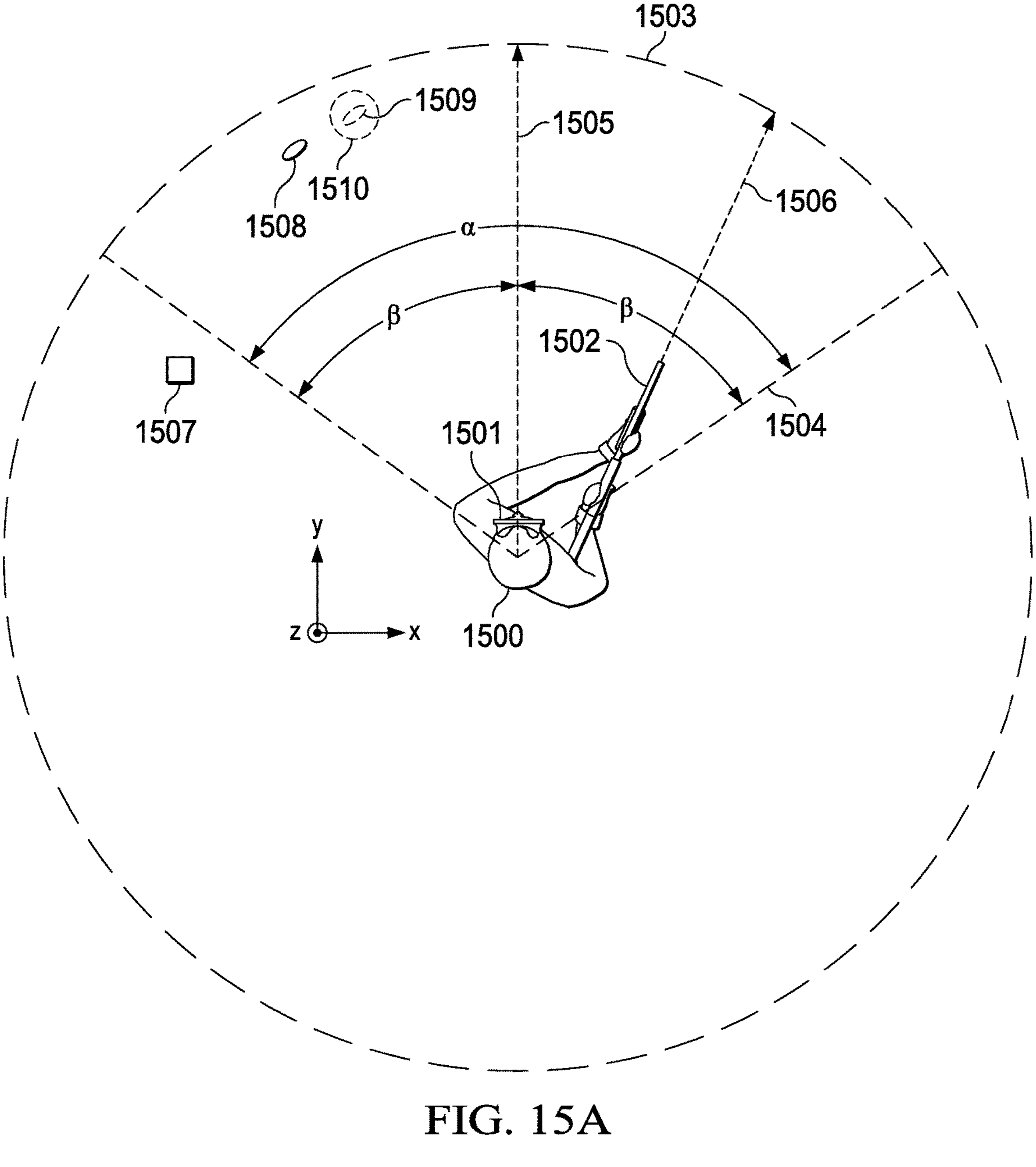

1400
1401
SET BASE POSITIONS AND ORIENTATIONS
1402
DETERMINE TARGET, ENVIRONMENT, AND WEAPON DATA
1403
GENERATE TARGET AND ENVIRONMENT
1404
GENERATE WEAPON
1405
LAUNCH AND DISPLAY GENERATED TARGET
1406
DETERMINE USER VIEW
1407
GENERATE PHANTOM/HALO OVERLAY
1408
OUTPUT PHANTOM/HALO AND WEAPON TO DISPLAY
VIRTUAL REALITY RUNTIME
TRIGGER PULL?
NO
1409
YES
1410
DETERMINE SHOT STRING
1411
DISPLAY SHOT STRING
1412
PHANTOM HIT?
YES
NO
HALO HIT?
NO
RECORD MISS
1415
YES
1416
DISPLAY TARGET HIT
1413
RECORD HIT
1414
DONE?
NO
NEXT TARGET
1417
YES
1418
ANALYZE RESULTS
1419
END
1420

FIG. 14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β
β
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1504
1507
1501
y
z
x
1500

FIG. 15A

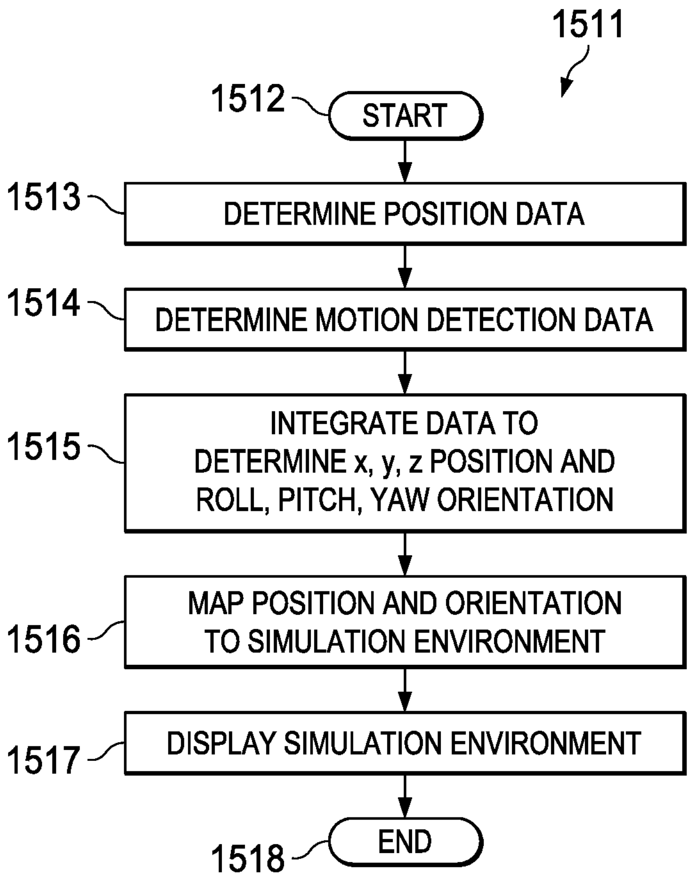
1511
1512
START
1513
DETERMINE POSITION DATA
1514
DETERMINE MOTION DETECTION DATA
1515
INTEGRATE DATA TO DETERMINE x, y, z POSITION AND ROLL, PITCH, YAW ORIENTATION
1516
MAP POSITION AND ORIENTATION TO SIMULATION ENVIRONMENT
1517
DISPLAY SIMULATION ENVIRONMENT
1518
END

FIG. 15B

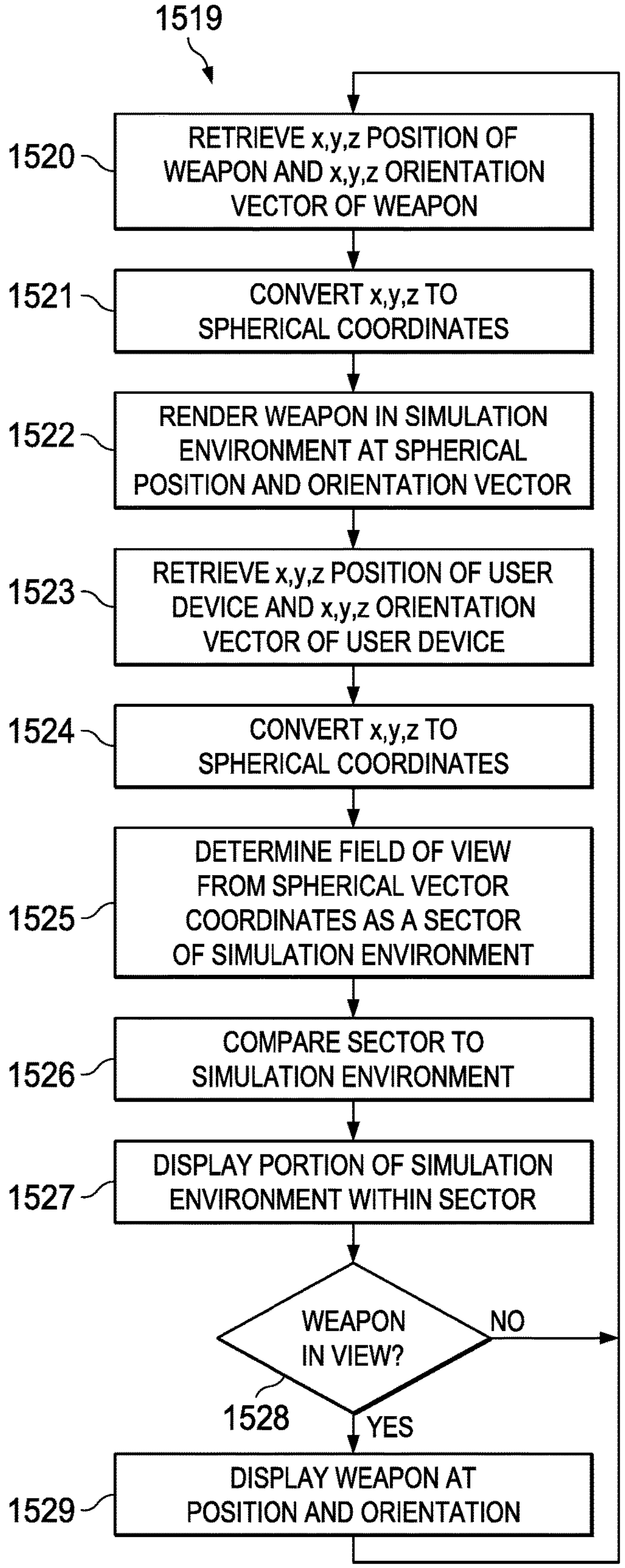
1519
1520
RETRIEVE x,y,z POSITION OF WEAPON AND x,y,z ORIENTATION VECTOR OF WEAPON
1521
CONVERT x,y,z TO SPHERICAL COORDINATES
1522
RENDER WEAPON IN SIMULATION ENVIRONMENT AT SPHERICAL POSITION AND ORIENTATION VECTOR
1523
RETRIEVE x,y,z POSITION OF USER DEVICE AND x,y,z ORIENTATION VECTOR OF USER DEVICE
1524
CONVERT x,y,z TO SPHERICAL COORDINATES
1525
DETERMINE FIELD OF VIEW FROM SPHERICAL VECTOR COORDINATES AS A SECTOR OF SIMULATION ENVIRONMENT
1526
COMPARE SECTOR TO SIMULATION ENVIRONMENT
1527
DISPLAY PORTION OF SIMULATION ENVIRONMENT WITHIN SECTOR
WEAPON IN VIEW?
NO
1528
YES
1529
DISPLAY WEAPON AT POSITION AND ORIENTATION

FIG. 15C

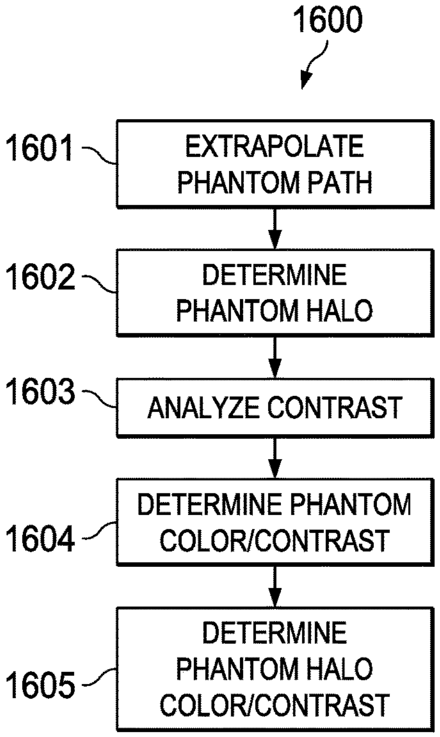

FIG. 16A

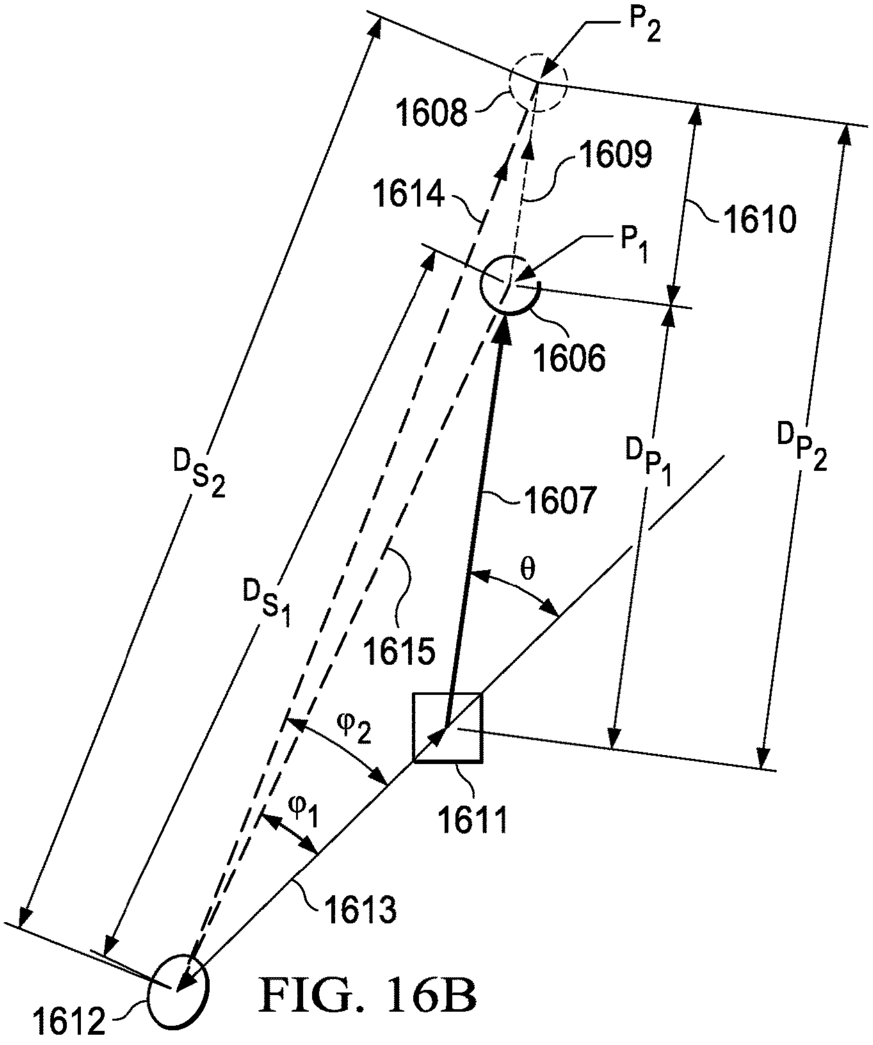

FIG. 16B

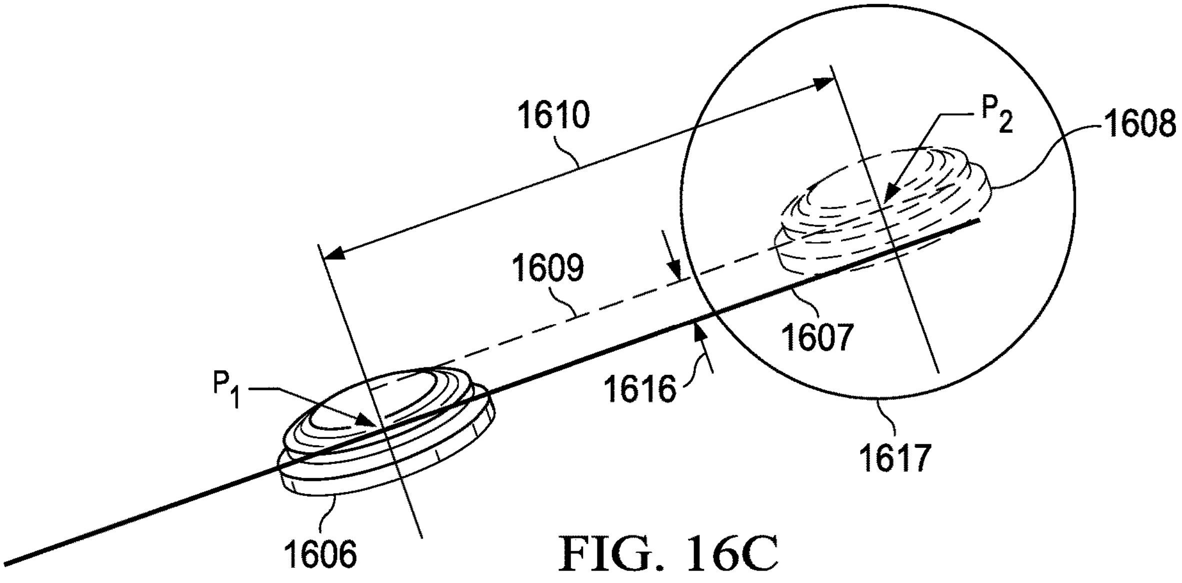

FIG. 16C

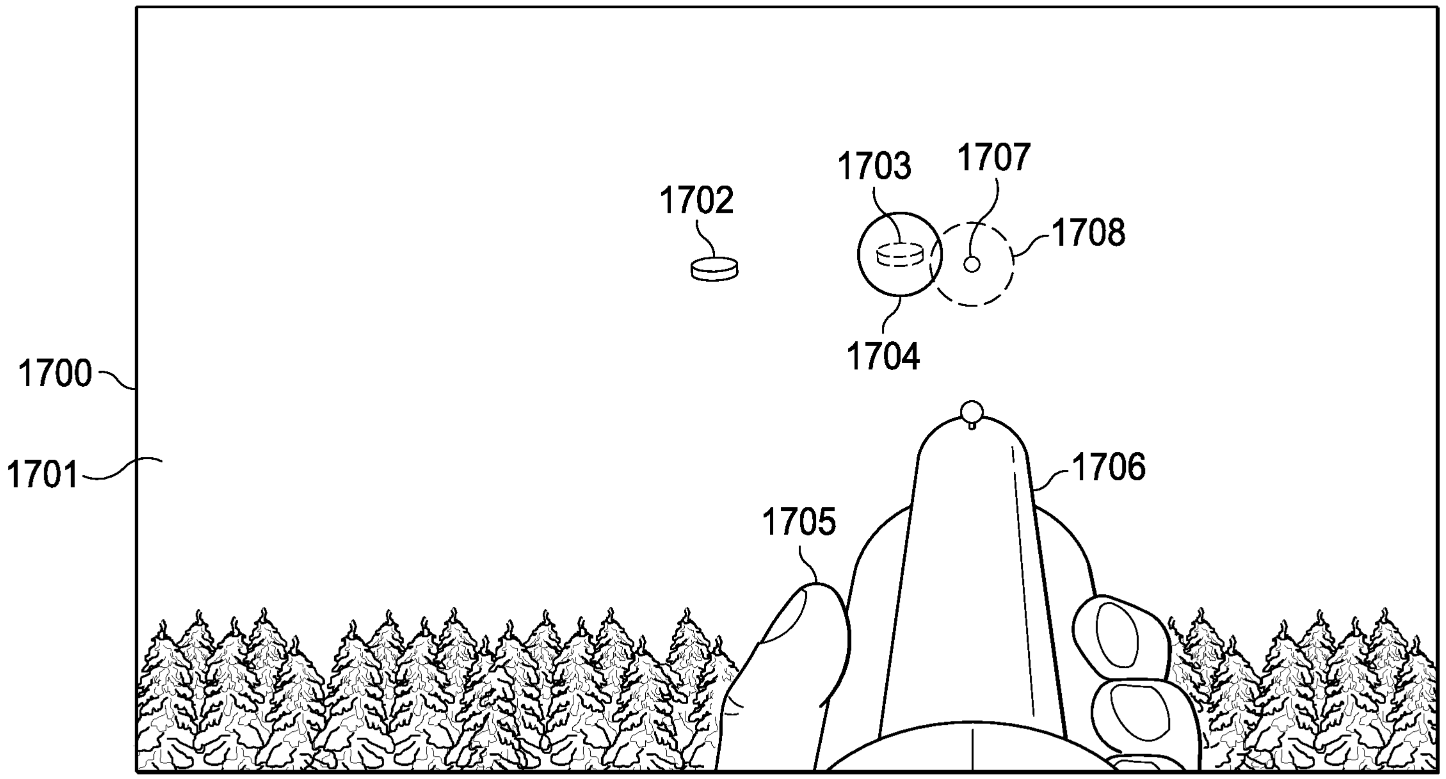

FIG. 17

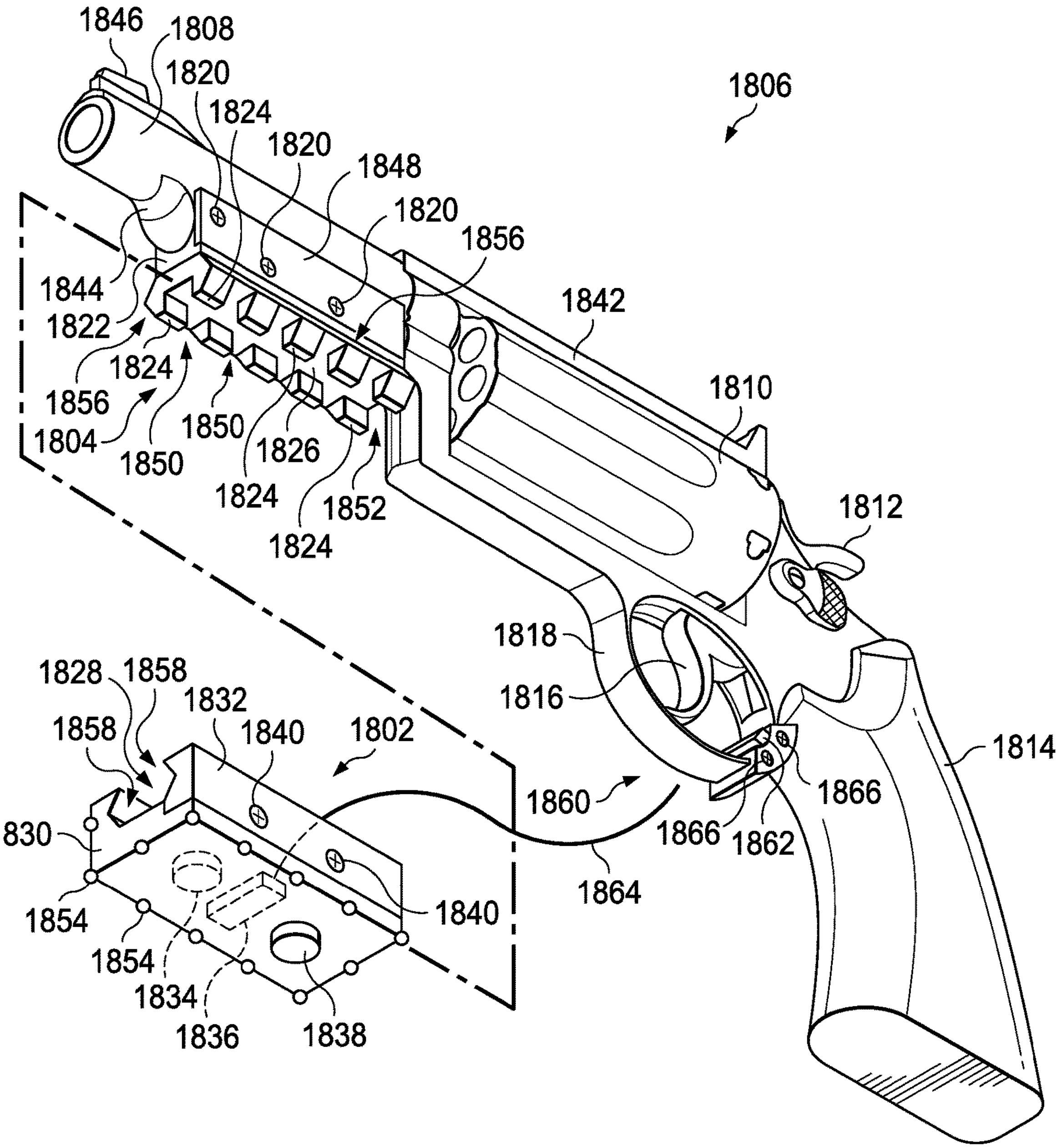
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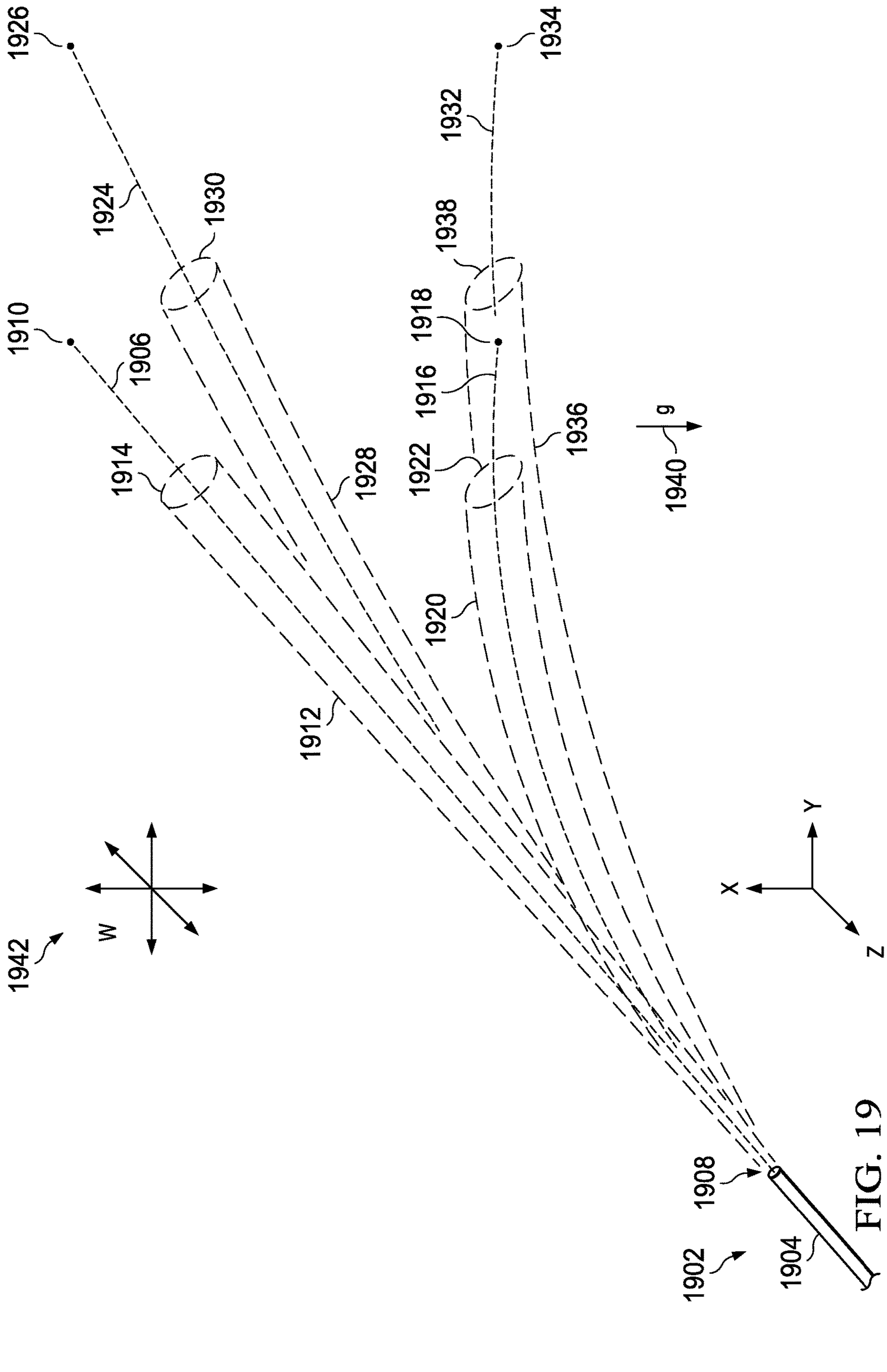
FIG. 18


1926
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Y
X
Z
W
1942
1908
1902
1904

FIG. 19

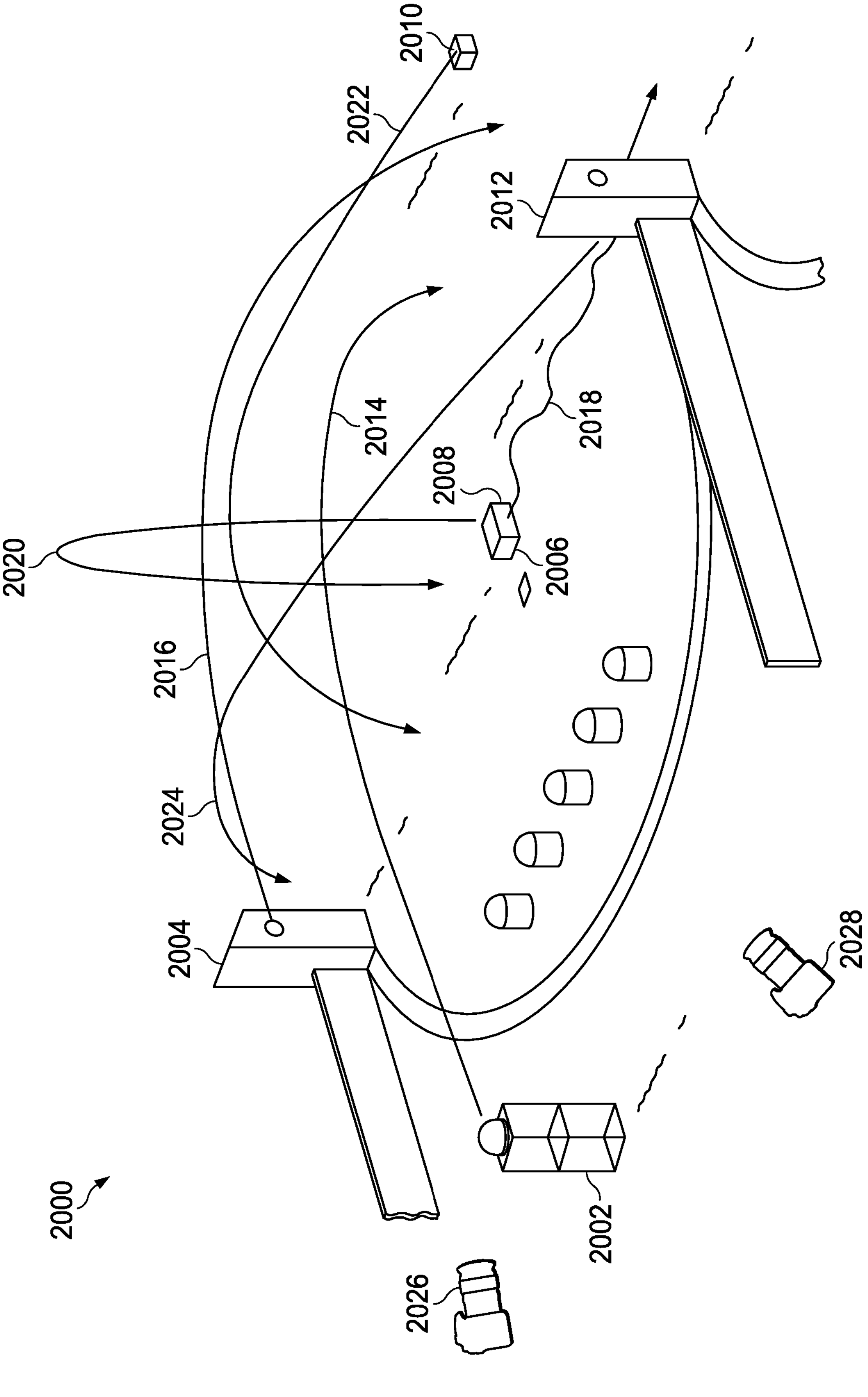
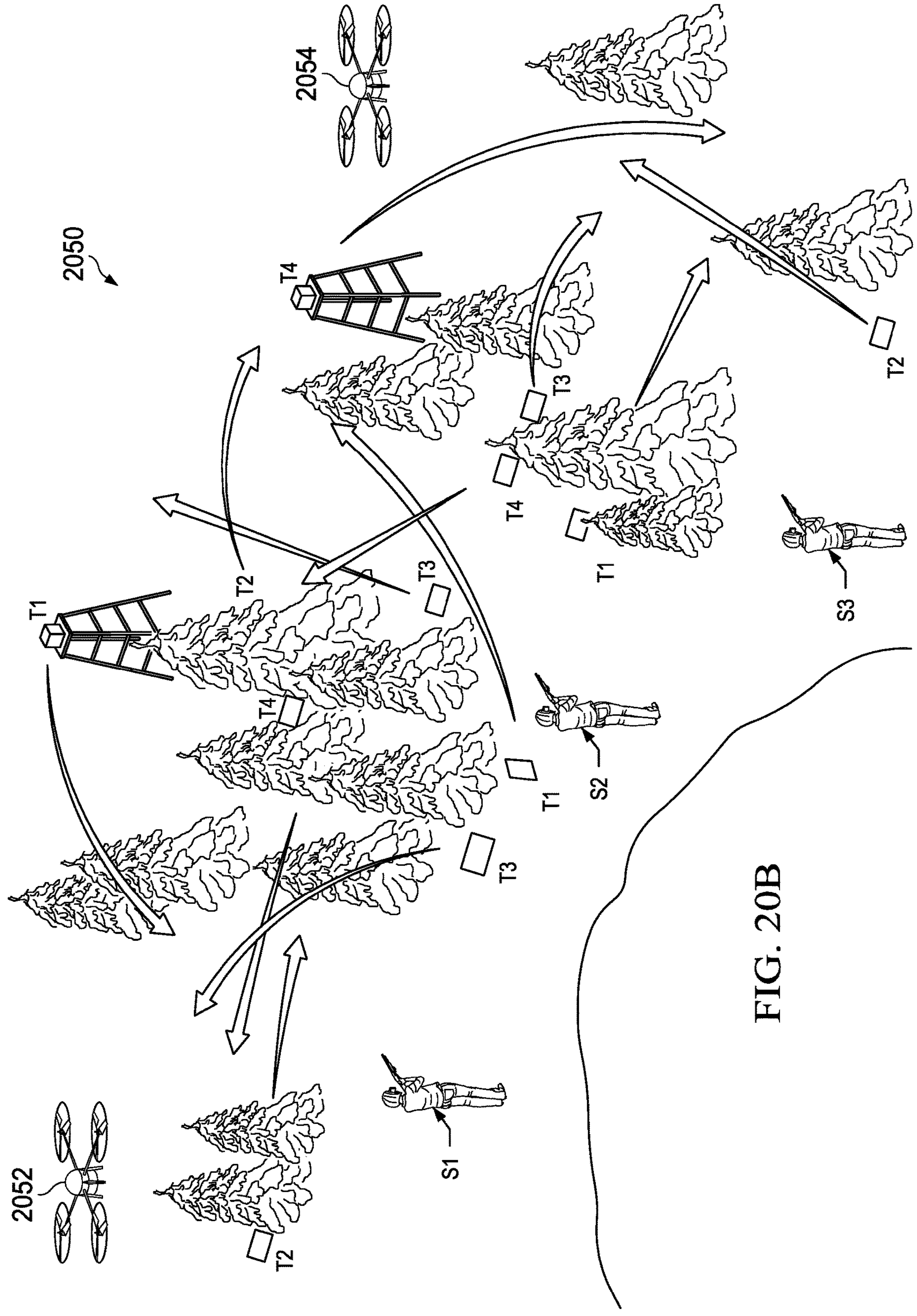

2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

FIG. 20A


2050
2052
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T1
T2
T3
T4
T1
T2
T3
T4
T1
T2
T3
T4
T1
T2
T3
T4
S1
S2
S3

FIG. 20B

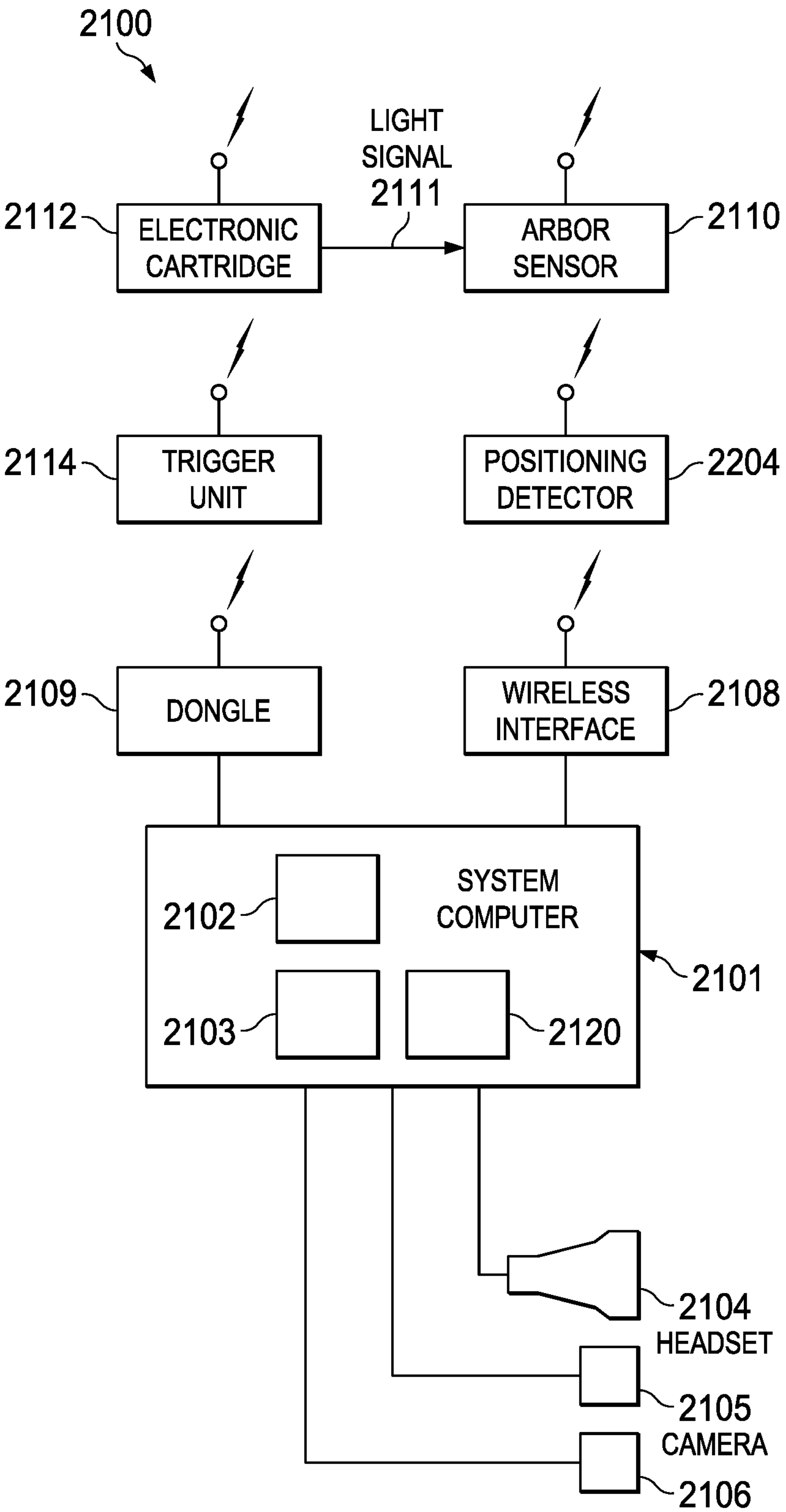
2100
LIGHT SIGNAL 2111
2112
ELECTRONIC CARTRIDGE
ARBOR SENSOR
2110
2114
TRIGGER UNIT
POSITIONING DETECTOR
2204
2109
DONGLE
WIRELESS INTERFACE
2108
2102
SYSTEM COMPUTER
2101
2103
2120
2104
HEADSET
2105
CAMERA
2106
CAMERA

FIG. 21A

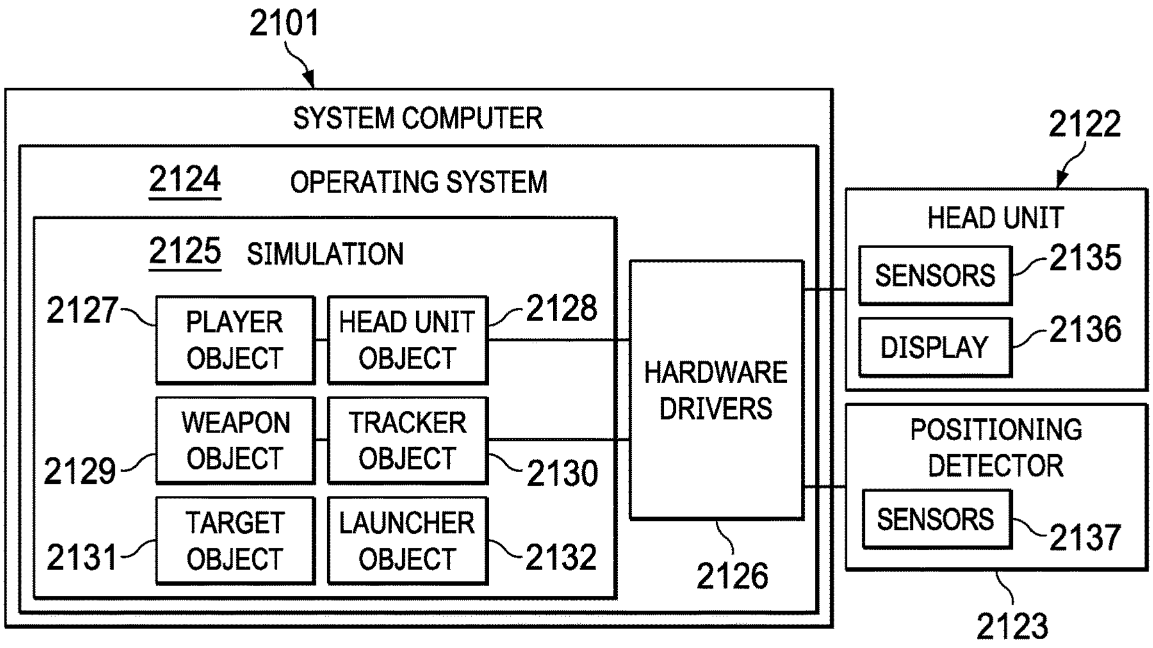

FIG. 21B

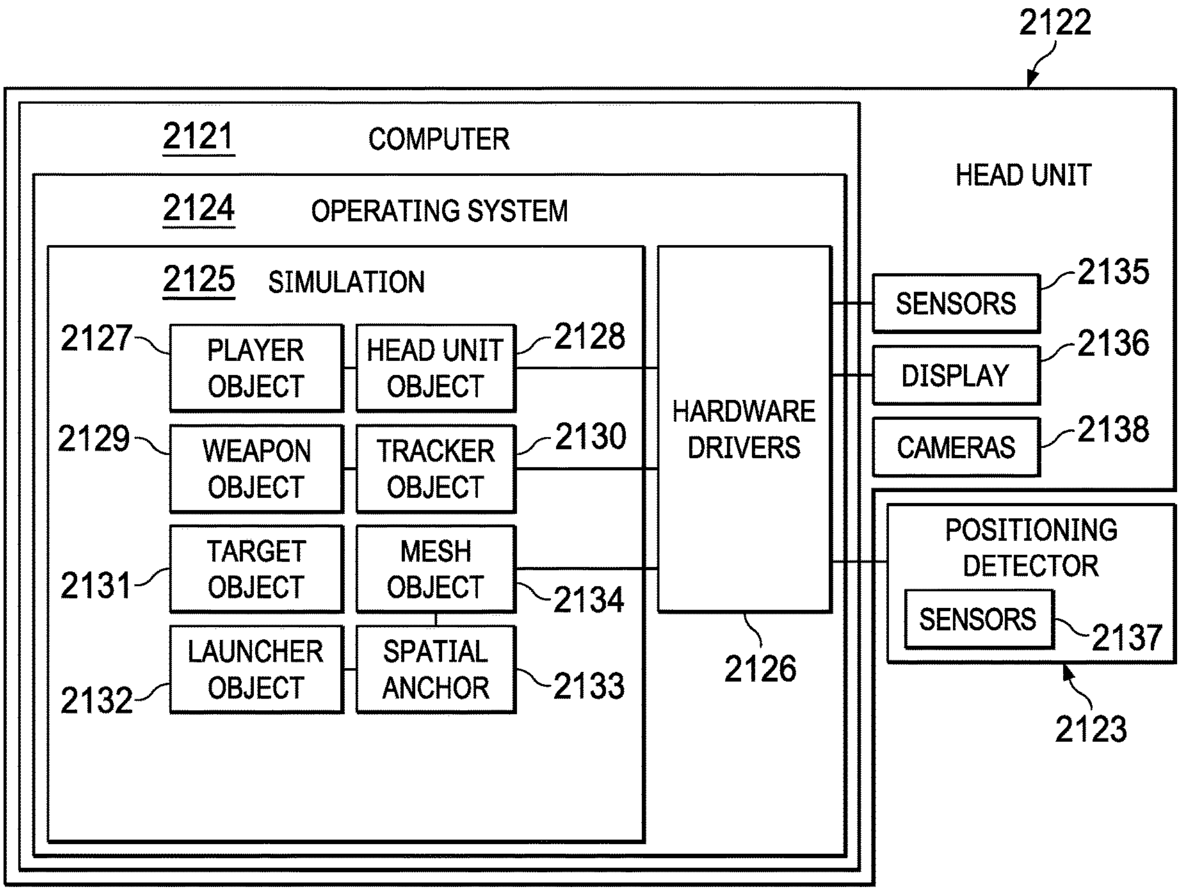

FIG. 21C

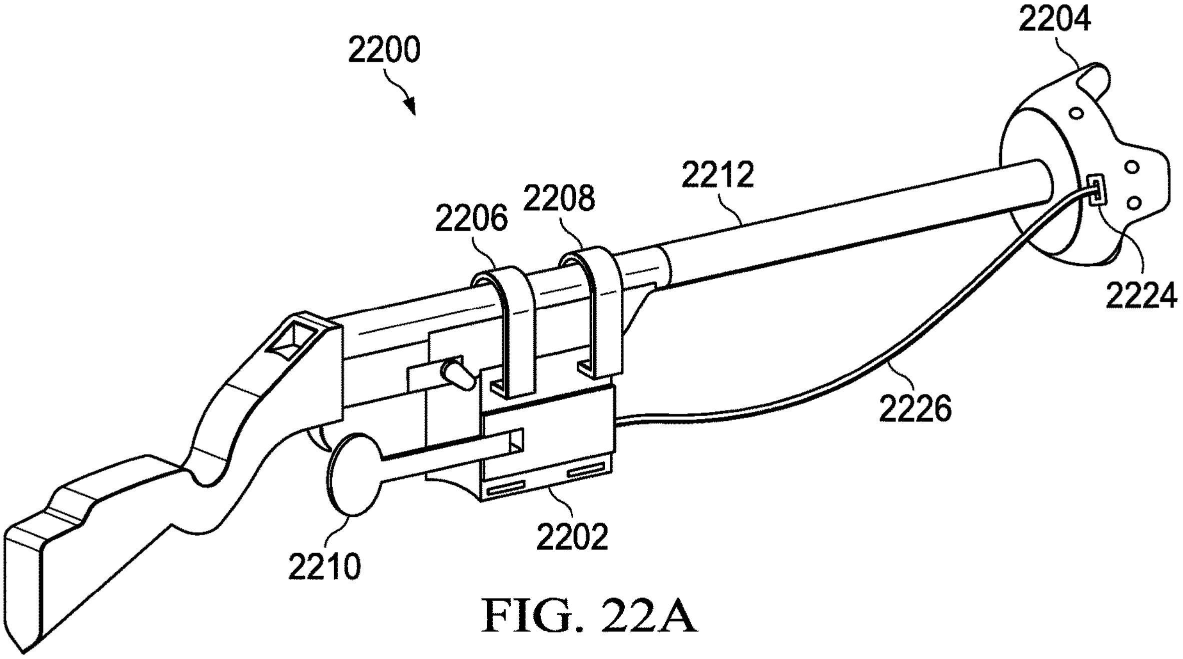

FIG. 22A

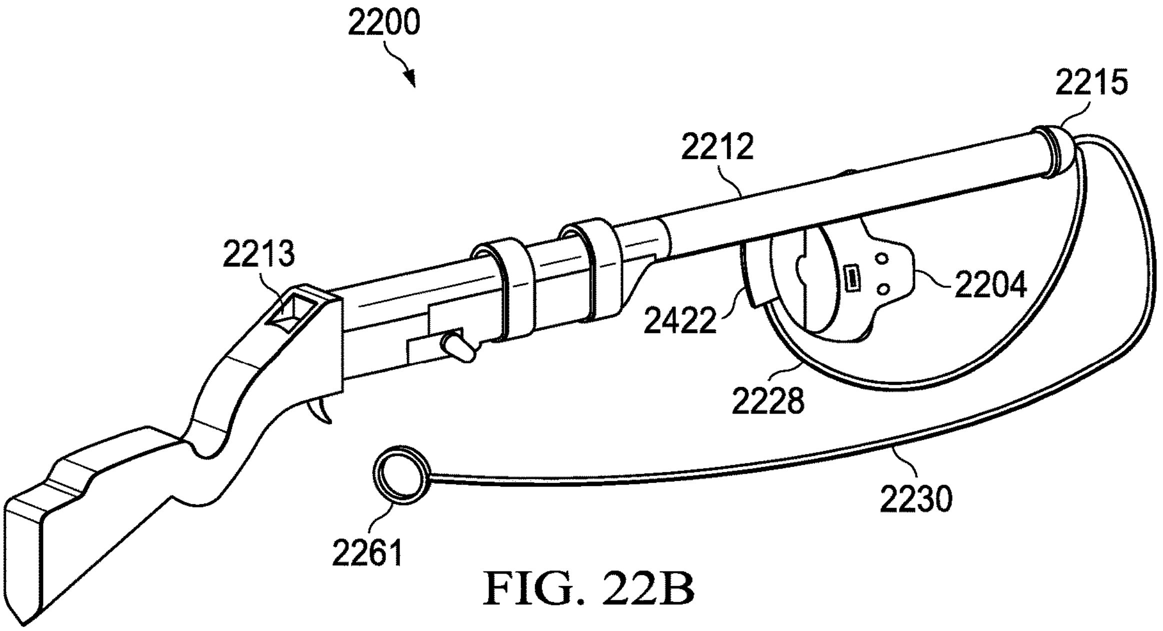

FIG. 22B

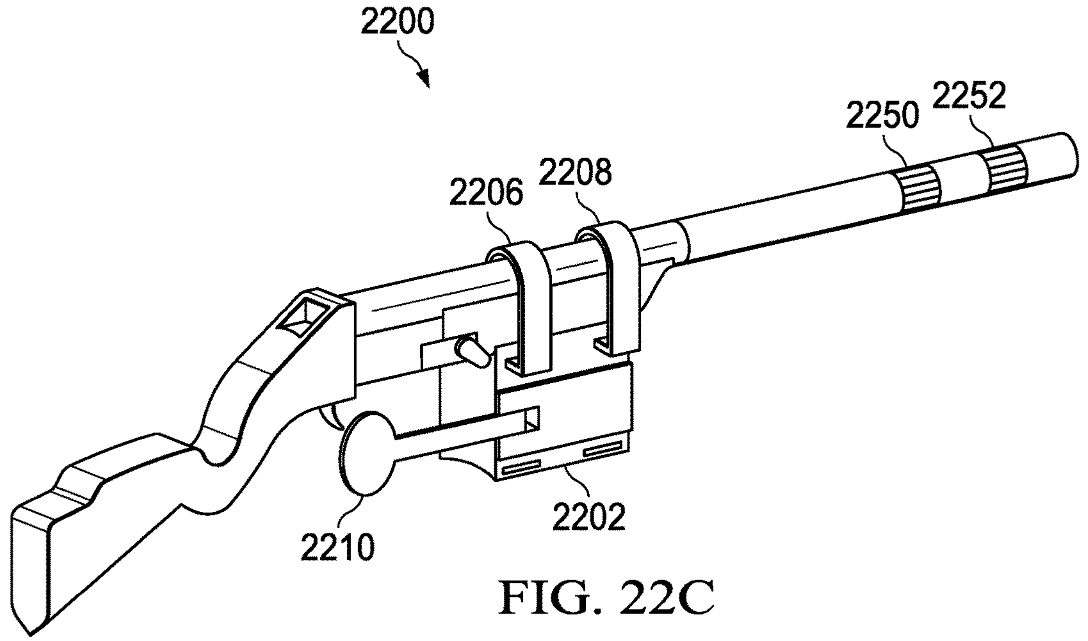

FIG. 22C

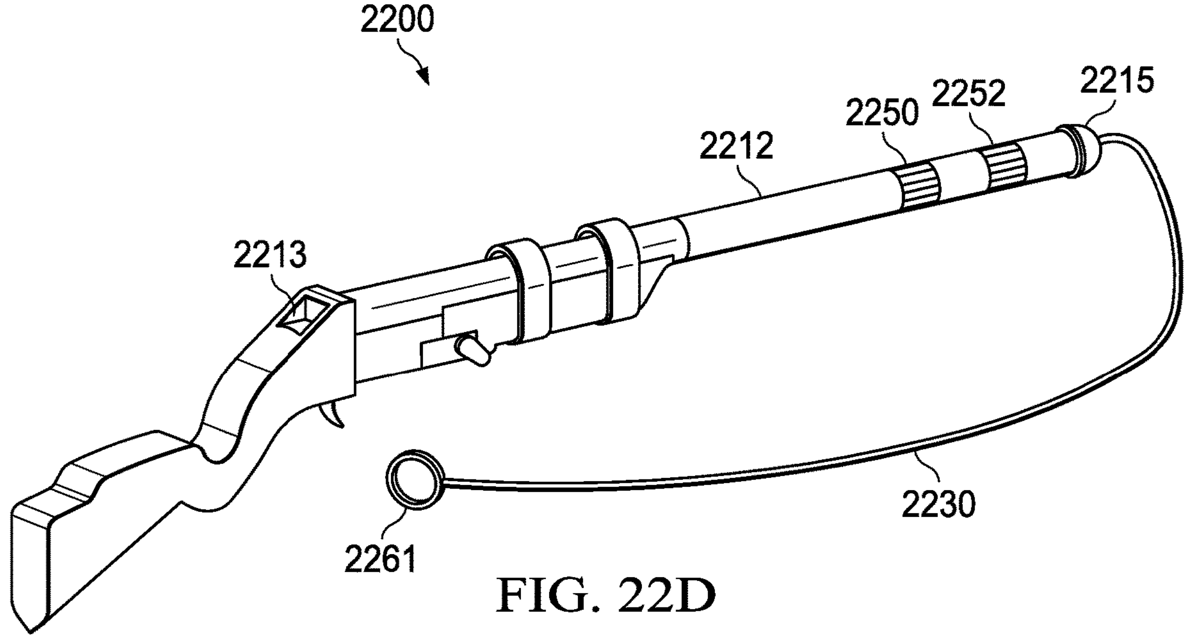

FIG. 22D

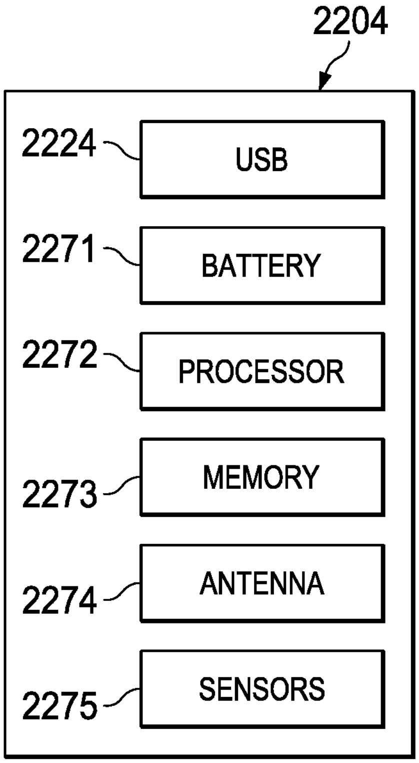
2204
2224
USB
2271
BATTERY
2272
PROCESSOR
2273
MEMORY
2274
ANTENNA
2275
SENSORS

FIG. 22E

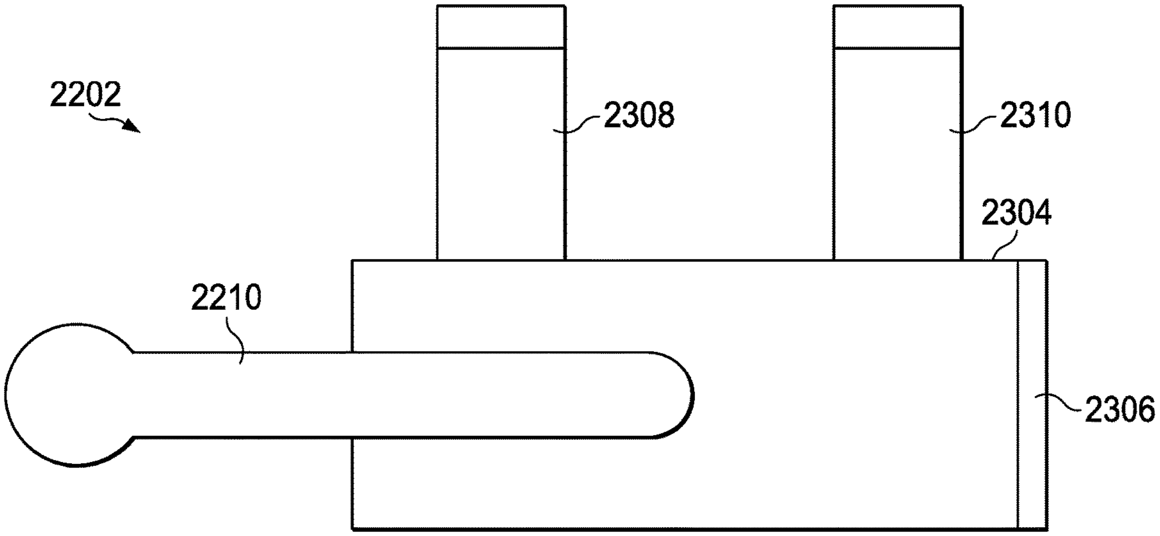

FIG. 23A

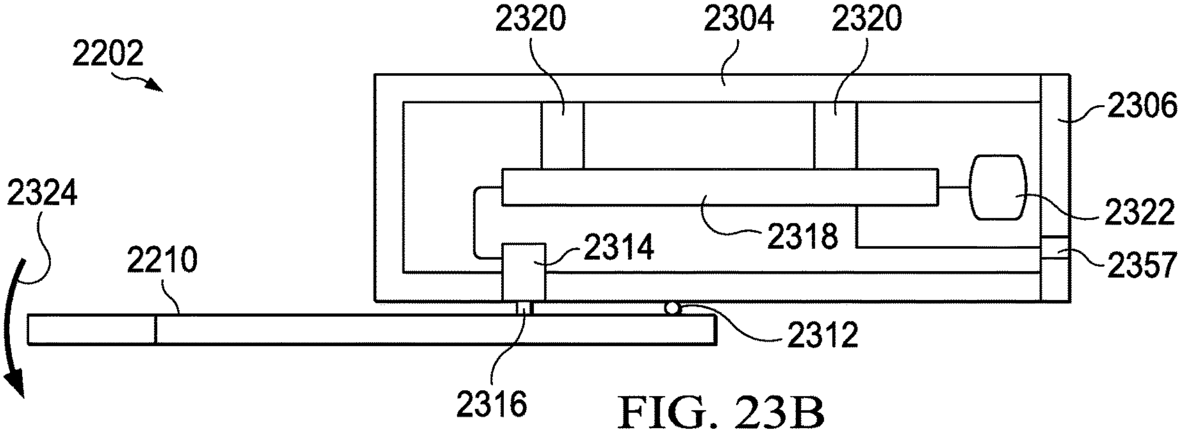

FIG. 23B

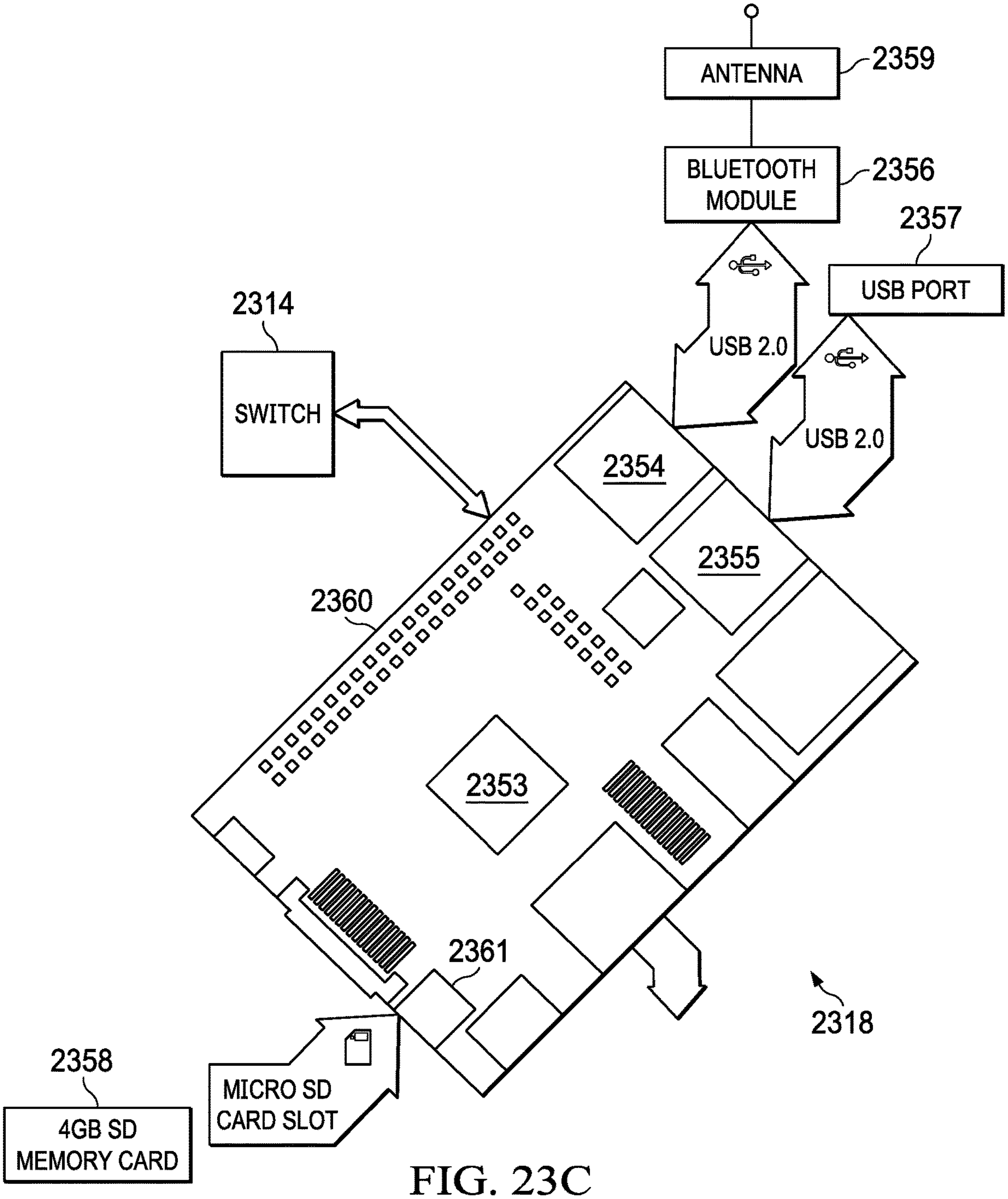
ANTENNA
2359
BLUETOOTH MODULE
2356
2357
USB PORT
USB 2.0
USB 2.0
2314
SWITCH
2354
2355
2360
2353
2361
2318
2358
4GB SD MEMORY CARD
MICRO SD CARD SLOT

FIG. 23C

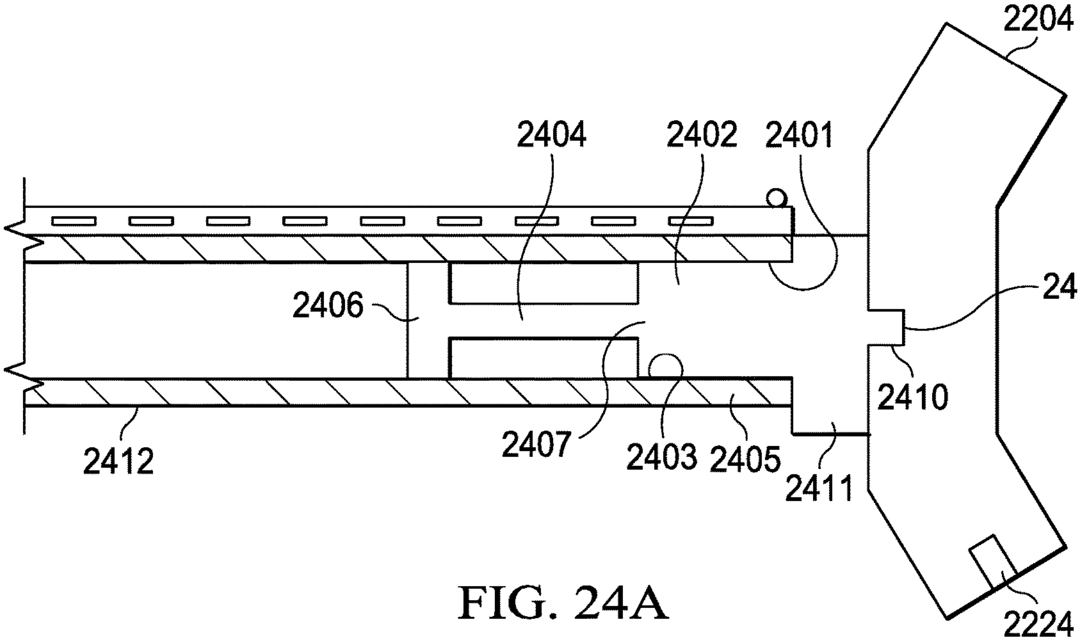

FIG. 24A

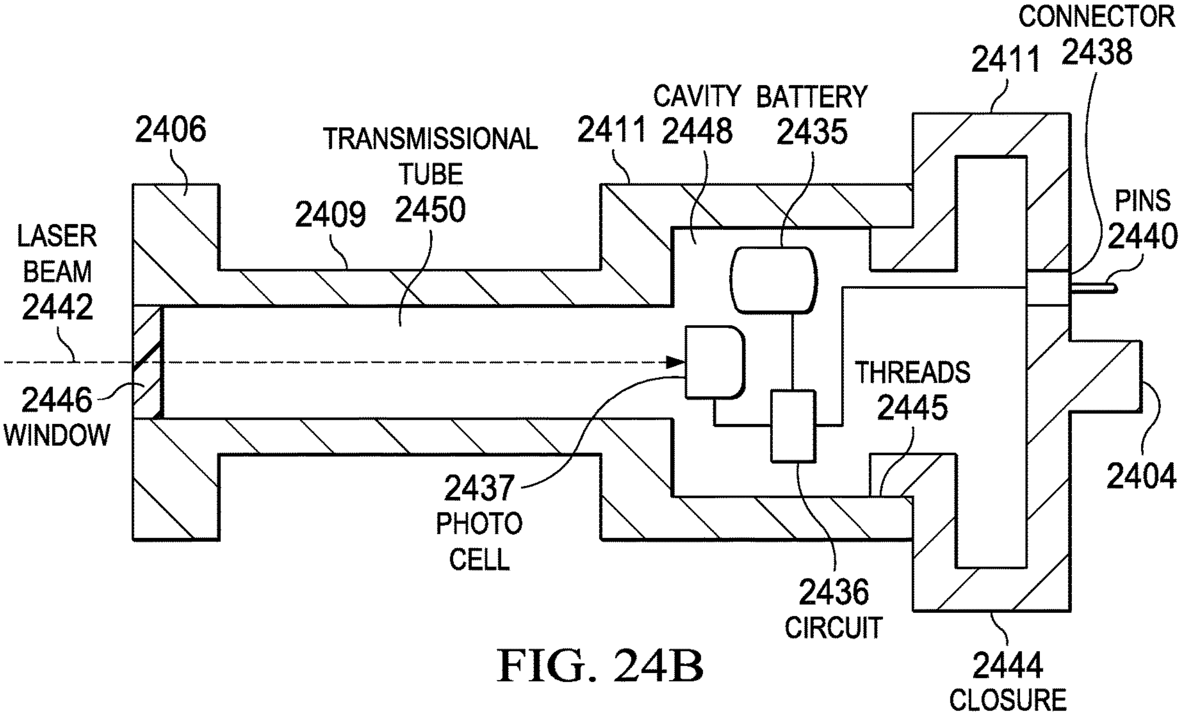

FIG. 24B

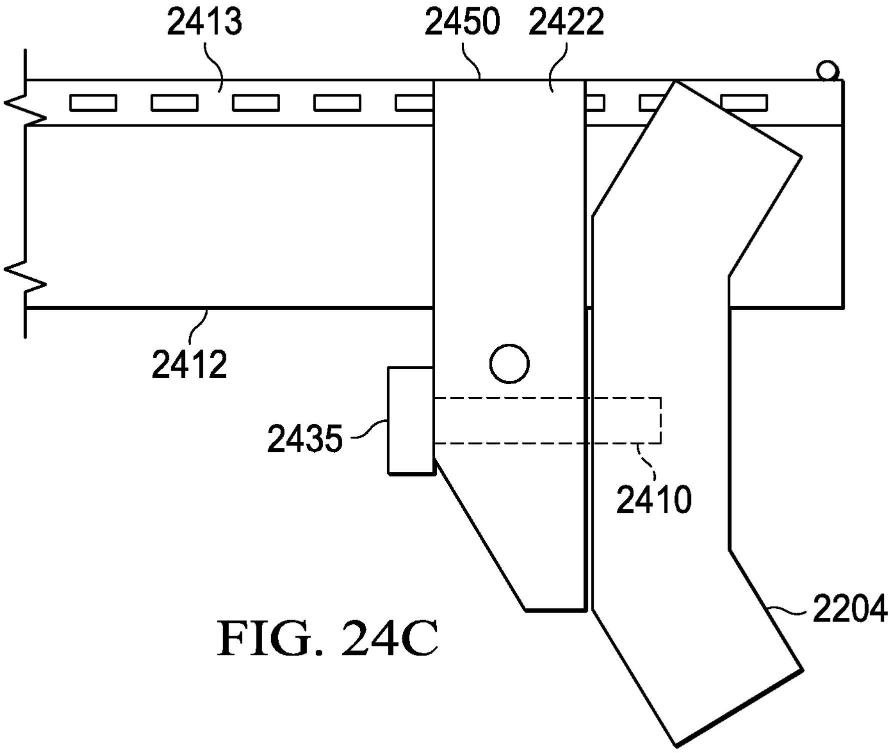

FIG. 24C

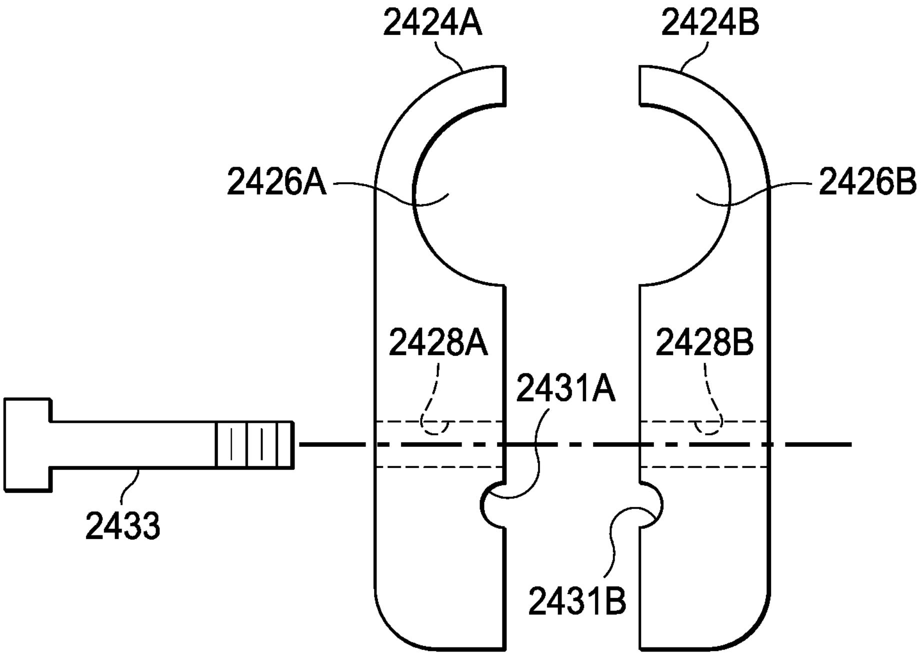

FIG. 24D

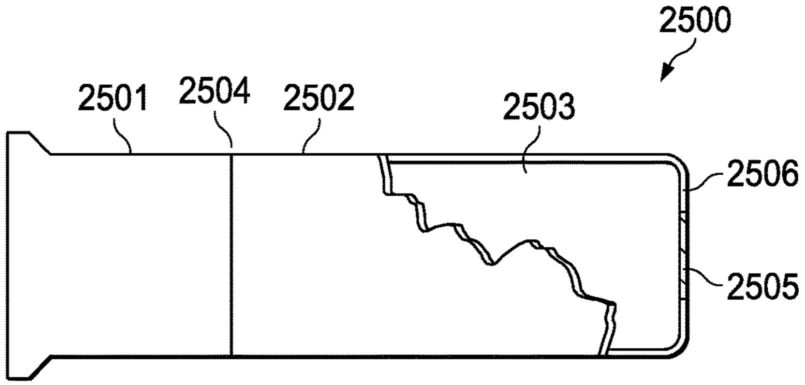

FIG. 25A

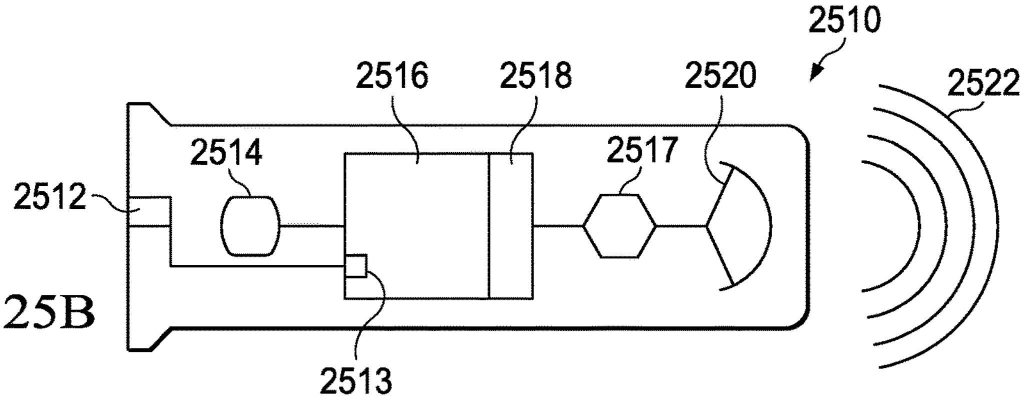

FIG. 25B

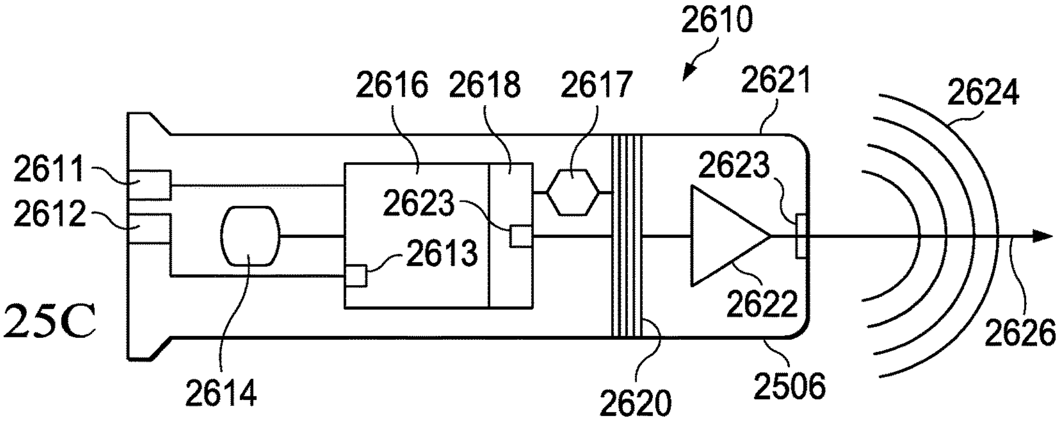

FIG. 25C

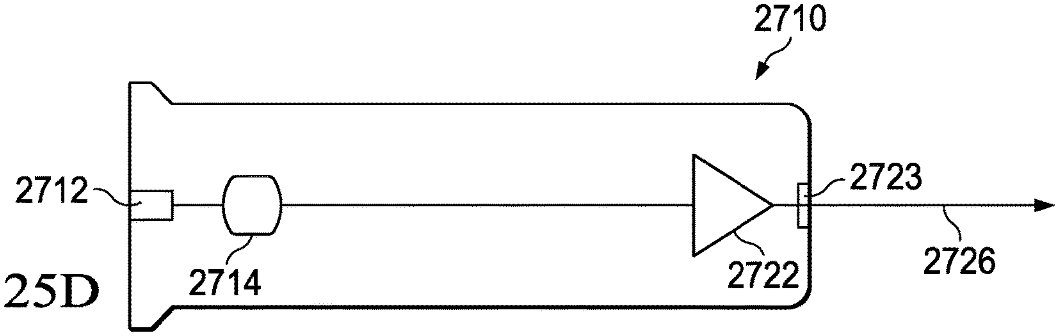

FIG. 25D

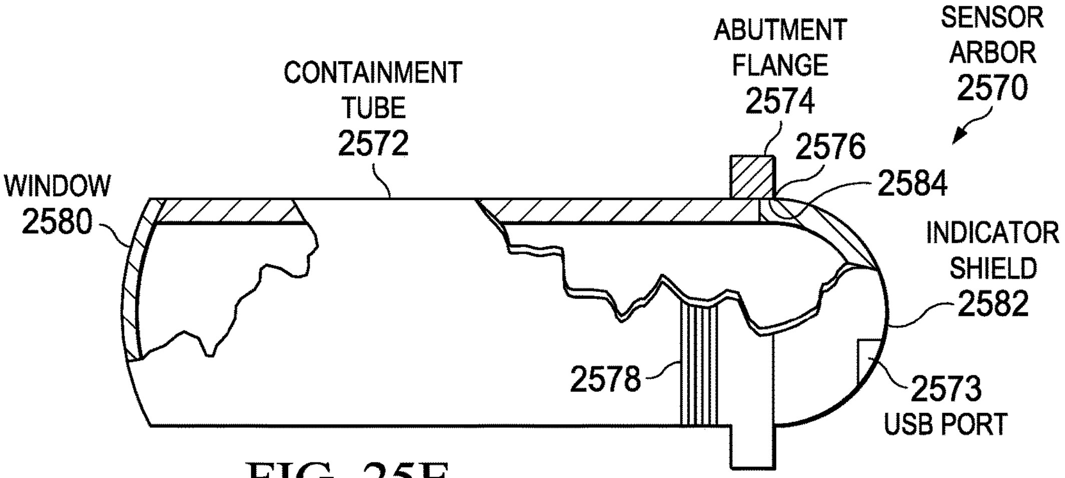

FIG. 25E

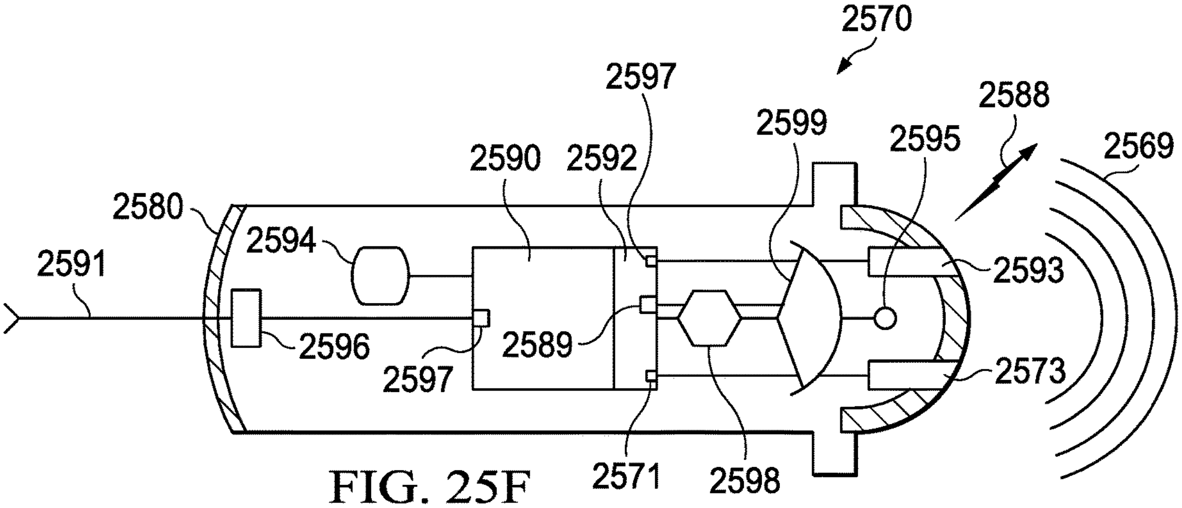

FIG. 25F

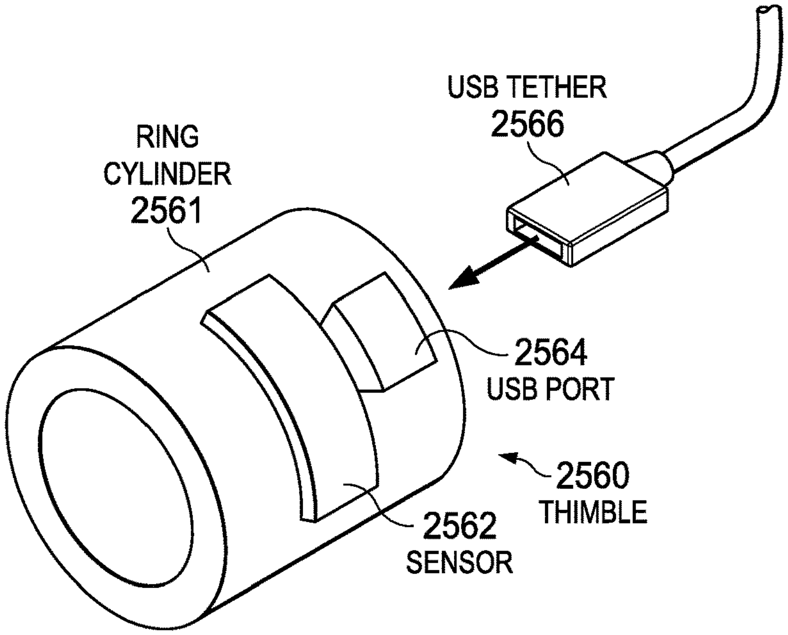

FIG. 25G

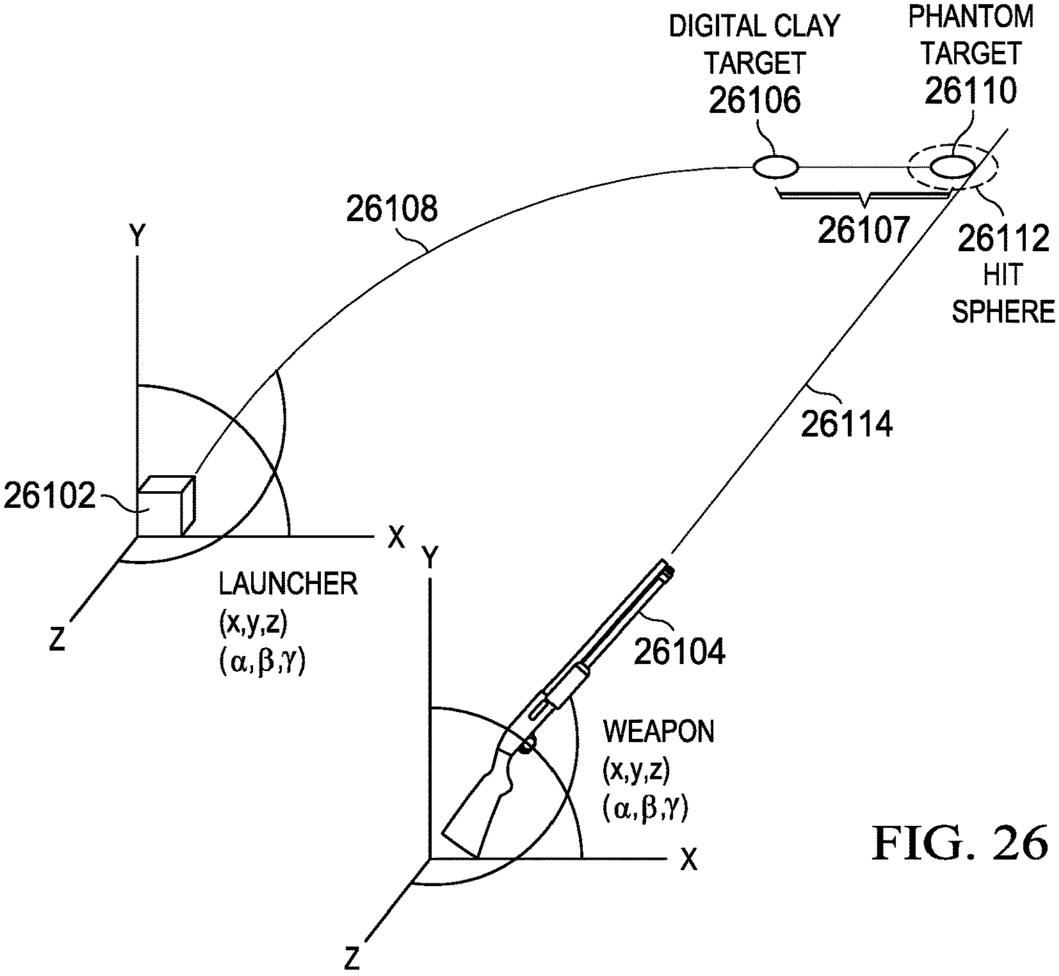

FIG. 26

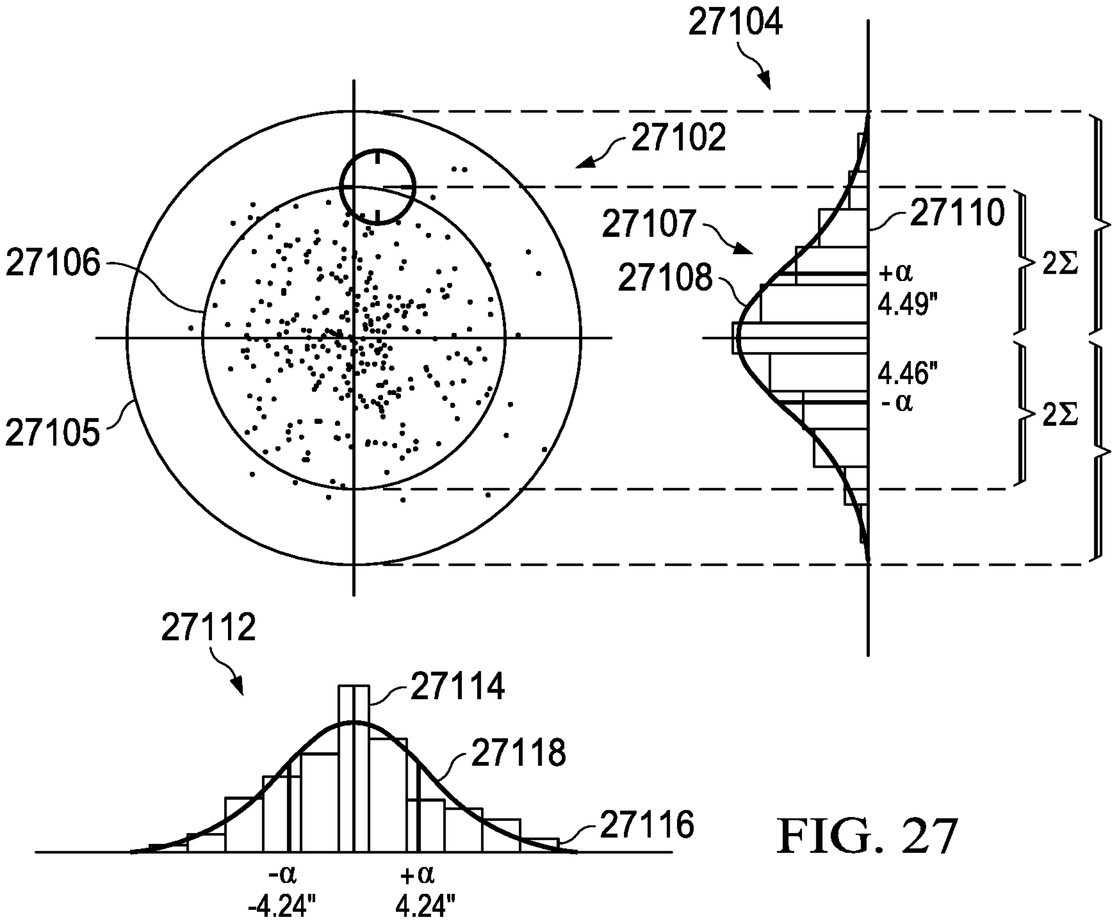

FIG. 27

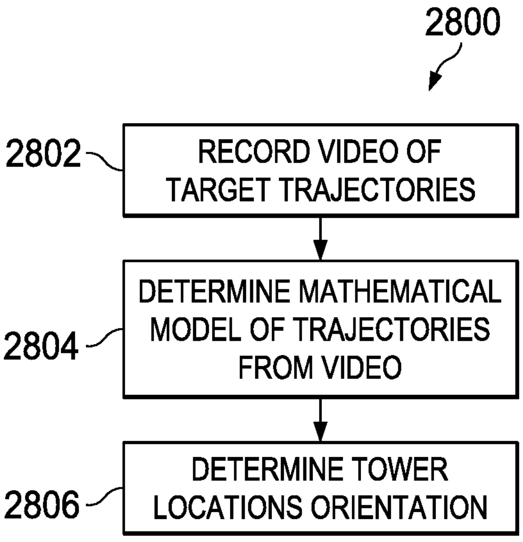
2800
2802
RECORD VIDEO OF TARGET TRAJECTORIES
2804
DETERMINE MATHEMATICAL MODEL OF TRAJECTORIES FROM VIDEO
2806
DETERMINE TOWER LOCATIONS ORIENTATION

FIG. 28A

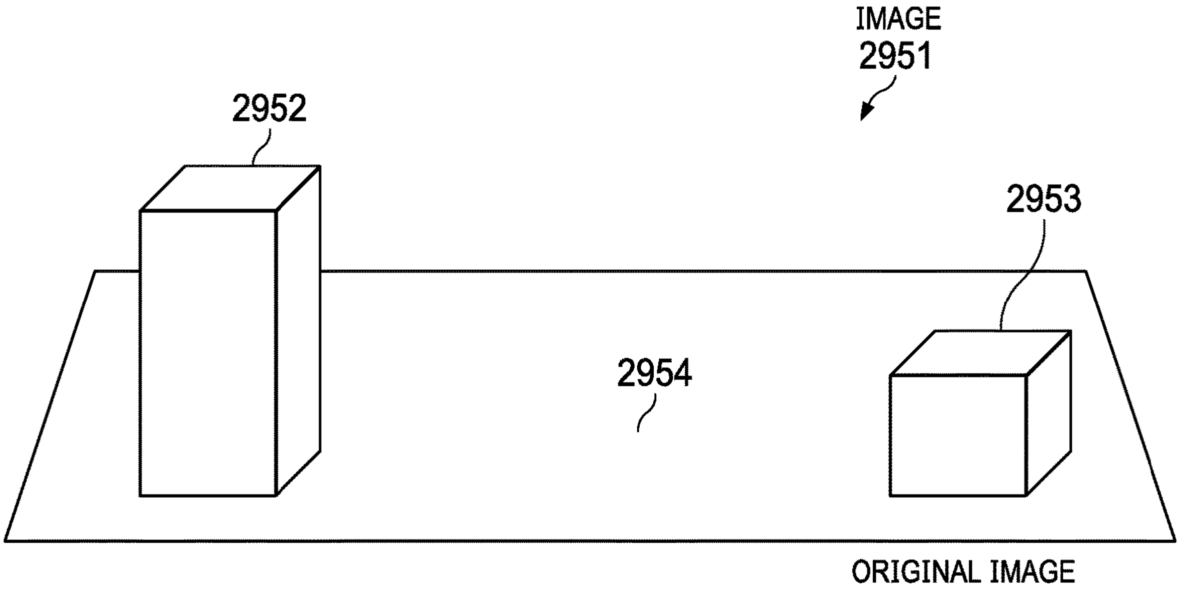

FIG. 28B

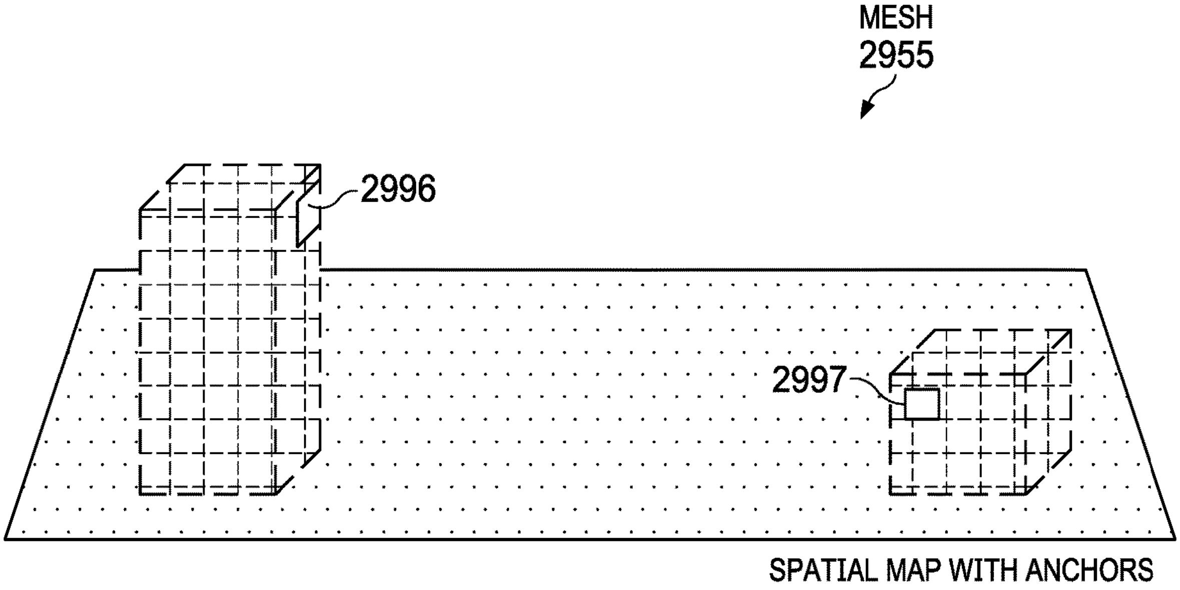

FIG. 28C

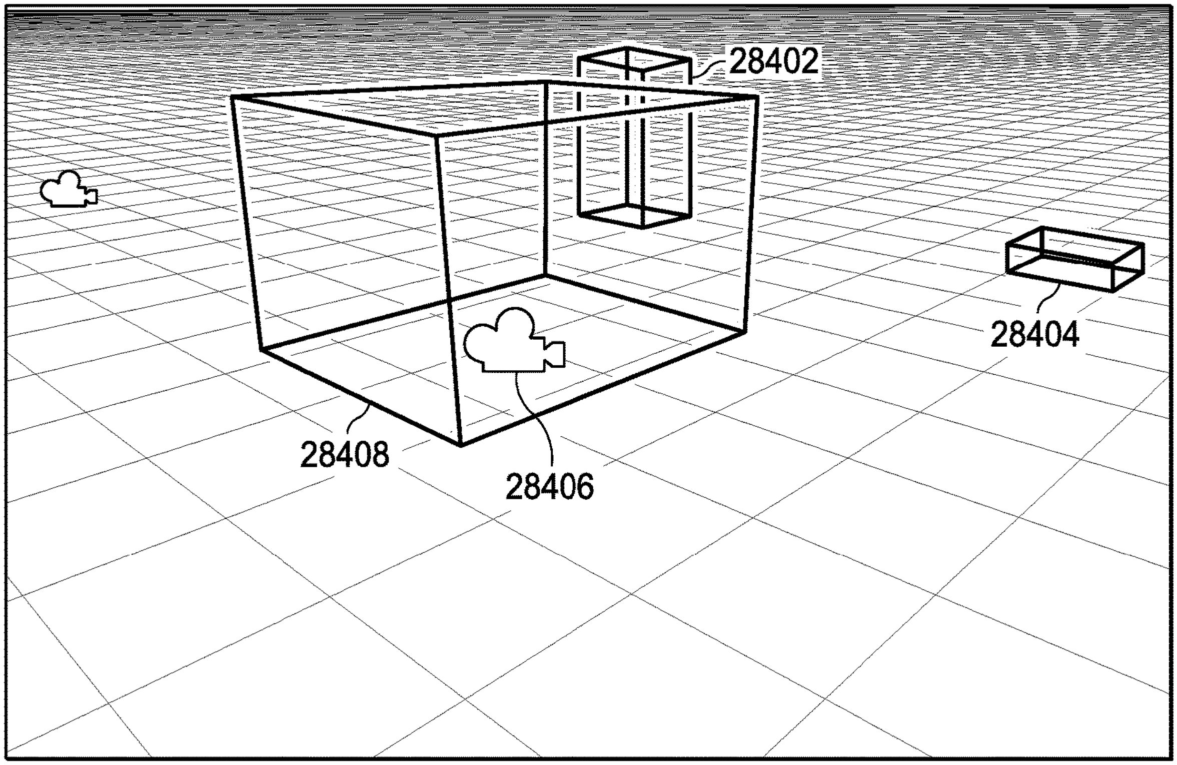

FIG. 28D

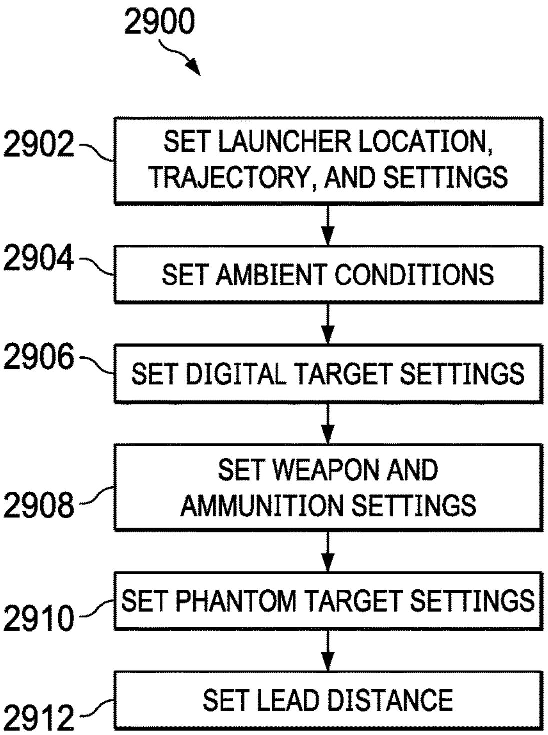
2900
2902
SET LAUNCHER LOCATION, TRAJECTORY, AND SETTINGS
2904
SET AMBIENT CONDITIONS
2906
SET DIGITAL TARGET SETTINGS
2908
SET WEAPON AND AMMUNITION SETTINGS
2910
SET PHANTOM TARGET SETTINGS
2912
SET LEAD DISTANCE

FIG. 29A

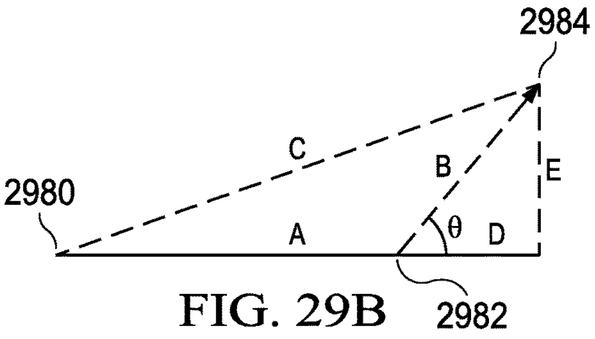

FIG. 29B

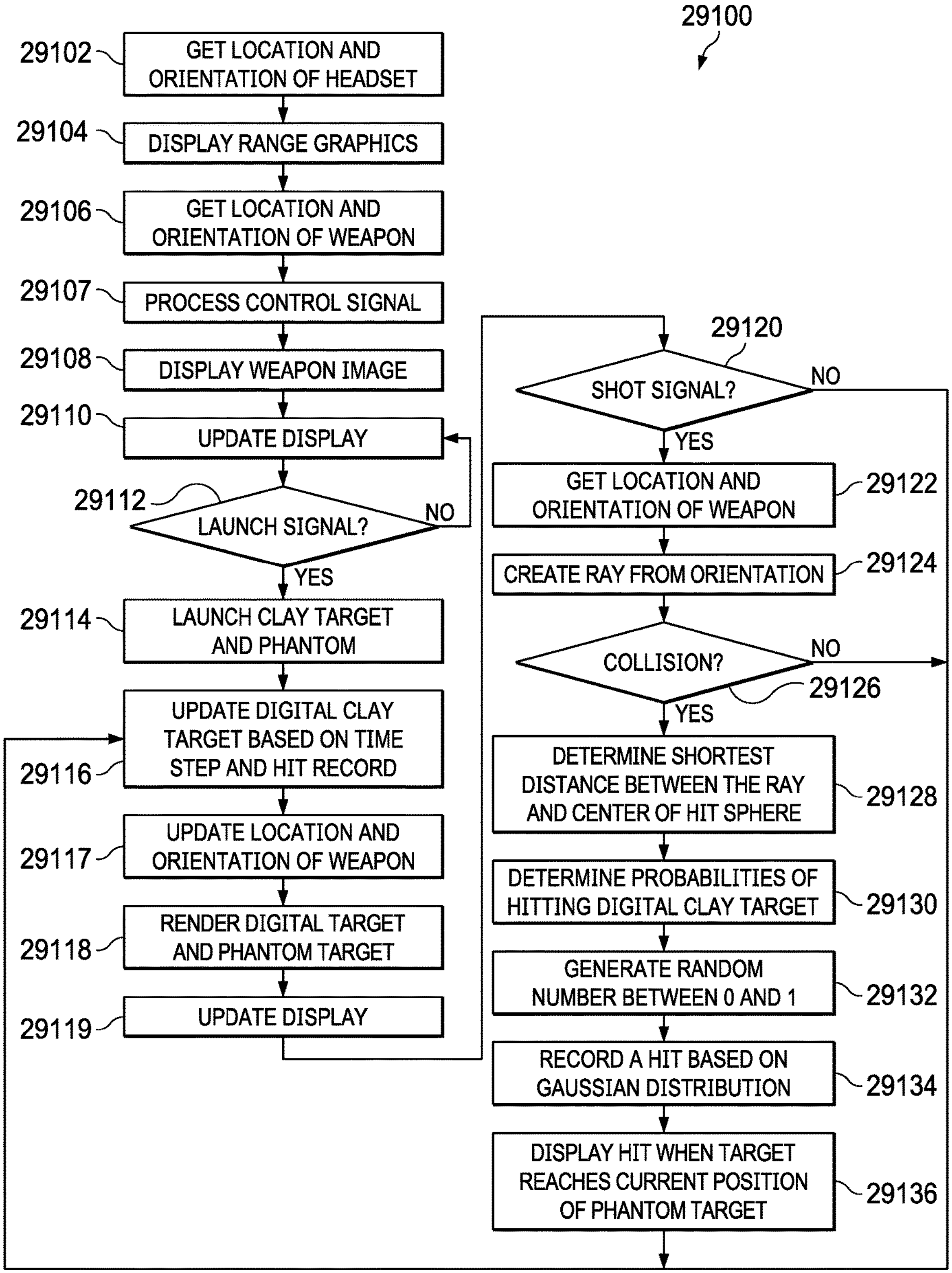
29100
29102
GET LOCATION AND ORIENTATION OF HEADSET
29104
DISPLAY RANGE GRAPHICS
29106
GET LOCATION AND ORIENTATION OF WEAPON
29107
PROCESS CONTROL SIGNAL
29108
DISPLAY WEAPON IMAGE
29110
UPDATE DISPLAY
29112
LAUNCH SIGNAL?
NO
YES
29114
LAUNCH CLAY TARGET AND PHANTOM
UPDATE DIGITAL CLAY TARGET BASED ON TIME STEP AND HIT RECORD
29116
UPDATE LOCATION AND ORIENTATION OF WEAPON
29117
RENDER DIGITAL TARGET AND PHANTOM TARGET
29118
UPDATE DISPLAY
29119
29120
SHOT SIGNAL?
NO
YES
GET LOCATION AND ORIENTATION OF WEAPON
29122
CREATE RAY FROM ORIENTATION
29124
COLLISION?
NO
29126
YES
DETERMINE SHORTEST DISTANCE BETWEEN THE RAY AND CENTER OF HIT SPHERE
29128
DETERMINE PROBABILITIES OF HITTING DIGITAL CLAY TARGET
29130
GENERATE RANDOM NUMBER BETWEEN 0 AND 1
29132
RECORD A HIT BASED ON GAUSSIAN DISTRIBUTION
29134
DISPLAY HIT WHEN TARGET REACHES CURRENT POSITION OF PHANTOM TARGET
29136

FIG. 29C

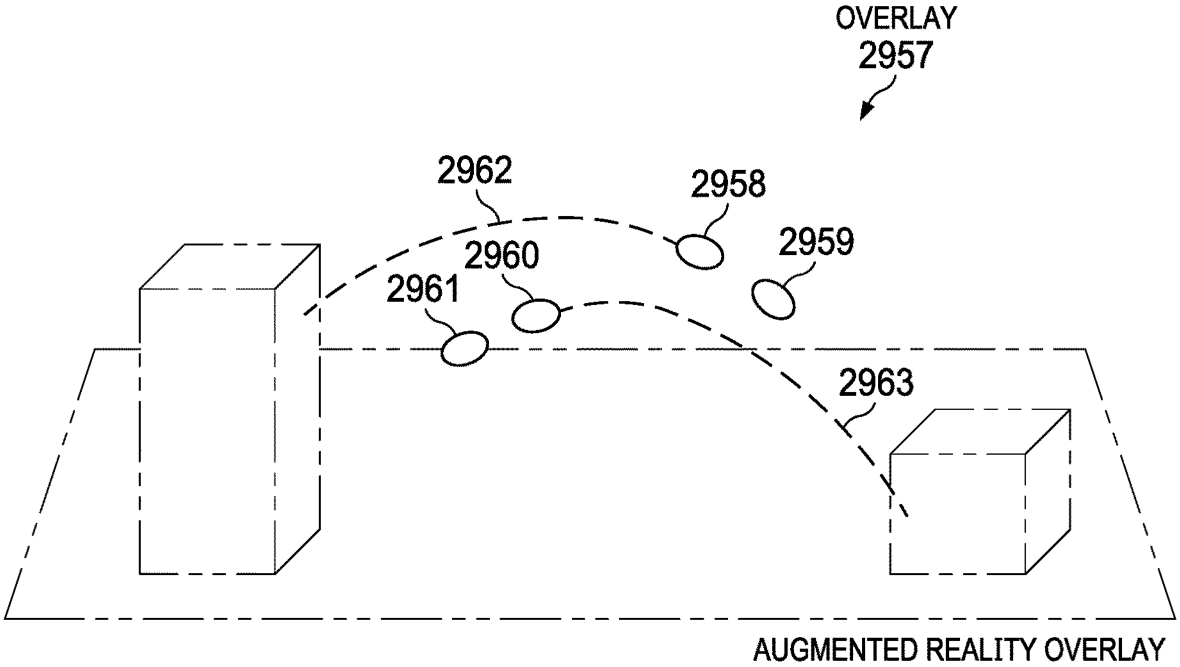

FIG. 29D

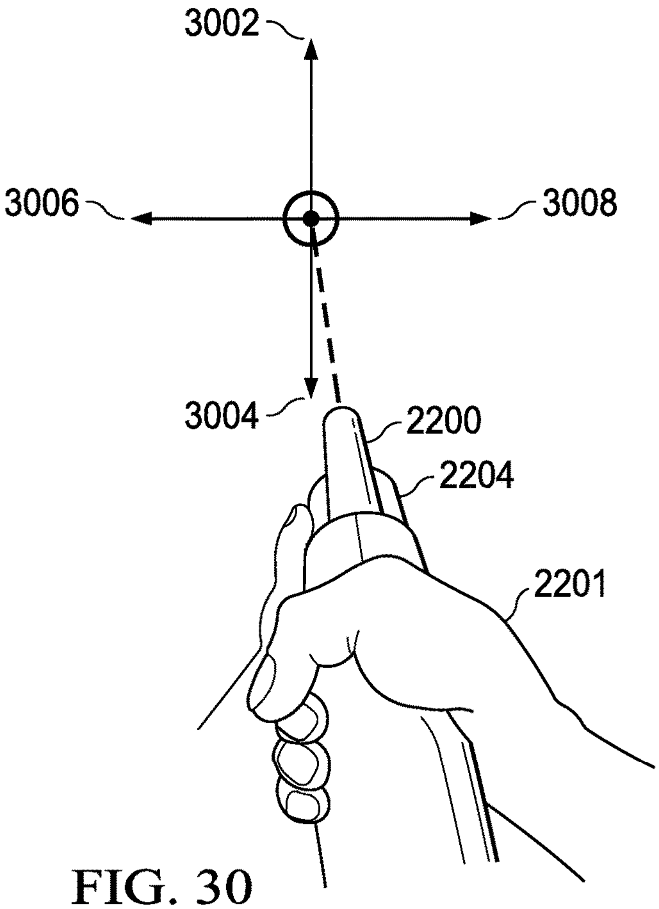

FIG. 30

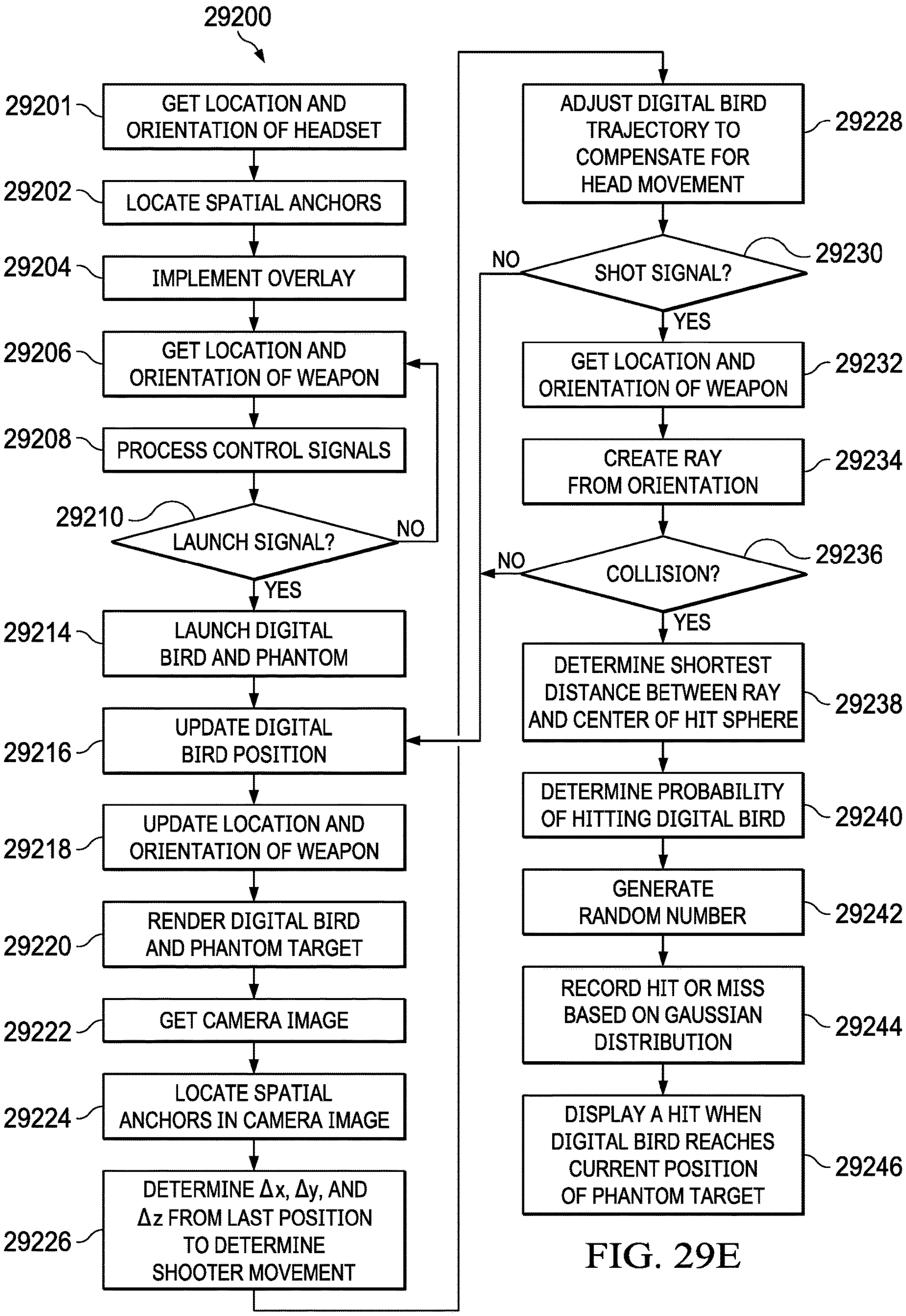
29200
29201
GET LOCATION AND ORIENTATION OF HEADSET
29202
LOCATE SPATIAL ANCHORS
29204
IMPLEMENT OVERLAY
29206
GET LOCATION AND ORIENTATION OF WEAPON
29208
PROCESS CONTROL SIGNALS
29210
LAUNCH SIGNAL?
NO
YES
29214
LAUNCH DIGITAL BIRD AND PHANTOM
29216
UPDATE DIGITAL BIRD POSITION
29218
UPDATE LOCATION AND ORIENTATION OF WEAPON
29220
RENDER DIGITAL BIRD AND PHANTOM TARGET
29222
GET CAMERA IMAGE
29224
LOCATE SPATIAL ANCHORS IN CAMERA IMAGE
29226
DETERMINE Δx, Δy, AND Δz FROM LAST POSITION TO DETERMINE SHOOTER MOVEMENT
ADJUST DIGITAL BIRD TRAJECTORY TO COMPENSATE FOR HEAD MOVEMENT
29228
NO
SHOT SIGNAL?
29230
YES
GET LOCATION AND ORIENTATION OF WEAPON
29232
CREATE RAY FROM ORIENTATION
29234
NO
COLLISION?
29236
YES
DETERMINE SHORTEST DISTANCE BETWEEN RAY AND CENTER OF HIT SPHERE
29238
DETERMINE PROBABILITY OF HITTING DIGITAL BIRD
29240
GENERATE RANDOM NUMBER
29242
RECORD HIT OR MISS BASED ON GAUSSIAN DISTRIBUTION
29244
DISPLAY A HIT WHEN DIGITAL BIRD REACHES CURRENT POSITION OF PHANTOM TARGET
29246

FIG. 29E

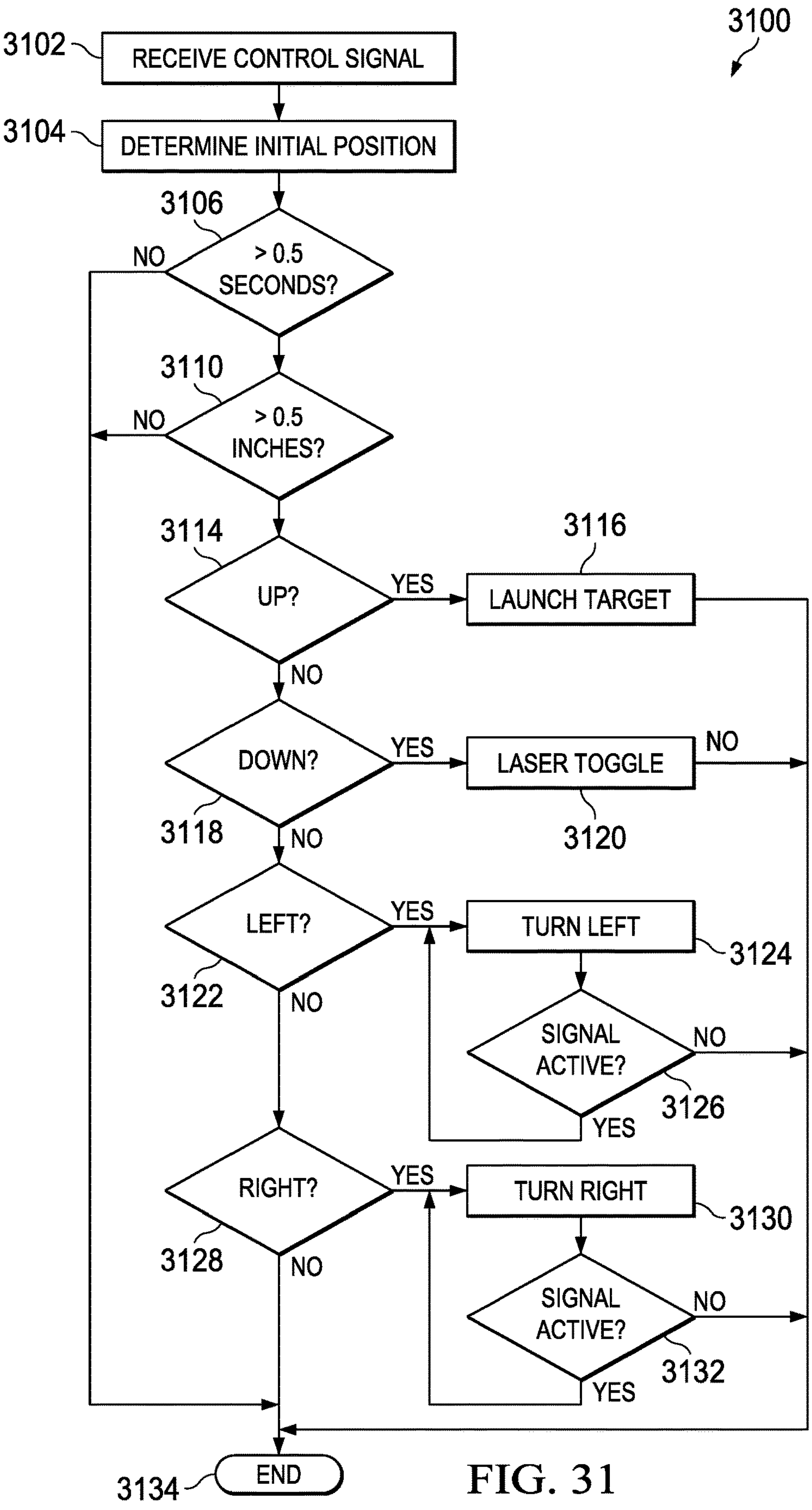
3100
3102
RECEIVE CONTROL SIGNAL
3104
DETERMINE INITIAL POSITION
3106
> 0.5 SECONDS?
NO
3110
> 0.5 INCHES?
NO
3114
UP?
YES
3116
LAUNCH TARGET
NO
DOWN?
YES
LASER TOGGLE
NO
3118
3120
NO
LEFT?
YES
TURN LEFT
3124
3122
NO
SIGNAL ACTIVE?
NO
3126
YES
RIGHT?
YES
TURN RIGHT
3130
3128
NO
SIGNAL ACTIVE?
NO
3132
YES
3134
END

FIG. 31

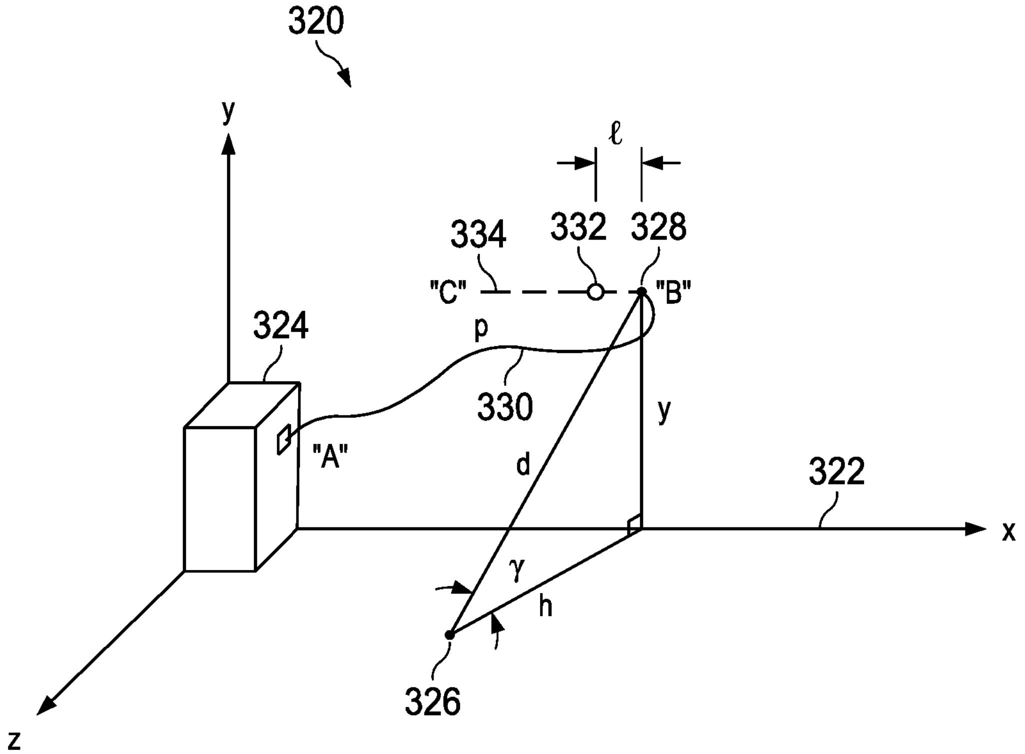
320
y
ℓ
334
332
328
"C"
"B"
324
p
330
y
"A"
d
322
x
γ
h
326
z

FIG. 32

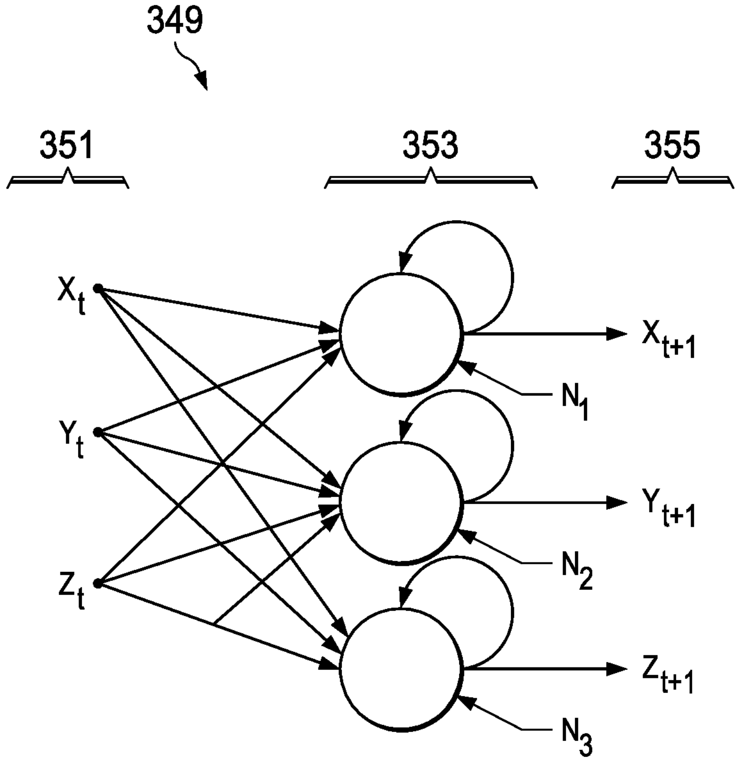
349
351
353
355
$X_t$
$Y_t$
$Z_t$
$X_{t+1}$
$Y_{t+1}$
$Z_{t+1}$
$N_1$
$N_2$
$N_3$

FIG. 35

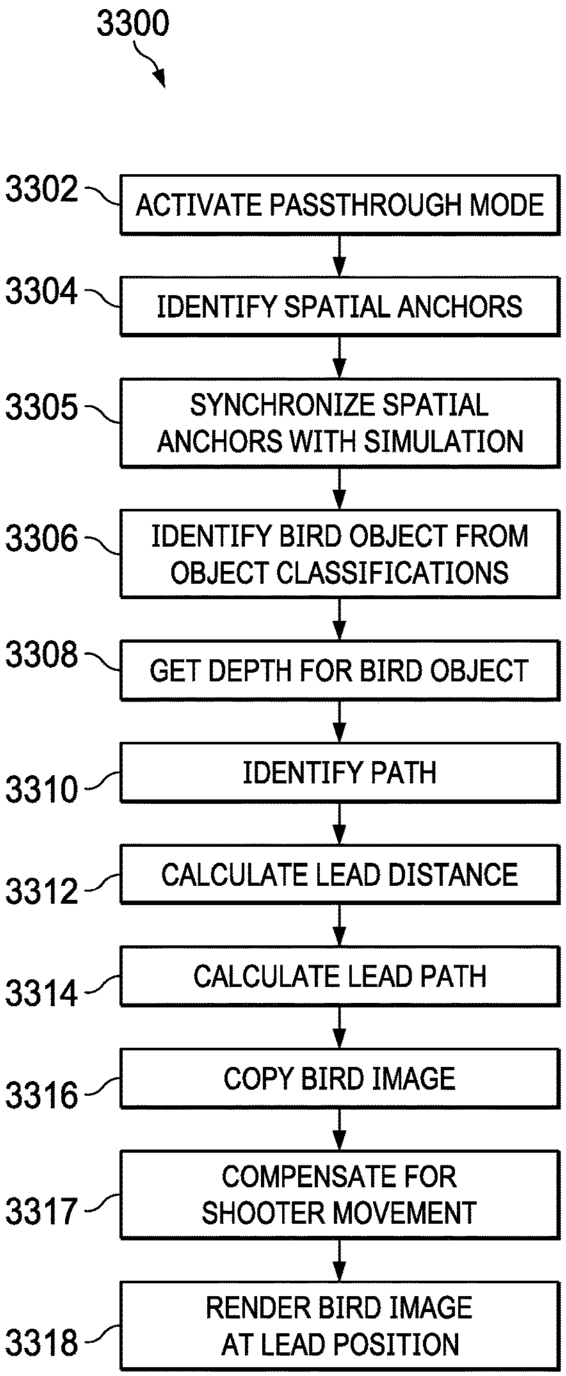
3300
3302
ACTIVATE PASSTHROUGH MODE
3304
IDENTIFY SPATIAL ANCHORS
3305
SYNCHRONIZE SPATIAL ANCHORS WITH SIMULATION
3306
IDENTIFY BIRD OBJECT FROM OBJECT CLASSIFICATIONS
3308
GET DEPTH FOR BIRD OBJECT
3310
IDENTIFY PATH
3312
CALCULATE LEAD DISTANCE
3314
CALCULATE LEAD PATH
3316
COPY BIRD IMAGE
3317
COMPENSATE FOR SHOOTER MOVEMENT
3318
RENDER BIRD IMAGE AT LEAD POSITION

FIG. 33

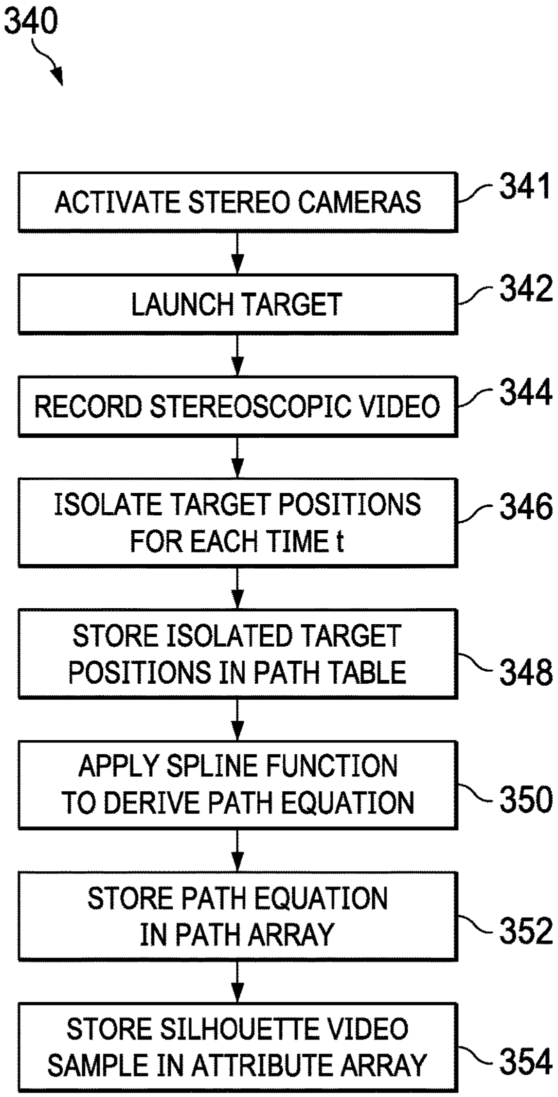
340
ACTIVATE STEREO CAMERAS
341
LAUNCH TARGET
342
RECORD STEREOSCOPIC VIDEO
344
ISOLATE TARGET POSITIONS FOR EACH TIME t
346
STORE ISOLATED TARGET POSITIONS IN PATH TABLE
348
APPLY SPLINE FUNCTION TO DERIVE PATH EQUATION
350
STORE PATH EQUATION IN PATH ARRAY
352
STORE SILHOUETTE VIDEO SAMPLE IN ATTRIBUTE ARRAY
354

FIG. 34

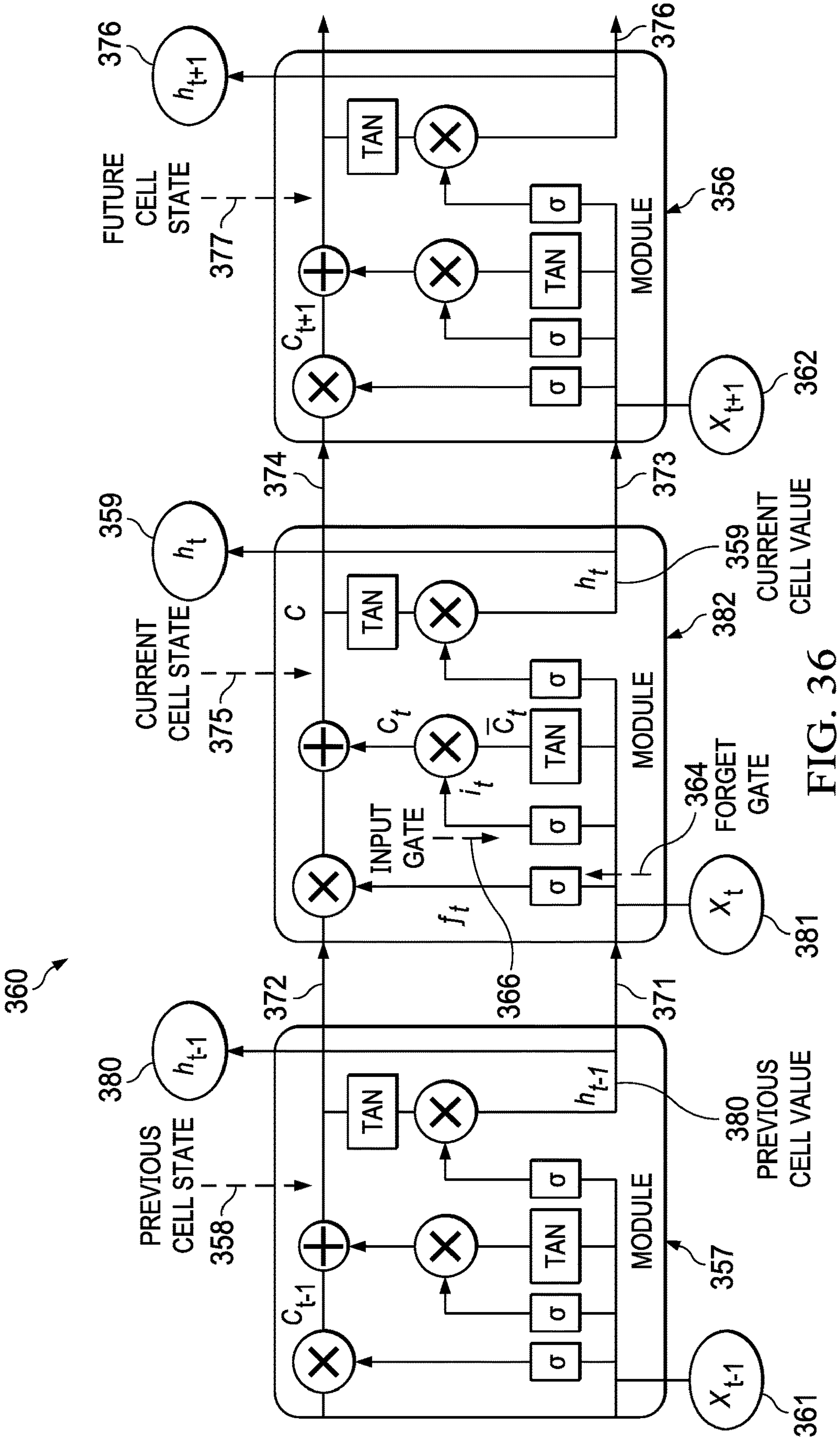
360
PREVIOUS CELL STATE
358
380
$h_{t-1}$
$C_{t-1}$
TAN
σ
MODULE
357
$h_{t-1}$
380 PREVIOUS CELL VALUE
$X_{t-1}$
361
372
371
366
CURRENT CELL STATE
375
359
$h_t$
$C_t$
$\bar{C}_t$
$i_t$
$f_t$
INPUT GATE
364 FORGET GATE
C
$h_t$
359 CURRENT CELL VALUE
382
$X_t$
381
374
373
FUTURE CELL STATE
377
376
$h_{t+1}$
$C_{t+1}$
356
$X_{t+1}$
362

FIG. 36

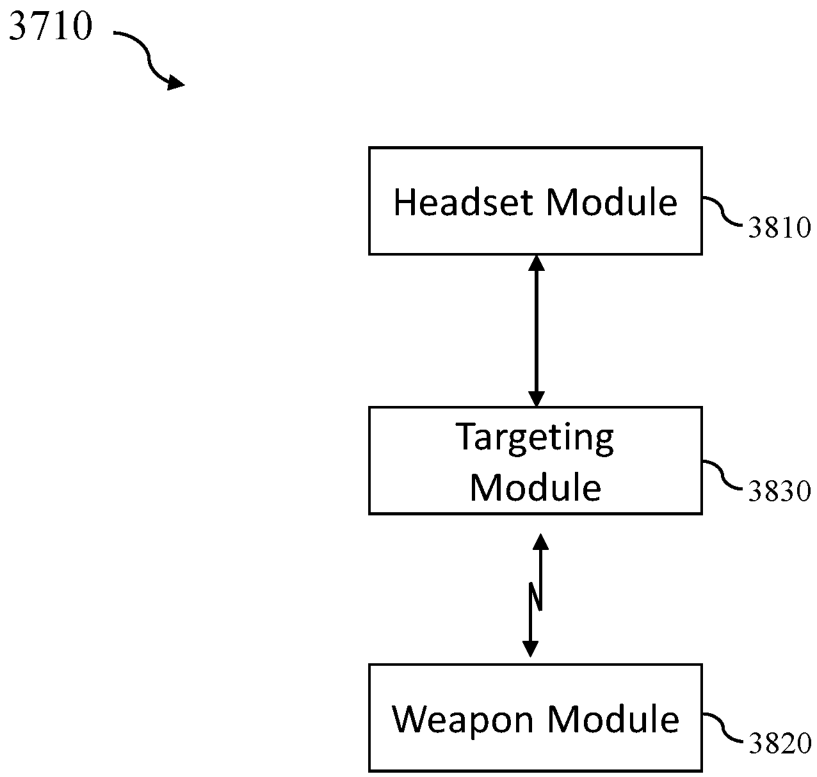
3710
Headset Module
3810
Targeting Module
3830
Weapon Module
3820

Figure 37A

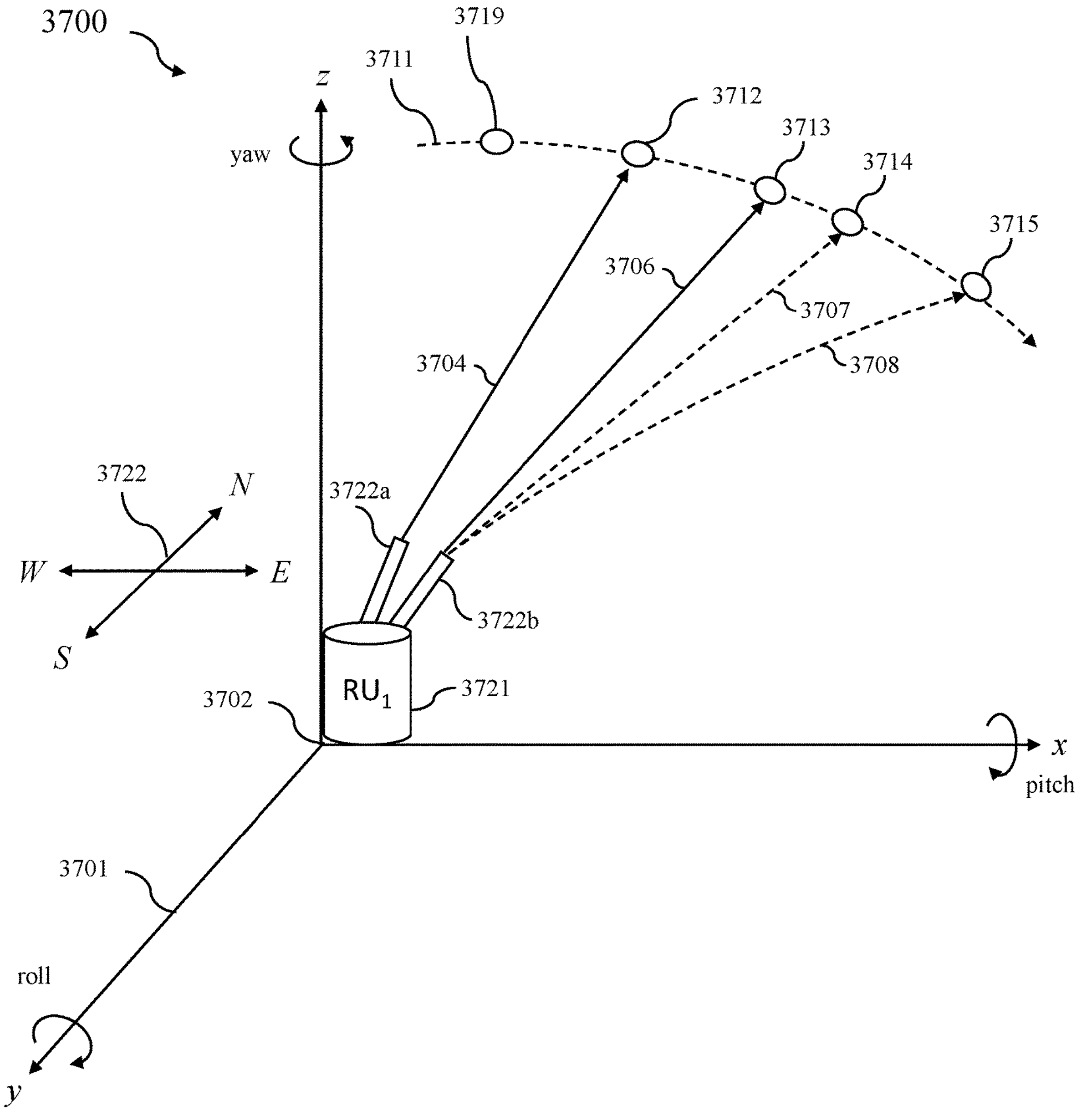
3700
3719
3711
z
3712
3713
3714
yaw
3715
3706
3707
3704
3708
3722
N
3722a
W
E
3722b
S
RU$_1$
3721
3702
x
pitch
3701
roll
y

Figure 37B

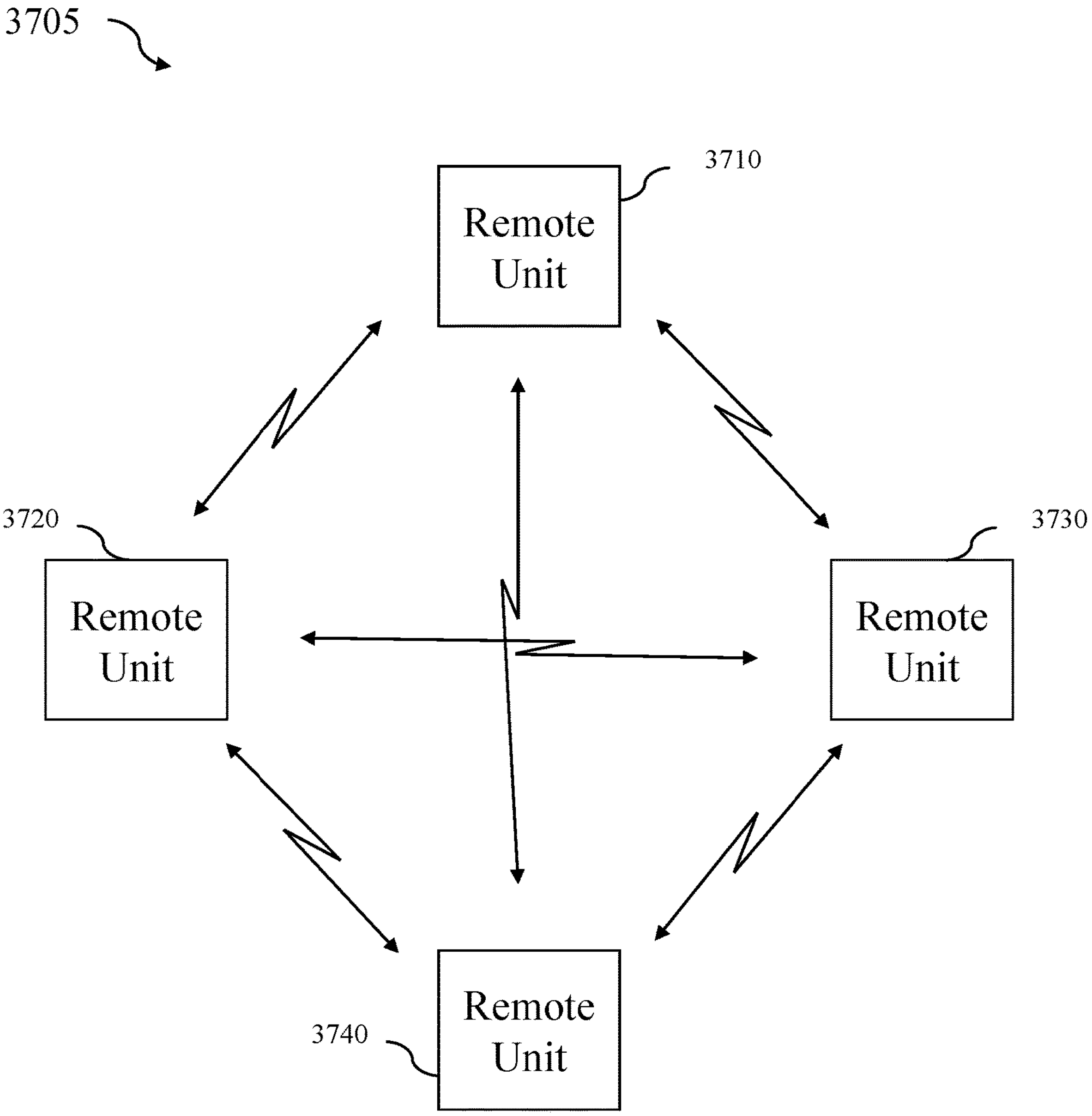
3705
3710
Remote Unit
3720
Remote Unit
3730
Remote Unit
3740
Remote Unit

Figure 38A

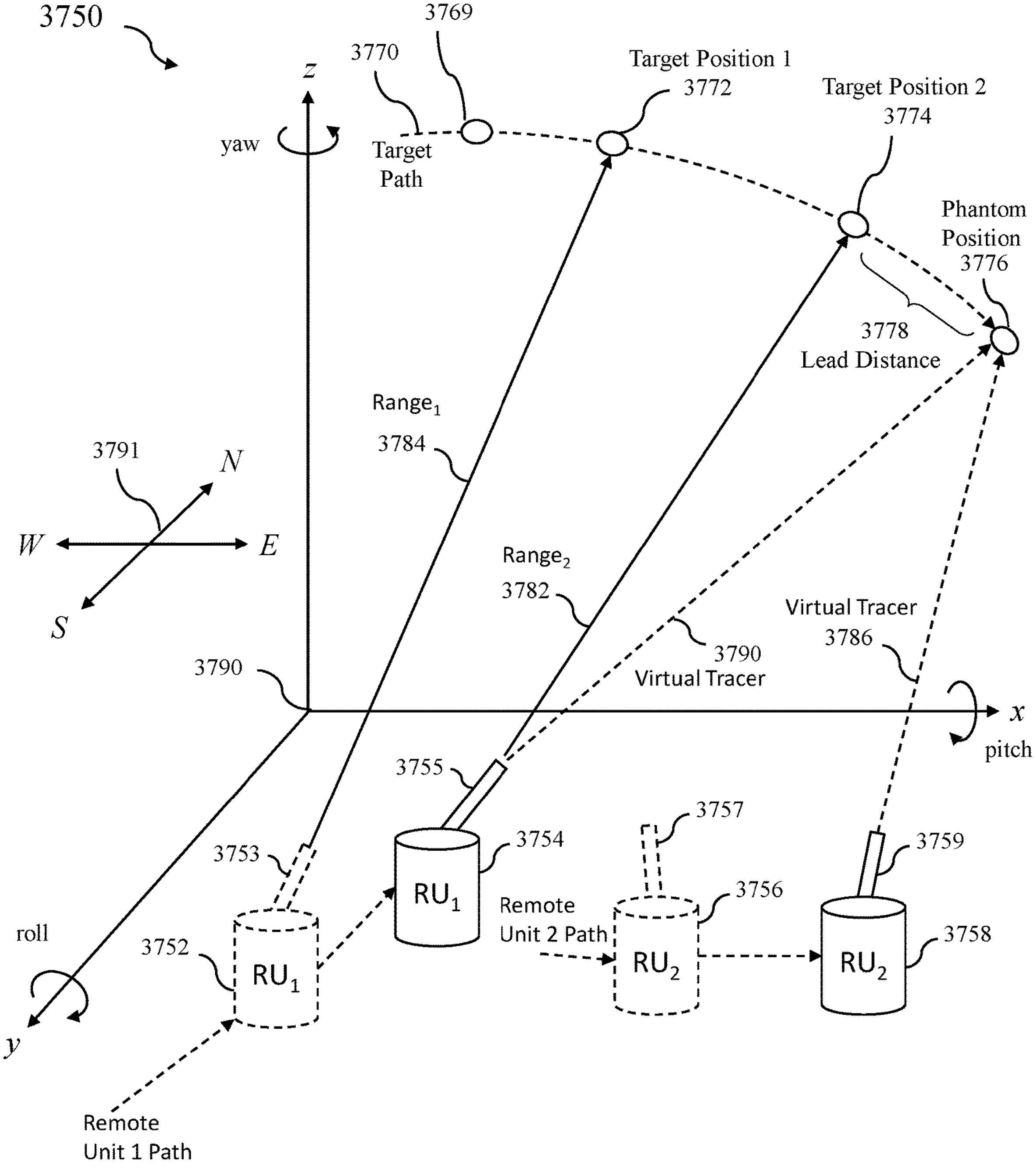
3750
3769
3770
Target Position 1
3772
Target Position 2
3774
z
yaw
Target Path
Phantom Position
3776
3778
Lead Distance
Range$_1$
3784
3791
N
W
E
S
Range$_2$
3782
Virtual Tracer
3786
3790
Virtual Tracer
3790
x
pitch
3755
3757
3753
3754
3759
RU$_1$
3756
Remote Unit 2 Path
3758
roll
3752
RU$_1$
RU$_2$
RU$_2$
y
Remote Unit 1 Path

Figure 38B

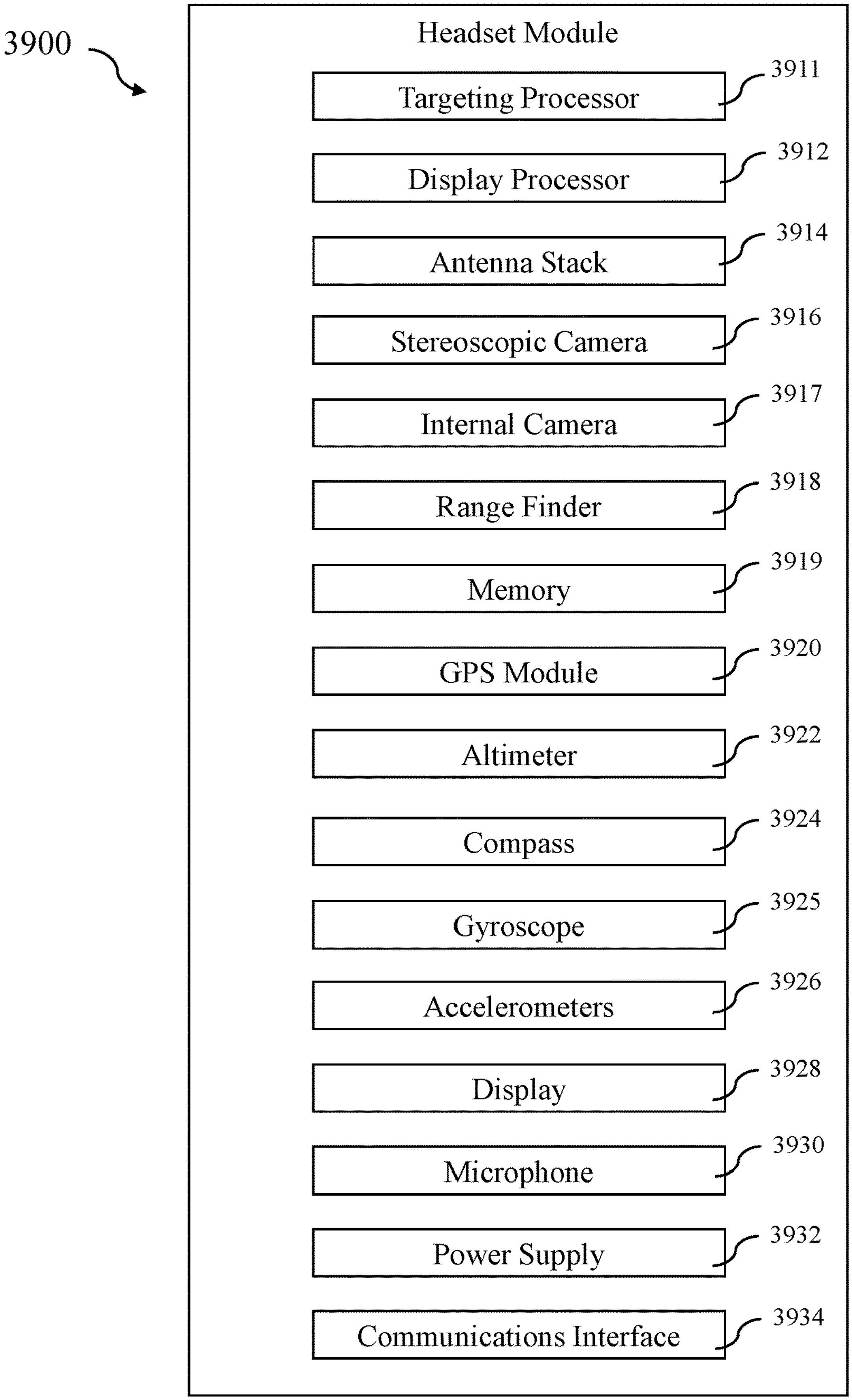
3900
Headset Module
Targeting Processor
3911
Display Processor
3912
Antenna Stack
3914
Stereoscopic Camera
3916
Internal Camera
3917
Range Finder
3918
Memory
3919
GPS Module
3920
Altimeter
3922
Compass
3924
Gyroscope
3925
Accelerometers
3926
Display
3928
Microphone
3930
Power Supply
3932
Communications Interface
3934

Figure 39

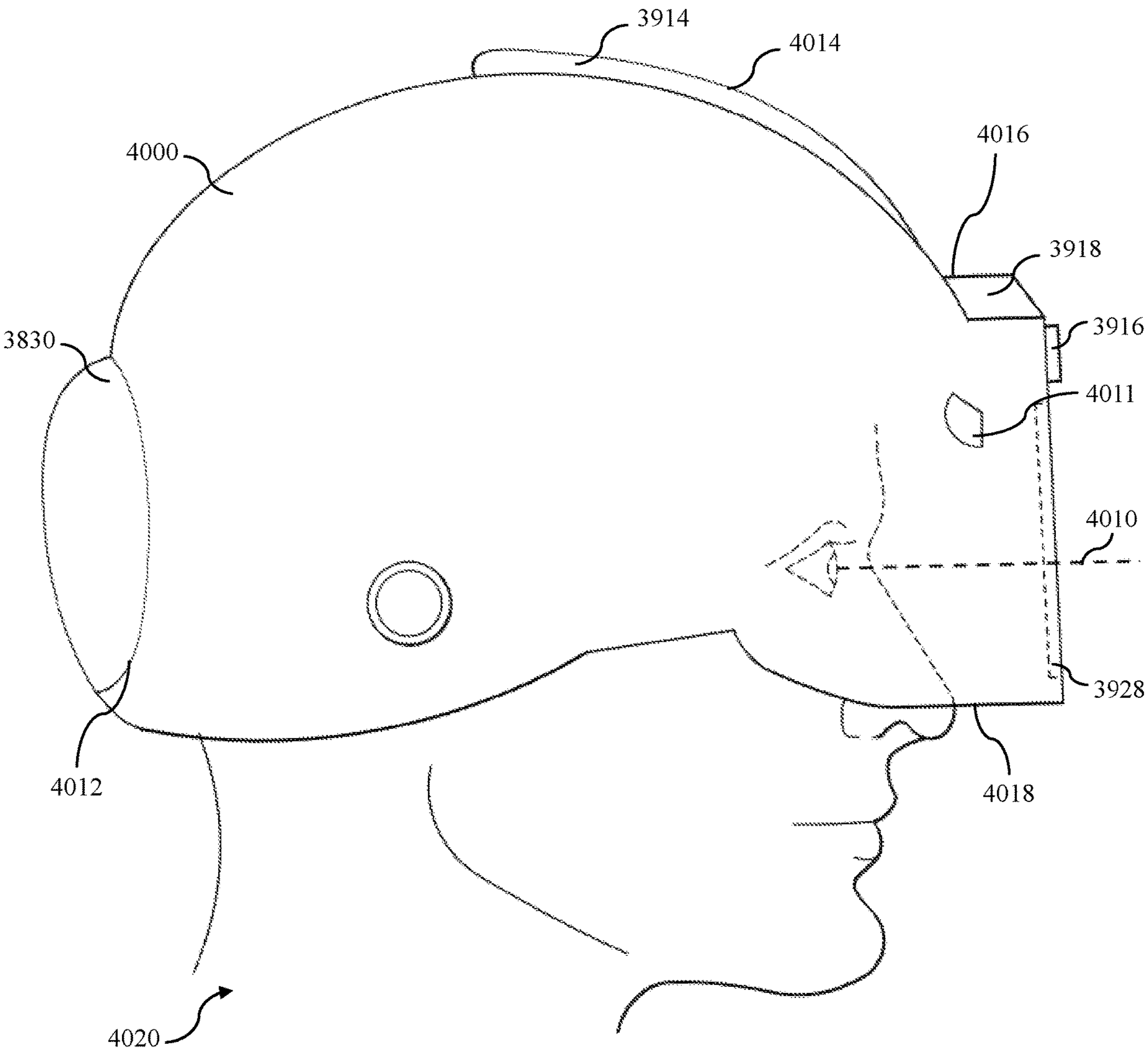
3914
4014
4000
4016
3918
3916
3830
4011
4010
3928
4012
4018
4020

Figure 40A

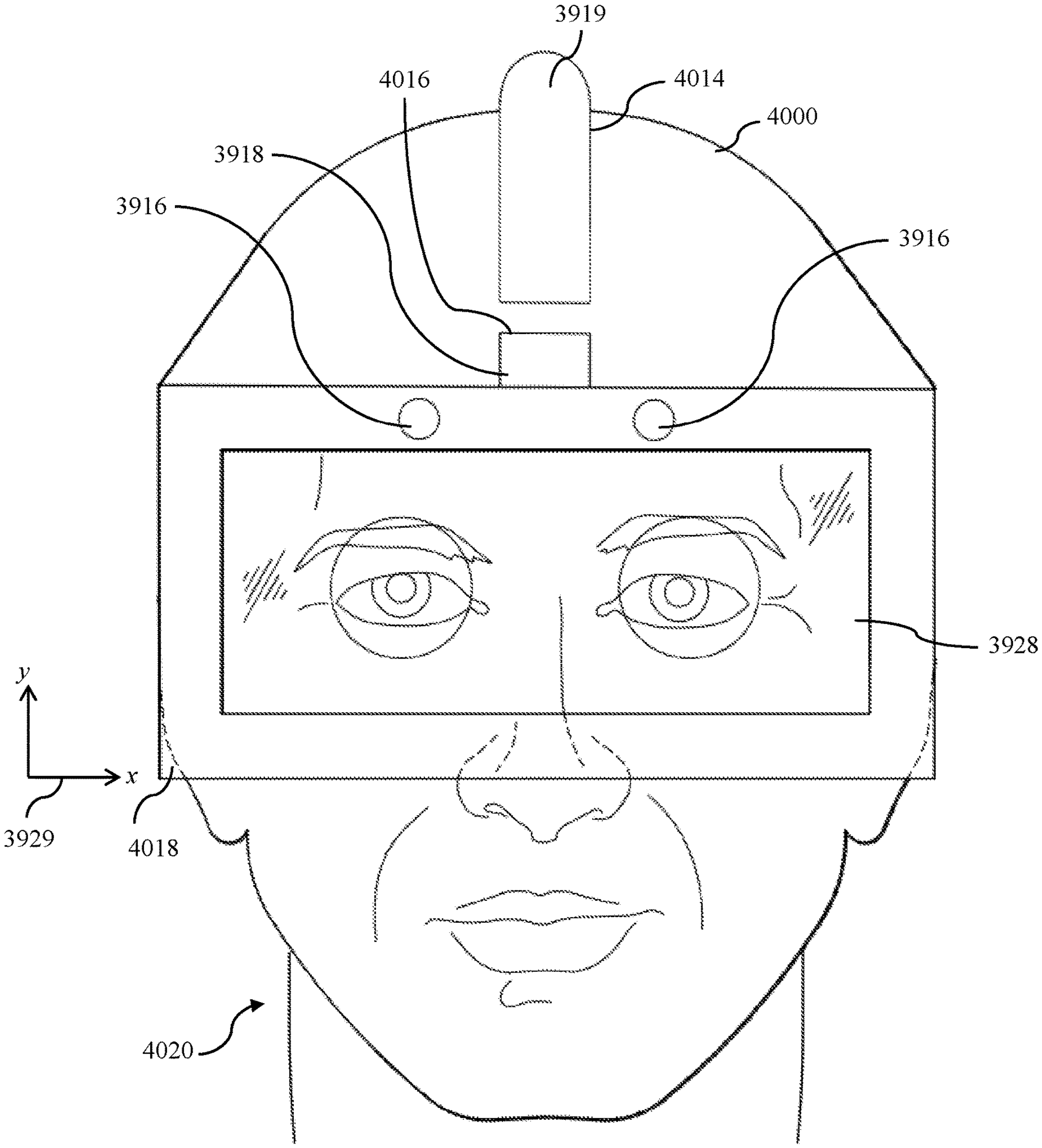

Figure 40B

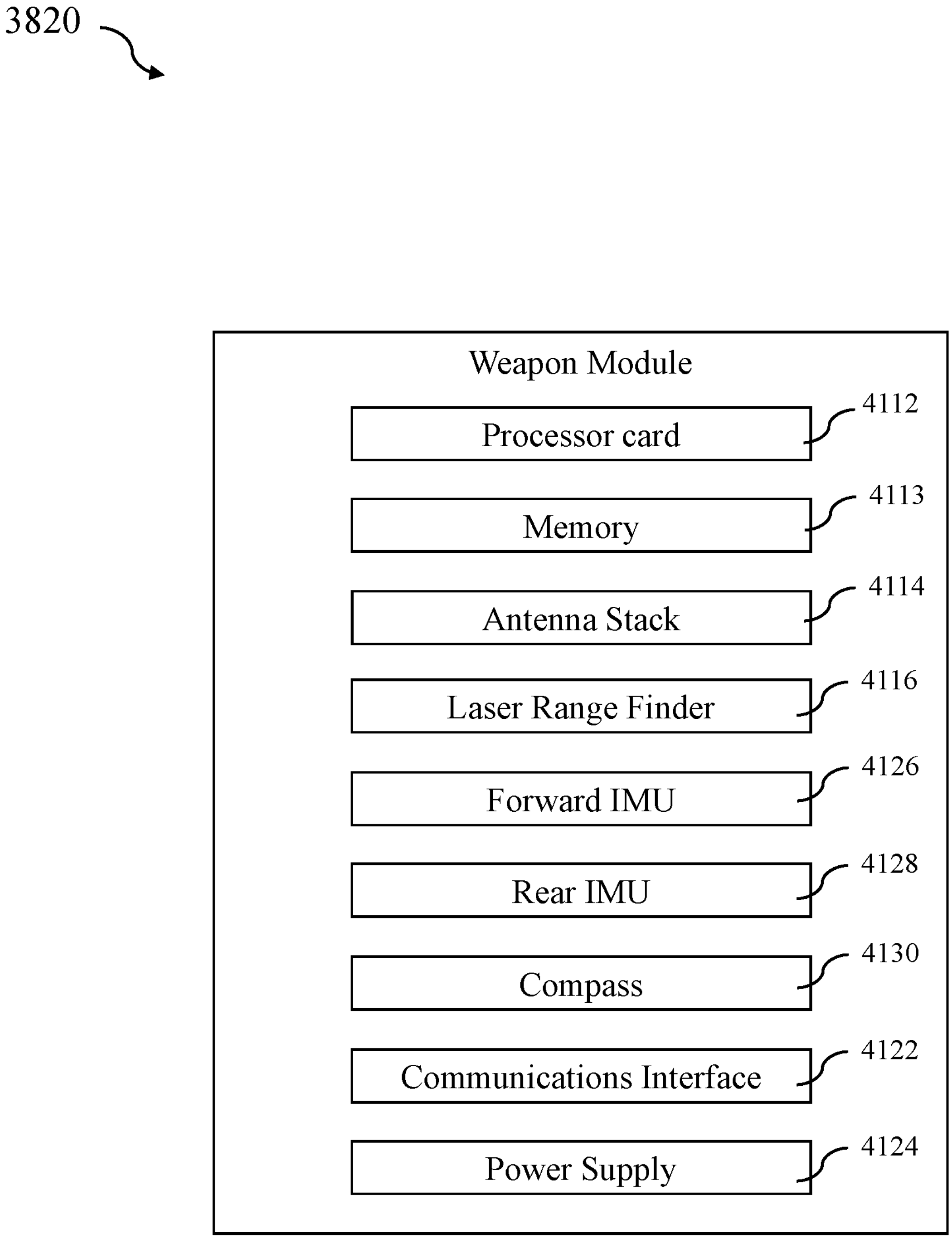
3820
Weapon Module
Processor card
4112
Memory
4113
Antenna Stack
4114
Laser Range Finder
4116
Forward IMU
4126
Rear IMU
4128
Compass
4130
Communications Interface
4122
Power Supply
4124

Figure 41A

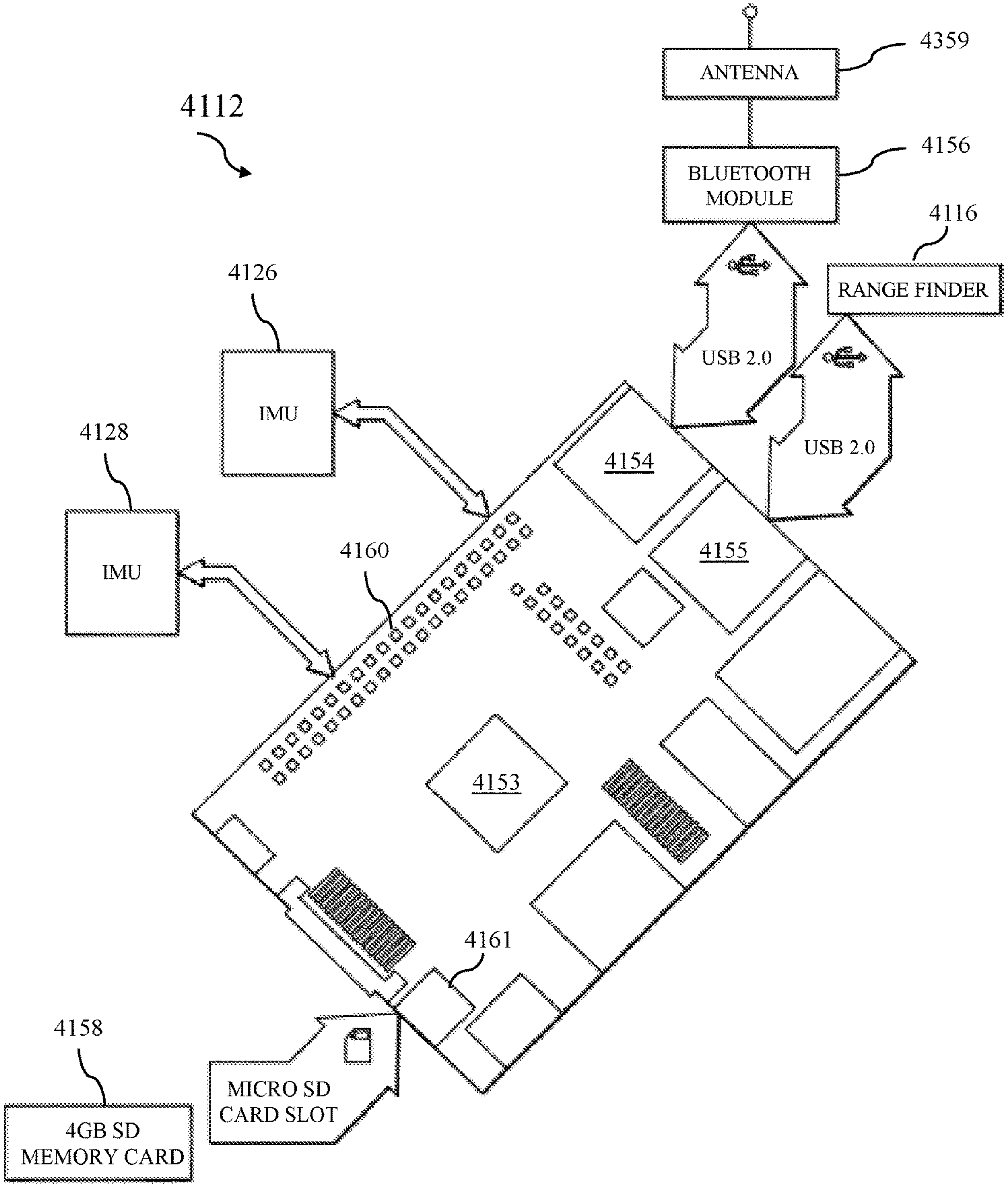
4359
ANTENNA
4112
4156
BLUETOOTH MODULE
4116
RANGE FINDER
4126
IMU
USB 2.0
USB 2.0
4128
IMU
4154
4155
4160
4153
4161
4158
4GB SD MEMORY CARD
MICRO SD CARD SLOT

Figure 41B

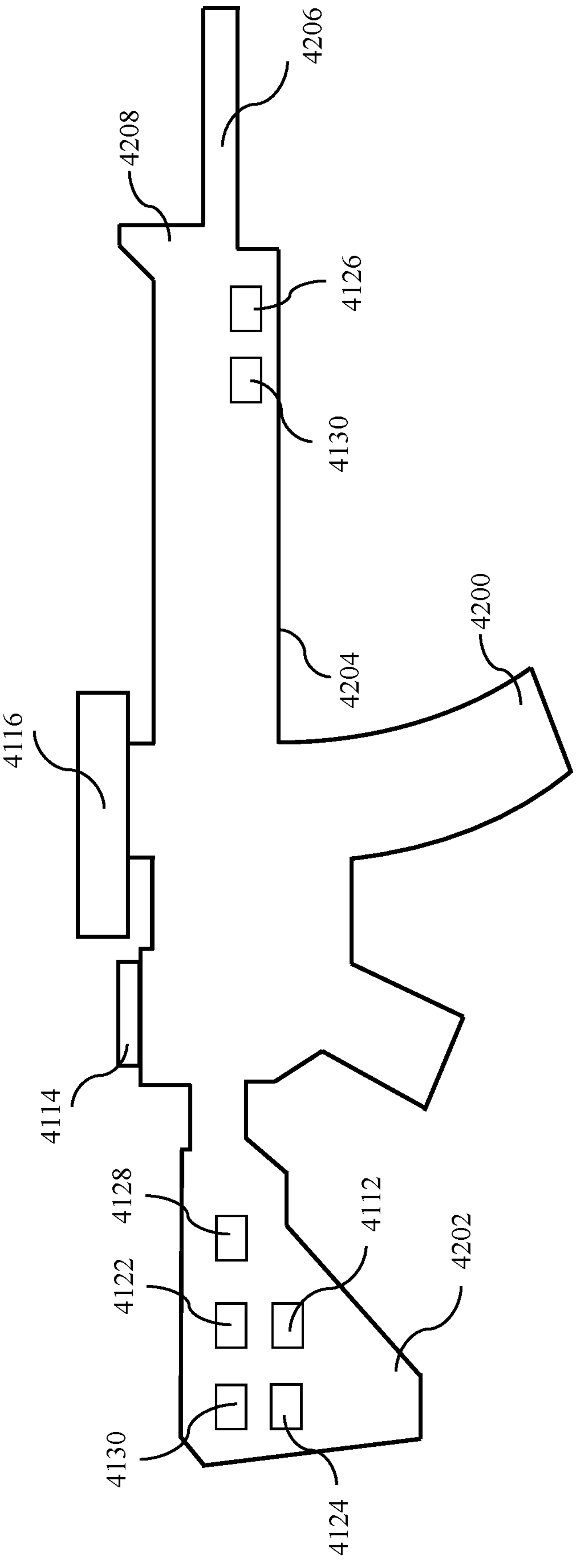
4206
4208
4126
4130
4200
4204
4116
4114
4128
4112
4202
4122
4130
4124

Figure 42A

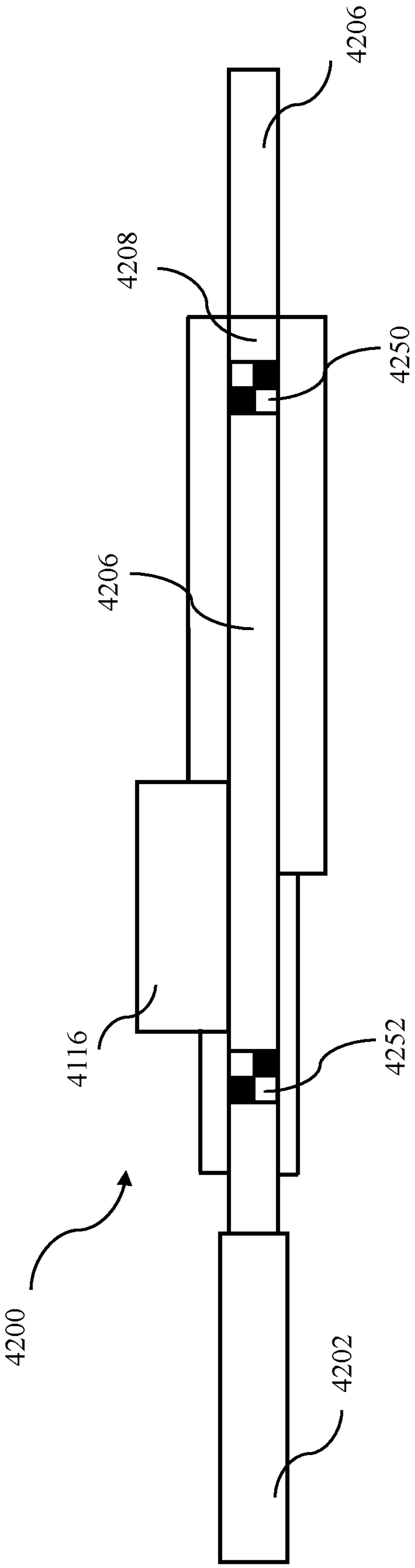

Figure 42B

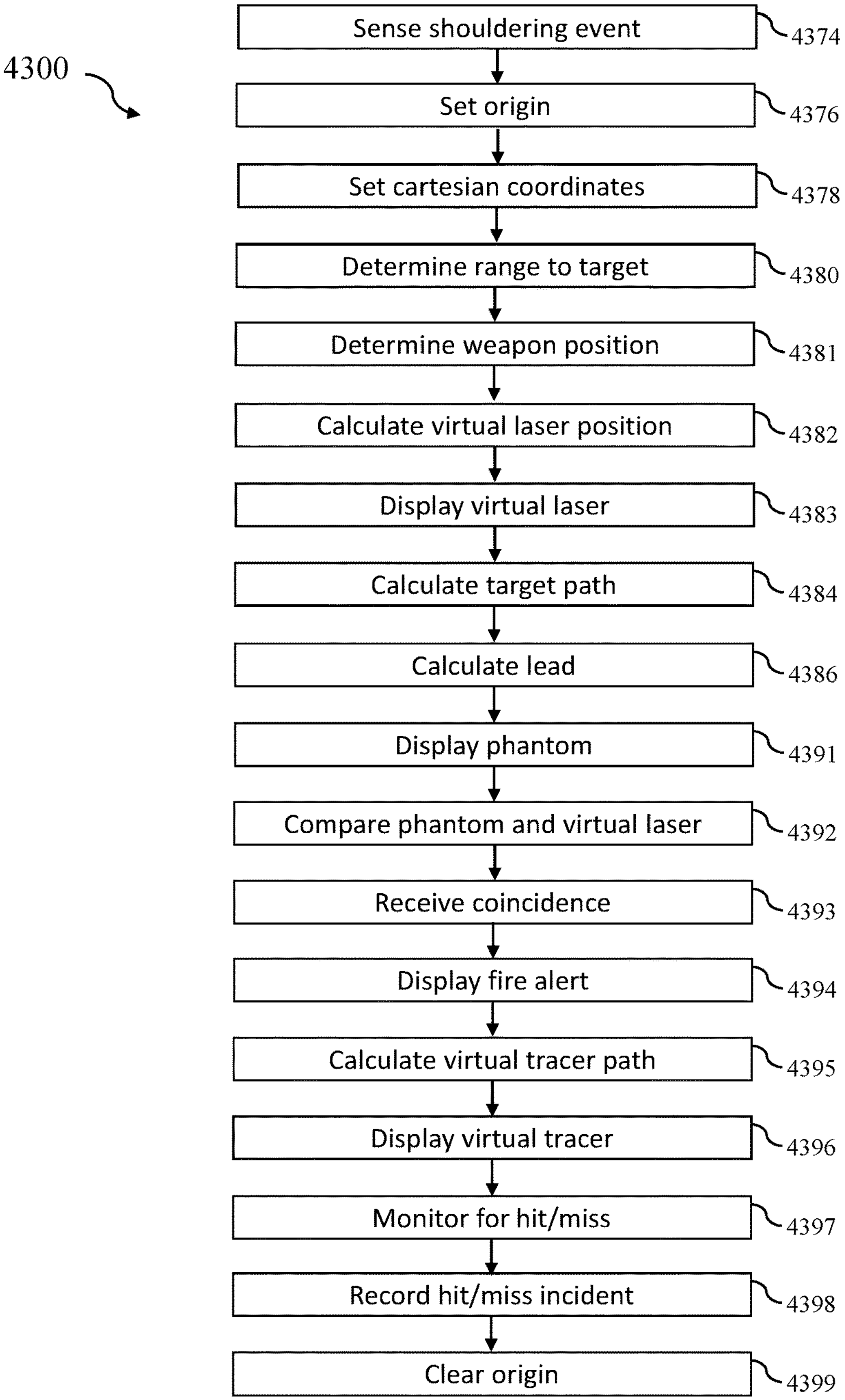
4300
Sense shouldering event
4374
Set origin
4376
Set cartesian coordinates
4378
Determine range to target
4380
Determine weapon position
4381
Calculate virtual laser position
4382
Display virtual laser
4383
Calculate target path
4384
Calculate lead
4386
Display phantom
4391
Compare phantom and virtual laser
4392
Receive coincidence
4393
Display fire alert
4394
Calculate virtual tracer path
4395
Display virtual tracer
4396
Monitor for hit/miss
4397
Record hit/miss incident
4398
Clear origin
4399

Figure 43A

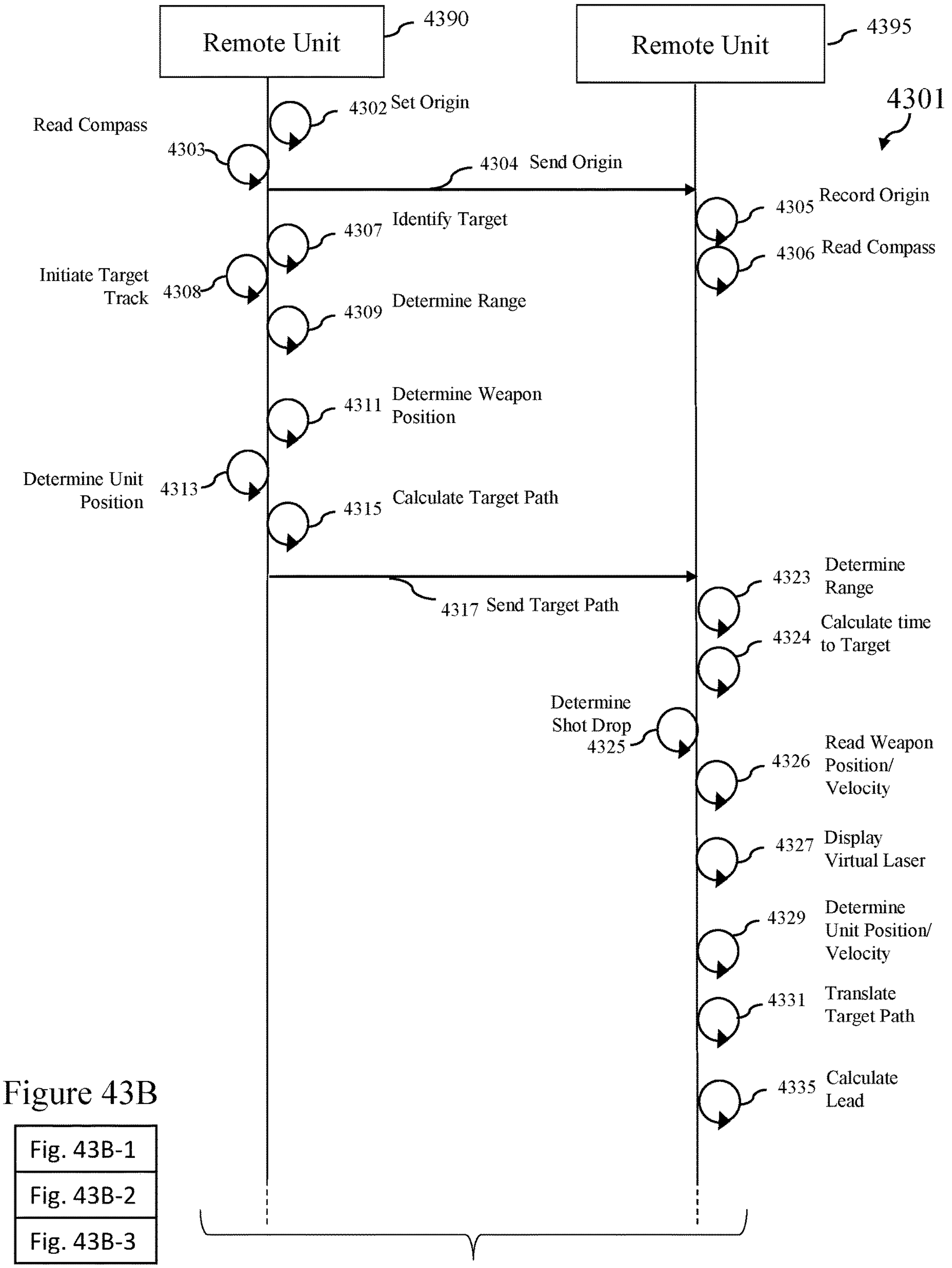
Remote Unit
4390
Remote Unit
4395
4301
4302 Set Origin
Read Compass
4303
4304 Send Origin
4305 Record Origin
4306 Read Compass
4307 Identify Target
Initiate Target Track
4308
4309 Determine Range
4311 Determine Weapon Position
Determine Unit Position
4313
4315 Calculate Target Path
4317 Send Target Path
4323 Determine Range
4324 Calculate time to Target
Determine Shot Drop
4325
4326 Read Weapon Position/ Velocity
4327 Display Virtual Laser
4329 Determine Unit Position/ Velocity
4331 Translate Target Path
4335 Calculate Lead
Figure 43B
Fig. 43B-1
Fig. 43B-2
Fig. 43B-3
To Figure 43B-2

Figure 43B-1

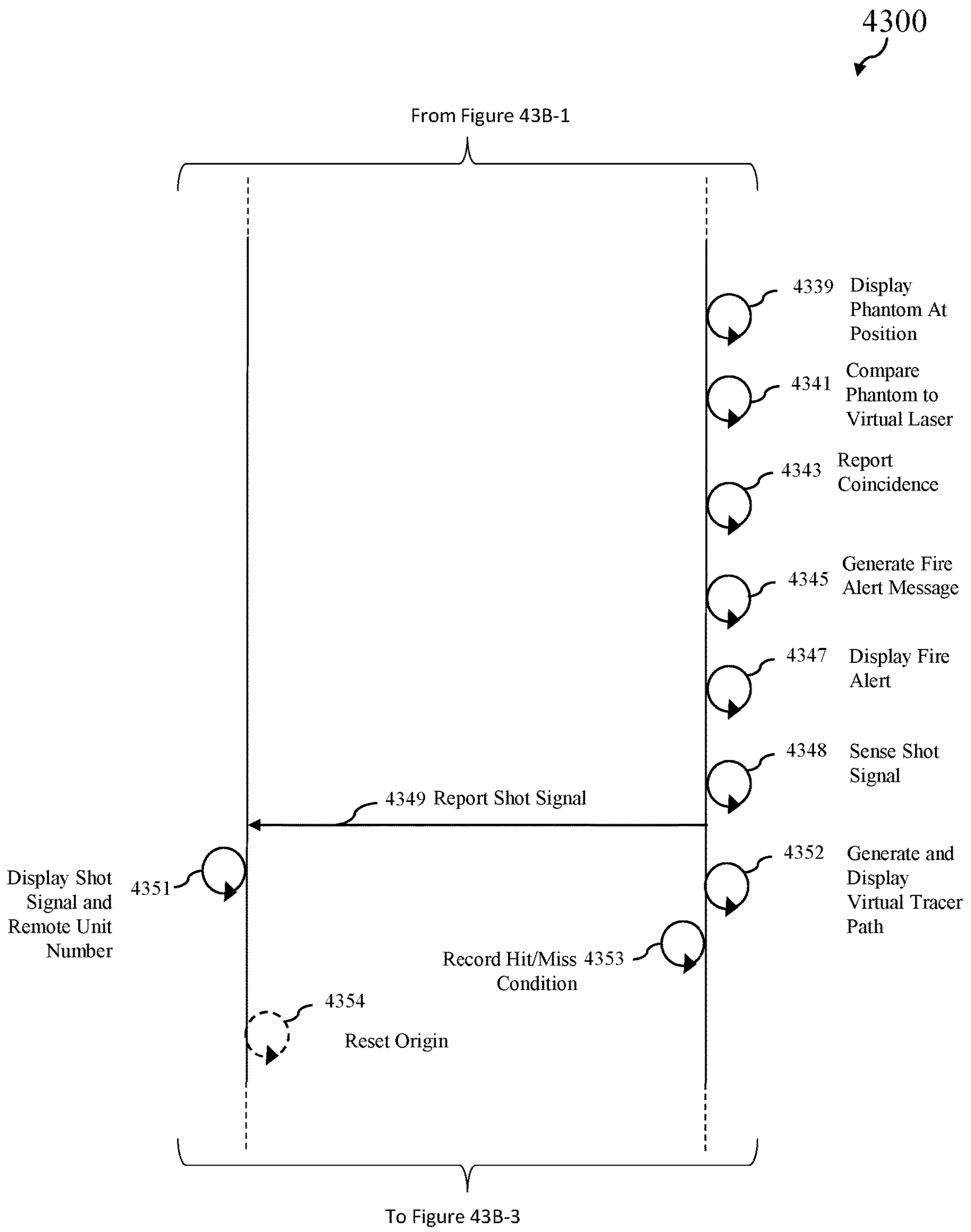
4300
From Figure 43B-1
4339 Display Phantom At Position
4341 Compare Phantom to Virtual Laser
4343 Report Coincidence
4345 Generate Fire Alert Message
4347 Display Fire Alert
4348 Sense Shot Signal
4349 Report Shot Signal
Display Shot Signal and Remote Unit Number 4351
4352 Generate and Display Virtual Tracer Path
Record Hit/Miss 4353 Condition
4354
Reset Origin
To Figure 43B-3

Figure 43B-2

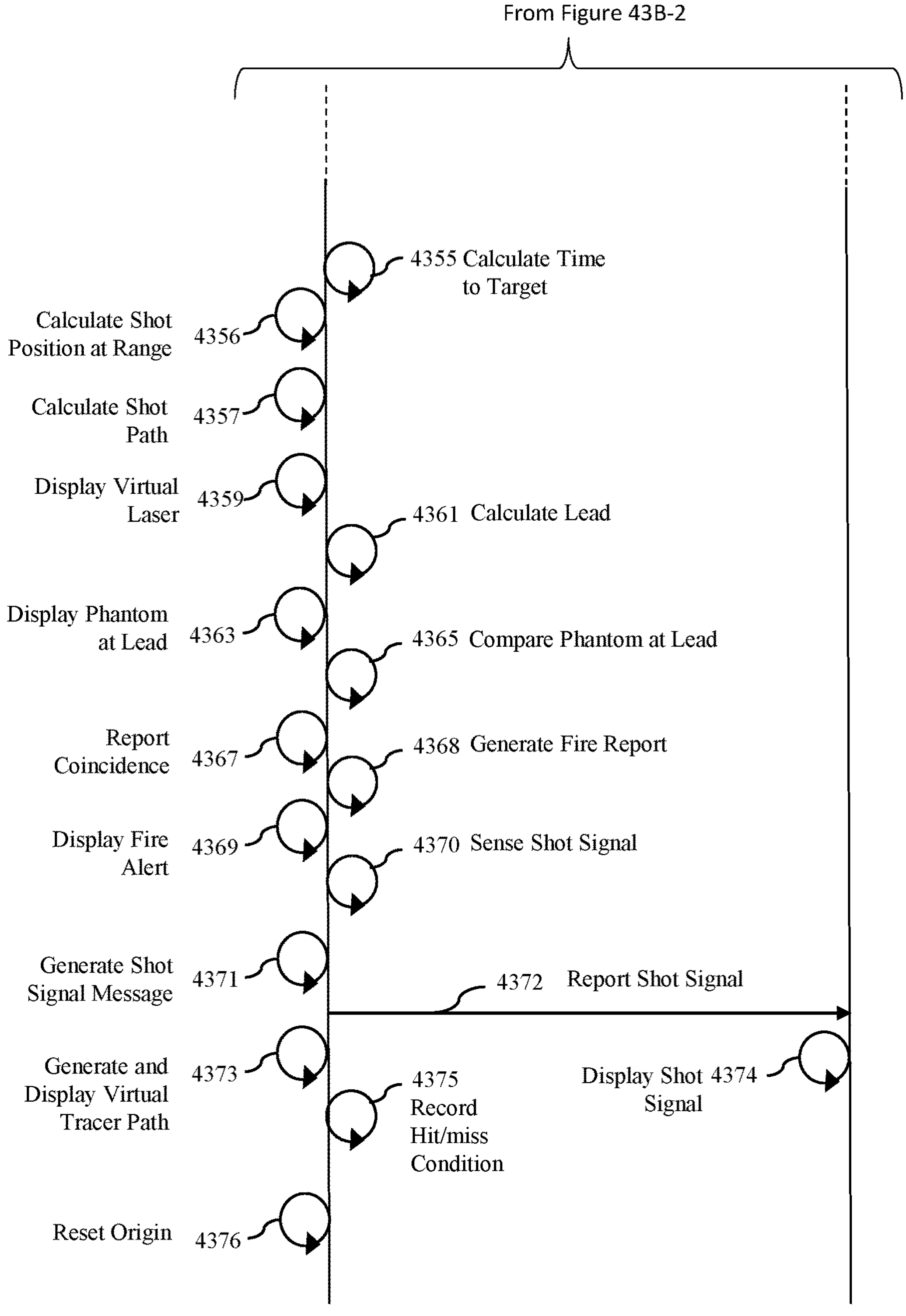
From Figure 43B-2
4355 Calculate Time to Target
Calculate Shot Position at Range 4356
Calculate Shot Path 4357
Display Virtual Laser 4359
4361 Calculate Lead
Display Phantom at Lead 4363
4365 Compare Phantom at Lead
Report Coincidence 4367
4368 Generate Fire Report
Display Fire Alert 4369
4370 Sense Shot Signal
Generate Shot Signal Message 4371
4372 Report Shot Signal
Generate and Display Virtual Tracer Path 4373
4375 Record Hit/miss Condition
Display Shot Signal 4374
Reset Origin 4376

Figure 43B-3

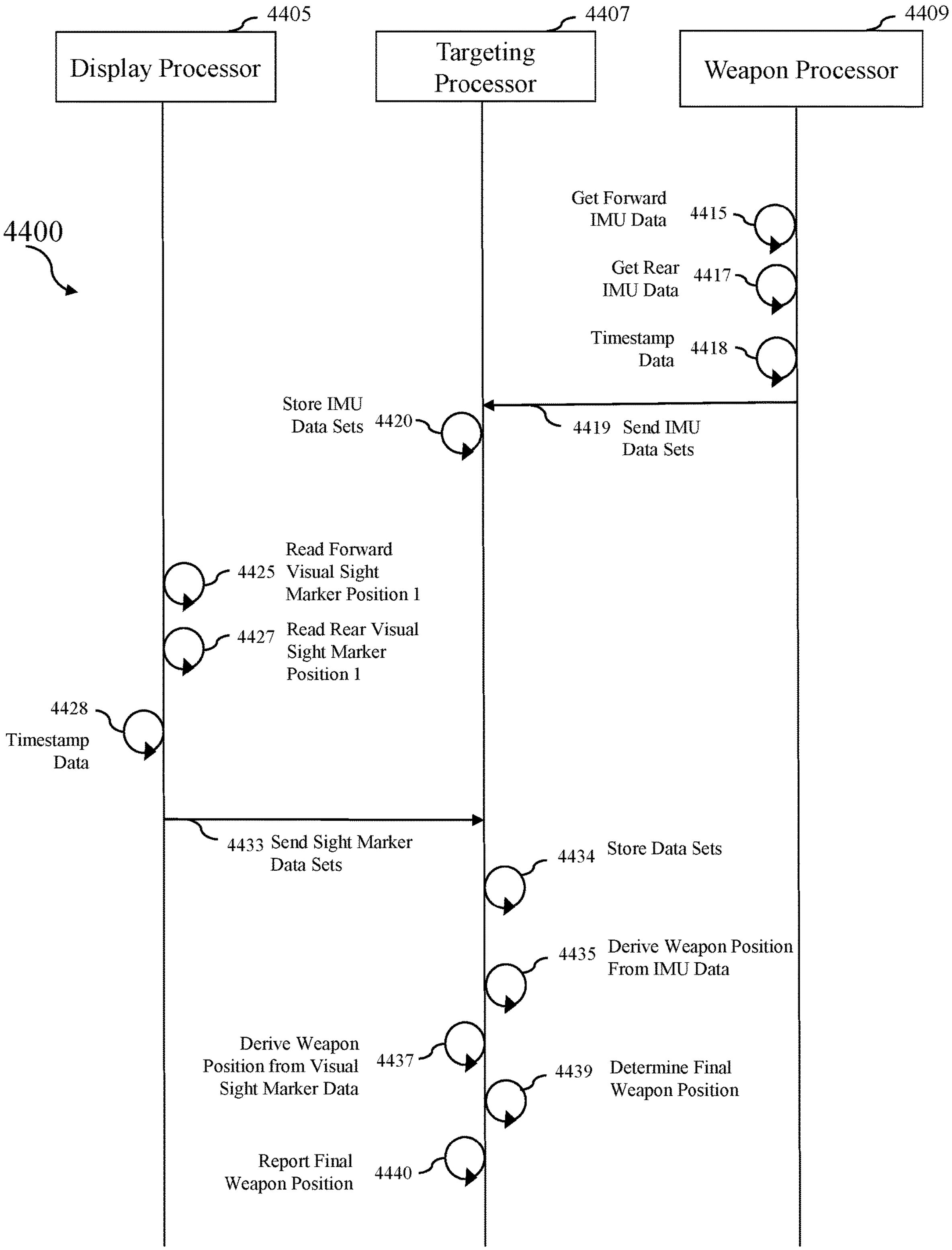
4405
Display Processor
4407
Targeting Processor
4409
Weapon Processor
4400
Get Forward IMU Data
4415
Get Rear IMU Data
4417
Timestamp Data
4418
Store IMU Data Sets
4420
4419
Send IMU Data Sets
Read Forward Visual Sight Marker Position 1
4425
Read Rear Visual Sight Marker Position 1
4427
4428
Timestamp Data
4433
Send Sight Marker Data Sets
4434
Store Data Sets
4435
Derive Weapon Position From IMU Data
Derive Weapon Position from Visual Sight Marker Data
4437
4439
Determine Final Weapon Position
Report Final Weapon Position
4440

Figure 44
Determine Weapon Position

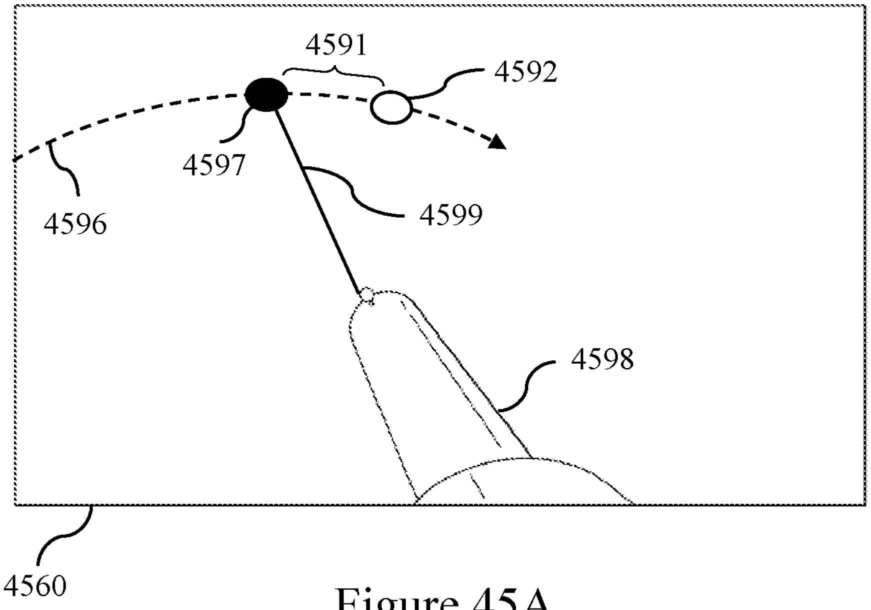

Figure 45A

Phantom Display

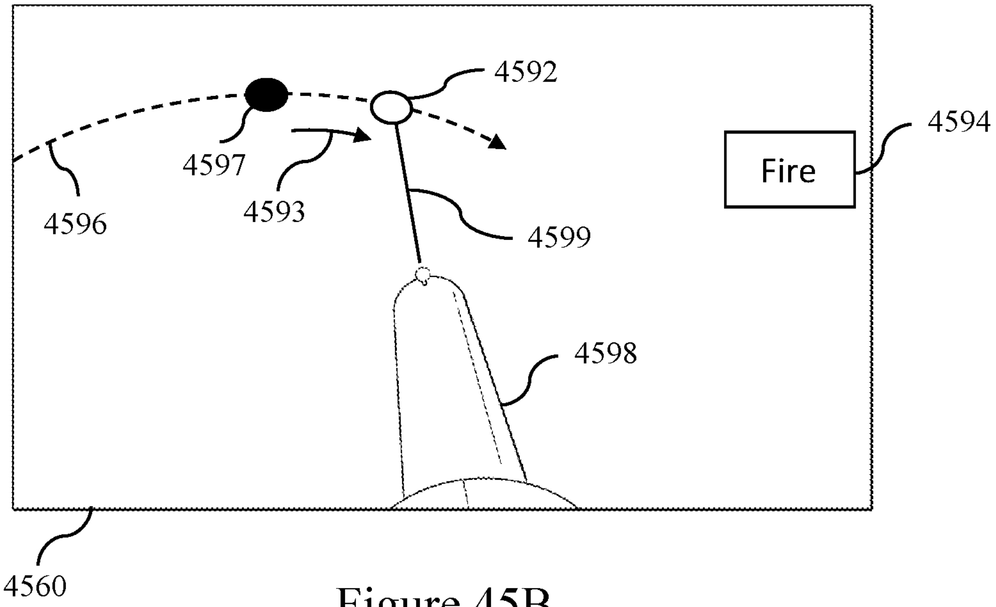

Figure 45B

Virtual Laser and Pull-Away Display

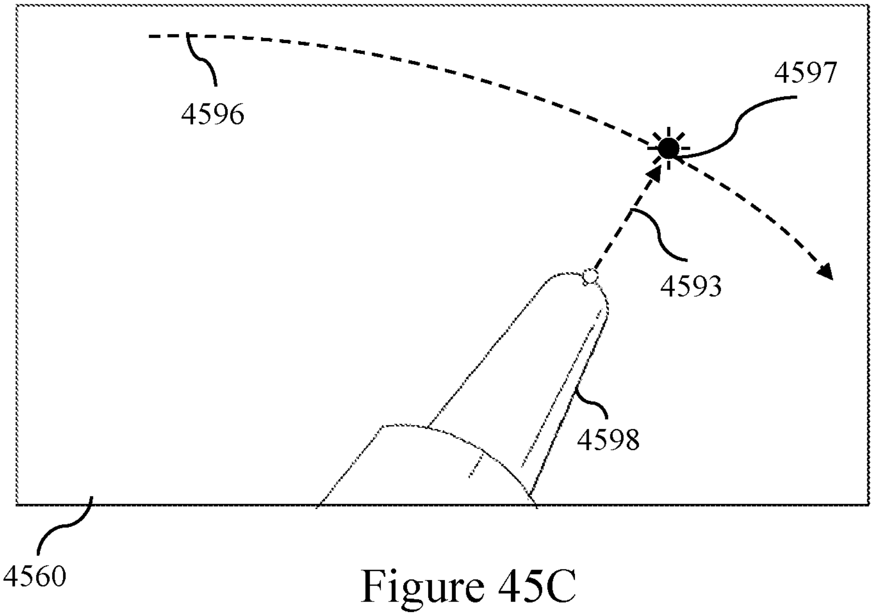

Figure 45C

Virtual Tracer and Ballistic Intercept Display

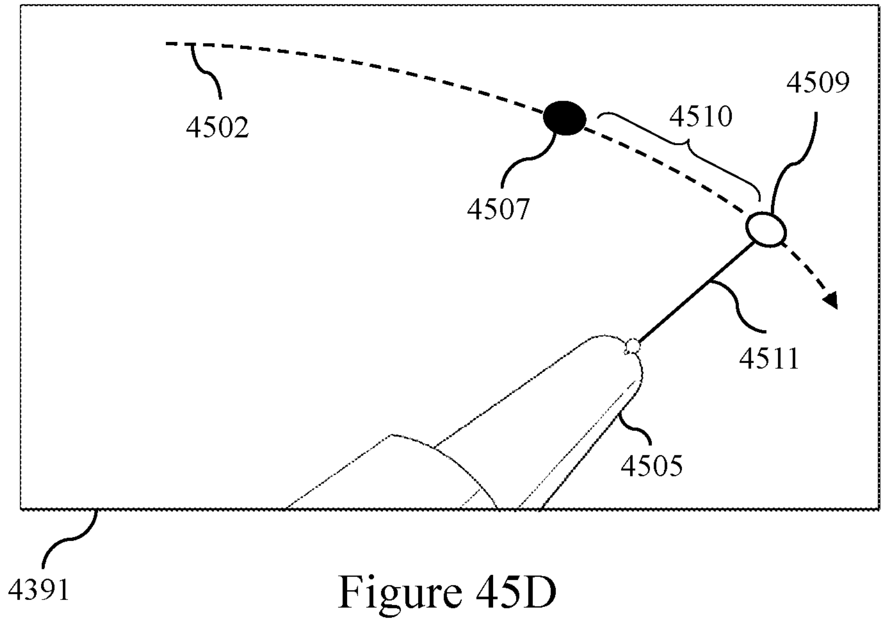

Figure 45D

Remote Unit 1 Virtual Laser Display

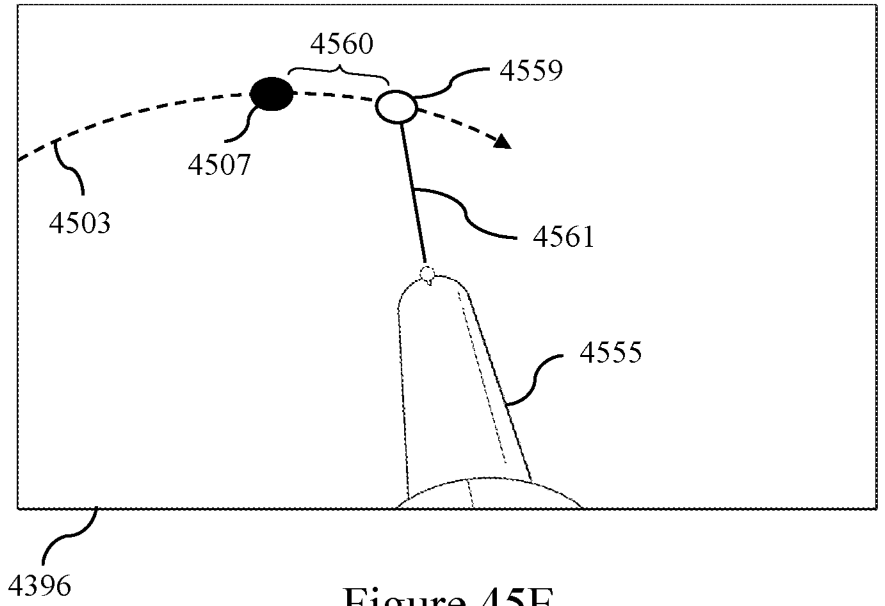

Figure 45E

Remote Unit 2 Virtual Laser Display

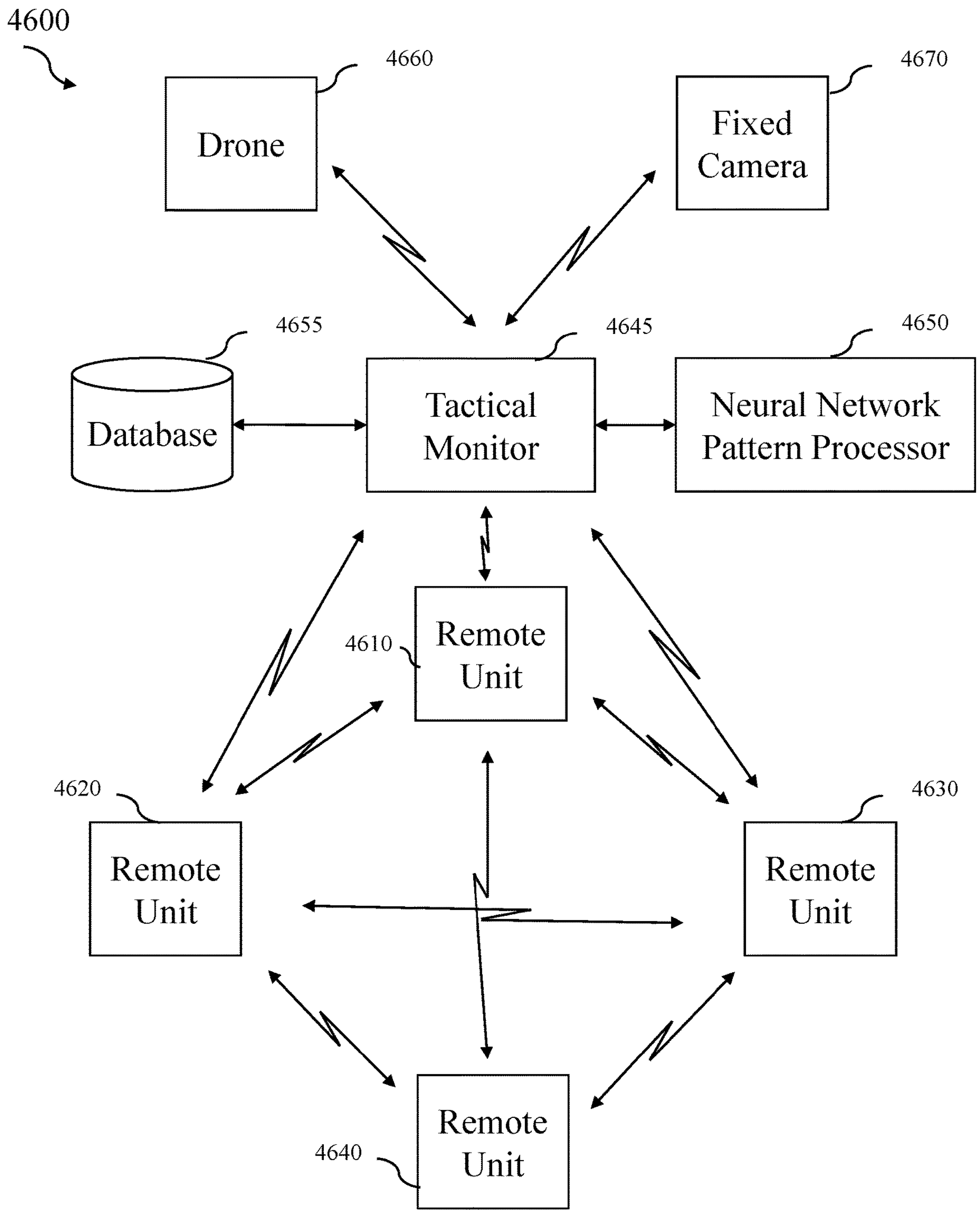
4600
Drone
4660
Fixed Camera
4670
4655
Database
Tactical Monitor
4645
Neural Network Pattern Processor
4650
4610
Remote Unit
4620
Remote Unit
4630
Remote Unit
4640
Remote Unit

Figure 46A

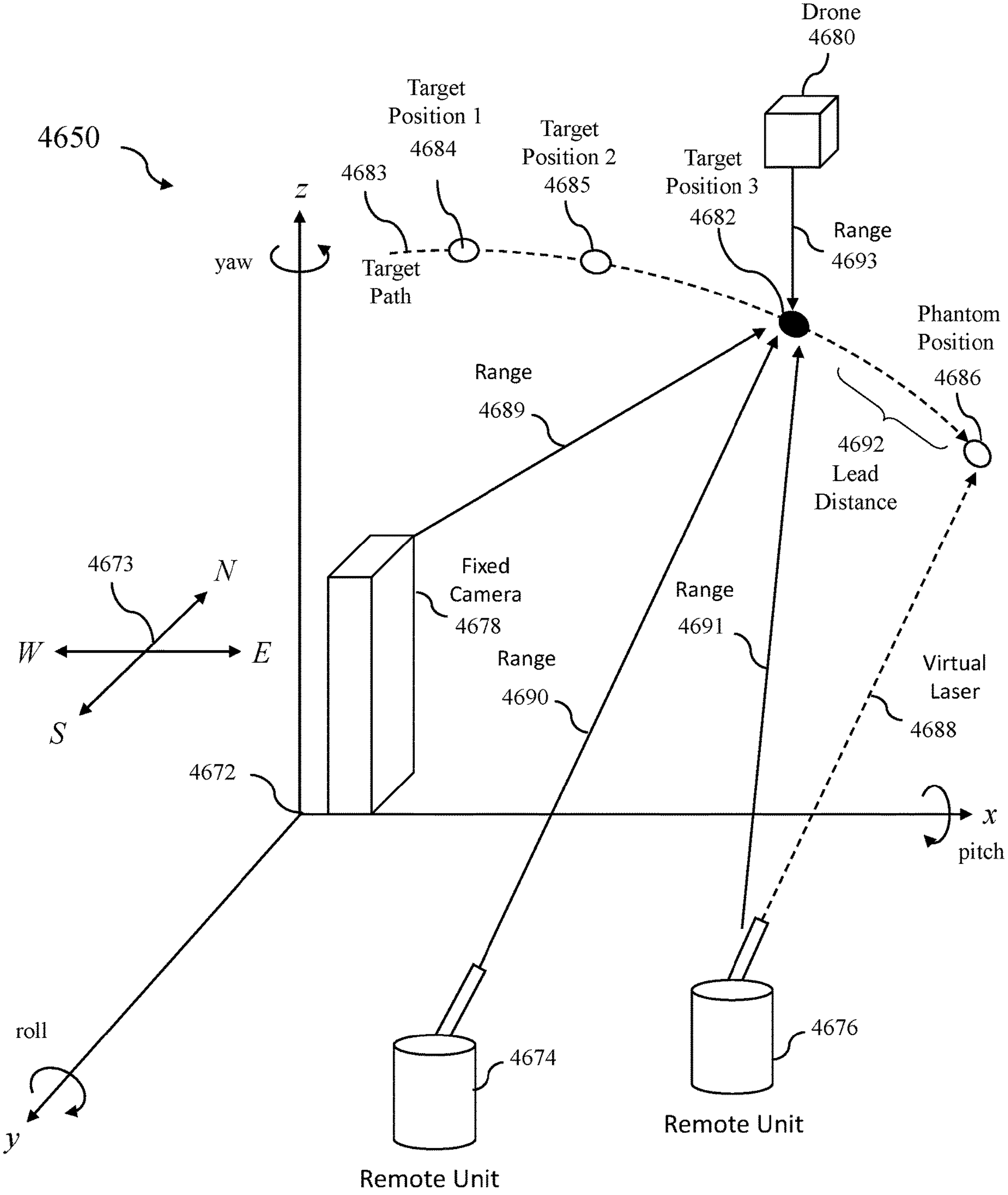
Drone
4680
Target
Position 1
4684
Target
Position 2
4685
Target
Position 3
4682
4650
4683
z
yaw
Target
Path
Range
4693
Phantom
Position
4686
Range
4689
4692
Lead
Distance
4673
N
W
E
S
Fixed
Camera
4678
Range
4691
Range
4690
Virtual
Laser
4688
4672
x
pitch
roll
y
4674
Remote Unit
4676
Remote Unit

Figure 46B

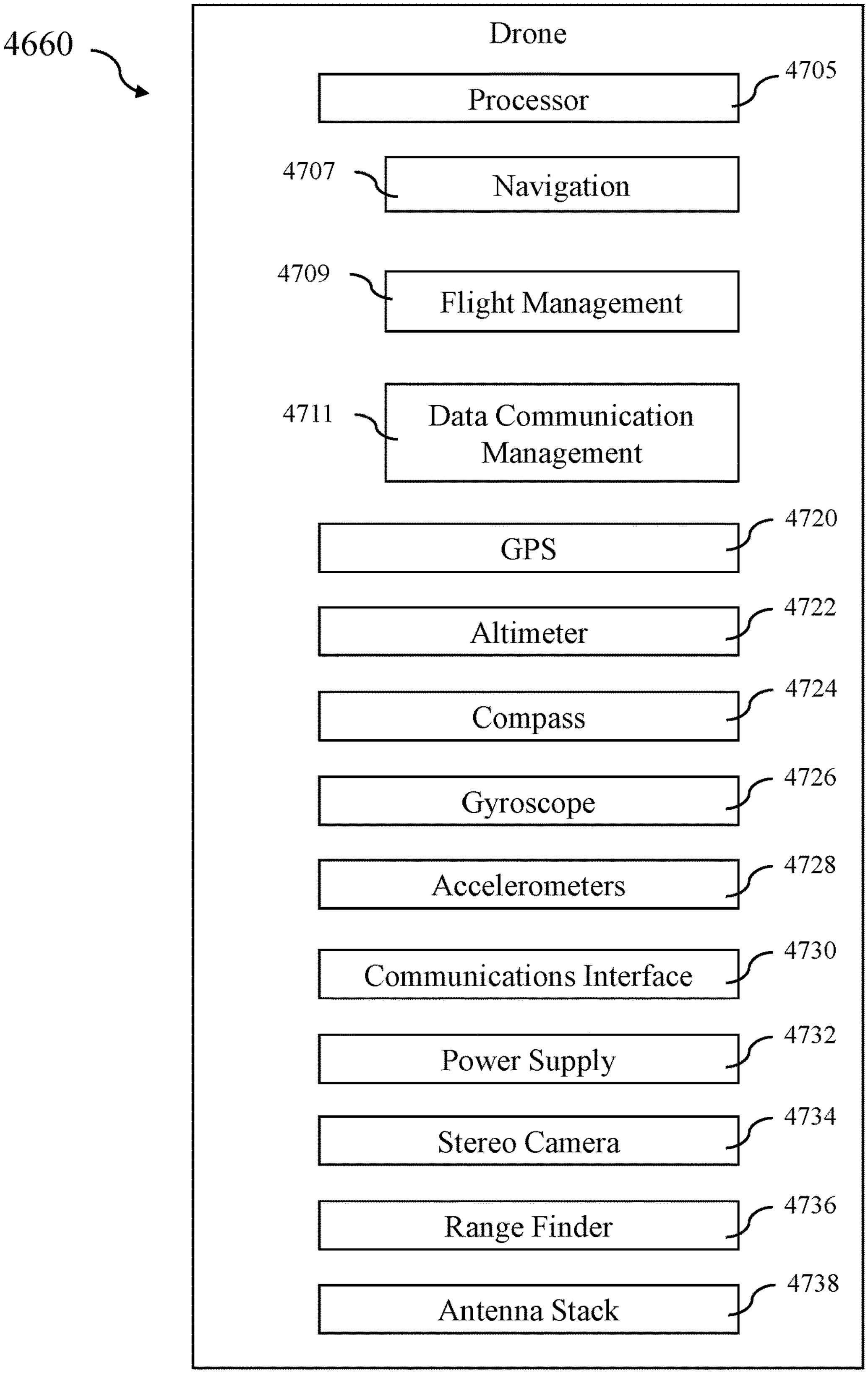
4660
Drone
Processor
4705
4707
Navigation
4709
Flight Management
4711
Data Communication Management
GPS
4720
Altimeter
4722
Compass
4724
Gyroscope
4726
Accelerometers
4728
Communications Interface
4730
Power Supply
4732
Stereo Camera
4734
Range Finder
4736
Antenna Stack
4738

Figure 47

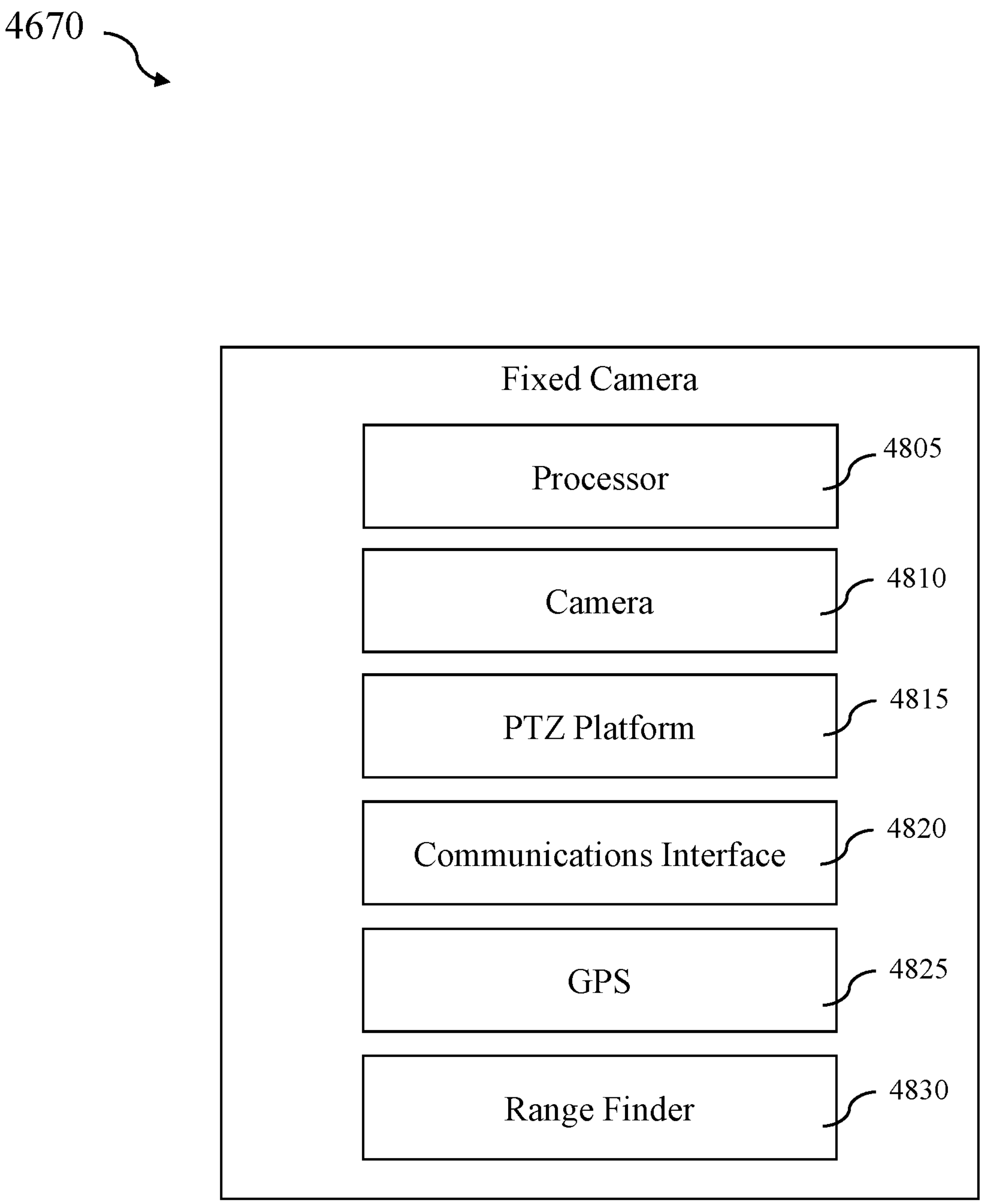
4670
Fixed Camera
Processor
4805
Camera
4810
PTZ Platform
4815
Communications Interface
4820
GPS
4825
Range Finder
4830

Figure 48

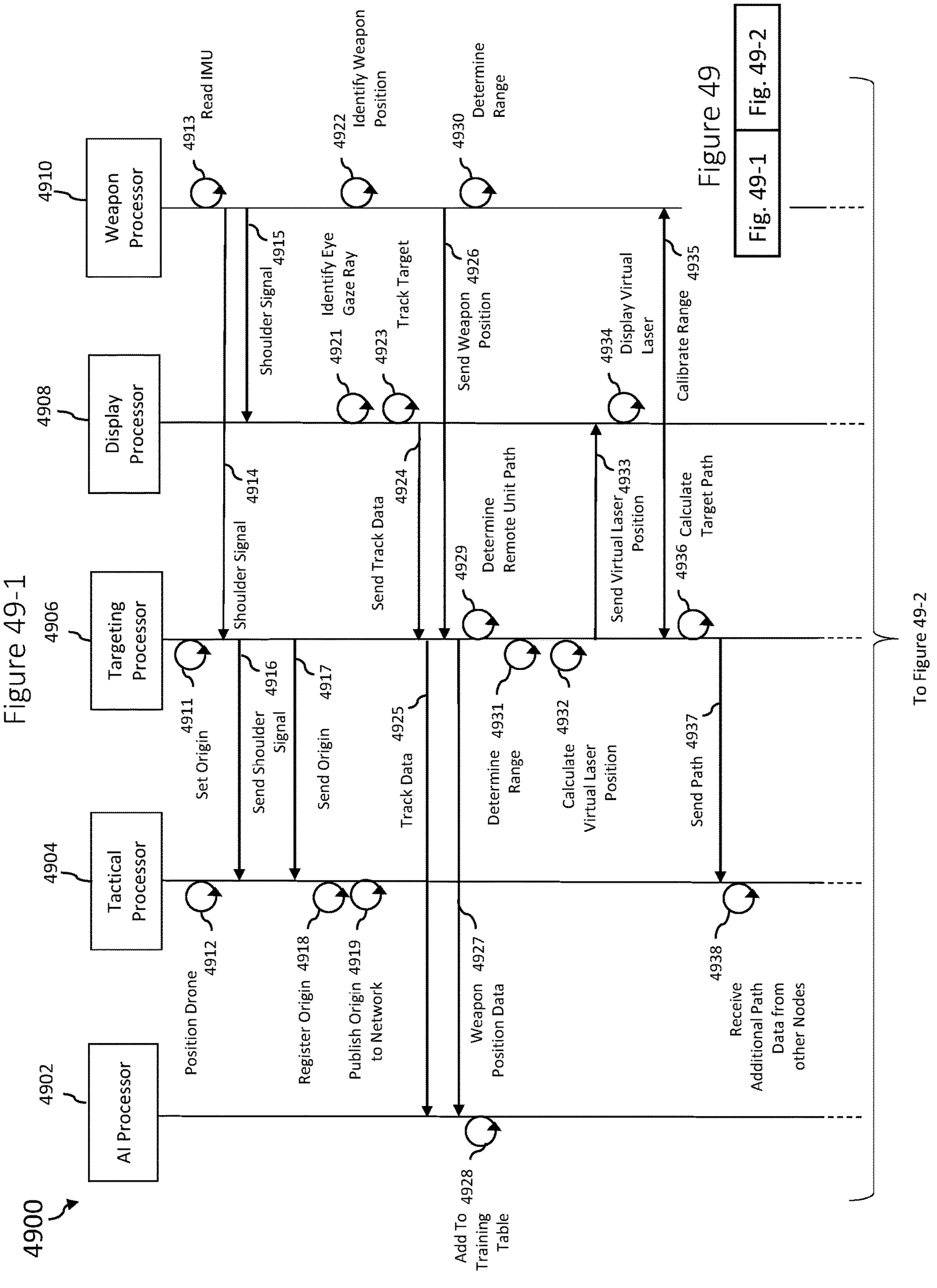
Figure 49-1
4900
4902
AI Processor
4904
Tactical Processor
4906
Targeting Processor
4908
Display Processor
4910
Weapon Processor
4911
Set Origin
4912
Position Drone
4913
Read IMU
4914
Shoulder Signal
4915
Shoulder Signal
4916
Send Shoulder Signal
4917
Send Origin
4918
Register Origin
4919
Publish Origin to Network
4921
Identify Eye Gaze Ray
4922
Identify Weapon Position
4923
Track Target
4924
Send Track Data
4925
Track Data
4926
Send Weapon Position
4927
Weapon Position Data
4928
Add To Training Table
4929
Determine Remote Unit Path
4930
Determine Range
4931
Determine Range
4932
Calculate Virtual Laser Position
4933
Send Virtual Laser Position
4934
Display Virtual Laser
4935
Calibrate Range
4936
Calculate Target Path
4937
Send Path
4938
Receive Additional Path Data from other Nodes
To Figure 49-2
Figure 49
Fig. 49-1
Fig. 49-2

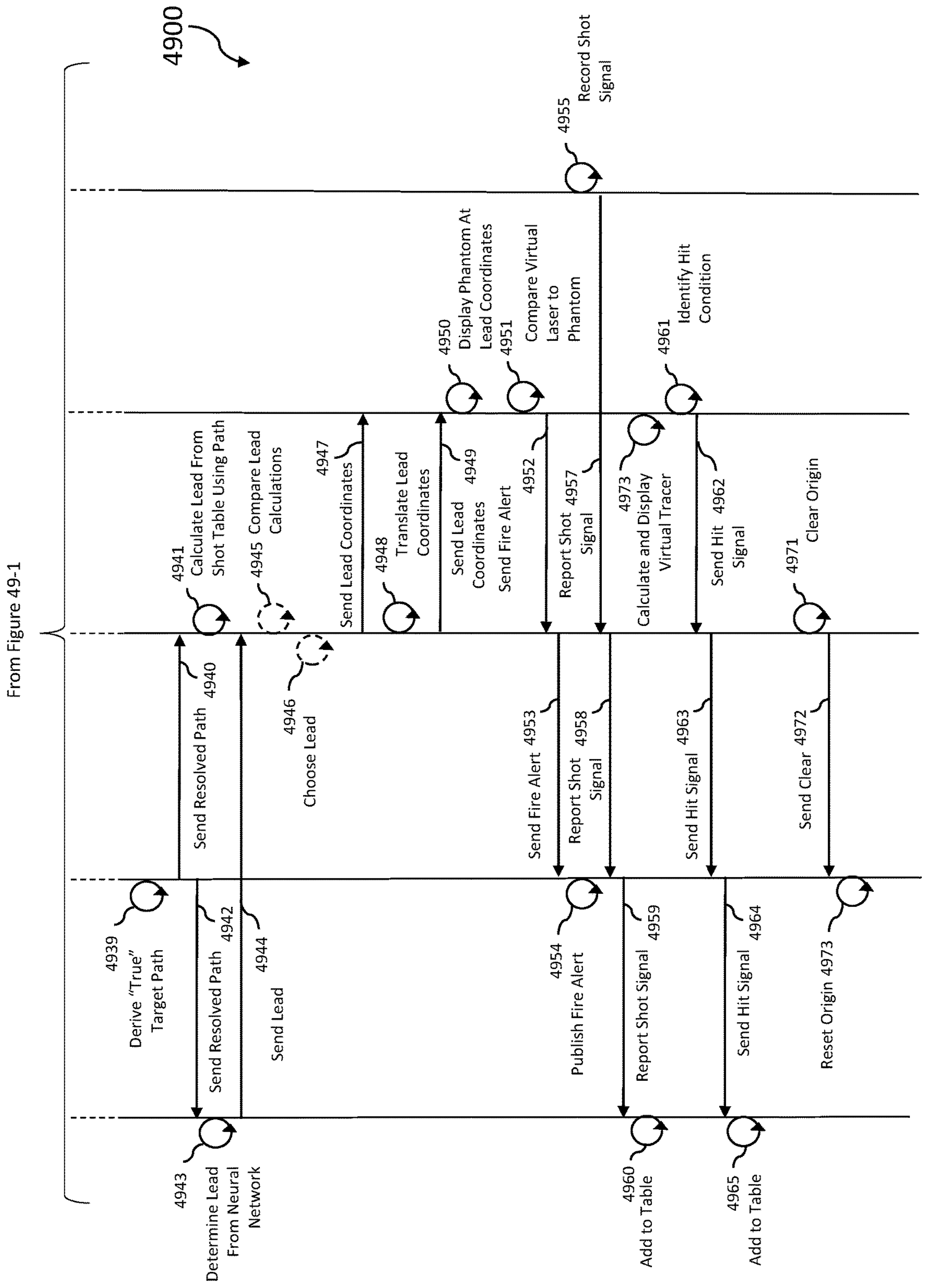
4900
From Figure 49-1
4955 Record Shot Signal
4950 Display Phantom At Lead Coordinates
4951 Compare Virtual Laser to Phantom
4961 Identify Hit Condition
4941 Calculate Lead From Shot Table Using Path
4945 Compare Lead Calculations
4947 Send Lead Coordinates
4948 Translate Lead Coordinates
4949 Send Lead Coordinates
Send Fire Alert 4952
Report Shot Signal 4957
4973 Calculate and Display Virtual Tracer
Send Hit Signal 4962
4971 Clear Origin
Send Resolved Path 4940
4946 Choose Lead
Send Fire Alert 4953
Report Shot Signal 4958
Send Hit Signal 4963
Send Clear 4972
4939 Derive "True" Target Path
Send Resolved Path 4942
4944 Send Lead
4954 Publish Fire Alert
Report Shot Signal 4959
Send Hit Signal 4964
Reset Origin 4973
4943 Determine Lead From Neural Network
4960 Add to Table
4965 Add to Table

Figure 49-2

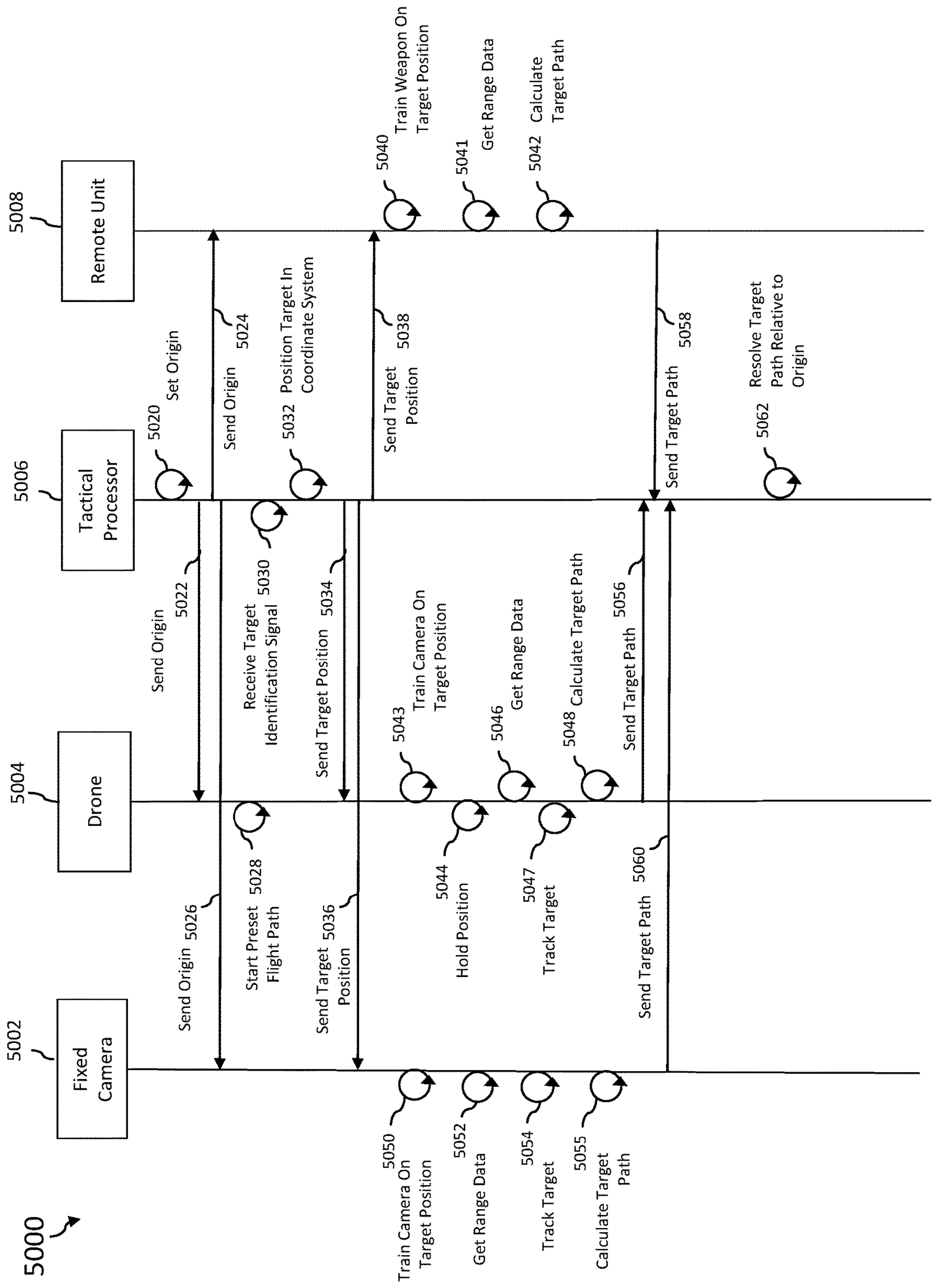
5000
5002
Fixed Camera
5004
Drone
5006
Tactical Processor
5008
Remote Unit
5020
Set Origin
5022
Send Origin
5024
Send Origin
5026
Send Origin
5028
Start Preset Flight Path
5030
Receive Target Identification Signal
5032
Position Target In Coordinate System
5034
Send Target Position
5036
Send Target Position
5038
Send Target Position
5040
Train Weapon On Target Position
5041
Get Range Data
5042
Calculate Target Path
5043
Train Camera On Target Position
5044
Hold Position
5046
Get Range Data
5047
Track Target
5048
Calculate Target Path
5050
Train Camera On Target Position
5052
Get Range Data
5054
Track Target
5055
Calculate Target Path
5056
Send Target Path
5058
Send Target Path
5060
Send Target Path
5062
Resolve Target Path Relative to Origin

Figure 50

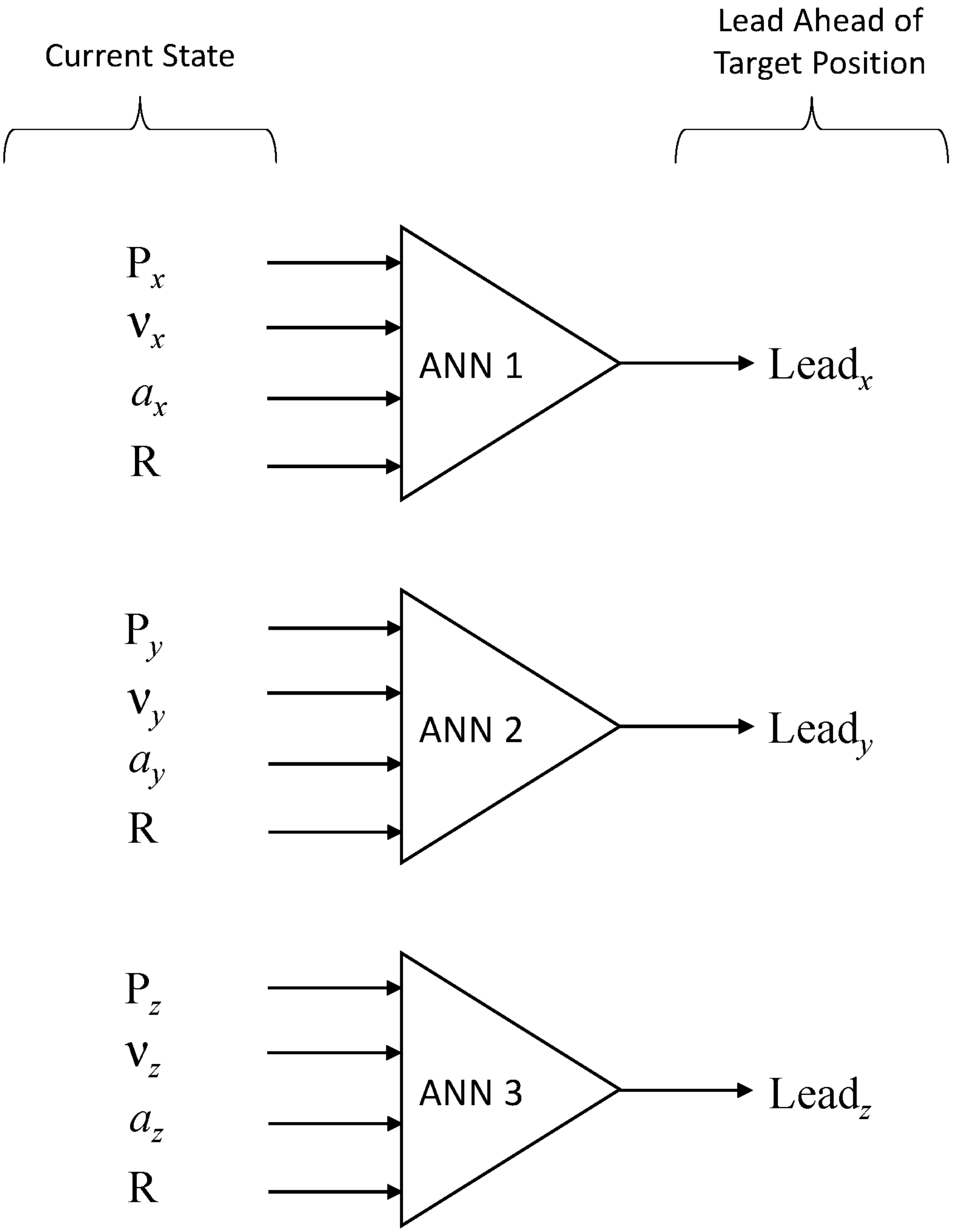
Current State
Lead Ahead of Target Position
$P_x$
$v_x$
$a_x$
R
ANN 1
$\text{Lead}_x$
$P_y$
$v_y$
$a_y$
R
ANN 2
$\text{Lead}_y$
$P_z$
$v_z$
$a_z$
R
ANN 3
$\text{Lead}_z$

Figure 51

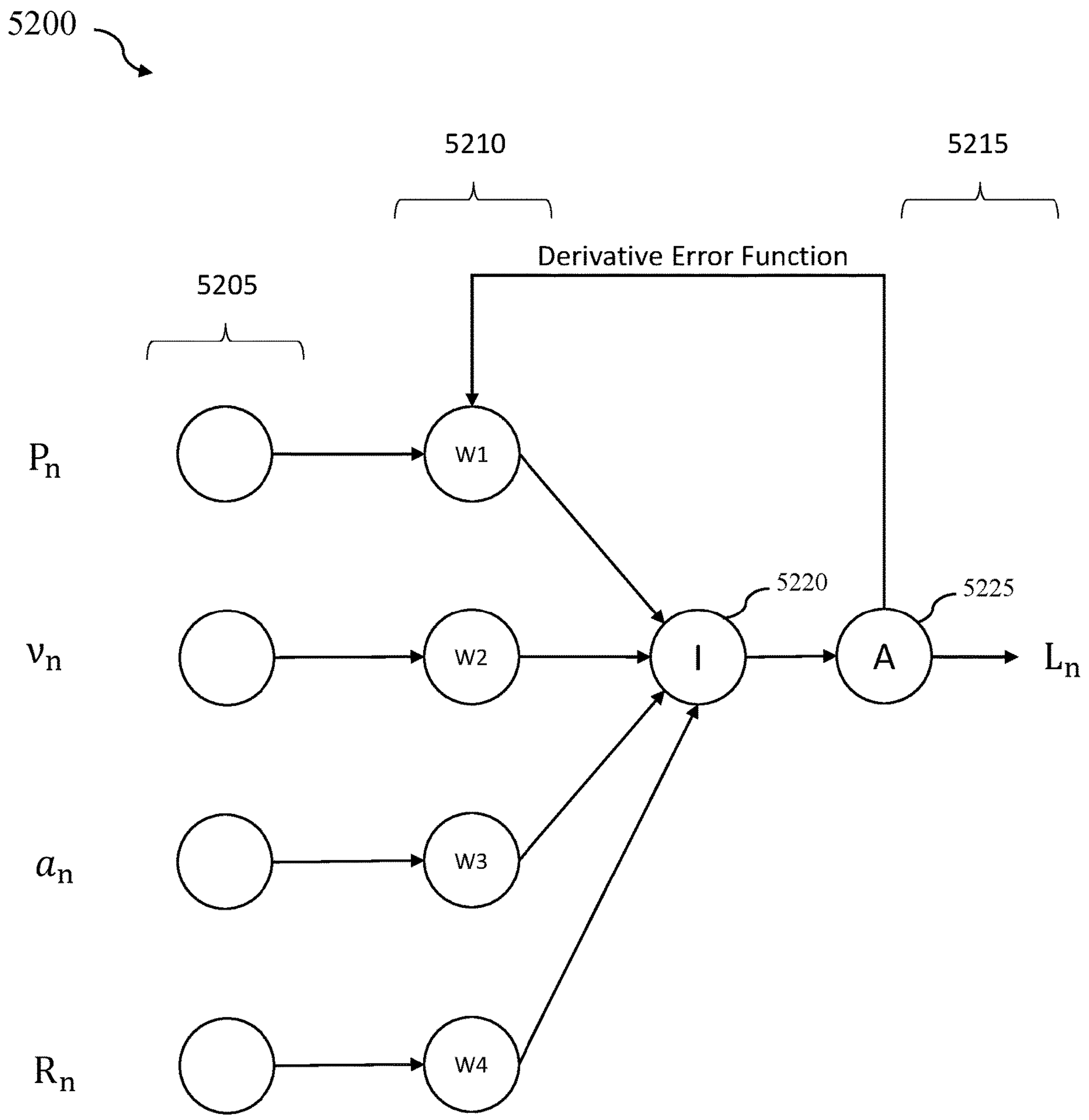
5200
5210
5215
Derivative Error Function
5205
$P_n$
$v_n$
$a_n$
$R_n$
W1
W2
W3
W4
I
5220
A
5225
$L_n$

Figure 52

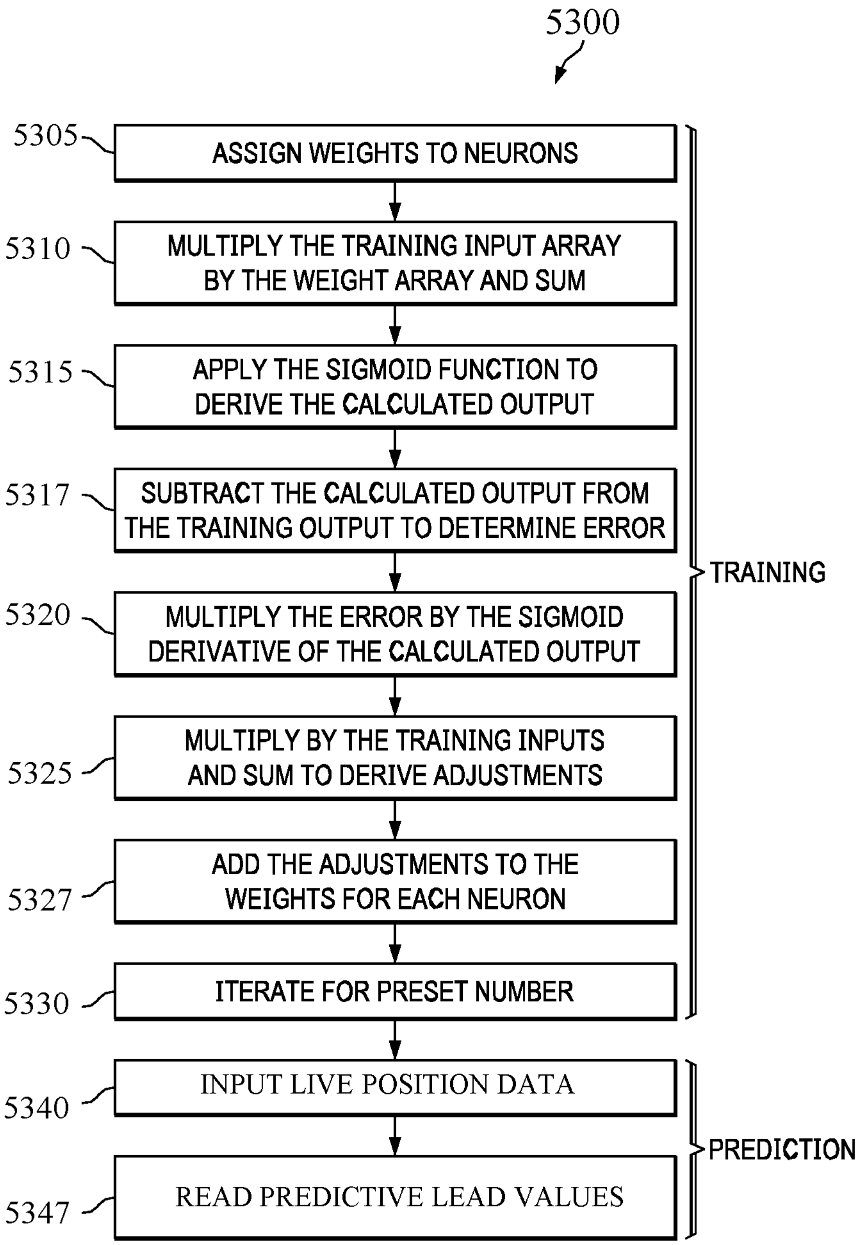
5300
5305
ASSIGN WEIGHTS TO NEURONS
5310
MULTIPLY THE TRAINING INPUT ARRAY BY THE WEIGHT ARRAY AND SUM
5315
APPLY THE SIGMOID FUNCTION TO DERIVE THE CALCULATED OUTPUT
5317
SUBTRACT THE CALCULATED OUTPUT FROM THE TRAINING OUTPUT TO DETERMINE ERROR
5320
MULTIPLY THE ERROR BY THE SIGMOID DERIVATIVE OF THE CALCULATED OUTPUT
5325
MULTIPLY BY THE TRAINING INPUTS AND SUM TO DERIVE ADJUSTMENTS
5327
ADD THE ADJUSTMENTS TO THE WEIGHTS FOR EACH NEURON
5330
ITERATE FOR PRESET NUMBER
TRAINING
5340
INPUT LIVE POSITION DATA
5347
READ PREDICTIVE LEAD VALUES
PREDICTION

FIG. 53

```
class InterlockNeural():

   def __init__(self):
    # setting node weights – starting weight is any value between -1 and 1
    node.synaptic_weights = numpy.array([[.3,.4,0,-.3]])

  def sigmoid(self, x):
    # sigmoid function
    return 1 / (1 + numpy.exp(-x))

  def sigmoid_derivative(self, x):
    # derivative of sigmoid function
    return x * (1 - x)


  def train(self, training_inputs, training_outputs, training_iterations):

    #training the model
    for iteration in range(training_iterations):
      output = self.train(training_inputs)
      error = training_outputs - output
      adjustments = numpy.dot(training_inputs.T, error * self.sigmoid_derivative(output))
         node.synaptic_weights += adjustments

  def train(self, inputs):

    #passing inputs through the node
    inputs = inputs.astype(float)
    output = self.sigmoid(np.dot(inputs, self.synaptic_weights))
    return output

  if __name__ == "__main__":

  #initializing
  neural_network = InterlockNeural()

  #training data consisting of 4 examples--4 input values and 1 output
  #in practice this array will hold a running accumulation of scaled path and lead data in a table
of increasing size.
  training_inputs = numpy.array([[.25,.45,.75,.8],
                                  [.75,.35,.25,.9],
                                  [.4,.3,.60,.82],
                                  [.72,.41,.42,.76]])

  training_outputs = numpy.array([[.37,.42,.76,.99,1]]).T

  #training neural network
  neural_network.train(training_inputs, training_outputs, 100000)
```

Fig. 54

# SYSTEM AND METHOD FOR MARKSMANSHIP TRAINING

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation in part of U.S. application Ser. No. 16/397,983, filed on Apr. 29, 2019, now U.S. Pat. No. 10,584,940 granted on Mar. 10, 2020, which is a continuation in part of U.S. patent application Ser. No. 15/589,603 filed on May 8, 2017, now U.S. Pat. No. 10,274,287 granted on Apr. 30, 2019, which is a continuation in part of U.S. patent application Ser. No. 14/969,302 filed Dec. 15, 2015, now U.S. Pat. No. 10,234,240 granted on Mar. 19, 2019, which is a continuation in part of U.S. patent application Ser. No. 14/686,398 filed Apr. 14, 2015, now U.S. Pat. No. 10,030,937 granted on Jul. 24, 2018, which is a continuation in part of U.S. patent application Ser. No. 14/149,418 filed Jan. 7, 2014, now U.S. Pat. No. 9,261,332 granted on Feb. 16, 2016, which is a continuation in part of U.S. patent application Ser. No. 13/890,997 filed May 9, 2013, now U.S. Pat. No. 9,267,762 granted on Feb. 23, 2016. Each of the patent applications identified above is incorporated herein by reference in its entirety to provide continuity of disclosure.

## FIELD OF THE INVENTION

The present invention relates to devices for teaching marksmen how to properly lead a moving target with a weapon. More particularly, the invention relates to optical projection systems to monitor and simulate trap, skeet, and sporting clay shooting.

## BACKGROUND OF THE INVENTION

Marksmen typically train and hone their shooting skills by engaging in skeet, trap or sporting clay shooting at a shooting range. The objective for a marksman is to successfully hit a moving target by tracking at various distances and angles and anticipating the delay time between the shot and the impact. In order to hit the moving target, the marksman must aim the weapon ahead of and above the moving target by a distance sufficient to allow a projectile fired from the weapon sufficient time to reach the moving target. The process of aiming the weapon ahead of the moving target is known in the art as "leading the target." "Lead" is defined as the distance between the moving target and the aiming point. The correct lead distance is critical to successfully hit the moving target. Further, the correct lead distance is increasingly important as the distance of the marksman to the moving target increases, the speed of the moving target increases, and the direction of movement becomes more oblique.

Trap shooting range **200** comprises firing lanes **201** and trap house **202**. Stations **203**, **204**, **205**, **206**, and **207** are positioned along radius **214** from center **218** of trap house **202**. Radius **214** is distance **216** from center **218**. Distance **216** is 48 feet. Each of stations **203**, **204**, **205**, **206**, and **207** is positioned at radius **214** at equal arc lengths. Arc length **213** is 9 feet. Stations **208**, **209**, **210**, **211**, and **212** are positioned along radius **215** from center **218**. Radius **215** is distance **217** from center **218**. Distance **217** is 81 feet. Each of stations **208**, **209**, **210**, **211**, and **212** is positioned at radius **215** at equal arc lengths. Arc length **227** is 12 feet. Field **226** has length **221** from center **218** along center line **220** of trap house **202** to point **219**. Length **221** is 150 feet. Boundary line **222** extends 150 feet from center **218** at angle **224** from center line **220**. Boundary line **223** extends 150 feet from center **218** at angle **225** from center line **220**. Angles **224** and **225** are each 22° from center line **220**. Trap house **202** launches clay targets at various trajectories within field **226**. Marksman **228** positioned at any of stations **203**, **204**, **205**, **206**, **207**, **208**, **209**, **210**, **211**, and **212** attempts to shoot and break the launched clay targets.

FIGS. **3**A, **3**B, **3**C, and **3**D depict examples of target paths and associated projectile paths illustrating the wide range of lead distances and distances required of the marksman. The term "projectile," as used in this application, means any projectile fired from a weapon but more typically a shotgun round comprised of pellets of various sizes. For example, FIG. **3**A shows a left to right trajectory **303** of target **301** and left to right intercept trajectory **304** for projectile **302**. In this example, the intercept path is oblique, requiring the lead to be a greater distance along the positive X axis. FIG. **3**B shows a left to right trajectory **307** of target **305** and intercept trajectory **308** for projectile **306**. In this example, the intercept path is acute, requiring the lead to be a lesser distance in the positive X direction. FIG. **3**C shows a right to left trajectory **311** of target **309** and intercepting trajectory **312** for projectile **310**. In this example, the intercept path is oblique and requires a greater lead in the negative X direction. FIG. **3**D shows a proximal to distal and right to left trajectory **315** of target **313** and intercept trajectory **316** for projectile **314**. In this example, the intercept path is acute and requires a lesser lead in the negative X direction.

FIGS. **4**A and **4**B depict a range of paths of a clay target and an associated intercept projectile. The most typical projectile used in skeet and trap shooting is a shotgun round, such as a 12-gauge round or a 20 gauge round. When fired, the pellets of the round spread out into a "shot string" having a generally circular cross-section. The cross-section increases as the flight time of the pellets increases. Referring to FIG. **4**A, clay target **401** moves along path **402**. Shot string **403** intercepts clay target **401**. Path **402** is an ideal path, in that no variables are considered that may alter path **402** of clay target **401** once clay target **401** is launched.

Referring to FIG. **4**B, path range **404** depicts a range of potential flight paths for a clay target after being released on a shooting range. The flight path of the clay target is affected by several variables. Variables include mass, wind, drag, lift force, altitude, humidity, and temperature, resulting in a range of probable flight paths, path range **404**. Path range **404** has upper limit **405** and lower limit **406**. Path range **404** from launch angle θ is extrapolated using:

$$x=x_o+v_{xo}t+½a_xt^2+C_x \qquad \text{Eq. 1}$$

$$y=y_o+v_{yo}t+½a_yt^2+C_y \qquad \text{Eq. 2}$$

where x is the clay position along the x-axis, $x_o$ is the initial position of the clay target along the x-axis, $v_{xo}$ is the initial velocity along the x-axis, $a_x$ is the acceleration along the x-axis, t is time, and $C_x$ is the drag and lift variable along the x-axis, y is the clay position along the y-axis, $y_o$ is the initial position of the clay target along the y-axis, $v_{yo}$ is the initial velocity along the y-axis, $a_y$ is the acceleration along the y-axis, t is time, and $C_y$ is the drag and lift variable along the x-axis. Upper limit **405** is a maximum distance along the x-axis with $C_x$ at a maximum and a maximum along the y-axis with $C_y$ at a maximum. Lower limit **406** is a minimum distance along the x-axis with $C_x$ at a minimum and a minimum along the y-axis with $C_y$ at a minimum. Drag and lift are given by:

$$F_{drag}=½\rho v^2C_DA \qquad \text{Eq. 3}$$

where $F_{drag}$ is the drag force, $\rho$ is the density of the air, $v$ is $v_o$, A is the cross-sectional area, and $C_D$ is the drag coefficient;

$$F_{lift}=½\rho v^2 C_L A \qquad \text{Eq. 4}$$

where $F_{lift}$ is the lift force, $\rho$ is the density of the air, $v$ is $v_o$, A is the planform area, and $C_L$ is the lift coefficient.

Referring to FIG. **5**, an example of lead from the perspective of the marksman is described. Marksman **501** aims weapon **502** at clay target **503** moving along path **504** left to right. In order to hit clay target **503**, marksman **501** must anticipate the time delay for a projectile fired from weapon **502** to intercept clay target **503** by aiming weapon **502** ahead of clay target **503** at aim point **505**. Aim point **505** is lead distance **506** ahead of clay target **503** along path **504**. Marksman **501** must anticipate and adjust aim point **505** according to a best guess at the anticipated path of the target.

Clay target **503** has initial trajectory angles $\gamma$ and $\beta$, positional coordinates $y_1$ and a velocity $v_1$. Aim point **505** has coordinates $x_2$, $y_2$. Lead distance **506** has x-component **507** and y-component **508**. X-component **507** and y-component **508** are calculated by:

$$\Delta x=x_2-x_1 \qquad \text{Eq. 5}$$

$$\Delta y=y_2-y_1 \qquad \text{Eq. 6}$$

where $\Delta$x is x component **507** and $\Delta$y is y component **508**. As $\gamma$ increases, $\Delta$y must increase. As $\gamma$ increases, $\Delta$x must increase. As $\beta$ increases, $\Delta$y must increase.

The prior art has attempted to address the problems of teaching proper lead distance with limited success. For example, U.S. Pat. No. 3,748,751 to Breglia, et al. discloses a laser, automatic fire weapon simulator. The simulator includes a display screen, a projector for projecting a motion picture on the display screen. A housing attaches to the barrel of the weapon. A camera with a narrow band-pass filter positioned to view the display screen detects and records the laser light and the target shown on the display screen. However, the simulator requires the marksman to aim at an invisible object, thereby making the learning process of leading a target difficult and time-consuming.

U.S. Pat. No. 3,940,204 to Yokoi discloses a clay shooting simulation system. The system includes a screen, a first projector providing a visible mark on the screen, a second projector providing an infrared mark on the screen, a mirror adapted to reflect the visible mark and the infrared mark to the screen, and a mechanical apparatus for moving the mirror in three dimensions to move the two marks on the screen such that the infrared mark leads the visible mark to simulate a lead-sighting point in actual clay shooting. A light receiver receives the reflected infrared light. However, the system in Yokoi requires a complex mechanical device to project and move the target on the screen, which leads to frequent failure and increased maintenance.

U.S. Pat. No. 3,945,133 to Mohon, et al. discloses a weapons training simulator utilizing polarized light. The simulator includes a screen and a projector projecting a two-layer film. The two-layer film is formed of a normal film and a polarized film. The normal film shows a background scene with a target with non-polarized light. The polarized film shows a leading target with polarized light. The polarized film is layered on top of the normal non-polarized film. A polarized light sensor is mounted on the barrel of a gun. However, the weapons training simulator requires two cameras and two types of film to produce the two-layered film making the simulator expensive and time-consuming to build and operate.

U.S. Pat. No. 5,194,006 to Zaenglein, Jr. discloses a shooting simulator. The simulator includes a screen, a projector for displaying a moving target image on the screen, and a weapon connected to the projector. When a marksman pulls the trigger a beam of infrared light is emitted from the weapon. A delay is introduced between the time the trigger is pulled and the beam is emitted. An infrared light sensor detects the beam of infrared light. However, the training device in Zaenglein, Jr. requires the marksman to aim at an invisible object, thereby making the learning process of leading a target difficult and time-consuming.

U.S. Patent Publication No. 2010/0201620 to Sargent discloses a firearm training system for moving targets. The system includes a firearm, two cameras mounted on the firearm, a processor, and a display. The two cameras capture a set of stereo images of the moving target along the moving target's path when the trigger is pulled. However, the system requires the marksman to aim at an invisible object, thereby making the learning process of leading a target difficult and time-consuming. Further, the system requires two cameras mounted on the firearm making the firearm heavy and difficult to manipulate leading to inaccurate aiming and firing by the marksman when firing live ammunition without the mounted cameras.

The prior art fails to disclose or suggest a system and method for simulating a lead for a moving target using generated images of targets projected at the same scale as viewed in the field and a phantom target positioned ahead of the targets having a variable contrast. The prior art further fails to disclose or suggest a system and method for simulating lead in a virtual reality system. Therefore, there is a need in the art for a shooting simulator that recreates moving targets at the same visual scale as seen in the field with a phantom target to teach proper lead of a moving target in a virtual reality platform.

## SUMMARY OF THE INVENTION

A system and method for simulating lead of a target includes a network, a simulation administrator connected to the network, a database connected to the simulation administrator, and a user device connected to the network. The user device includes a set of virtual reality unit, and a computer connected to the virtual reality unit and to the network. A set of position trackers are connected to the computer.

In a preferred embodiment, a target is simulated. In one embodiment, a simulated weapon is provided. In another embodiment, a set of sensors is attached to a real weapon. In another embodiment, a set of gloves having a set of sensors is worn by a user. The system generates a simulated target and displays the simulated target upon launch of the generated target. The computer tracks the position of the generated target and the position of the virtual reality unit and the weapon to generate a phantom target and a phantom halo. The generated phantom target and the generated phantom halo are displayed on the virtual reality unit at a lead distance and a drop distance from the live target as viewed through the virtual reality unit. The computer determines a hit or a miss of the generated target using the weapon, the phantom target, and the phantom halo. In one embodiment, the disclosed system and method is implemented in a two-dimensional video game.

The present disclosure provides a system which embodies significantly more than an abstract idea including technical advancements in the field of data processing and a transformation of data which is directly related to real-world objects and situations. The disclosed embodiments create and transform imagery in hardware, for example, a weapon peripheral and a sensor attachment to a real weapon.

## BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed embodiments will be described with reference to the accompanying drawings.

FIG. **1** is a plan view of a skeet shooting range.

FIG. **2** is a plan view of a trap shooting range.

FIG. **3**A is a target path and an associated projectile path.

FIG. **3**B is a target path and an associated projectile path.

FIG. **3**C is a target path and an associated projectile path.

FIG. **3**D is a target path and an associated projectile path.

FIG. **4**A is an ideal path of a moving target.

FIG. **4**B is a range of probable flight paths of a target.

FIG. **5** is a perspective view of a marksman aiming at a moving target.

FIG. **6** is a schematic of a simulator system of a preferred embodiment.

FIG. **7** is a schematic of a simulation administrator of a preferred embodiment.

FIG. **8** is a schematic of a user device of a simulator system of a preferred embodiment.

FIG. **9**A is a side view of a user device of a virtual reality simulator system of a preferred embodiment.

FIG. **9**B is a front view of a user device of a virtual reality simulator system of a preferred embodiment.

FIG. **9**C is a side view of a user device of an augmented reality simulator system of a preferred embodiment.

FIG. **9**D is a front view of a user device of an augmented reality simulator system of a preferred embodiment.

FIG. **10**A is a side view of a simulated weapon for a virtual reality system of a preferred embodiment.

FIG. **10**B is a side view of a real weapon with a set of sensors attached for a virtual reality system of a preferred embodiment.

FIG. **10**C is a detail view of a trigger sensor of a preferred embodiment.

FIG. **10**D is a detail view of a set of muzzle sensors of a preferred embodiment.

FIG. **10**E is a detail view of a set of a transmitter base of a preferred embodiment.

FIG. **10**F is a detail view of a set of muzzle sensors used with the transmitter base of FIG. **10**E of a preferred embodiment.

FIG. **10**G is a detail view of a removable plug with light emitting diodes for a weapon of a preferred embodiment.

FIG. **10**H is a detail view of a removable plug with light emitting diodes attached to a weapon of a preferred embodiment.

FIG. **10**I is a detail view of a removable collar with light emitting diodes attached to a weapon of a preferred embodiment.

FIG. **10**J is a side view of a weapon with an adjustable stock for a virtual reality simulator system of a preferred embodiment.

FIG. **10**K is a detail view of a trigger sensor of a preferred embodiment.

FIG. **11**A is a simulation view of a weapon having an iron sight of a preferred embodiment.

FIG. **11**B is a simulation view of a weapon having a reflex sight of a preferred embodiment.

FIG. **11**C is a simulation view of a weapon having a holographic sight of a preferred embodiment.

FIG. **12** is a schematic view of a virtual reality simulation environment of a preferred embodiment.

FIG. **13** is a command input menu for a virtual reality simulator system of a preferred embodiment.

FIG. **14** is a flow chart of a method for runtime process of a virtual reality simulation system of a preferred embodiment.

FIG. **15**A is top view of a user and a simulation environment of a preferred embodiment.

FIG. **15**B is a flow chart of a method for determining a view for a user device with respect to a position and an orientation of the user device and the weapon.

FIG. **15**C is a flow chart of a method for mapping the position and orientation of the user device and the weapon to the simulation environment for determining a display field of view a preferred embodiment.

FIG. **16**A is a flowchart of a method for determining a phantom and halo of a preferred embodiment.

FIG. **16**B is a plan view of a target and a phantom of a preferred embodiment.

FIG. **16**C is an isometric view of a target and a phantom of a preferred embodiment.

FIG. **17** is a user point of view of a virtual reality simulation system of a preferred embodiment.

FIG. **18** is an isometric view of an input device configured to be mounted on a rail system of a weapon of a preferred embodiment.

FIG. **19** is a simulation view that shows beams being projected from a barrel of a weapon of a preferred embodiment.

FIG. **20**A is a five stand field of a preferred embodiment.

FIG. **20**B is a sporting clay field of a preferred embodiment.

FIG. **21**A is diagram of a preferred embodiment of a simulation system.

FIG. **21**B is a diagram of a virtual reality system of a preferred embodiment.

FIG. **21**C is a diagram of an augmented reality system of a preferred embodiment.

FIG. **22**A is a diagram of a system using a positioning detector at an end of a barrel in a preferred embodiment.

FIG. **22**B is a diagram of a system using a positioning detector mounted under a barrel in a preferred embodiment.

FIG. **22**C is a diagram of a system using sight markings in a preferred embodiment.

FIG. **22**D is a diagram of a system using sight markings and a sensor thimble in a preferred embodiment.

FIG. **22**E is a diagram of a positioning detector in a preferred embodiment.

FIGS. **23**A and **23**B are diagrams of a trigger unit in a preferred embodiment.

FIG. **23**C is a diagram of a processor board of a trigger unit in a preferred embodiment.

FIGS. **24**A and **24**B are diagrams of a mounting arbor in a preferred embodiment.

FIGS. **24**C and **24**D are diagrams of a barrel clamp in a preferred embodiment.

FIGS. **25**A through **25**D are diagrams of electronic cartridges in preferred embodiments.

FIGS. **25**E and **25**F are diagrams of a sensor arbor in a preferred embodiment.

FIG. **25**G is a diagram of a sensor thimble in a preferred embodiment.

FIG. **26** is a diagram of a computer implemented method for determining a launcher location of a preferred embodiment.

FIG. **27** is a diagram of graphs of a pellet spread of a preferred embodiment.

FIG. **28**A is a diagram of a computer implemented method for simulating digital clay targets of a preferred embodiment.

FIG. **28**B is a diagram of an original image captured by an augmented reality system in a preferred embodiment.

FIG. **28**C is a diagram spatial map and anchors in an augmented reality system in a preferred embodiment.

FIG. **28**D is a diagram of a virtual reality simulation in a preferred embodiment.

FIG. **29**A is a diagram of initializing a computer implemented simulation of shooting a digital clay target.

FIG. **29**B is a diagram for calculating a lead distance.

FIG. **29**C is a flowchart of a preferred method of generating a simulation.

FIG. **29**D is a diagram of a spatial map from the system.

FIG. **29**E is a flowchart of a preferred method of generating a simulation.

FIG. **30** is a diagram control movements in a preferred embodiment.

FIG. **31** is a flowchart of a method for processing control signals in a preferred embodiment.

FIG. **32** is a diagram of a preferred embodiment of an augmented reality overlay of a simulation.

FIG. **33** is a preferred method of generating a phantom target ahead of a live bird target.

FIG. **34** is a flowchart of a preferred method of a deriving path equations.

FIG. **35** is a node architecture drawing of a preferred embodiment of a neural network for use with the system.

FIG. **36** is a node design drawing of a preferred embodiment.

FIG. **37**A is an architecture of an exemplary embodiment of a tactical unit.

FIG. **37**B is an overview of the operation of a preferred embodiment of a system employing a tactical unit.

FIG. **38**A is a preferred embodiment of a system employing multiple remote units.

FIG. **38**B is an overview of a preferred embodiment of the operation of a system employing multiple remote units.

FIG. **39** is a architecture diagram of a preferred embodiment of a headset module.

FIG. **40**A is a side view of a preferred embodiment of a tactical helmet.

FIG. **40**B is a front view of a preferred embodiment of a tactical helmet.

FIG. **41**A is an architecture diagram of a preferred embodiment of a weapon module.

FIG. **41**B is a drawing of a preferred embodiment of a processor card and memory.

FIG. **42**A is a schematic side view of a weapon used in the system.

FIG. **42**B is a schematic top view of a weapon used in the system.

FIG. **43**A is a method flow chart of a single tactical unit operating in a tactical theatre.

FIG. **43**B is a flow chart of a preferred embodiment of the functions of a plurality of remote units operating in a tactical theatre.

FIG. **44** is a flow chart of a preferred method for determining weapon position.

FIGS. **45**A, **45**B and **45**C show examples of the display of a single tactical unit showing a phantom and a pull away lead.

FIGS. **45**D and **45**E show exemplary displays of two remote units operating in the same tactical theatre.

FIG. **46**A shows a preferred embodiment of an architecture of an alternate system embodiment.

FIG. **46**B shows an overview of a preferred embodiment of an alternate architecture of the system.

FIG. **47** shows a preferred embodiment of an architecture of a drone spotter unit.

FIG. **48** shows a preferred embodiment of an architecture of a fixed camera spotter unit.

FIG. **49** shows a preferred method of operation of an alternate embodiment of the system.

FIG. **50** shows a preferred embodiment of a method of target path resolution.

FIG. **51** is a preferred embodiment of the AI processor.

FIG. **52** shows a preferred embodiment of a single artificial neural network for predicting a vector component of a lead distance.

FIG. **53** shows a flow chart of a method for training and using an artificial neural network of a preferred embodiment.

FIG. **54** shows preferred implementation of a preferred embodiment of a neural network.

## DETAILED DESCRIPTION OF THE INVENTION

It will be appreciated by those skilled in the art that aspects of the present disclosure may be illustrated and described herein in any of a number of patentable classes or context including any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof. Therefore, aspects of the present disclosure may be implemented entirely in hardware, entirely in software (including firmware, resident software, micro-code, etc.) or combining software and hardware implementation that may all generally be referred to herein as a “circuit,” “module,” “component,” or “system.” Further, aspects of the present disclosure may take the form of a computer program product embodied in one or more computer readable media having computer readable program code embodied thereon.

Any combination of one or more computer readable media may be utilized. The computer readable media may be a computer readable signal medium or a computer readable storage medium. For example, a computer readable storage medium may be, but not limited to, an electronic, magnetic, optical, electromagnetic, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium would include, but are not limited to: a portable computer diskette, a hard disk, a random access memory (“RAM”), a read-only memory (“ROM”), an erasable programmable read-only memory (“EPROM” or Flash memory), an appropriate optical fiber with a repeater, a portable compact disc read-only memory (“CD-ROM”), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. Thus, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. The propagated data signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device. Program code embodied on a computer readable signal medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, or any suitable combination thereof.

Computer program code for carrying out operations for aspects of the present disclosure may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Scala, Smalltalk, Eiffel, JADE, Emerald, C++, C#, VB.NET, Python or the like, conventional procedural programming languages, such as the "C" programming language, Visual Basic, Fortran 2003, Perl, COBOL 2002, PHP, ABAP, dynamic programming languages such as Python, Ruby and Groovy, or other programming languages.

Aspects of the present disclosure are described with reference to flowchart illustrations and/or block diagrams of methods, systems and computer program products according to embodiments of the disclosure. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable instruction execution apparatus, create a mechanism for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable medium that when executed can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions when stored in the computer readable medium produce an article of manufacture including instructions which when executed, cause a computer to implement the function/act specified in the flowchart and/or block diagram block or blocks. The computer program instructions may also be loaded onto a computer, other programmable instruction execution apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatuses or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

Referring to FIG. **6**, system **600** includes network **601**, simulation administrator **602** connected to network **601**, and user device **604** connected to network **601**. Simulation administrator **602** is further connected to simulation database **603** for storage of relevant data. For example, data includes a set of target data, a set of weapon data, and a set of environment data.

In one embodiment, network **601** is a local area network. In another embodiment, network **601** is a wide area network, such as the internet. In other embodiments, network **601** includes a combination of wide area networks and local area networks, includes cellular networks.

In a preferred embodiment, user device **604** communicates with simulation administrator **602** to simulation database **603** to generate and project a simulation that includes a target, a phantom, and a phantom halo adjacent to the target as will be further described below.

In another embodiment, simulation administrator **602** generates a simulation that includes a target, a phantom, a phantom halo adjacent to the target, and a weapon image as will be further described below and sends the simulation to user device for projection.

FIG. **1** depicts the general dimensions of a skeet shooting range. Skeet shooting range **100** is a skeet field that includes eight shooter positions with **2** launcher locations. Cameras **150** and **151** are located in positions to view houses **101** and **102** and launchers **103** and **109**. Skeet shooting range **100** has high house **101** and low house **102** separated by distance **111**. Distance **111** is about 120 feet. Launcher **103** is adjacent high house **101**. Launcher **109** is adjacent low house **102**. Station **110** is equidistant from high house **101** and low house **102** at distance **112**. Distance **112** is about 60 feet. Station **106** is equidistant from high house **101** and low house **102** and generally perpendicular to distance **111** at distance **113**. Distance **113** is 45 feet. Station **106** is distance **114** from launcher **103**. Distance **114** is about 75 feet. Stations **104** and **105** are positioned along arc **121** between launcher **103** and station **106** at equal arc lengths. Each of arc lengths **122**, **123**, and **124** is about 27 feet. Stations **107** and **108** are positioned along arc **121** between station **106** and launcher **109** at equal arc lengths. Each of arc lengths **125**, **126**, and **127** is 26 feet, 8⅜ inches.

Target flight path **116** extends from high house **101** to marker **117**. Marker **117** is positioned about 130 feet from high house **101** along target flight path **116**. Target flight path **115** extends from low house **102** to marker **118**. Marker **118** is about 130 feet from low house **102** along target flight path **115**. Target flight paths **115** and **116** intersect at target crossing point **119**. Target crossing point **119** is positioned distance **120** from station **110** and is 15 feet above the ground. Distance **120** is 18 feet. Clay targets are launched from high house **101** and low house **102** along target flight paths **116** and **115**, respectively. Marksman **128** positioned at any of stations **104**, **105**, **106**, **107**, **108**, and **110** and launchers **103** and **109** attempts to shoot and break the launched clay targets.

FIG. **2** depicts the general dimensions of a trap shooting range. Trap shooting range **200** is a trap field that includes five shooter locations with one launcher location. Cameras **250** and **251** are located in positions to view trap house **202**. Once all of the coordinates are set and the field dimensions are known, one good video at a normal lens setting at 60 frames per second (fps) of one trajectory can be used to recreate a trajectory and phantom position from any point of view (POV).

In a preferred embodiment, cameras **150** and **151** (shown in FIG. **1**) and **250** and **251** (shown in FIG. **2**) can be used to record many target flights of clay targets from which flight paths may be derived for later use in simulations, as will be later described. In the same way, cameras **150** and **151** and **250** and **251** can be used to record the flight of live targets (such as birds) as they are released from the launch or other locations. Similarly, stereo cameras (such as that described in relation to FIG. **9**C) can be used outside a controlled skeet range or trap range to record flight paths of either clay targets or live targets from which mathematical flight paths may be recorded for later use in simulation, as will be further described.

Referring to FIG. **34**, a method storing launch target information in a path table and path array will be described.

At step **341**, the stereo cameras are activated and directed toward the projected flight path of the target.

At step **342**, the target is launched. At step **344**, both cameras simultaneously record the flight path of the target.

At step **346**, the synchronized video images from the stereoscopic cameras are analyzed to isolate the target position along the flight path for each time "t". In a preferred embodiment, each of the cameras records approximately 60 frames per second, or 360 frames per minute. In a preferred embodiment, the target positions are stored in cartesian coordinates. The origin of the cartesian coordinate system, x=0, y=0, z=0, is taken at the launch point of the target. The x-coordinate for each position is derived from the horizontal distance of the target from a launch point. The y-coordinate is derived from altitude of the target as the vertical distance from the ground. The depth, or z-coordinate is derived from the depth function of the stereoscopic cameras and is translated to agree with the origin.

At step **348**, the isolated target positions are stored in a path table.

At step **350**, a spline function available from the 3D unity engine is applied to interpolate path equations from the isolated target positions for each flight recorded. At step **352**, the path equation is stored in a path array indexed by the date and time of the target launch.

At step **354**, a 3 second video sample of the target is recorded and stored in an attribute array, indexed according to date and time of the target launch. Other lengths of video samples can also be used.

Referring to FIG. **7**, simulation administrator **701** includes processor **702**, network interface **703** connected to processor **702**, and memory **704** connected to processor **702**. Simulation application **705** is stored in memory **704** and executed by processor **702**. Simulation application **705** includes position application **706**, statistics engine **707**, and target and phantom generator **708**.

In a preferred embodiment, simulation administrator **701** is a PowerEdge C6100 server and includes a PowerEdge C410x PCIe Expansion Chassis available from Dell Inc. Other suitable servers, server arrangements, and computing devices known in the art may be employed.

In one embodiment, position application **706** communicates with a position tracker connected to the user device to detect the position of the user device for simulation application **705**. Statistics engine **707** communicates with a database to retrieve relevant data and generate renderings according desired simulation criteria, such as desired weapons, environments, and target types for simulation application **705**. Target and phantom generator **708** calculates and generates a target along a target path, a phantom target, and a phantom halo for the desired target along a phantom path for simulation application, as will be further described below.

Referring to FIG. **8**, user device **800** includes computer **801** connected to headset **802**. Computer **801** is further connected to replaceable battery **803**, microphone **804**, speaker **805**, and position tracker **806**.

Computer **801** includes processor **807**, memory **809** connected to processor **807**, and network interface **808** connected to processor **807**. Simulation application **810** is stored in memory **809** and executed by processor **807**. Simulation application **810** includes position application **811**, statistics engine **812**, and target and phantom generator **813**. In a preferred embodiment, position application **811** communicates with position tracker **806** to detect the position of headset **802** for simulation application **810**. Statistics engine **812** communicates with a database to retrieve relevant data and generate renderings according desired simulation criteria, such as desired weapons, environments, and target types for simulation application **810**. Target and phantom generator **813** calculates and generates a target along a target path, a phantom target, and a phantom halo for the desired target along a phantom path for simulation application **810**, as will be further described below.

Input device **814** is connected to computer **801**. Input device **814** includes processor **815**, memory **816** connected to processor **815**, communication interface **817** connected to processor **815**, a set of sensors **818** connected to processor **815**, and a set of controls **819** connected to processor **815**.

In one embodiment, input device **814** is a simulated weapon, such as a shot gun, a rifle, or a handgun. In another embodiment, input device **814** is a set of sensors connected to a disabled real weapon, such as a shot gun, a rifle, or a handgun, to detect movement and actions of the real weapon. In another embodiment, input device **814** is a glove having a set of sensors worn by a user to detect positions and movements of a hand of a user.

Headset **802** includes processor **820**, battery **821** connected to processor **820**, memory **822** connected to processor **820**, communication interface **823** connected to processor **820**, display unit **824** connected to processor **820**, and a set of sensors **825** connected to processor **820**.

Referring to FIGS. **9**A and **9**B, a preferred implementation of user device **800** is described as user device **900**. User **901** wears virtual reality unit **902** having straps **903** and **904**. Virtual reality unit **902** is connected to computer **906** via connection **905**. Computer **906** is preferably a portable computing device, such as a laptop or tablet computer, worn by user **901**. In other embodiments, computer **906** is a desktop computer or a server, not worn by the user. Any suitable computing device known in the art may be employed. Connection **905** provides a data and power connection from computer **906** to virtual reality unit **902**.

Virtual reality unit **902** includes skirt **907** attached to straps **903** and **904** and display portion **908** attached to skirt **907**. Skirt **907** covers eyes **921** and **916** of user **901**. Display portion **908** includes processor **911**, display unit **910** connected to processor **911**, a set of sensors **912** connected to processor **911**, communication interface **913** connected to processor **911**, and memory **914** connected to processor **911**. Lens **909** is positioned adjacent to display unit **910** and eye **921** of user **901**. Lens **915** is positioned adjacent to display unit **910** and eye **916** of user **901**. Virtual reality unit **902** provides a stereoscopic three-dimensional view of images to user **901**.

User **901** wears communication device **917**. Communication device **917** includes earpiece speaker **918** and microphone **919**. Communication device **917** is preferably connected to computer **906** via a wireless connection such as a Bluetooth connection. In other embodiments, other wireless or wired connections are employed. Communication device **917** enables voice activation and voice control of a simulation application stored in the computer **906** by user **901**.

In one embodiment, virtual reality unit **902** is the Oculus Rift headset available from Oculus VR, LLC. In another embodiment, virtual reality unit **902** is the HTC Vive headset available from HTC Corporation. In this embodiment, a set of laser position sensors **920** is attached to an external surface virtual reality unit **902** to provide position data of virtual reality unit **902**. In another preferred embodiment, virtual reality unit **902** can take the form of the Magic Leap One headset available from Magic Leap, Inc. of Plantation, Fla., the Oculus S, or Oculus Quest, available from Oculus VR, LLC or the HMD Odyssey from Samsung of San Jose, Calif. Any suitable virtual reality unit or mixed reality unit known in the art may be employed.

In certain embodiments, set of sensors **912** include sensors related to eye tracking. When the sensors related to eye tracking are based on infrared optical tracking, the set of sensors **912** includes one or more infrared light sources and one or more infrared cameras. Light from the infrared light sources is reflected from one or more surfaces of the user eye and is received by the infrared cameras. The reflected light is reduced to a digital signal which is representative of the positions of the user eye. These signals are transmitted to the computer. Computer **906** and processor **911** then determine the positioning and direction of the eyes of the user and record eye tracking data. With the eye tracking data, computer **906** determines whether the user is focusing on the simulated target or on the phantom target; how quickly a user focusses on the simulated target or phantom target; how long it takes for the user to aim the weapon after focusing on the simulated target or phantom target; how long the user focusses on the simulated target or phantom target before pulling the trigger; how long it takes the user to see and focus on the next target; whether the user's eyes were shut or closed before, during, or after the pull of the trigger; and so on. Computer **906** also determines eye training statistics based on the eye training data and the eye tracking data collected over multiple shots and rounds of the simulation. Feedback is given to the user that includes and is based on the eye tracking data, the eye training data, and the eye training statistics.

Referring then to FIGS. **9**C and **9**D a preferred implementation of user device **800** is described as mixed reality unit **950**. User **901** wears mixed reality unit **950**. Mixed reality unit **950** is connected to computer **906** via connection **905**. Connection **905** provides data and power connection from computer **906** to processor **954** communication interface **952** and display **958**. Mixed reality unit **950** further comprises visor **956**. Visor **956** operatively supports display **958** in front of the user's eyes. When mixed reality unit **950** is in operation, it includes visual axis **960**. The visual axis is generally coaxial with the pupils of the user. Display **958** displays a stereoscopic view to the user.

Mixed reality unit **950** further supports stereo camera **925**. Stereo camera **925** incorporates two independent digital cameras, right camera **927** and left camera **929**. The central axis of each of the cameras is parallel with visual axis **960** and is positioned directly in line with one eye of the user. In a preferred embodiment, the digital input from each of right camera **927** and left camera **929** can be displayed on display **958** for viewing by user **901** in near real time.

In one embodiment, mixed reality unit **950** comprises the Oculus rift headset available from Oculus VR, LLC. In this embodiment, stereo camera **925** is the Ovrvision Pro PV high performance stereo camera USB 3.0 available from Ovrvision of Osaka, Japan. Camera **925** is attached to mixed reality unit **950** by screws or appropriate adhesive. It allows high resolution wide angle viewing with two eye synchronization with appropriately low delay times. In this embodiment, communication with the processor is carried out through the GPIO communications channel which supports game engines such as Unity 5 and the Unreal Engine. In a preferred embodiment, the wide angle lens is capable of supporting a 120° viewing angle, and a delay of 50 microseconds at 60 frames per second.

In another embodiment, mixed reality unit **950** is the HTC Vive mixed reality headset available from HTC of Taiwan. In this embodiment, stereo camera **925** are the onboard cameras available on the HTC Vive unit are employed in "pass through" mode.

In yet another embodiment, mixed reality unit **950** is the HMD Odyssey mixed reality headset from Samsung of Seoul, South Korea. In this embodiment, stereo camera **925** is likewise the onboard camera system of the HMD Odyssey system employed in "pass through" mode.

In certain embodiments, the laser position sensors **920** are light emitting diodes (LEDs) that act as markers that can be seen or sensed by one or more cameras or sensors. Data from the cameras or sensors is processed to derive the location and orientation of virtual reality unit **902** based on the LEDs. Each LED emits light using particular transmission characteristics, such as phase, frequency, amplitude, and duty cycle. The differences in the phase, frequency, amplitude, and duty cycle of the light emitted by the LEDs allows for a sensor to identify each LED by the LED's transmission characteristics. In certain embodiments, the LEDs on virtual reality unit **902** are spaced with placement characteristics so that there is a unique distance between any two LEDs, which gives the appearance of a slightly randomized placement on virtual reality unit **902**. The transmission characteristics along with placement characteristics of the LEDs on virtual reality unit **902** allows the simulation system to determine the location and orientation of virtual reality unit **902** by sensing as few as three LEDs with a camera or other sensor.

In a preferred embodiment, a simulation environment that includes a target is generated by computer **906**. Computer **906** further generates a phantom target and a phantom halo in front of the generated target based on a generated target flight path. The simulation environment including the generated target, the phantom target, and the phantom halo are transmitted from computer **906** to virtual reality unit **902** for viewing adjacent eyes **916** and **921** of user **901**, as will be further described below. The user aims a weapon at the phantom target to attempt to shoot the generated target.

Referring FIG. **10**A in one embodiment, simulated weapon **1001** includes trigger **1002** connected to set of sensors **1003**, which is connected to processor **1004**. Communication interface **1005** is connected to processor **1004** and to computer **1009**. Battery **1026** is connected to processor **1004**. Simulated weapon **1001** further includes a set of controls **1006** attached to an external surface of simulated weapon **1001** and connected to processor **1004**. Set of controls **1006** includes directional pad **1007** and selection button **1008**. Battery **1026** is connected to processor **1004**. Actuator **1024** is connected to processor **1004** to provide haptic feedback.

In a preferred embodiment, simulated weapon **1001** is a shotgun. It will be appreciated by those skilled in the art that other weapon types may be employed.

In one embodiment, simulated weapon **1001** is a Delta Six first person shooter controller available from Avenger Advantage, LLC. In another embodiment, simulated weapon **1001** is an airsoft weapon or air gun replica of a real weapon. In another embodiment, simulated weapon **1001** is a firearm simulator that is an inert detailed replica of an actual weapons, such as "blueguns" from Ring's Manufacturing. Other suitable simulated weapons known in the art may be employed.

In a preferred embodiment, set of sensors **1003** includes a position sensor for trigger **1002** and a set of motion sensors to detect an orientation of simulated weapon **1001**.

In a preferred embodiment, the position sensor is a Hall Effect sensor. In this embodiment, a magnet is attached to trigger **1002**. Other types of Hall Effect sensor or any other suitable sensor type known in the art may be employed.

In a preferred embodiment, the set of motion sensors is a 9-axis motion tracking system-in-package package sensor, model no. MP11-9150 available from InverSense®, Inc. In this embodiment, the 9-axis sensor combines a 3-axis gyroscope, a 3-axis accelerometer, an on-board digital motion processor, and a 3-axis digital compass. In other embodiments, other suitable sensors and/or suitable combinations of sensors may be employed.

Referring to FIGS. **10**B, **10**C, and **10**D in another embodiment, weapon **1010** includes simulation attachment **1011** removably attached to its stock. Simulation attachment **1011** includes on-off switch **1012** and pair button **1013** to communicate with computer **1009** via Bluetooth connection. Any suitable wireless connection may be employed. Trigger sensor **1014** is removably attached to trigger **1022** and in communication with simulation attachment **1011**. A set of muzzle sensors **1015** is attached to a removable plug **1016** which is removable inserted into barrel **1023** of weapon **1010**. Set of muzzle sensors **1015** include a processor **1017**, battery **1018** connected to processor **1017**, gyroscope **1019** connected to processor, accelerometer **1020** connected to processor **1017**, and compass **1021** connected to processor **1017**.

In one embodiment, set of muzzle sensors **1015** and removable plug **1016** are positioned partially protruding outside of barrel **1023** of weapon **1010**.

In one embodiment, weapon **1010** includes rail **1025** attached to its stock in any position. In this embodiment, set of muzzle sensors **1015** is mounted to rail **1025**.

In one embodiment, weapon **1010** fires blanks to provide live recoil to a user.

It will be appreciated by those skilled in the art that any weapon may be employed as weapon **1010**, including any rifle or handgun. It will be further appreciated by those skilled in the art that rail **1025** is optionally mounted to any type of weapon. Set of muzzle sensors **1015** may be mounted in any position on weapon **1010**. Any type of mounting means known in the art may be employed.

Referring to FIG. **10**E, base **1028** comprises a sensor system that includes a magnetic field detector used to determine the location and orientation of a weapon, such as weapon **1010** with removable plug **1016** shown in FIG. **10**F. Base **1028** includes processor **1032**, which is connected to communication interface **1034**, power source **1036**, memory **1038**, first coil **1040**, second coil **1042**, and third coil **1044**. First coil **1040**, second coil **1042**, and third coil **1044** form the magnetic field detector of the sensor system of base **1028**.

Processor **1032** of base **1028** receives positioning signals via first coil **1040**, second coil **1042**, and third coil **1044** that are used to determine the position and orientation of a weapon used in the simulation system. In a preferred embodiment, each of the positioning signals received via first coil **1040**, second coil **1042**, and third coil **1044** can be differentiated from one another by one or more of each positioning signal's phase, frequency, amplitude, and duty cycle so that each positioning signal transmitted by each coil is distinct. The differences in the positioning signals allow base **1028** to determine the position of a transmitting device, such as removable plug **1016** of FIG. **10**F, based on the positioning signals that indicates the relative position between base **1028** and the transmitting device.

Referring to FIG. **10**F, removable plug **1016** is inserted into an under barrel of weapon **1010** and transmits positioning signals used to determine the location an orientation of removable plug **1016** and the weapon removable plug **1016** is connected to. Removable plug **1016** includes processor **1017**, which is connected to battery **1018**, communication interface **1046**, first coil **1048**, second coil **1050**, and third coil **1052**. First coil **1048**, second coil **1050**, and third coil **1052** form magnetic field transmitters of a sensor system of removable plug **1016**. The magnetic fields generated and transmitted by first coil **1048**, second coil **1050**, and third coil **1052** are positioning signals used to determine the location and orientation of removable plug **1016**, for example, by base **1028** of FIG. **10**E.

Processor **1017** transmits positioning signals from first coil **1048**, second coil **1050**, and third coil **1052** that are received by processor **1032** of base **1028**. From the transmitted positioning signals, the relative location and orientation between removable plug **1016** and base **1028** is determined so that the precise location of removable plug **1016** with respect to base **1028** is derived. The determinations and derivations may be performed by one or more of processor **1032** of base **1028**, processor **1017** of removable plug **1016**, and a processor of another computer of the simulation system, such as computer **1009**. Once the position of removable plug **1016** is known, the position and orientation of weapon **1010** is determined based on the location and orientation of removable plug **1016**, the geometry of removable plug **1016**, the geometry of weapon **1010**, and the placement of removable plug **1016** on weapon **1010**. With the position and orientation of weapon **1010**, the simulation application can display a simulated version of weapon **1010**, calculate the proper position of a phantom target, and provide suggested adjustments to improve a user's marksmanship.

In an alternative embodiment, the sensor system of base **1028** includes the magnetic field transmitter and the sensor system of removable plug **1016** includes the magnetic field detector. In alternative embodiments, removable plug **1016** includes threading that corresponds to threading with the barrel of the weapon that is commonly used for a shotgun choke and removable plug **1016** is fitted and secured to the barrel of the weapon via the threading.

Referring to FIG. **10**G, removable collar **1054** fits onto barrel **1056** of a weapon, such as weapon **1010** of FIG. **10**B. Removable collar **1054** includes tip **1058** and three members **1060**, **1062**, and **1064**. Members **1060**, **1062**, and **1064** extend from a first side of tip **1058** that touches barrel **1056** when removable collar **1054** is fitted to barrel **1056**. Removable collar **1054** includes light emitting diodes (LEDs), such as LEDs **1066** on member **1060**, LEDs **1068** on member **1062**, and LEDs on member **1064**, and LEDs **1070** on tip **1058**. Removable collar **1054** includes additional LEDs that are occluded on FIG. **10**G, such as on member **1064** and on tip **1058**. The LEDs on removable collar **1054** may emit infrared light to be invisible to a user or may emit light in the visible spectrum. Removable collar **1054** acts as a marker from which the location and orientation of the weapon can be derived.

The LEDs on removable collar **1054** each emit light using particular transmission characteristics, such as phase, frequency, amplitude, and duty cycle. The differences in the phase, frequency, amplitude, and duty cycle of the light emitted by the LEDs allows for a sensor to identify each LED on removable collar **1054** by the LED's transmission characteristics. The LEDs on removable collar **1054** are spaced with placement characteristics so that there is a unique distance between any two LEDs, which gives the appearance of a slightly randomized placement on removable collar **1054**. The transmission characteristics along with placement characteristics of the LEDs on removable collar **1054** allows the simulation system to determine the location and orientation of the removable plug by sensing as few as three LEDs with a camera or other sensor. Once the location and orientation of removable collar **1054** is determined, the location and orientation of the weapon to which removable collar **1054** is attached is derived based on the known geometries of removable collar **1054** and the weapon, which are stored in a database.

Referring to FIG. **10**H, removable collar **1054** is fitted onto barrel **1056** of a weapon. Inner portions of members **1060**, **1062**, and **1064** are rubberized and may contain an adhesive to prevent movement of removable collar **1054** with respect to the weapon it is attached to. After removable collar **1054** is installed for the first time to a weapon, the simulation system is calibrated to associate the location and orientation, including a roll angle, of removable collar **1054** to the location and orientation of the weapon.

In alternative embodiments, the portion of removable collar **1054** that fits against the barrel of the weapon is shaped to fit with only one orientation with respect to the weapon. The removable collar **1054** may include additional members that fit around the iron sight of the weapon so that there is only one possible fitment of removable collar **1054** to the weapon and the process of calibration can be reduced or eliminated.

Referring to FIG. **10**I, removable collar **1054** is fitted to weapon **1010**. Weapon **1010** is an over-under shotgun with barrel **1056**, under barrel **1057**, and top rail **1059**. Removable collar **1054** comprises a hollow portion **1055** that allows for the discharge of live or blank rounds of ammunition during the simulation. A front surface of removable collar **1054** is flush with the front surfaces of under barrel **1057** so that the position of removable collar **1054** with respect to each of barrels **1056** and **1057** is known and the trajectory of shots from weapon **1010** can be properly simulated. Removable collar **1054** includes hollow portion **1055**, member **1061**, mounting screws **1063**, battery **1018**, processor **1017**, and LEDs **1067**. Removable collar **1054** is customized to the particular shape of weapon **1010**, which may include additional iron sights. Removable collar **1054** does not interfere with the sights of weapon **1010** so that weapon **1010** can be aimed normally while removable collar **1054** is fitted to weapon **1010**.

Member **1061** is a flat elongated member that allows for removable collar **1054** to be precisely and tightly fitted to the end of under barrel **1057** of weapon **1010** after removable collar **1054** is slid onto the end of under barrel **1057**. Member **1061** with mounting screws **1063** operate similar to a C-clamp with mounting screws **1063** pressing into member **1061** and thereby securing removable collar **1054** to the end of under barrel **1057** with sufficient force so that the position and orientation of removable collar **1054** with respect to weapon **1010** is not altered by the firing of live rounds or blank rounds of ammunition with weapon **1010**.

Battery **1018** is connected to and powers the electrical components within removable collar **1054** including processor **1017** and LEDs **1067**. Processor **1017** controls LEDs **1067**. In additional embodiments removable collar **1054** includes one or more, accelerometers, gyroscopes, compasses, and communication interfaces connected to processor **1017**. The sensor data from the accelerometers, gyroscopes, and compasses is sent from removable collar **1054** to computer **1009** via the communication interface. Removable collar **1054** includes button **1069** to turn on, turn off, and initiate the pairing of removable collar **1054**.

LEDs **1067** emit light that is sensed by one or more cameras or sensors, from which the locations and orientations of removable collar **1054** and weapon **1010** can be determined. The locations and orientations are determined from the transmission characteristics of the light emitted from LEDs **1067**, and the placement characteristics of LEDs **1067**.

Weapon **1010**, to which removable collar **1054** is fitted, is loaded with one or more live or blank rounds of ammunition that discharge through the hollow portion **1055** of removable collar **1054** when a trigger of weapon **1010** is pulled so that blank rounds or live rounds of ammunition can be used in conjunction with the simulation. Using blank rounds or live rounds with the simulation allows for a more accurate and realistic simulation of the shooting experience, including the experience of re-aiming weapon **1010** for a second shot after feeling the kickback from the discharge of a blank or live round from a first shot.

In alternative embodiments, the weapon is a multiple shot weapon, such as an automatic rifle, a semi-automatic shotgun, or a revolver. With a multiple shot weapon the simulation experience includes the feeling of the transition between shots, such as the cycling of the receiver of a semi-automatic shotgun. When the weapon comprises an automatic or semi-automatic receiver, the simulation displays the ejection of a spent shell casing that may not correspond to the actual path or trajectory of the actual spent shell casing. Additional embodiments track the location of the spent shell casing as it is ejected and match the location and trajectory of the simulated shell casing to the location and trajectory of the spent shell casing. Additional embodiments also include one or more additional sensors, electronics, and power supplies embedded within the housing of removable collar **1054**.

Referring to FIG. **10**J, weapon **1072** is adapted for use in a simulation by the fitment of removable collar **1054** to the barrel of weapon **1072**. Weapon **1072** is a try gun that includes a stock **1074** with adjustable components to fit users of different heights and statures. Each component may include electronic sensors that measure the length, angle, or position of the component so that weapon **1072** can be properly displayed in a simulation.

Stock **1074** of weapon **1072** includes comb **1076** with comb angle adjuster **1078** and comb height adjuster **1080**. Comb **1076** rests against a cheek of a user to improve stability of weapon **1072** during use. The height of comb **1076** is adjustable via manipulation of comb height adjuster **1080**. The angle of comb **1076** is adjustable via manipulation of comb angle adjuster **1078**.

Stock **1074** of weapon **1072** also includes butt plate **1082** with butt plate angle adjuster **1084** and trigger length adjuster **1086**. Trigger length **1088** is the length from trigger **1090** to butt plate **1082**. Butt plate **1082** rests against a shoulder of a user to improve stability of weapon **1072** during use. Trigger length **1088** from butt plate **1082** to trigger **1090** is adjustable via manipulation of trigger length adjuster **1086**. The angle of butt plate **1082** is adjustable via manipulation of butt plate angle adjuster **1084**.

When weapon **1072** used in a virtual reality simulation system with removable collar **1054**, suggested adjustments to comb **1076** and butt plate **1082** are optionally provided. If shots are consistently to the right or left of an ideal shot placement for a right handed shooter, it may be suggested to increase or decrease trigger length **1088**, respectively. If shots are consistently above or below the ideal shot placement, it may be suggested to decrease or increase the height of comb **1076**, respectively.

Referring to FIG. **10**K, an alternative embodiment of trigger sensor **1014** is shown. Weapon **1010** includes trigger **1022** and trigger guard **1027**. Trigger sensor **1014** is specially shaped and contoured to fit securely to the front of trigger guard **1027**. Once trigger sensor **1014** is slid onto trigger guard **1027**, screws **1041** are tightened to further secure trigger sensor **1014** to trigger guard **1027** and weapon **1010**.

Pull ring **1029** is connected to string **1030**, which winds upon spindle **1031**. Spindle **1031** includes spring **1033**, which keeps tension on string **1030** and biases pull ring **1029** to be pulled away from trigger **1022** and towards trigger guard **1027** and trigger sensor **1014**. In the resting state, there is no slack in string **1030** and pull ring **1029** rests against trigger sensor **1014**.

Sensor **1035** provides data indicative of the rotation and/or position of spindle **1031**. In one preferred embodiment, sensor **1035** is a potentiometer that is connected to and turns with spindle **1031**, where a voltage of the potentiometer indicates the position of spindle **1031** and a change in voltage indicates a rotation of spindle **1031**. In another preferred embodiment, sensor **1035** includes one or more photo emitters and photo detectors that surround an optical encoder wheel that is attached to spindle **1031**, where light from the photo emitters passes through the encoder wheel to activate certain photo detectors to indicate the position of spindle **1031**.

Controller **1037** receives data from sensor **1035** to determine the state of trigger sensor **1014** and communicates the state of trigger sensor **1014** by controlling the output of LED **1039** to create a coded signal that corresponds to the state of trigger sensor **1014**. In a preferred embodiment, the states of trigger sensor **1014** include: pull ring not engaged, pull ring engaged but trigger not pulled, pull ring engaged and trigger is pulled. Controller **1037**, LED **1039**, and sensor **1035** are powered by battery **1043**.

The state of trigger sensor **1014** is communicated by controlling the output LED **1039** with controller **1037**. The output of LED **1039** forms a coded signal to indicate the state of trigger sensor **1014** and can also be used to aid in the determination of the position and orientation of weapon **1010** when the position of trigger sensor **1014** with respect to weapon **1010** and the geometry of weapon **1010** are known. The output of LED **1039** is cycled on and off to flash with a particular phase, frequency, amplitude, and duty cycle that form a set of output characteristics. Different output characteristics are used to indicate different states of trigger sensor **1014**. A first set of output characteristics or first code is used to indicate the pull ring not engaged state, a second set of output characteristics or second code is used to indicate the pull ring engaged but trigger not pulled state, and a third set of output characteristics or third code is used to indicate the pull ring engaged and trigger is pulled state. In one embodiment, the pull ring not engaged state is indicated by a set of output characteristics where the duty cycle is 0% and/or the amplitude is 0 so that LED **1039** does not turn on. An external sensor or camera, such as one of position trackers **1205**, **1206**, and **1215** can be used to determine the state of trigger sensor **1014** by detecting the output from LED **1039** and decoding the output characteristics to determine which state trigger sensor **1014** is in.

In an alternative embodiment, pull ring **1029** and string **1030** each include conductive material, trigger sensor **1014** includes a pull-up resistor connected to an input of controller **1037**, and controller **1037** is electrically grounded to trigger guard **1027**. When trigger **1022** and trigger guard **1027** are electrically connected and conductive pull ring **1029** is touched to trigger **1022**, the pull-up resister is grounded to change the state of the input of controller **1037** so that controller **1037** can determine whether pull ring **1029** is touching trigger **1022**. Assuming that the user only touches pull ring **1029** to trigger **1022** when attempting to pull trigger **1022**, the determination of whether pull ring **1029** is touching trigger **1022** can be used to indicate that the trigger has been pulled, which is communicated by changing the output coding of LED **1039**.

Referring to FIGS. **11A**, **11B**, and **11C**, different types and styles of sights may be used on weapons used with the simulation. Additionally, the simulation may display a sight on a weapon that is different from the sight actually on the weapon to allow different types of sights to be tested. In alternative embodiments, the halo around the phantom target can be adjusted to match or include the sight profile of the sight being used on the weapon.

In FIG. **11A**, weapon **1102** includes iron sight **1104**. Iron sight **1104** comprises two components, one proximate to the tip of the barrel of weapon **1102** and one distal to the tip of weapon **1102**, that when aligned indicate the orientation of weapon **1102** to a user of weapon **1102**.

In FIG. **11B**, weapon **1102** includes reflex sight **1106**, also referred to as a red-dot sight, which may be in addition to an iron sight on weapon **1102**. Reflex sight **1106** is mounted on the barrel of weapon **1102** and includes sight profile **1108** shown as a dot. Sight profile **1108** may take any size, shape, color, or geometry and may include additional dots, lines, curves, and shapes of one or more colors. A user can only see the sight profile **1108** when the head of the user is properly positioned with respect to reflex sight **1106**.

In FIG. **11C**, weapon **1102** includes holographic sight **1110**, which may be in addition to an iron sight. Holographic sight **1110** is mounted to the receiver of weapon **1102** and includes sight profile **1112** shown as a combination circle with dashes. Sight profile **1112** may take any size, shape, color, or geometry and may include additional dots, lines, curves, and shapes of one or more colors. A user can only see the sight profile **1112** when the head of the user is properly positioned with respect to holographic sight **1110**.

Referring to FIG. **12**, in simulation environment **1200**, user **1201** wears user device **1202** connected to computer **1204** and holds weapon **1203**. Each of position trackers **1205**, **1206**, and **1215** is connected to computer **1204**. Position tracker **1205** has field of view **1207**. Position tracker **1206** has field of view **1208**. Position tracker **1215** has field of view **1216**. User **1201** is positioned in fields of view **1207**, **1208**, and **1216**.

In one embodiment, weapon **1203** is a simulated weapon. In another embodiment, weapon **1203** is a real weapon with a simulation attachment. In another embodiment, weapon **1203** is a real weapon and user **1201** wears a set of tracking gloves **1210**. In other embodiments, user **1201** wears the set of tracking gloves **1210** and uses the simulated weapon or the real weapon with the simulation attachment.

In a preferred embodiment, each of position trackers **1205**, **1206**, and **1215** is a near infrared CMOS sensor having a refresh rate of 60 Hz. Other suitable position trackers known in the art may be employed. For example, position trackers **1205**, **1206**, and **1215** can be embodiments of base **1028** of FIG. **10E**.

In a preferred embodiment, position trackers **1205**, **1206**, and **1215** capture the vertical and horizontal positions of user device **1202**, weapon **1203** and/or set of tracking gloves **1210**. For example, position tracker **1205** captures the positions and movement of user device **1202** and weapon **1203**, and/or set of tracking gloves **1210** in the y-z plane of coordinate system **1209** and position tracker **1206** captures the positions and movement of user device **1202** and weapon **1203** and/or set of tracking gloves **1210** in the x-z plane of coordinate system **1209**. Further, a horizontal angle and an inclination angle of the weapon are tracked by analyzing image data from position trackers **1205**, **1206**, and **1215**. Since the horizontal angle and the inclination angle are sufficient to describe the aim point of the weapon, the aim point of the weapon is tracked in time.

In a preferred embodiment, computer **1204** generates the set of target data includes a target launch position, a target launch angle, and a target launch velocity of the generated target. Computer **1204** retrieves a set of weapon data based on a desired weapon, including a weapon type e.g., a shotgun, a rifle, or a handgun, a set of weapon dimensions, a weapon caliber or gauge, a shot type including a load, a caliber, a pellet size, and shot mass, a barrel length, a choke type, and a muzzle velocity. Other weapon data may be employed. Computer **1204** further retrieves a set of environmental data that includes temperature, amount of daylight, amount of clouds, altitude, wind velocity, wind direction, precipitation type, precipitation amount, humidity, and barometric pressure for desired environmental conditions. Other types of environmental data may be employed.

Position trackers **1205**, **1206**, and **1215** capture a set of position image data of user device **1202**, weapon **1203** and/or set of tracking gloves **1210** and the set of images is sent to computer **1204**. In different preferred embodiments, the position trackers can include a light detection and ranging (LIDAR) system, a radio beacon system or a real time locating system such as an ultra-sonic ranging system (US-RTLS), ultra-wide band (UWB) or wide-over-narrow band wireless local area network, (WLAN, WiFi) Bluetooth system. Sensors in user device **1202**, weapon **1203** and/or set of tracking gloves **1210** detect a set of orientation data and sends the set of orientation data to computer **1204**. Computer **1204** then calculates a generated target flight path for the generated target based on the set of target data, the set of environment data, and the position and orientation of the user device **1202**. The position and orientation of the user device **1202**, the weapon **1203** and/or set of tracking gloves **1210** are determined from the set of position image data and the set of orientation data. Computer **1204** generates a phantom target and a phantom halo based on the generated target flight path and transmits the phantom target and the phantom halo to user device **1202** for viewing by user **1201**. User **1201** aims weapon **1203** at the phantom target and the phantom halo to attempt to hit the generated target. Computer **1204** detects a trigger pull on weapon **1203** by a trigger sensor and/or a finger sensor and determines a hit or a miss of the generated target based on the timing of the trigger pull, the set of weapon data, the position and orientation of user device **1202**, weapon **1203**, and/or set of tracking gloves **1210**, the phantom target, and the phantom halo.

In an alternative embodiment, the set of gloves is replaced by a thimble worn on the trigger finger of the shooter and a simulation attachment on the weapon. The simulation attachment on the weapon indicates the position and direction of the weapon and the trigger finger thimble is used to indicate when the trigger is pulled. The positions of the simulation attachment and the thimble are tracked by position trackers **1205**, **1206**, and **1215**. When the user provides a “pull” command, such as by vocalizing the word “pull” that is picked up via voice recognition, the system launches a target and arms the trigger finger thimble, so that when sufficient movement of the thimble relative to the weapon is detected, the system will identify the trigger as being pulled and fire the weapon in the simulation. When the thimble is not armed, movement of the thimble with respect to the weapon is not used to identify if the trigger has been pulled.

When weapon **1203** is loaded with live or blank rounds of ammunition, the discharge of the live or blank rounds of ammunition are detected by one or more sensors, such as a microphone, of user device **1202**. When the discharge of a live or blank round of ammunition is detected and weapon **1203** is a multi-shot weapon that includes a receiver that cycles between shots, the simulation displays the cycling of the receiver after the discharge of the live or blank round of ammunition is detected. When weapon **1203** is a revolver, the simulation displays the rotation of the cylinder. When the system detects the discharge of a number of rounds of live or blank ammunition that is equal to the maximum number of rounds that can be stored in weapon **1203**, the system provides an indication to the user, via user device **1202**, that it is time to reload weapon **1203**.

Referring to FIG. **13**, command menu **1300** includes simulation type **1301**, weapon type **1302**, weapon options **1312**, ammunition **1303**, target type **1304**, station select **1305**, phantom toggle **1306**, day/night mode **1307**, environmental conditions **1308**, freeze frame **1309**, instant replay **1310**, and start/end simulation **1311**. Simulation type **1301** enables a user to select different types of simulations. For example, the simulation type includes skeet shooting, trap shooting, sporting clays, and hunting. Weapon type **1302** enables the user to choose from different weapon types and sizes. Weapon types include shot guns, rifles, handguns, airsoft weapons, air guns, and so on. Weapon sizes include the different calibers or gauges for the weapon’s type. The user further enters a weapon sensor location, for example, in the muzzle or on a rail, and whether the user is right or left handed. Weapon options **1312** enables the user to select different weapon options relating the weapon selected via weapon type **1302**. Weapon options **1312** include optional accessories that can be mounted to the weapon, such as tactical lights, laser aiming modules, forward hand grips, telescopic sights, reflex sights, red-dot sights, iron sights, holographic sights, bipods, bayonets, and so on, including iron sight **1104**, reflex sight **1106**, and holographic sight **1110** of FIG. **11**. Weapon options **1312** also include one or more beams to be simulated with the weapon, such as beams **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** of FIG. **19**, which show an approximated trajectory of a shot and are optionally adjusted for one or more of windage and gravity. Ammunition **1303** enables the user to select different types of ammunition for the selected weapon type. Target type **1304** enables the user to select different types of targets for the simulation, including clay targets, birds, rabbits, drones, helicopters, airplanes, and so on. Each type of target includes a target size, a target color, and a target shape. Station select **1305** enables the user to choose different stations to shoot from, for example, in a trap shooting range, a skeet shooting range, a sporting clays course, or a field. The user further selects a number of shot sequences for the station select. In a preferred embodiment, the number of shot sequences in the set of shot sequences is determined by the type of shooting range used and the number of target flight path variations to be generated. For example, the representative number of shot sequences for a skeet shooting range is at least eight, one shot sequence per station. More than one shot per station may be utilized.

In a preferred embodiment, each simulation type **1301** is associated with one or more animated virtual reality shooting scenarios. As one example, when simulation type **1301** is hunting, the animated virtual reality shooting scenario includes a scenario for learning how to shoot over dogs. The shooting over dogs scenario displays an animated dog going on point as a part of the hunt in the simulation so that the user can learn to shoot the target and avoid shooting the dog.

Phantom toggle **1306** allows a user to select whether to display a phantom target and a phantom halo during the simulation. The user further selects a phantom color, a phantom brightness level, and a phantom transparency level.

In certain embodiments, phantom toggle **1306** includes additional help options that adjust the amount of "help" given to the user based on how well the user is doing, such as with aim sensitive help and with dynamic help. When aim sensitive help is selected, aim sensitive help is provided that adjusts one or more of the transparency, color, and size of one or more beams from weapon options **1312**, phantom targets, and halos based on how close the aim point of the weapon is to a phantom target. With aim sensitive help, the beams, phantom targets, and halos are displayed with less transparency, brighter colors, and larger sizes the further off-target the aim point of the weapon is. Conversely, the beams, phantom targets, and halos are displayed with more transparency, darker colors, and smaller sizes when the weapon is closer to being aimed on-target.

When dynamic help is selected, the amount of help provided to the user for each shot is adjusted dynamically based on how well the user is performing with respect to one or more of each shot, each round, and the simulation overall. When more help is provided, beams, phantom targets, and halos are given more conspicuous characteristics and, conversely, when less help is provided, the beams, phantom targets, and halos are shown more passively or not at all. The amount of help is dynamic in that when the previous one or more shots hit the target, a lesser amount of help is provided on the next one or more shots and, conversely, when the previous one or more shots did not hit the target, more help is provided for the subsequent one or more shots. As the user's skill level advances, the brightness of the phantom target can diminish until it is transparent—the user has learned correct lead by rote repetition and no longer needs the phantom as a visual aide.

Day/night mode **1307** enables the user to switch the environment between daytime and nighttime. Environmental conditions **1308** enables the user to select different simulation environmental conditions including temperature, amount of daylight, amount of clouds, altitude, wind velocity, wind direction, precipitation type, precipitation amount, humidity, and barometric pressure. Other types of environmental data may be employed. Freeze frame **1309** allows the user to "pause" the simulation. Instant replay **1310** enables the user replay the last shot sequence including the shot attempt by the user. Start/end simulation **1311** enables the user to start or end the simulation. In one embodiment, selection of **1301**, **1302**, **1312**, **1303**, **1304**, **1305**, **1306**, **1307**, **1308**, **1309**, **1310**, and **1311** is accomplished via voice controls. In another embodiment, selection of **1301**, **1302**, **1312**, **1303**, **1304**, **1305**, **1306**, **1307**, **1308**, **1309**, **1310**, and **1311** is accomplished via a set of controls on a simulated weapon as previously described.

Referring to FIG. **14**, runtime method **1400** for a target simulation will be described. At step **1401**, a baseline position and orientation of the user device and a baseline position and orientation of the weapon are set. In this step, the computer retrieves a set of position image data from a set of position trackers, a set of orientation data from a set of sensors in the user device, the weapon and/or a set of gloves and saves the current position and orientation of the user device and the weapon into memory. Based on the simulation choice, the virtual position of the launcher relative to the position and orientation of the user device is also set. If the user device is oriented toward the virtual location of the launcher, a virtual image of the launcher will be displayed.

At step **1402**, a set of target flight data, a set of environment data, and a set of weapon data are determined from a set of environment sensors and a database.

In a preferred embodiment, the set of weapon data is downloaded and saved into the database based on the type of weapon that is in use and the weapon options selected to be used with the weapon. In a preferred embodiment, the set of weapon data includes a weapon type e.g., a shotgun, a rifle, or a handgun, a weapon caliber or gauge, a shot type including a load, a caliber, a pellet size, and shot mass, a barrel length, a choke type, and a muzzle velocity. Other weapon data may be employed. In a preferred embodiment, the weapon options include one or more accessories and beams, including iron sight **1104**, reflex sight **1106**, and holographic sight **1110** of FIG. **11**, and including beams **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** of FIG. **19**.

In a preferred embodiment, the set of environment data is retrieved from the database and includes a wind velocity, an air temperature, an altitude, a relative air humidity, and an outdoor illuminance. Other types of environmental data may be employed.

In a preferred embodiment, the set of target flight data is retrieved from the database based on the type of target in use. In a preferred embodiment, the set of target flight data includes a launch angle of the target, an initial velocity of the target, a mass of the target, a target flight time, a drag force, a lift force, a shape of the target, a color of the target, and a target brightness level. In alternative embodiments, the target is a self-propelled flying object, such as a bird or drone, which traverses the simulated environment at a constant air speed.

At step **1403**, the target and environment are generated from the set of target flight data and the set of environmental data. At step **1404**, a virtual weapon image that includes the selected weapon options is generated and saved in memory. In this step, images and the set of weapon data of the selected weapon and the selected weapon options for the simulation is retrieved from the database. At step **1405**, the target is launched and the target and environment are displayed in the user device. In a preferred embodiment, a marksman will initiate the launch with a voice command such as "pull."

At step **1406**, a view of the user device with respect to a virtual target launched is determined, as will be further described below.

At step **1407**, a phantom target and a phantom halo are generated based on a target path and the position and orientation of the user, as will be further described below. The target path is determined from the target position the target velocity using Eqs. 1-4. At step **1408**, the generated phantom target and the generated phantom halo are sent to the user device and displayed, if the user device is oriented toward the target path. The generated weapon is displayed with the selected weapon options if the user device is oriented toward the position of the virtual weapon or the selected weapon options.

At step **1409**, whether the trigger on the weapon has been pulled is determined from a set of weapon sensors and/or a set of glove sensors. In one preferred embodiment with the trigger sensor of FIG. **10**K, the determination of whether the trigger is pulled is made responsive to detecting one of the codes that correspond to the state of trigger sensor **1014** from the output of LED **1039** by a sensor, such as one of position trackers **1205**, **1206**, and **1215** of FIG. **12**.

If the trigger has not been pulled, then method **1400** returns to step **1405**. If the trigger has been pulled, then method **1400** proceeds to step **1410**.

At step **1410**, a shot string is determined. In this step, a set of position trackers capture a set of weapon position images. In this step, a set of weapon position data is received from a set of weapon sensors. The shot string is calculated by:

$$A_{shot\ string}=\pi R_{string}^{2} \qquad \text{Eq. 7}$$

$$R_{string}=R_{initial}+v_{spread}t \qquad \text{Eq. 8}$$

where $A_{shot\ string}$ is the area of the shot string, $R_{string}$ is the radius of the shot string, $R_{initial}$ is the radius of the shot as it leaves the weapon, $v_{spread}$ is the rate at which the shot spreads, and t is the time it takes for the shot to travel from the weapon to the target. An aim point of the weapon is determined from the set of weapon position images and the set of weapon position data. A shot string position is determined from the position of the weapon at the time of firing and the area of the shot string.

At step **1411**, if the user device is oriented along the muzzle of the weapon, the shot string is displayed on the user device at the shot string position. Separately, a gunshot sound is played and weapon action is displayed. Weapon action is based on the type of the weapon and includes the display of mechanical movements of the weapon, such as the movement of a semi-automatic receiver and the strike of a hammer of the weapon.

At step **1412**, whether the phantom target has been "hit" is determined. The simulation system determines the position of the shot string, as previously described. The simulation system compares the position of the shot string to the position of the phantom target. The shot string is optionally displayed as an elongated cloud of any color that moves from the tip of the user device towards the shot location, which, ideally, is the target and provides visual feedback to the user of the path taken by the shot string. When the elongated cloud is close to the user device shortly after firing, the diameter of the elongated cloud is about one inch. When the elongated cloud is close to the target, about twenty five yards away from the user, the diameter of the cloud has expanded linearly to about twenty five inches.

If the position of the shot string overlaps the position of the phantom target, then the phantom target is "hit." If the position of the shot string does not overlap the phantom target, then the phantom target is "missed."

If the phantom target is hit and the user device is oriented toward the hit location, then method **1400** displays an animation of the target being destroyed on the user device at the appropriate coordinates and plays a sound of the target being destroyed at step **1413**. At step **1414**, the simulation system records a "hit" in the database.

If a "miss" is determined at step **1412**, then method **1400** proceeds to step **1415**. At step **1415**, whether the phantom halo is hit is determined. In this step, whether the shot string overlaps an area of the phantom halo by a percentage greater than or equal to a predetermined percentage is determined. For example, the predetermined percentage is 50%. Whether the shot string overlaps at least 50% of the area of the phantom halo is determined. Any predetermined percentage may be employed.

If the position of the shot string overlaps the phantom halo by a percentage greater than or equal to the predetermined percentage, then a "hit" is determined and method **1400** proceeds to step **1413**, where the target hit is displayed.

If at step **1415**, the shot string does not overlap the area of the phantom halo by a percentage greater than or equal to the predetermined percentage, then a "miss" is determined and the simulation system records a "miss" in the database at step **1416**.

The number of targets that are hit, the number of targets that are missed, the location of each shot with respect to the phantom target, and the location of the shot string with respect to the trajectory of the target are generated to form tracking data. The tracking data is analyzed to provide insights and suggested adjustments for how to improve the user's performance with the simulation system.

At step **1417**, whether an end command has been received to complete the simulation is determined. If not received, then method **1400** advances to the next target at step **1418**.

If an end command has been received and the simulation is complete, then a trend of shot attempts is analyzed at step **1419** by retrieving a number of "hits" in the set of shot sequences and a number of "misses" in the set of shot sequences from the database. In this step, a shot improvement is determined by evaluating the number of hits in the set of shot sequences and the number of misses in the set of shot sequences. Method **1400** ends at step **1420**.

Referring to FIG. **15**A, user **1500** wears user device **1501** and holds weapon **1502** in simulation environment **1503**. Simulation environment **1503** is a virtual sphere spanning 360° in all directions surrounding user **1500**. User device **1501** has field of view **1504**. Field of view **1504** is a cone that has angular range a and spans an arcuate portion (in two dimensions) or a sectorial portion (in three dimensions) of simulation environment **1503**. User device orientation vector **1505** bisects field of view **1504** and angular range a into equal angles **13**. Weapon **1502** has weapon orientation vector **1506**. Each of user device orientation vector **1505** and weapon orientation vector **1506** is independent of each other. The positions of user device **1501**, weapon **1502**, user device orientation vector **1505**, and weapon orientation vector have Cartesian x,y,z coordinates. Simulation environment **1503** has spherical coordinates. Simulation environment **1503** includes virtual target launcher **1507**, virtual target **1508**, phantom target **1509** and phantom halo **1510**. As can be seen, weapon **1502**, virtual target **1508**, phantom target **1509**, and phantom halo **1510** are in field of view **1504** of user device **1501**. Virtual target launcher **1507** is not in field of view **1504** of user device **1501**. Weapon **1502**, virtual target **1508**, phantom target **1509** and phantom halo **1510** will be displayed in user device **1501** and virtual target launcher **1507** will not be displayed in user device **1501**.

In a preferred embodiment, angular range a is approximately 110° and each of equal angles β is approximately 55°. Other angular ranges may be employed.

Referring to FIG. **15**B, step **1406** will be further described as method **1511** for determining a view for a user device with respect to a position and an orientation of the user device and the weapon. Method **1511** begins at step **1512**. At step **1513**, a set of current position image data is retrieved from a set of position trackers and a set of current position and orientation data is retrieved from the user device and the weapon and/or set of gloves. At step **1514**, a set of motion detection data is received from a set of sensors in the user device to determine movement of the user device and from the weapon and/or set of gloves to determine movement of the weapon. At step **1515**, the set of motion detection data and the position of the user device and the weapon and/or set of gloves are combined to determine an x, y, z position of the user device and the weapon and a roll, pitch, and yaw or detection of the user device and the weapon. The current x, y, z orientation vectors for the user device and the weapon are calculated from the difference between the baseline position and orientation and the current position and orientation of the user device and the weapon. The set of motion detection data received is the roll, pitch, and yaw orientation movement of the head of the user and the weapon. At step **1516**, the current positions and orientation vectors of the user device and the weapon are mapped to the simulation environment. In a preferred embodiment, the current positions and orientation vectors are a 1:1 ratio to the positions and orientation vectors in the simulation environment. For example, for every inch and/or degree that the user device and/or the weapon moves and/or rotates, the view of the user and/or the simulated weapon moves one inch and/or rotates one degree in the simulated environment. Other ratios may be employed. The mapping determines the display view, as will be further described below. At step **1517**, the simulation environment that would be visible to the user based on the orientation of the user device and the weapon is displayed. Method **1500** ends at step **1518**.

Referring to FIG. **15**C, step **1516** will be further described as method **1519** for mapping the position and orientation of the user device and the weapon to the simulation environment for determining a display field of view. At step **1520**, the x, y, z positions of the weapon and the weapon orientation vector are retrieved. At step **1521**, the x, y, z positions of the weapon and the weapon orientation vector are converted to spherical coordinates (r, θ, φ) using:

$$r = \sqrt{x^2 + y^2 + z^2} \qquad \text{Eq. 9}$$

$$\theta = \arccos\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right) \qquad \text{Eq. 10}$$

$$\varphi = \arctan\left(\frac{y}{x}\right) \qquad \text{Eq. 11}$$

At step **1522**, the weapon is rendered in the simulation environment at the spherical position and orientation vector. At step **1523**, the x, y, z positions of the user device and the user device orientation vector are retrieved. At step **1524**, the x, y, z positions of the user device and the user device orientation vector are converted to spherical coordinates (r, θ, φ) using Eqs. 9, 10, and 11. At step **1525**, the display field of view is determined from the spherical orientation vector coordinates. In this step, equal angles β are measured from the user device orientation vector to define the display field of view as a sector of the simulation environment in spherical coordinates. At step **1526**, the field of view sector is compared to the simulation environment to determine a portion of the simulation environment within the field of view sector. At step **1527**, the portion of the simulation environment within the field of view sector is displayed on the user device as the display field of view. At step **1528**, the spherical position and orientation vector of the weapon is compared to the field of view sector to determine whether the weapon is in the display field of view. If the weapon is not in the display field of view, then method **1519** returns to step **1520**. If the weapon is in the display field of view, then at step **1529**, the weapon is displayed on the user device at the spherical position and orientation. Method **1519** then returns to step **1520**.

Referring to FIG. **16**A, step **1407** will be further described as method **1600** for generating a phantom target and a phantom halo. At step **1601**, a phantom path is extrapolated. Referring to FIGS. **16**B and **16**C, target **1606** is launched from launch point **1611** and moves along target path **1607** at position $P_1$. Phantom target **1608** moves along phantom path **1609** ahead of target **1606** at position $P_2$. Position $P_2$ is lead distance **1610** and drop distance **1616** from position $P_1$. Phantom path **1609** varies as target **1606** and target path **1607** varies, thereby varying lead distance **1610**. Marksman **1612** is positioned at distance **1613** from launch point **1611**. Marksman **1612** aims at phantom target **1608** and shoots along shot path **1614** to intercept target **1606**. Target path **1607** is extrapolated over time using the set of target flight data. Target path **1607** is calculated using Eqs. 1-4.

Referring to FIG. **16**B, lead distance **1610** is calculated using target path **1607**, the relative marksman location, and the set of weapon data.

$$D_{P_2} \approx \frac{D_{S_2}\tan\varphi_2}{\cos\theta\tan\varphi_2 - \sin\theta} \qquad \text{Eq. 12}$$

$$D_{P_1} \approx \frac{D_{S_1}\tan\varphi_1}{\cos\theta\tan\varphi_1 - \sin\theta} \qquad \text{Eq. 13}$$

where $D_{P_2}$ is the distance of phantom target **1608** at position $P_2$ from launch point **1611**, $D_{S_2}$ is the distance from marksman **1612** to phantom target **1608** along shot path **1614**, $\varphi_2$ is the angle between shot path **1614** and distance **1613**, θ is the launch angle between target path **1607** and distance **1613**, $D_{P_1}$ is the distance of target **1606** at position $P_1$ from launch point **1611**, $D_{S_1}$ is the distance from marksman **1612** to target **1606** along shot path **1615**, $\varphi_1$ is the angle between shot path **1615** and distance **1613**, θ is the launch angle between target path **1607** and distance **1613**. Lead distance **1610** is:

$$D_{Lead} \approx D_{P_2} - D_{P_1} \qquad \text{Eq. 14}$$

$$D_{Lead} \approx \frac{A\Delta D_S\tan C\Delta\varphi}{\cos B\theta\tan C\Delta\varphi - \sin B\theta} \qquad \text{Eq. 15}$$

where $D_{Lead}$ is lead distance **1610**, $\Delta D_S$ is the difference between the distances of shot paths **1614** and **1615**, Δφ is the difference between angles $\varphi_2$ and $\varphi_1$, θ is the launch angle between target path **1607** and distance **1613**, A is a variable multiplier for shot size, gauge, and shot mass, B is a variable multiplier for θ including vibration of a target thrower and a misaligned target in the target thrower, and C is a variable multiplier for drag, lift, and wind.

For example, the approximate times it takes for a 7½ shot size shell with an initial muzzle velocity of approximately 1,225 feet per second to travel various distances is shown in Table 1.

TABLE 1

Time and Distances of a 7 ½ Shot

| Distance from barrel | Time (seconds) |
|---|---|
| 30 feet | 0.027 |
| 60 feet | 0.060 |
| 90 feet | 0.097 |
| 120 feet | 0.139 |
| 150 feet | 0.186 |
| 180 feet | 0.238 |

Various lead distances between target **1606** and phantom target **1608** for target **1606** having an initial velocity of approximately 30 mph is shown in Table 2.

TABLE 2

| Lead Distances with a 7 ½ Shot on a Full Crossing Shot | |
|---|---|
| Distance from Barrel | Lead Distance |
| 60 feet | 2.64 feet |
| 90 feet | 4.62 feet |
| 120 feet | 5.56 feet |

Referring to FIG. **16**C, phantom path **1609** is offset from target path **1607** by drop distance **1616** to simulate and compensate for the average exterior ballistics drop of a shot.

The "drop of a shot" is the effect of gravity on the shot during the distance traveled by the shot. The shot trajectory has a near parabolic shape. Due to the near parabolic shape of the shot trajectory, the line of sight or horizontal sighting plane will cross the shot trajectory at two points called the near zero and far zero in the case where the shot has a trajectory with an initial angle inclined upward with respect to the sighting device horizontal plane, thereby causing a portion of the shot trajectory to appear to "rise" above the horizontal sighting plane. The distance at which the weapon is zeroed, and the vertical distance between the sighting device axis and barrel bore axis, determine the amount of the "rise" in both the X and Y axes, i.e., how far above the horizontal sighting plane the rise goes, and over what distance it lasts.

Drop distance **1616** is calculated by:

$$D_{Drop} \approx v_t \tau \ln\left[\cosh\left(\frac{t_{impact}}{\tau}\right)\right] \qquad \text{Eq. 16}$$

where $D_{Drop}$ is drop distance **1616**, $t_{impact}$ is the time required for a shot string fired by marksman **1612** to impact phantom target **1608**. $T_{impact}$ is determined by a set of lookup tables having various impact times at predetermined distances for various shot strings.

$$v_t = \sqrt{\frac{2mg}{C\rho A}}\text{, and} \qquad \text{Eq. 17}$$

$$\tau = \frac{v_t}{g} \qquad \text{Eq. 18}$$

where $v_t$ is the terminal velocity of target **1606**, m is the mass of target **1606**, g is the vertical acceleration due to gravity, C is the drag coefficient for target **1606**, ρ is the density of the air, A is the planform area of target **1606**, and τ is the characteristic time.

Referring to FIGS. **16**A and **16**C, at step **1602**, phantom halo **1617** is determined. Phantom halo **1617** is a simulation of a shot string at a distance of the phantom target from the position of the marksman. In a preferred embodiment, an area of phantom halo **1617** is determined from the set of weapon data and calculated by:

$$A_{shot\ string}=\pi R_{string}^{2} \qquad \text{Eq. 19}$$

$$R_{string}=\gamma R_{initial}+v_{spread}t \qquad \text{Eq. 20}$$

$$A_{phantom\ halo}=A_{shot\ string} \qquad \text{Eq. 21}$$

where $A_{shot\ string}$ is the area of the shot string, $R_{string}$ is the radius of the shot string, $R_{initial}$ is the radius of the shot as it leaves the weapon, γ is a variable multiplier for any choke applied to the weapon as determined from the set of weapon data, $v_{spread}$ is the rate at which the shot spreads, and t is the time it takes for the shot to travel from the weapon to the target. $A_{phantom\ halo}$ is the area of phantom halo **1617**.

In one embodiment, the area of phantom halo **1617** varies as the amount of choke applied to the weapon varies.

Returning to FIG. **16**A, at step **1603**, a relative contrast value between the target and a background surrounding the target is analyzed by calculating the difference between a grayscale brightness of the target and an average brightness of the background surrounding the target and the difference between an average color of the target and a color of the background surrounding the target based on a desired day/night setting and a set of desired environmental conditions.

At step **1604**, a color and a contrast level of a phantom target is determined. In a preferred embodiment, the phantom target includes a set of pixels set at a predetermined contrast level. The predetermined contrast level is determined by the difference of the color between the phantom target and the target and the difference of the brightness between the phantom target and the target. In this embodiment, the predetermined contrast level is a range from a fully opaque image to a fully transparent image with respect to the image of the target and the image of the background.

In a preferred embodiment, the set of pixels is set at a predetermined color. For example, blaze orange has a pixel equivalent setting of R 232, G 110, B0.

At step **1605**, a color and contrast level of the phantom halo is determined. In a preferred embodiment, the phantom halo includes a set of pixels set at a predetermined contrast level. The predetermined contrast level is determined by the difference of the color between the phantom halo and the target and the difference of the brightness between the phantom halo and the target. In this embodiment, the predetermined contrast level is a range from a fully opaque image to a fully transparent image with respect to the image of the target and the image of the background.

In a preferred embodiment, the set of pixels is set at a predetermined color. For example, black has a pixel equivalent setting of R 0, G 0, B 0. Any color may be employed.

Referring to FIG. **17**, a view of a simulation from the perspective of a marksman wearing a user device, such as user device **900**, is shown. Through display **1700**, background environment **1701** and target **1702** are viewed. Phantom target **1703** is projected at a lead distance and at a drop distance from target **1702**. Phantom halo **1704** is projected surrounding phantom target **1703**. Marksman **1705** aims weapon **1706** at phantom target **1703**.

In a preferred embodiment, shot center **1707** appears on display **1700** when marksman **1705** pulls a trigger of weapon **1706**. Shot string **1708** surrounds shot center **1707**. In a preferred embodiment, shot string **1708** is a simulation of a shot pellet spread fired from weapon **1706**.

In an alternative embodiment, shot center **1707** is not displayed and shot string **1708** is displayed traveling from the barrel of weapon **1706** along a trajectory. The trajectory, size, positioning, and flight path of shot string **1708** are based on the location and orientation of weapon **1706** and are based on the type of ammunition selected for the simulation. When shot string **1708** intersects target **1702**, target **1702** is destroyed. An image of one or more of target **1702**, phantom target **1703**, and phantom halo **1704** can be paused and displayed at their respective locations when the trigger of weapon **1706** was pulled while the target **1702** continues to move along its trajectory and shot string **1708** continues to move along its trajectory.

Referring to FIG. **18**, an isometric view shows an input device configured to be mounted on a rail system of a weapon. Input device **1802** is to be mounted to rail interface system **1804** of weapon **1806**.

Weapon **1806** includes barrel **1808**, sight **1846**, frame **1842**, member **1844**, cylinder **1810**, hammer **1812**, handle **1814**, trigger **1816**, trigger guard **1818**, trigger sensor **1860**, and rail interface system **1804**. Weapon **1806** is a double-action revolver wherein operation of trigger **1816** cocks and releases hammer **1812**. Rotation of cylinder **1810** is linked to movement of hammer **1812** and trigger **1816**.

Barrel **1808** is connected to frame **1842** and member **1844**. Member **1844** supports barrel **1808** and is the portion of weapon **1806** to which rail interface system **1804** is mounted. In alternative embodiments, rail interface system **1804** is mounted to other parts or portions of weapon **1806**, such as being directly mounted to barrel **1808**.

Frame **1842** connects barrel **1808**, member **1844**, trigger guard **1818**, trigger **1816**, handle **1814**, hammer **1812**, and cylinder **1810**. Frame **1842** and handle **1814** house the mechanisms that create action between trigger **1816**, cylinder **1810**, and hammer **1812**.

Rail interface system **1804** is a rail system for interfacing additional accessories to weapon **1806**, such as tactical lights, laser aiming modules, forward hand grips, telescopic sights, reflex sights, red-dot sights, iron sights, holographic sights, bipods, bayonets, and so on. Rail interface system **1804** may conform to one or more standard rail systems, such as the Weaver rail mount, the Picatinny rail (also known as MIL-STD-1913), and the NATO Accessory Rail. Rail interface system **1804** includes screws **1820**, base **1822**, member **1848**, and rail **1826**.

Screws **1820** fit and secure rail interface system **1804** to member **1844** of weapon **1806**. Screws **1820** compress base **1822** and member **1848** of rail interface system **1804** against member **1844** of weapon **1806**.

Rail **1826** includes ridges **1824**, slots **1850**, and angled surfaces **1856**. The longitudinal axis of rail **1826** is substantially parallel to the longitudinal axis of barrel **1808**. Slots **1850** are the lateral voids or slots between ridges **1824** that are perpendicular to both the longitudinal axis of rail **1826** and the longitudinal axis of barrel **1808**. Rail **1826** also includes a longitudinal slot **1852** that runs along the length of rail **1826** and is substantially parallel to the longitudinal axis of barrel **1808**. Angled surfaces **1856** of rail **1826** allow for the precise mounting of accessories to rail **1826**.

Input device **1802** includes rail mount **1828**, first portion **1830**, second portion **1832**, battery **1834**, processor **1836**, LEDs **1854**, button **1838**, and screws **1840**. Input device **1802** slides longitudinally onto rail **1826** of rail interface system **1804** of weapon **1806** and its position is secured by screws **1840**. The front surface of input device **1802** is flush with a ridge **1824** of rail **1826** so that the location and orientation of input device **1802** with respect to barrel **1808** is known and the firing of weapon **1806** can be accurately simulated.

Rail mount **1828** of input device **1802** includes first portion **1830**, second portion **1832**, and angled surfaces **1858**. Angled surfaces **1858** of rail mount **1828** correspond to angled surfaces **1856** of rail **1826** to allow for a tight and precise fitment of input device **1802** to rail interface system **1804**. Screws **1840** of input device **1802** compress first portion **1830** and second portion **1832** against rail **1826** of rail interface system **1804** with sufficient force to prevent changes in the positioning or orientation of input device **1802** with respect to weapon **1806** as weapon **1806** is being used.

Battery **1834** of input device **1802** is connected to and powers the electrical components within input device **1802** including processor **1836** and LEDs **1854**. Processor **1836** controls LEDs **1854**. In additional embodiments, input device **1802** includes one or more sensors, accelerometers, gyroscopes, compasses, and communication interfaces. The sensor data from the sensors, accelerometers, gyroscopes, and compasses is sent from input device **1802** to a computer, such as computer **801** of FIG. **8**, via the communication interface. Input device **1802** includes button **1838** to turn on, turn off, and initiate the pairing of input device **1802**.

LEDs **1854** emit light that is sensed by one or more cameras or sensors, from which the locations and orientations of input device **1802** and weapon **1806** can be determined. The locations and orientations are determined from the transmission characteristics of the light emitted from LEDs **1854**, and the placement characteristics of LEDs **1854**.

Trigger sensor **1860** detects the pull of trigger **1816** when trigger **1816** presses onto pressure switch **1862** with sufficient movement and force. When hammer **1812** is fully cocked, trigger **1816** rests just above pressure switch **1862** so that any additional movement will release hammer **1812** and will activate pressure switch **1862**. One or more wires **1864** electrically connect trigger sensor **1860** to processor **1836** so that processor **1836** can determine when trigger **1816** is pulled when blanks or live rounds are not used. Trigger sensor **1860** is contoured to fit onto the back end of trigger guard **1818** behind trigger **1816** and trigger sensor **1860** is secured onto trigger guard **1818** by screws **1866**.

In a two wire embodiment, current from processor **1836** through a first wire of wires **1864** to trigger sensor **1860** is returned through a second wire of wires **1864**. In an alternative embodiment, wire **1864** is a single wire and a return path for the current from processor **1836** through wire **1864** to trigger sensor **1860** is created by electrically connecting trigger sensor **1860** to trigger guard **1818**, which is electrically connected to frame **1842**, rail interface system **1804**, input device **1802**, and processor **1836**.

In alternative embodiments, weapon **1806** is loaded with one or more live or blank rounds of ammunition that discharge through barrel **1808** after hammer **1812** is cocked and trigger **1816** is then pulled. Weapon **1806** does not include sensors for measuring the precise location of cylinder **1810**, hammer **1812**, and trigger **1816**. During simulation and after a round has been fired, the simulation shows the movement of cylinder **1810**, hammer **1812**, and trigger **1816** to prepare for a subsequent shot, which may or may not correspond to the actual state of weapon **1806**.

In alternative embodiments, the computer that receives data from one or more sensors from input device **1802** derives the state of weapon **1806** from data received from one or more sensors and updates the display of weapon **1806** to show the state and/or firing of weapon **1806** in the simulation. For example, data from sensors, accelerometers, and gyroscopes within input device **1802** can indicate the click for when hammer **1812** is fully cocked, indicate the click for when cocked hammer **1812** is released and the chamber in cylinder **1810** is unloaded, and indicate the discharge of a live or blank round of ammunition. Data from a microphone, such as microphone **919** of FIG. **9**, can be used to similarly detect one or more states of weapon **1806** and the discharge of live or blank rounds of ammunition. When cylinder **1810** is configured to hold six rounds of ammunition and six shots have been fired successively, the simulation may indicate to the user that it is time to reload weapon **1806**. The simulation displays changes to the state of weapon **1806** as mechanical movements on weapon **1806** and displays the firing of weapon **1806** with associated mechanical movements of weapon **1806**.

Referring to FIG. **19**, a simulation view shows "beams" being projected from a barrel of a weapon. Weapon **1902** includes barrel **1904** with one or more simulated beams **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** that emanate from the tip of barrel **1904**. Beams **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** follow and are adjusted with the movement of barrel **1904** of weapon **1902**.

The beam of a laser in a real-world environment is generally not visible to an observer unless reflected from an object in the environment. In a virtual reality environment, however, a simulated laser beam can be calculated and displayed. Simulated beams can be displayed with any level of transparency and can demonstrate characteristics that are not possible in the real-world. For example, the simulated beam can be displayed as visible, and with a dispersion pattern or in a curved path.

As an example, beam **1906** is a beam of a simulated laser and is displayed as visible along its entire length. The beam is displayed as a line or as a tight cylinder. Beam **1906** emanates from point **1908** that is central to and aligned with barrel **1904**. Beam **1906** indicates the precise direction that barrel **1904** is pointed. Beam **1906** extends to point **1910** that is on the central longitudinal axis of barrel **1904** and is a fixed distance away from barrel **1904**.

In another embodiment, beam **1912** is displayed as a conical frustum starting from barrel **1904** and extending to circular cross section **1914**. The increase of the radius of beam **1912** from the radius of barrel **1904** to circular cross section **1914** approximates the increasing spread of a shot as it travels away from barrel **1904**. Circular cross section **1914** is displayed at the termination plane of beam **1912** and provides an indication of the maximum distance that a shot on target can reliably register as a hit.

Beams **1906** and **1912** maintain their respective shapes and orientation with respect to barrel **1904** as it is moved. Pulling the trigger of weapon **1902** while beam **1906** or beam **1912** is aligned with a phantom target or phantom target, such as phantom target **1703** or phantom halo **1704** of FIG. **17**, registers as a hit to the simulated target.

Beam **1916** is displayed as a curved line that extends from point **1908** at barrel **1904**. Beam **1916** is tangential to beam **1906** at point **1908** and ends at point **1918**.

In another embodiment, beams **1916** and **1920** are curved to approximate the drop of a shot due to gravity. The curvature of beams **1916** and **1920** is calculated based on the amount of simulated force due to gravity **1940** and the angle of barrel **1904** when the trigger is pulled. Pulling the trigger of weapon **1902** while beam **1916** or beam **1920** is aligned with a phantom target or phantom target, such as phantom target **1703** or phantom halo **1704**, registers as a hit to the simulated target.

In another embodiment, beam **1920** is displayed as a curved conical frustum beginning at barrel **1904** and ending at circular cross section **1922**. Beam **1920** is curved to approximate the drop of a shot due to gravity and has a radius that increases along the length from barrel **1904** to circular cross section **1922** to simulate the spread of a shot.

In another embodiment, beams **1924** and **1928** are curved to approximate changes in shot trajectory due to windage **1942**. The amount of curvature of beams **1924** and **1928** is based on the amount of simulated force due to windage **1942** and the angle of barrel **1904** with respect to windage **1942**. The simulation of windage may approximate changes in wind velocity and direction, such as found in a gusty wind. In this embodiment, the simulation is calculated so that the beam moves with respect to the longitudinal axis of the barrel to indicate how the shot would be affected by windy conditions. When windage **1942**, is simulated, pulling the trigger of weapon **1902** while beam **1924** or beam **1928** is aligned with a phantom target or phantom target, such as phantom target **1703** or phantom halo **1704**, registers as a hit to the simulated target.

Beam **1924** is displayed as a curved line that extends from point **1908** at the tip of barrel **1904**. Beam **1924** is tangential to beam **1906** at point **1908** and ends at point **1926**.

Beam **1928** is displayed as a curved conical frustum starting at the circular tip of barrel **1904** and ending at circular cross section **1930**. Beam **1928** is curved to approximate the drop of a shot due to gravity and has a radius that increases along the length from the tip of barrel **1904** to circular cross section **1930** to simulate the spread of a shot.

Beams **1932** and **1936** are curved to approximate changes in shot trajectory due to both gravity **1940** and windage **1942**. The curvature of beams **1932** and **1936** is based on the amount of gravity **1940** and windage **1942** and based on the angle of barrel **1904** with respect to gravity **1940** and windage **1942**. When both gravity **1940** and windage **1942** are simulated, pulling the trigger of weapon **1902** while beam **1932** or beam **1936** is aligned with a phantom target or phantom target, such as phantom target **1703** or phantom halo **1704**, registers as a hit to the simulated target.

Beam **1932** is displayed as a curved line that extends from point **1908** at the tip of barrel **1904**. Beam **1932** is tangential to beam **1906** at point **1908** and ends at point **1934**.

Beam **1936** is formed as a curved conical frustum starting at 'barrel **1904** and ending at circular cross section **1938**. Beam **1936** is curved to approximate the changes to the trajectory of a shot due to both gravity **1940** and windage **1942** and the radius of beam **1936** increases along the length from the tip of barrel **1904** to circular cross section **1938** to approximate the spread of a shot.

In one preferred embodiment, a video capture system, such as Microsoft HoloLens, in combination with prerecorded videos of the shooting field and multiple actual clay target launches are used to create a virtual model of the surroundings and trajectories of clay targets for display and use in the system.

The locations and orientations of the launchers are derived based on the known location of the camera with respect to the field, the known size and weight of the targets, and the known physical constraints of the environment (e.g., gravity). After deriving the launcher locations and orientations, virtual or holographic launchers can be placed at similar positions in virtual reality or augmented reality simulations of the fields, as will be further described.

Referring to FIG. **20**A, five stand field **2000** includes five shooter locations with six launchers. Five stand field **2000** includes launchers **2002**, **2004**, **2006**, **2008**, **2010**, and **2012** that launch targets onto paths **2014**, **2016**, **2018**, **2020**, **2022**, and **2024**, respectively. Cameras **2026** and **2028** are positioned to view all towers and launchers. A video of the high tower and the low tower shot with a normal lens at 60 fps from station **4** can be processed and used to show correct trajectory and correct lead from any point of view at any station. The trajectory of the target is the same, being viewed from different angles.

Referring to FIG. **20**B, sporting clays field **2050** includes three shooter locations that each have four launcher locations. The shooter and launch locations in sporting clays are unique to the venue. Sporting clays field **2050** includes four launchers labeled T1 through T**4** for each of the three shooter positions S1, S2, and S3. Drones **2052** and **2054** include cameras that record the paths of the clay targets. Drones **2052** and **2054** are capable of sensing and recording their respective GPS locations while in flight. The same process can be used to record the flight trajectories of birds, drones, helicopters and airplanes for purposes of simulating correct spatial lead.

Referring to FIG. 21A, an alternate embodiment of the simulation system will be described. System **2100** includes system computer **2101**. System computer **2101** includes programs **2102**, **2103**, and **2120**. Program **2102** is software capable of operating the Microsoft HoloLens system, as will be further described. Program **2103** includes instructions to operate a unity 3D simulation of the system, as will be further described. Program **2120** is simulation software capable of communicating with programs **2102** and **2103**. In a preferred embodiment, program **2120** is the Unity 3D simulation engine, as will be further described.

Head set **2104** is connected to system computer **2101**. Head set **2104** includes an augmented reality display or a virtual reality display, as will be further described. System computer **2101** is further connected to camera **2105** and camera **2106**. The cameras are used in registering fixed objects such as launchers and towers and in creating trajectory models of moving objects such as clay targets in the Microsoft HoloLens system, as will be further described.

System computer **2101** is attached to wireless interface **2108**. In a preferred embodiment, wireless interface **2108** is a Bluetooth interface. System computer is also attached to dongle **2109**. In a preferred embodiment, dongle **2109** is compatible with the Vive Tracker, available from HTC.

System **2100** further includes trigger unit **2114**. Trigger unit **2114**, in a preferred embodiment, is attached to the weapon and includes sensors to detect trigger pulls. The sensors communicate signals through an onboard wireless interface to wireless interface **2108**.

System **2100** further includes electronic cartridge **2112** and barrel bore arbor mounted sensor **2110**. In a preferred embodiment, both include onboard wireless interfaces which communicate with wireless interface **2108**. Electronic cartridge **2112** communicates with barrel bore arbor mounted sensor **2110** via light signal **2111**, as will be further described.

Electronic cartridge **2112** in a typical usage is chambered in the weapon. In a typical embodiment, barrel bore arbor mounted sensor **2110** is secured in the muzzle of the weapon.

System **2100** also includes positioning detector **2204**, as will be further described.

Referring to FIG. 21B, in a preferred embodiment of a virtual reality system, a system computer **2101** is connected to head unit **2122** and positioning detector **2123**.

System computer **2101** runs operating system **2124**, which runs virtual reality simulation engine **2125**. System computer **2101** receives input from head unit **2122** and positioning detector **2123** that includes measurement data, which is used to identify the positions of head unit **2122** and positioning detector **2123**. System computer **2101** outputs images to head unit **2122** that are rendered using virtual reality simulation engine **2125**.

Head unit **2122** includes sensors **2135** that provide measurement data that is used to identify the position of head unit **2122**. Head unit **2122** also includes display **2136** that shows three dimensional images. The measurement data is processed by system computer **2101** and used to generate the images displayed by the one or more display screens.

Positioning detector **2123** includes sensors **2137**, is mounted to a weapon, and provides measurement data. System computer **2101** receives and processes the measurement data from positioning detector **2123** to update the position of the weapon inside of the simulation.

Operating system **2124** runs on system computer **2101** and provides standard interfaces for applications to run and access external hardware. Applications running under operating system **2124** on system computer **2101** access data provided by hardware devices, such as head unit **2122** and positioning detector **2123**, through hardware drivers **2126**.

Hardware drivers **2126** include device drivers for each of head unit **2122** and positioning detector **2123**. Hardware drivers **2126** allows virtual reality simulation engine **2125** to access the measurement data provided by head unit **2122** and positioning detector **2123** and to send images to head unit **2122**.

Virtual reality simulation engine **2125** runs under operating system **2124**. In a preferred embodiment, the virtual reality simulation engine runs in program **2120**. The simulation engine receives measurement data from head unit **2122** and positioning detector **2123**, renders virtual reality images based on the measurement data and the state of the simulation, and sends the images back to head unit **2122** to be displayed to the user. In a preferred embodiment, virtual reality simulation engine **2125** uses one or more software objects to run the virtual reality simulation, including player object **2127**, head unit object **2128**, weapon object **2129**, tracker object **2130**, target object **2131**, and launcher object **2132**. Every time a new frame or image is generated, virtual reality simulation engine **2125** updates each of the objects based on the measurement data, the amount of time since the last update, and the previous state of the simulation.

Player object **2127** represents the user inside of virtual reality simulation engine **2125** and its location is based on the location of head unit **2122**. Player object **2127** is linked to head unit object **2128**, which stores the current location of head unit **2122**. Head unit object **2128** identifies the current location of head unit **2122** by accessing the measurement data provided by head unit **2122** through hardware drivers **2126**.

Weapon object **2129** represents, in virtual reality simulation engine **2125**, the weapon to which positioning detector **2123** is attached. The position of weapon object **2129** is linked to the position of positioning detector **2123** so that movements of positioning detector **2123** result in movements of weapon object **2129** inside of virtual reality simulation engine **2125**. Weapon object **2129** is linked to tracker object **2130** so that when tracker object **2130** updates its position, the position of weapon object **2129** is also updated.

Tracker object **2130** receives measurement data from positioning detector **2123** through hardware drivers **2126**. Tracker object **2130** updates the position of positioning detector **2123**, which is used by virtual reality simulation engine **2125** and weapon object **2129** to update the visible location of weapon object **2129** within virtual reality simulation engine **2125**. Tracker object **2130** also receives button status data within the measurement data. The button status data is used to identify when a shot is fired and when a target should be launched.

Target object **2131** is a digital representation of a clay target. Target object **2131** is instantiated when a button is pressed on positioning detector **2123**. The button press is identified by tracker object **2130** and target object **2131** is brought into the simulation at the location and direction specified by the launcher object. Target object **2131** is identified as a rigid body to a physics engine of virtual reality simulation engine **2125** and its position is updated based on the simulated weight, position, and velocity of target object **2131**. Upon initial placement, target object **2131** a simulated force is applied to target object **2131** to make it move inside of virtual reality simulation engine **2125**.

Launcher object **2132** represents the starting location of target object **2131** and can be placed at any position inside of virtual reality simulation engine **2125**. For simulations that include a launcher in a high house, launcher object **2132** is located inside a digital representation of the high house.

Referring to FIG. 21C, an augmented reality system includes head unit **2122** and positioning detector **2123**.

Head unit **2122** includes computer **2121**, sensors **2135**, and display **2136**.

Positioning detector **2123** includes sensors **2137** and is mounted to the weapon. Positioning detector **2123** provides measurement data that allows is used to determine the location of positioning detector **2123** with respect to the environment and the location of head unit **2122**.

Sensors **2135** of head unit **2122** are used to provide measurement data that identifies the position of head unit **2122** and generates and updates mesh object **2134**. Camera **2138** of head unit **2122** are used to locate and track registration marks on the towers and the weapon, as will be further described.

Display **2136** is mounted within head unit **2122** and displays three dimensional images or holograms to the user.

Computer **2121** receives measurement data from sensors **2135** of head unit **2122** and from sensors **2137** of positioning detector **2123** and renders an overlay image or hologram for each time step that is shown in display **2136**. Computer **2121** hosts operating system **2124**.

Operating system **2124** runs on computer **2121** and contains several applications, including virtual reality simulation engine **2125** and hardware drivers **2126**. Operating system **2124** provides standard interfaces for the applications to access data from hardware devices by using hardware drivers **2126**. In a preferred embodiment, operating system **2124** is Windows 10 from Microsoft Corp.

Virtual reality simulation engine **2125** renders each image shown through display **2136** based upon the measurement data from sensors **2135** and **2137**, the amount of time since the last image was rendered, and the state of the simulation. Virtual reality simulation engine **2125** includes several objects that are used to render an image, including player object **2127**, head unit object **2128**, weapon object **2129**, tracker object **2130**, target object **2131**, launcher object **2132**, spatial anchor **2133**, and mesh object **2134**. In a preferred embodiment virtual reality simulation engine **2125** is the Unity 3D engine from Unity Technologies.

Player object **2127** represents the user in virtual reality simulation engine **2125**. In an augmented reality simulation, Player object **2127** is not shown, but the position of the player is constantly updated. The position of player object **2127** is associated with head unit object **2128** so that when the position of head unit object is updated, the position of player object **2127** is also updated.

Head unit object **2128** maintains the current position of head unit **2122** within virtual reality simulation engine **2125**. For each frame, the position of head unit object **2128** is updated based on measurement data from sensors **2135** that is received through hardware drivers **2126**.

Weapon object **2129** is the representation of the weapon inside virtual reality simulation engine **2125**. For an augmented reality simulation, weapon object **2129** is not graphically displayed. The position of weapon object **2129** is associated with the position of tracker object **2130** and is updated for each frame of the simulation based on the movement of positioning detector **2123**. The location and orientation of weapon object **2129** is used to determine if a shot hits a target.

Tracker object **2130** represents positioning detector **2123** inside of virtual reality simulation engine **2125** and identifies the position of positioning detector **2123** and the status of one or more buttons connected to positioning detector **2123**. Tracker object **2130** communicates with sensors **2137** of positioning detector **2123** through hardware drivers **2126**. The measurement data provided by sensors **2137** of positioning detector **2123** include position data and button status data from which the current position of positioning detector **2123** is identified and stored into tracker object **2130**.

Target object **2131** in virtual reality simulation engine **2125** represents the virtual clay target. In a preferred embodiment, target object **2131** is displayed as a hologram using display **2136**. Target object **2131** is initially created and instantiated at the location of launcher object **2132** with the same direction as launcher object **2132**. Target object **2131** is identified as an object to which physics apply (e.g., gravity) by making it a rigid body object. Once placed into virtual reality simulation engine **2125**, target object **2131** is given an initial force that causes it to move through virtual reality simulation engine **2125**. For each frame, the position of target object **2131** is updated by the physics engine of virtual reality simulation engine **2125** based on a simulated weight, velocity, and any other applied forces.

Launcher object **2132** represents the location of a launcher in virtual reality simulation engine **2125**. Launcher object **2132** is locked to a specific point on mesh object **2134** that is represented by spatial anchor **2133**. To position launcher object **2132**, spatial anchor **2133** is placed on to mesh object **2134**. In a preferred embodiment, launcher object **2132** is placed on or within a tower or high house. When spatial anchor **2133** is placed on or inside a real life tower, virtual reality simulation engine **2125** does not render a model of the tower. When spatial anchor **2133** is placed on the ground, virtual reality simulation engine **2125** renders and displays a model of tower, within which launcher object **2132** is located.

Mesh object **2134** represents the three dimensional environment in which the user is located. Mesh object **2134** is a three dimensional surface of the environment measured by sensors **2135** of head unit **2122** and includes representation of the buildings and trees or, if indoors, walls, ceilings, floors, and objects surrounding the user.

Referring to FIG. 22A, weapon **2200** is used with the simulation system. Trigger unit **2202** is secured to weapon **2200** with fasteners **2206** and **2208**. Trigger unit **2202** includes paddle **2210**. Upon deflection of the paddle, the trigger unit sends electric signals utilized by the system. In one embodiment, trigger unit **2202** is in electronic communication with the simulation computer using a short range wireless communications protocol, such as Bluetooth, as will be further described. Positioning detector **2204** is fitted to a known position on weapon **2200** with respect to barrel **2212**, as will be further described. In one embodiment, positioning detector **2204** includes USB port **2224**. Cable **2226** connects the USB port to the trigger unit for communication of operational signals, as will be further described.

Referring to FIG. 22B, weapon **2200** is alternatively used with the simulation system. Weapon **2200** includes electronic cartridge **2213** chambered in the weapon (not shown). Weapon **2200** further includes sensor arbor **2215** secured in the muzzle of the weapon. The weapon further includes positioning detector **2204** positioning below and attached to barrel **2212**. Sensor arbor **2215** is connected to positioning detector **2204** by USB cable **2228**. Weapon **2200** includes sensor thimble or ring **2261**. Sensor arbor **2215** is connected to thimble **2261** by USB cable **2230**.

Referring to FIG. **22**C, weapon **2200** is alternatively used in the simulation system. Trigger unit **2202** is secured to the weapon as previously described. Trigger unit **2202** is in electronic communication with the simulation computer as will be further described. Weapon **2200** includes visual sight markers **2250** and **2252** capable of being recognized by the Microsoft HoloLens system and are used to locate the position orientation of the weapon during a simulation, as will be further described.

Referring to FIG. **22**D, weapon **2200** is alternatively used with the simulation system. Weapon **2200** includes electronic cartridge **2213** chamber in the weapon, as previously described. Weapon **2200** includes sensor arbor **2215** secured in the muzzle of the weapon, as previously described. Weapon **2200** includes sensor thimble **2261** connected to the sensor arbor, as will be further described. Weapon **2200** includes visual sight markers **2250** and **2252** capable of being recognized by the Microsoft HoloLens system and are used to locate the position orientation of the weapon during a simulation.

In a preferred embodiment, the augmented reality system is the Microsoft HoloLens running the Vuforia augmented reality platform and SDK with the Unity 3D engine. The visual sight markers **2250** and **2252** include an image (not limited to a barcode) that is printed on a flat two dimensional surface. The image is fixed to the weapon, either directly to the barrel of the weapon or to sensor arbor **2215**, so that movement of the weapon causes similar movements of the image. The images of visual sight markers **2250** and **2252** are in the field of view of a camera of the head unit when the weapon is being aimed by the user. The augmented reality system identifies the position and orientation of the head unit with respect to an origin of the current augmented reality scene. When the augmented reality system processes the data from its sensors, including the camera, the image is identified and compared with a reference image stored in a database. From this comparison, the augmented reality system determines the position and orientation of the image with respect to head unit. The augmented reality system identifies the position and orientation of the head unit with respect to an origin of the current augmented reality scene. The augmented reality system then also determines the position and orientation of the weapon based on the positions and orientations of the image and the head unit with respect to the origin of the scene.

Referring to FIG. **22**E, positioning detector **2204** includes USB port **2224**, battery **2271**, processor **2272**, memory **2273**, antenna **2274**, and sensors **2275**, all operatively connected together. Processor **2272** executes instructions stored in memory **2273** that cause positioning detector **2204** to continuously measure its position and orientation using sensors **2275** and to broadcast its position and orientation using antenna **2274**. In a preferred embodiment, positioning detector **2204** is a Vive Tracker manufactured by HTC Corporation. Positioning detector **2204** communicates over a short range wireless connection to the simulation computer through dongle **2109**, as will be further described. In other preferred embodiments, the positioning detector can transmit a launch signal or a shot signal to the system computer, as will be further described.

Referring to FIGS. **23**A and **23**B, trigger unit **2202** includes external case **2304** sealed by closure **2306**. Barrel clamps **2308**, and **2310** are rigidly attached to external case **2304**. Barrel clamps **2308** and **2310** are adapted to connect with a standard picatinny or weaver rail mount system. Paddle **2210** is pivotally attached to the enclosure at hinge **2312**. Switch **2314** is a spring loaded switch that is resident in external case **2304** and operatively connected to the paddle at pivot **2316**. In a preferred embodiment, all the mechanical components of the trigger unit are formed of high impact plastic.

Processor board **2318** is centrally mounted in external case **2304** through standoffs **2320**. Processor board **2318** is operatively connected to battery **2322** which powers its operation. Processor board **2318** is connected to switch **2314**. Processor board **2318** also operatively connected to external USB port **2357**. In use, paddle **2210** is deflected in direction **2324** thereby activating switch **2314**. After deflection the spring loaded switch returns the paddle to its original position.

Referring then to FIG. **23**C, a preferred embodiment of the electronics of trigger unit **2202** is shown. Processor board **2318** is a Razberi Pi 3 Model B board available from digikey.com. Processor board **2318** includes processor **2353**. In a preferred embodiment, processor **2353** is a Broadcom BCM 2837 1.2 GHz Quad-Core processor. Two USB ports **2354** and **2355** are included. USB port **2354** is connected to Bluetooth module **2356** which provides a short range wireless networking connection. The Bluetooth module in a preferred embodiment is Product ID 1327 Bluetooth 4.0 USB Module (v2.1 Back-Compatible) available from Ada Fruit at adafruit.com. The Bluetooth module includes antenna **2359**.

Processor **2353** is connected to general purpose input output pins **2360**, which are connected to switch **2314**. In one embodiment, switch **2314** is normally an open contact switch that when closed, completes a circuit to provide current through one of the pins to be detected by processor **2353**. Switch **2314** sends a signal to the processor which, in turn, sends a Bluetooth signal to the host computer, as will be further described.

Processor **2353** is connected to memory card **2358** via access slot **2361**. Code resident on the memory card is used to boot the processor and perform the operations necessary to control its operation, as will be further described.

FIGS. **24**A, **24**B, **24**C, and **24**D show alternate embodiments of mechanisms for attachment of the positioning detector to the barrel of the weapon.

Referring to FIGS. **24**A and **24**B, mounting arbor **2402** is positioned within muzzle **2401** of barrel **2412**. Mounting arbor **2402** includes threads **2403** designed to fit choke threads **2405**. Mounting arbor **2402** includes rigid extension **2404**. Positioning detector **2204** is fitted to the rigid extension **2404** with receiver **2410**. Mounting arbor **2402** also includes stabilizer **2406** connected to arbor body **2407** by standoff **2409**. Arbor body **2407** includes rubberized grip cylinder **2411**.

In a preferred embodiment, arbor body **2407** is formed of a durable plastic. Arbor body **2407** further includes removable closure **2444**. In a preferred embodiment, the removable closure is connected to the arbor body with a suitable set of mating threads **2445**. Arbor body **2407** includes window **2446**. In a preferred embodiment, window **2446** is a ruby crystal. In a preferred embodiment, the window may be a transparent plexiglass capable of transmission of radiation in the 650 nanometer range.

Arbor body **2407** includes transmission tube **2450** adjacent window **2446**. Transmission tube **2450** terminates in cavity **2448**. Cavity **2448** includes standoffs (not shown) capable of supporting internal circuitry.

Cavity **2448** encloses photo cell **2437**, circuit **2436**, and battery **2435**. Removable closure **2444** includes push pin connector **2438** and connector pins **2440**. Photo cell **2437** is connected to circuit **2436** and generates a current based on incident laser beam **2442**. Circuit **2436**, in a preferred embodiment, forms a commonly known transistor amplifier, which uses current from the battery to amplify the signal from the photo cell and transmit it to push pin connector **2438**. The signal generated by the circuit is received by positioning detector and used for operation of the simulation, as will be further described.

In use, the mounting arbor is threaded into the muzzle of the weapon using the rubberized grip cylinder. Laser beam **2442** from the electronic cartridge is incident on the photo cell during operation of the system. The photo cell sends a binary signal to push pin connector **2438** and connector pins **2440** which, in turn, activate the positioning detector.

Referring then to FIGS. **24**C and **24**D, an alternate embodiment of transmission tube **2450** will be described. Barrel clamp **2422** includes mating sections **2424**A and **2424**B. The sections have mating semi-cylindrical cavities **2426**A and **2426**B. Section **2424**A includes hole **2428**A. Section **2424**B includes threaded hole **2428**B.

When assembled, section **2424**A and **2424**B are fitted around barrel **2412** and into engagement with picatinny rail **2413**. Bolt **2433** is positioned through hole **2428**A and threaded into hole **2428**B. Bolt **2435** is positioned in the hole formed by cavities **2431**A and **2431**B and threaded into receiver **2410**. In this way, positioning detector is held securely adjacent the barrel of the weapon. The placement of the positioning detector below the barrel allows live rounds to be fired from the weapon for practice shooting in combination with the simulation system.

Referring to FIGS. **25**A, **25**B, **25**C, and **25**D, several embodiments of the electronic cartridge component will be described.

Referring to FIG. **25**A, the generalized exterior of electronic cartridge **2500** of each embodiment includes rim section **2501** and a shell case section **2502**. The rim section and shell case form a hollow central chamber or cavity **2503** used for placement of electronic components. The two sections are joined by a threaded connection **2504** and may be disassembled to service interior components. In a preferred embodiment, the rim section and shell case are formed of a high impact plastic, such as polycarbonate or nylon. Generalized exterior of electronic cartridge **2500**, in one preferred embodiment, includes a ruby window **2505** imbedded in shell case section **2502** at crimped end **2506**. Other transparent plastics may be used. The window is graded to transmit radiation in the 650 nanometer range. In general, chambering electronic cartridge **2500** during operation of the simulation prevents the accidental discharge of a live round.

Referring to FIG. **25**B, one embodiment of the electric cartridge is described.

Electronic cartridge **2510** includes cylindrical micro switch **2512**. Cylindrical micro switch **2512** is centrally located in the rim section at the position of a primer. In a preferred embodiment, the micro switch is part no. EGT12, N12 available from Euchner. Cylindrical micro switch **2512** is connected to I/O pin **2513** of processor **2516**. In a preferred embodiment, processor **2516** is a Razberi pi zero, machined to fit within cavity **2503**. Processor **2516** is operatively connected to battery **2514**. Processor **2516** is operatively connected to onboard memory **2518**. Processor **2516** is operatively connected to Bluetooth module **2517**. Bluetooth module **2517** is operatively connected to antenna **2520**. In a preferred embodiment, Bluetooth module **2517** is the Arduino cc2541 Bluetooth 4.0 BOE data transmission module compatible with Razberi pi, available from newegg.com.

In operation, processor **2516** is booted by and receives instructions from onboard memory **2518**. Once booted, the processor enters a wait state waiting for a closure signal from cylindrical micro switch **2512**. Cylindrical micro switch **2512** generates a closure signal when impacted by the hammer of the weapon upon an actual trigger pull by the user. Once the signal is received, the processor activates Bluetooth module **2517** which sends a signal **2522** via antenna **2520**, to wireless interface **2108**.

Referring to FIG. **25**C, an alternate embodiment of the electronic cartridge **2610** will be described. Electronic cartridge **2610** includes centrally positioned cylindrical micro switch **2612**, as previously described. The micro switch is connected to I/O port **2613** of processor **2616**, as previously described. Processor **2616** includes memory **2618** which provides boot-up and operating instructions on board. Processor **2616** is powered by battery **2614** as previously described. Processor **2616** is connected to Bluetooth module **2617** as previously described. Bluetooth module **2617** is connected to cylindrical Bluetooth antenna **2620**. In this preferred embodiment, Bluetooth antenna **2620** is integrally constructed with the shell case section **2502** in a cylindrical pattern to direct radiation towards crimped end **2506**. Bluetooth antenna **2620** produces Bluetooth signal **2624**, upon receipt of a signal from processor **2616**, as previously described.

Electronic cartridge **2621** includes micro slide switch **2611** connected to processor **2616**. The micro slide switch activates the processor and the functions of the cartridge.

Processor **2616** is also connected to laser diode **2622** via I/O port **2623**. In a preferred embodiment, the laser diode is a 5 milo watt 650 nanometer red laser product ID 1054 available from adafruit.com. In this and other preferred embodiments, the laser diode can take the form of an infrared LED and the various windows are designed to transmit the LED light signal.

In operation, micro slide switch **2611** is activated by the user, then the electronic cartridge is chambered. The micro switch sends a signal to processor **2616**, which in turn activates laser diode **2622**. Upon activation laser diode **2622** produces laser radiation or beam **2626** which is directed coaxially to the barrel of the weapon. In further operation, when the trigger of the weapon is pulled, the hammer (not shown) impacts the cylindrical micro switch **2612** which sends a signal to processor **2616**, producing Bluetooth signal **2624**, as previously described.

Referring to FIG. **25**D, another embodiment of electronic cartridge **2710** is described. Electronic cartridge **2710** includes micro slide switch **2712** in the rim section of the cartridge. The micro slide switch is operatively connected to battery **2714**. Battery **2714** is operatively connected to laser diode **2722**. In another preferred embodiment, the laser diode may take the form of an infrared LED. Moving the slide switch to the “on” position activates the laser diode. When activated, the laser diode emits laser beam **2726** directed through ruby window **2723**. After activation, the electronic cartridge is chambered in the weapon. In a preferred embodiment, laser beam **2726** is coaxial to the barrel of the weapon.

Referring to FIGS. **25**E and **25**F a preferred embodiment of sensor arbor **2570** will be described. Sensor arbor **2570** is comprised of a containment tube **2572**. Containment tube **2572** is preferably construed of an aluminum alloy but also can be constructed of a rigid plastic such as polypropylene or delrin. Containment tube **2572** includes abutment flange **2574**. In a preferred embodiment abutment flange **2574** is integrally formed with containment tube **2572**. Containment tube **2572** is cylindrical and has the dimensions sufficient to allow placement within the muzzle of a standard 12-gauge shotgun. Other diameters may be used. Abutment flange **2574** includes interior threads **2576**. Adjacent abutment flange **2574** on containment tube **2572** are retaining threads **2578**. Retaining threads **2578** are arranged to mate with choke threads (not shown) in a standard 12-gauge shotgun. Window **2580** is affixed to containment tube **2572** with a suitable epoxy adhesive. Window **2580** in a preferred embodiment is plexiglass. In alternative embodiments, it may be ruby crystal. Containment tube **2572** is configured to receive indicator shield **2582**. Indicator shield **2582**, in a preferred embodiment, is a hemispherical frosted plexiglass material, which is translucent. Indicator shield **2582** includes threads **2584**. Threads **2584** sized to mate with threads **2576** and hold indicator shield **2582** in place in containment tube **2572**. Indicator shield **2582** includes rectangular USB ports **2573** and **2593**. The USB ports are operatively connected to connectors **2571** and **2597**, respectively.

Referring to FIG. **25**F, sensor arbor **2570** includes processor **2590**. Processor **2590** is functionally collected to memory **2592**. In a preferred embodiment, processor **2590** is a Razberi zero, as previously described. Memory **2592** includes instructions to boot the processor and operate the functions of the sensor arbor when in use in the system. Battery **2594** is connected to processor **2590** and supplies operational power for the functions of the device. Photo sensor **2596** is centrally located within the sensor arbor and positioned adjacent window **2580**. Photo sensor **2596**, in a preferred embodiment, is the four wire light sensor module available from Uugear and is compatible with the Razberi zero. Photo sensor **2596** is connected to processor **2590** through I/O connector **2597**. Processor **2590** is also connected to Bluetooth module **2598**. A preferred embodiment, Bluetooth module **2598** is the Arduino cc2541 Bluetooth 4.0 BOE data transmission module available from newegg.com. Bluetooth module **2598** is connected to antenna **2599**. Processor **2590** is also connected to indicator LED **2595** at input output data port **2589**.

In use, the sensor arbor is threaded into the muzzle of the weapon using retaining threads **2578**. Abutment flange **2574** is held in place against the outside of the muzzle. USB port **2593** is connected to the positioning detector through a USB cable (not shown). USB port **2573** is connected to sensor thimble **2560** through a USB cable (not shown). Laser radiation **2591** from the electronic cartridge is incident on photo sensor **2596** during operation of the system. Photo sensor **2596** sends a first signal to the processor which, in turn, activates a status indicator signal **2588** created by indicator LED **2595**. The status signal can be seen through the translucent indicator shield indicating the status of the system to the user or other observers. The processor also sends an activation signal to the positioning detector through USB port **2593**.

In response to a second signal from USB port **2573**, processor **2590** activates Bluetooth module **2598** and transmits a signal **2569** through antenna **2599**. In a preferred embodiment, the Bluetooth signal is received by the system computer and translated into system instructions. In an alternate embodiment, in response to the second signal, processor **2590** transmits a signal to the positioning detector through USB port **2593**. In this embodiment, the positioning detector then sends a third corresponding signal to the system computer.

In another preferred embodiment, upon receipt of the second signal from the USB port, processor **2590** also sends different signals to indicator LED **2595** causing it to illuminate red. In this way, in one embodiment, the indicator shield indicates a "ready" signal in green and a "shots fired" signal in red.

Referring to FIG. **25**G, a preferred embodiment of sensor thimble **2560** is described. Sensor thimble **2560** includes ring cylinder **2561**. In a preferred embodiment, ring cylinder **2561** is stainless steel. Attached to the exterior surface of ring cylinder **2561** is sensor **2562**. Sensor **2562**, in a preferred embodiment, is flexible pressure sensor part number SEN09375 available from Karlsson Robotics. The sensor can detect an impact of anywhere between 100 grams and 10 kilograms. In another preferred embodiment, sensor **2562** includes a photo emitter and a photo sensor combination, controlling circuits and a power supply, which enables the sensor to detect the proximity of the ring to a metallic object (such as a trigger).

Sensor **2562** is mechanically connected to the exterior surface of ring cylinder **2561** with an epoxy or other suitable adhesive. Sensor **2562** is electrically connected to USB port **2564**. USB port **2564** is mechanically attached to the exterior surface of ring cylinder **2561** with epoxy or another suitable adhesive. USB port **2564** is connected to USB tether **2566** through a removable connection. USB tether **2566** is also connected to USB port **2573** of sensor arbor **2570**.

In use, ring cylinder **2561** is placed on the trigger finger of the user and connected to USB tether **2566**. Sensor thimble **2560** is tapped on the trigger of the weapon one time to activate a target launch and a second time to simulate a trigger pull. In a preferred embodiment, the pressure exerted by the user on the thimble against the trigger of the weapon is sufficient to change the resistance in the sensor which is sensed by processor **2590**. In response, the processor sends a Bluetooth signal through antenna **2599** to the wireless interface **2108** indicating that a sensor event has occurred, as will be further described.

Referring to FIG. **26**, in use, the simulation system, generally, simulates launcher **26102** and digital clay target **26106**. Launcher **26102** is located at a fixed position in the simulation and provides the starting trajectory for digital clay target **26106**.

In the simulation, digital clay target **26106** is launched from the starting position and orientation of digital launcher **26102**. Digital clay target **26106** travels along path **26108**. In one embodiment, phantom target **26110** and hit sphere **26112** are collocated at the same point in the simulation. Phantom target **26110** and hit sphere **26112** lead digital clay target **26106** by the lead distance **26107**, along path **26108**.

When a trigger event occurs, the simulation program creates a "ray" object that starts at the muzzle of weapon **26104** and is coaxial to the central axis of the barrel. If ray **26114** intersects hit sphere **26112**, then a determination is made by the simulation program as to whether or not a hit has occurred. A "hit" is determined based on the statistical likelihood of a hit based on the Gaussian distribution of pellets in a typical spread pattern for the type of ammunition chosen in the simulation, as will be further described. The Gaussian distribution of pellets is also referred to as a shot distribution probability. The diameter of the hit sphere is also determined by the Gaussian distribution of pellets, as will be further described. In a preferred embodiment, the hit sphere is three standard deviations of the pellet spread.

Referring to FIG. **27**, the Gaussian distribution of pellets for a standard 12-gauge round at a target distance of 70 feet, as used in the simulation, is described. Spread pattern **27102** shows a particular spread pattern for a 12-gauge round. Spread patterns have different characteristics depending on pellet count, powder charge, weapon gauge, pellet size, and barrel length and distance to target.

Graph **27104** shows that the vertical distribution of pellets and obeys a standard Gaussian distribution. Similarly, graph **27104** shows that the horizontal distribution of pellets and obeys a standard Gaussian distribution. Each graph changes as a function of distance to target. As expected, the standard deviation distance increases with distance to target.

In this example, graph **27104** includes histogram **27107**, normal distribution **27108**, and standard deviation (σ) **27110**. Histogram **27107** shows that highest concentration of pellets are in the center of the spread pattern **27102**. Standard deviation **27110** is located at 4.49 inches away from the center for the vertical axis.

In this example, graph **27112** analyzes the horizontal spread of pellets with histogram **27114** and normal distribution **27116**. Standard deviation **27118** is 4.24 inches for graph **27112**, indicating that there is a tighter spread along the horizontal axis. There is a larger concentration of pellets in the central bucket of the histogram, as compared to graph **27104**, which correlates with standard deviation **27118** being smaller than standard deviation **27110**.

Ellipse **27105** identifies a boundary of spread pattern **27102** that is three standard deviations away from the center of the spread. The boundary of spread pattern **27102** that is two standard deviations away from the center of the spread is identified by ellipse **27106**.

Referring to FIG. **28**A, method **2800** is used to determine the location of a simulated launcher in a clay shooting field and a set of trajectories for the digital clay targets used for the simulation.

At step **2802**, several trajectories of actual targets are recorded by the video cameras as they are launched from actual towers at the clay shooting field. The cameras are placed at known GPS positions to record the flight path of a target for each tower and for each possible trajectory for a target from each tower.

In one embodiment, the actual targets are clay targets launched from actual clay target launchers. Because the clay targets are a regular shape they follow a generally arc path defined by physics, as would be expected. In another embodiment, the actual targets are live birds, for example, ducks, pigeons and chucker. Unlike actual clay targets, actual birds typically do not exhibit well defined flight paths or trajectories for a number of reasons, including first that the birds exhibit powered flight and second live animals exhibit unpredictable characteristics, upon occasion. Additionally, measurements of windage, humidity, temperature, and barometric pressure can be recorded for use by the simulation.

At step **2804**, the speed and trajectory of the target is determined from the video provided by the cameras. A mathematical model of each trajectory, of each target, from each tower is created by the simulation program, as will be further described. From these models the position of the target can be calculated and displayed relative to the tower as a function of time. However, slight variations from the mathematical model are necessary to provide the virtual target with a more realistic trajectory and appearance. For example, wind gusts randomly raise and lower the clay above the perfect trajectory. Likewise variations in velocity can occur due to wind and humidity. To correct for these variations the path of the mathematical model is compared frame to frame to the video viewed from a position in the simulation that matches the position of the camera that took the video. The mathematical model is changed to account for the variations and stored in a combined trajectory file. Additional embodiments incorporate trajectory variations from atmospheric conditions and other forces acting on the target, such as drag, turbulence, and powered flight into the mathematical models. The combined trajectory is stored as a file for use in the simulation engine.

In a preferred embodiment, the pure mathematical models are developed by a function of Unity 3D engine. For the digital clay target, a rigid body simulation object is created that includes the known quantities of the real life clay target, including, size, weight, launch angle, and launch velocity. Additional simulation parameters for the digital clay target are adjusted based on a comparison of the flight of the digital clay target compared with the real life video of the clay target. For example, the angular dampening of the digital clay target may be adjusted so that the digital clay target will stay aloft for about the same amount of time as a real clay target would stay aloft. To launch the digital clay target, a simulated force is applied to the digital clay target as soon as the digital clay target is instantiated into the simulation. From the initial parameters for the digital clay target, which includes the simulated force, the physics engine of the simulation system handles moving the digital clay target along a trajectory that approximates that of a real life clay target. In the case of a digital bird target, the simulation object is created that includes both a rotation and a translation attribute. A series of points is garnered from each test video which then is fitted with a spline function to interpolate all points on the trajectory. An array of trajectory paths is created which includes each of the different animations for each of the training videos. To launch the digital bird target, one array of the series of animated arrays is accessed as soon as the digital bird target is instantiated into the simulation. The digital bird target object operates from initial parameters for the digital bird which include a thrust direction based on powered flight as well as interactions with windage and humidity to result in the rotation and translation attributes which define the trajectory.

In another embodiment, the camera used to record the real clay target is a 360 degree camera, such as the Omni from GoPro, Inc. From this video, the position of the clay target is recorded and can used to adjust the mathematically generated model trajectory in the virtual or augmented reality simulation.

At step **2806**, the location and orientation of each tower is determined and stored in the simulation program.

In a preferred embodiment, the tower locations are modeled and set by the unity 3D engine.

Referring to FIGS. **28**B and **28**C, the registration of the launcher locations in the unity 3D engine is described. "Registration" of a point in a virtual reality space to a fixed point in the real-world is typically accomplished by creating a virtual copy of the critical features of the real-world in the unity 3D system. In one embodiment, the high house, the low house, and shooter pad locations are defined at predetermined measurements from a predefined common origin. The house dimensions are created with the "box" function in Unity 3D. The boxes each are defined with a virtual launch point that corresponds to the muzzle of the launcher in the real-world. In a similar way, the locations of the shooter pads are measured in the real-world and registered in the unity 3D engine.

"Registration" of a point in an augmented reality space to a fixed point in the real-world is typically accomplished by an augmented reality camera such as that used in the Microsoft HoloLens. In this case, a "spatial anchor" is chosen. The spatial anchor is chosen from an array called a spatial map. The spatial anchor is chosen by calling a function known as "gaze ray". The gaze ray function returns a set of coordinates in the mesh that is then named and identified as the spatial anchor. For example, image **2951**, from an augmented reality camera shows a high house **2952** and a low house **2953** in skeet field **2954**. The Microsoft HoloLens system creates mesh **2955**. Mesh **2955** is a three dimensional map of image **2951**. The registration identifies spatial anchor **2996** at a location in the mesh that corresponds to the location of the high house. The registration identifies spatial anchor **2997** is at a location in the mesh that corresponds to the location of a launcher.

Referring to FIG. **28**D, a virtual reality simulation includes high house **28402** and low house **28404**. Camera icon **28406** represents the current location of the user within defined space **28408**. Defined space **28408** is the safe space inside of the simulation that corresponds to the safe space in real life where the user is experiencing the simulation.

Defined space **28408** has a specific origin and orientation. High house **28402** and low house **28404** are placed with respect to the origin and orientation of defined space **28408**. Both high house **28402** and low house **28404** include launcher objects that are used for the launch of clay target objects in the simulation.

Referring to FIG. **29**A, method **2900** is shown. Method **2900**, performed by a simulation computer, to create a virtual reality or augmented reality shooting simulation is described.

At step **2902**, the location, orientation, and settings of a launcher are set. The location of each launcher includes Cartesian coordinates that identify where each launcher is placed in the simulation. The orientation of each launcher indicates the initial direction for the digital targets when launched, and is defined by three Euler angles. The Euler angles are unique for each trajectory model.

At step **2904**, ambient conditions for the simulated environment are set, which include simulated windage, humidity, temperature, and barometric pressure. In one embodiment, the simulated environmental factors are set to match the environmental factors that existed when the cameras recorded the images of the actual target trajectories.

At step **2906**, the settings of the digital clay target are selected. The settings include size, color, and mass. The settings are incorporated into the trajectory models.

At step **2908**, weapon ammunition settings are selected. The ammunition types include those that are appropriate for the selected weapon. The ammunition settings determine the Gaussian distributions used by the simulation to determine the probability of a "hit" and the diameter of the hit sphere.

At step **2910**, the phantom target settings are selected. The phantom target settings identify the color, transparency, and size of the phantom target. In a preferred embodiment, the phantom target is the same size as the digital clay target, but includes a different color and transparency in order to distinguish it from the digital clay target.

At step **2912**, the lead distance is selected.

The lead distance is the linear distance between the location of the center of the digital clay target and the location of the center of the phantom target. In a preferred embodiment, the lead distance is selected as a fixed distance, usually about three feet.

In an alternative embodiment, a lead time is selected and the lead distance is calculated based on velocity of the digital target. For example, the desired lead time is multiplied by the initial velocity of the digital target to calculate the lead distance.

Additionally, the lead time can be estimated using the known positions of the weapon and the digital target, the trajectory of the digital target, the velocity of the digital target, and the muzzle velocity for the selected weapon and ammunition type.

Referring to FIG. **29**B,

$$A=X_{clay}-X_{weapon} \qquad \text{Eq. 22}$$

$$B=v_{clay}\cdot t \qquad \text{Eq. 23}$$

$$C=v_{muzzle}\cdot t \qquad \text{Eq. 24}$$

$$D=B\cdot\cos\theta \qquad \text{Eq. 25}$$

$$E=B\cdot\sin\theta, \qquad \text{Eq. 26}$$

where:

A is the line segment of known length between the weapon location **2980** and the digital clay target location **2982**;

B is the distance between the digital clay target location **2982** and the point of impact;

C is the distance between the weapon location and the point of impact;

θ is the angle between D and B.

and:

$$(A+v_{clay}\cdot t\cdot\cos\theta)^2(v_{clay}\cdot t\cdot\sin\theta)^2=(v_{muzzle}\cdot t)^2 \qquad \text{(Eq. 27}$$

Solving for t yields an estimate of the time it will take a shot to reach point of impact **2984** from weapon location **2980** of the weapon, as follows:

$$t=\pm\frac{\sqrt{v_{muzzle^2}-4\cdot A\cdot v_{clay}\cdot v_{muzzle}\cdot\cos\theta-4\cdot A^2\cdot v_{clay}^2\sin^2\theta}\pm v_{muzzle}\mp 2\cdot A\cdot v_{clay}\cdot\cos\theta}{2\cdot v_{clay}^2\cdot(\sin^2\theta+\cos^2\theta)} \qquad \text{Eq. 28}$$

Other lead calculation equations may be used in other embodiments.

Referring to FIG. **29**C, method **29100** of generating a simulation of the system is described.

At step **29102**, the system obtains the location orientation of the headset from the headset object. In a preferred embodiment, the location is a set of Cartesian coordinates and the orientation includes an angle view.

At step **29104**, the system displays range graphics as previously described. In a preferred embodiment of the virtual reality system, the range graphics include a virtual image of a high house and a virtual image of a low house in appropriate background imagery. In a preferred embodiment of the augmented reality system, the images of the high house and the low house are set to "invisible" because the actual high house and the actual low house are visible to the user through the transparent headset.

At step **29106**, the system obtains the location and orientation of the weapon from the weapon object.

At step **29107**, the system processes control signals received from a peripheral connected to the weapon. As is described in FIG. **31** below, the control signals allow for the user to launch a digital target, display a laser from the weapon, and turn the point of view left or right.

At step **29108**, the system displays a weapon image if in virtual reality mode.

At step **29110**, the system updates the display in the headset object. In the augmented reality system, the towers and launchers are not displayed (or displayed as “invisible”) because they can be seen by the user through the transparent headset. In a virtual reality system or augmented reality system, where the real towers and launchers are not present, images of the towers and launchers may be displayed in the overlay.

At step **29112**, the method checks for a launch event signal from the trigger object in the weapon object. In one embodiment, the system computer generates the launch signal automatically at predetermined time intervals. In other embodiments, the user generates the launch signal through use of the trigger unit on thimble, as will be further described, which is then posted by the trigger object. If no launch event signal is received, the method returns to step **29110**. If a launch signal is received, the method moves to step **29114**.

At step **29114**, the virtual target object and the phantom target object are launched. The target object path is drawn from the modified trajectory recorded after manual manipulation based on camera recordings of the actual flight paths. The phantom target path is drawn from the virtual target path modified by a lead distance function, as will be further described. The simulation engine displays the target and the phantom target according to the positions assigned to the objects by the Unity 3D engine. The hit sphere object is instantiated, but invisible to the user. The phantom target is rendered as leading the digital target by a fixed distance set or calculated as previously described.

At step **29116**, the position and status of the digital target object is updated based on the time step and hit record. Updating the position of the target object updates the position of the phantom target object and the hit sphere object. For each update the new position and orientation of the digital target are calculated from the trajectory model of the target.

At step **29117**, the weapon position is updated based on measurements from the positioning detector on the weapon or based on the position information retrieved from the registration mark in the hololens system. The phantom target position is updated based on a new lead time or distance calculated from the updated positions of the digital target.

The size of the hit sphere is updated based on the current distance between the weapon and the digital target. The hit sphere is a mathematical construct centered at the centroid of the phantom target object. The hit sphere is used to determine a theoretical “hit” of the target by shot. In one embodiment, the radius of the hit sphere is equal to the pellet spread at the distance to target, for the chosen ammunition. In another embodiment, the hit sphere is an ellipsoid with the vertical radius based on the vertical shot spread and the horizontal axis based on the horizontal shot spread at the distance between the weapon and the centroid of the phantom target.

At step **29118**, the digital target and the phantom target are rendered. The rendering is based on the updated positions of the digital target and the phantom target. The appearance of the target and the phantom target are conditioned on the predetermined settings.

At step **29119**, the system updates the display showing the new position of the weapon, in the virtual reality mode.

At step **29120**, the system determines whether or not a shot signal event has occurred. When the shot signal event has not occurred, the simulation returns to step **29116**. When the shot signal event has occurred, the method proceeds to step **29122**.

At step **29122**, the current location and orientation of the weapon are retrieved from the weapon object. In one embodiment, the data is retrieved from a memory that stores the positioning data that is continuously broadcast by the positioning detector on the weapon. In another embodiment, the data is retrieved from a server that stores the positioning data that is derived by the observation of the registration structure on the weapon by the Microsoft HoloLens system.

At step **29124**, a ray is created. The ray is a mathematical vector whose starting point is the end of the barrel of the weapon. The orientation of the ray is set to be coaxial with the axis of the barrel of the weapon. As a result, the ray always points the same direction as the weapon.

At step **29126**, it is determined if there is a “collision” between the ray and the hit sphere. When there is no collision then the method returns to step **29116**. When there is a collision, then the method proceeds to step **29128**.

At step **29128**, the shortest distance between the ray and the center of the hit sphere is determined. This distance is tangential to the ray and includes a horizontal component and a vertical component.

At step **29130**, the probability of hitting the digital target is determined from the Gaussian pellet distribution at the time of collision. In one embodiment, the Gaussian pellet distribution may be calculated. Values from a cumulative distribution function for the normal distribution of the shot spread pattern are calculated using the equation:

$$CDF(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi\sigma}} e^{-\left(\frac{(t-\mu)^2}{2\sigma^2}\right)} dt \qquad \text{Eq. 31}$$

where:

$\sigma$ is the standard deviation of the spread pattern; and,

$\mu$ is the mean of the spread pattern, which is set to zero.

Using the cumulative distribution function, the hit probability is calculated in both the horizontal and vertical dimensions that are orthogonal to the direction of the weapon:

$$p_{horizontal}=CDF(x+r_x)-CDF(x-r_x) \qquad \text{Eq. 32}$$

$$p_{vertical}=CDF(y+r_y)-CDF(y-r_y) \qquad \text{Eq. 33}$$

where

$p_{horizontal}$ is the hit probability for the horizontal dimension;

$p_{vertical}$ is the hit probability for the vertical dimension;

x is the horizontal distance between the ray an the center of the hit sphere;

$r_x$ is the distribution hit radius for the horizontal dimension, which is calculated by multiplying the horizontal length of the digital target by the hit scaling factor;

y is the vertical distance between the ray and the center of the hit sphere; and,

$r_y$ is the distribution hit radius for the vertical dimension, which is calculated by multiplying the vertical length of the digital target by the hit scaling factor.

The “hit scaling factor” is set to 1 so long as the size of the digital clay target is the same as the actual clay target.

At step **29132**, a random number for each dimension is generated between 0 and 1.

At step **29134**, a hit is recorded based on the Gaussian pellet distribution when the random number for the horizontal dimension is less than the horizontal hit probability and the random number for the vertical dimension is less than the vertical hit probability. In one embodiment, steps **29128** through **29132** are bypassed and a hit is recorded when the ray collides with the phantom target.

At step **29136**, after recording a hit, the system identifies the point of impact, which is the point on the path of the digital clay target where the hit will occur in the future. The three dimensional position of the point of impact is the current three dimensional position of the phantom target. When the digital target reaches the point of impact, the hit will be displayed as a rapid disassembly or explosion of the digital target. After step **29136**, the method returns to step **29116**, to continue updating the simulation of the digital clay target until it is destroyed or until the trajectory model intersects the horizon line.

Referring to FIG. **29**D, an augmented reality overlay of the simulation resulting from method **2900** is described.

Overlay **2957** is an augmented reality overlay that includes digital clay target **2958**, phantom target **2959**, digital clay target **2960**, and phantom target **2961**. Digital clay target **2958** and phantom target **2959** follow path **2962** from the high house. Digital clay target **2960** and phantom target **2961** are displayed as being launched from the low house and follow path **2963**.

Preferred embodiments of the launch signal event of step **29112** and the shot signal event of step **29120** will be further described here.

In one preferred embodiment, trigger unit **2202** is attached to the weapon. Processor **2353** of the trigger unit is programmed to generate a first wireless signal indicative of a launch signal upon a first contact of the user with paddle **2210**. Processor **2353** is programmed to send a second, different wireless signal, indicative of a shot signal upon a second contact with paddle **2210**. When used in conjunction with the barrel clamp mechanism of FIGS. **24**B and **24**C, a live round may be loaded into the chamber of the weapon and discharged by pulling the trigger. In this way, the augmented reality system can be used in conjunction with actual clay targets and live ammunition on an actual shooting field in order to alternate practice scenarios in real time.

In another embodiment, the trigger unit is attached to the weapon and the electronic cartridge of FIG. **25**B is loaded into the chamber. In this embodiment, processor **2353** is programmed to send a wireless signal indicative of a launch signal to wireless interface **2108** upon a first contact with paddle **2210**. Upon physical release of the hammer by the trigger of the weapon, the trigger impacts cylindrical micro switch **2512** whereby processor **2516** sends a wireless signal indicative of a shot signal to wireless interface **2108**.

In another embodiment, the sensor arbor of FIG. **25**F is secured in the muzzle of the weapon. Micro slide switch **2611** of the electrical cartridge of FIG. **25**C is activated thereby instructing processor **2616** to activate laser diode **2622**. The electronic cartridge is then chambered in the weapon. Laser diode **2622** sends beam **2626** down the barrel of the weapon which is received by photo sensor **2596** of the sensor arbor. Upon receipt of the signal the processor activates indicator LED **2595** to a "green" state thereby illuminating the indicator shield to indicate system ready.

Upon a trigger pull of the weapon, the hammer (not shown) impacts cylindrical micro switch **2612** of the electronic cartridge. A signal generated by the micro switch is sensed by processor **2616**. Upon sensing the signal, the processor is programmed to send a signal from the wireless interface of the electronic cartridge, indicative of a shot signal to wireless interface **2108**. In an alternate embodiment, upon sensing the signal, the processor is programmed to change the signal sent by laser diode **2622** using a digital coding. When the digitally coded signal is received by photo sensor **2596** of the sensor arbor, processor **2616** activates Bluetooth module **2598** to send a shot signal **2569** from antenna **2599**, to wireless interface **2108**. At the same time, processor **2590** sends a second signal to indicator LED **2595** to eliminate "red" indicating a live fire condition. In this embodiment, the launch signal is generated automatically without warning to the shooter.

In another embodiment, the electronic cartridge of FIG. **25**D is activated and chambered in the weapon. The sensor arbor of FIG. **25**F is secured in the muzzle of the weapon. Activation of the electronic cartridge is accomplished by moving micro slide switch **2712** to an "on" position. The micro switch thereby activates laser diode **2722**. Laser diode **2722** generates laser beam **2726** which is incident upon photo sensor **2596**. Photo sensor **2596** sends a signal to processor **2590** which activates indicator LED **2595** to illuminate "green".

In another embodiment, the electronic cartridge of FIG. **25**D is activated and chambered in the weapon. The mounting arbor of FIGS. **24**A and **24**B are secured in the muzzle of the weapon. Activation of the electronic cartridge is accomplished by moving micro slide switch **2712** to an "on" position. Micro switch thereby activates laser diode **2722**. Laser diode **2722** generates laser beam **2726** which is incident upon photo cell **2437**. Photo cell **2437** sends signal to push pin connector **2438** and then to positioning detector **2204**. Positioning detector **2204** then activates itself and sends a "ready" signal to dongle **2109**. Dongle **2109** communicates the "ready" signal to system computer **2101**.

Sensor thimble **2560** and USB tether **2566** are connected to USB port **2224** of positioning detector **2204**. A first impact of the thimble on the trigger of the weapons sends a first signal to positioning detector which forwards it to the dongle and then on to the system computer. This first signal is interpreted as a "launch" signal. In the same way, a second impact of the thimble on the trigger of the weapon sends a signal to positioning detector which forwards it again to the dongle and the system computer. The second signal is interpreted as "shot" signal.

In this embodiment, sensor thimble **2560** is attached by USB tether **2566** to USB port **2573** of the sensor arbor. Upon impact of the ring cylinder against the trigger of the weapon, impact sensor sends a signal through USB tether **2566** to the sensor arbor. The signal is sensed first by processor **2590** which activates Bluetooth module **2598**. Bluetooth module **2598** sends a wireless signal to wireless interface **2108**, indicative of a launch signal. Upon a second impact of the ring cylinder on the trigger of the weapon, impact sensor **2562** sends a second signal through USB tether **2566** to USB port **2573**. The signal is received by processor **2590** which sends a second signal to indicator LED **2595** to eliminate "red" indicating a live condition. Processor **2590** also activates Bluetooth module **2598** to send a second different wireless signal to wireless interface **2108**. The second wireless signal is indicative of a shot signal.

Referring to FIG. **29**E, method **29200** of generating a simulation of the system is described. This method is preferably used with live or powered targets that exhibit attributes of powered flight trajectories. In a preferred embodiment, method **29200** is applied in association with a mixed reality headset set in "pass through" mode which allows "inside out" tracking from the display screen in the headset.

At step **29201**, the system obtains the location and orientation of the headset from the headset object. In a preferred embodiment, the location is a cartesian set of coordinates and the orientation includes an angle of view.

At step **29202**, the spatial anchors are located and the images of the high house and the low house are set to "invisible" because the actual high house and the actual low house are visible to the user through the pass through mode of the mixed reality headset.

At step **29204**, the system implements the spatial anchors and the digital overlay onto the signal from the cameras to be displayed for the user. In this way, the digital objects in the simulation such as the high house and the low house, are synchronized with the real-world background objects visible to the user.

At step **29206**, the system obtains the location and orientation of the weapon from the weapon object, as previously described.

At step **29208**, the system processes control signals received from the weapon peripheral, as previously described.

At step **29210**, the method checks for a launch event signal from the trigger attribute of the weapon object, as previously described. If no launch event signal is received, the method returns to step **29206**. If a launch event signal is received, the method moves to step **29214**.

At step **29214**, the digital bird target object and the phantom target object are launched. The launch point is derived from the object identified as a high tower in the spatial anchors in the point cloud. The digital bird target is displayed as "flying" along an object path. The digital bird target object path is drawn from a path equation in the path array. Preferably, the path array stores different paths derived from videos recorded by cameras **150**, **151**, **250** and **251**, as previously described. Since the path array is capable of storing many thousands of flight paths and path equations, one path equation may be chosen at random. In other embodiments, an ordered set of paths may be chosen to originate from different launch points with different targets to simulate competition skeet, trap or other ordered shooting events. At this step an animation array is also accessed. The animation array includes video samples of target attributes such as bird wing and head movement and different bird call audio files. The phantom target path is drawn from the digital bird target path. The simulation engine displays the digital bird target and the phantom target on the same path, but with the phantom target leading the digital bird target by a proper lead distance, calculated from the ballistic table and the distance to target as previously described. A hit sphere object is instantiated, and located at the position of the phantom, but yet is invisible to the user.

At step **29216**, the position and orientation of the digital bird object is updated and displayed based on the time step and hit record. The new position of the digital bird object is calculated from the path model. The orientation of the digital bird object is preferably drawn from the attribute array.

At step **29218**, the weapon position is updated based on measurements from the positioning detector on the weapon or based on the position information retrieved from the registration mark in the HoloLens system. The phantom target position is updated based on a lead distance calculated from the updated position of the digital bird target.

At step **29220**, the digital bird target and the phantom target are rendered. The phantom target is rendered as a semi-transparent bird target leading the digital bird target by a fixed distance set or calculated as previously described. The rendering is based on the rotation and translation attributes of the digital bird target and the animation array attributes based on predetermined settings. At step **29222**, the video image from the stereo camera is accessed.

At step **29224**, the spatial anchors are located in the camera image. At step **29226**, the change in view coordinates, Δx, Δy and Δz are calculated from the last position of the spatial anchors in order to determine head movement of the user. In this way, the movement of the user is synchronized with the simulation and the background image.

At step **29228**, the digital bird trajectory is adjusted to compensate for the head movement. In this embodiment, the trajectory of the digital bird is "tied" to either the high house or the low house object, which appears to the user to be stationary. As the user moves his head, the display is changed so that the path the bird appears to be consistent with actual flight.

At step **29230**, the system determines whether or not a shot signal event has occurred. When the shot signal event has not occurred, the simulation returns to step **29216**. When the shot signal even has occurred, the method proceeds to step **29232**.

At step **29232**, the current location or orientation of the weapon are retrieved from the weapon object, as previously described.

At step **29234**, a ray is created, as previously described.

At step **29236**, it is determined whether or not a "collision" between the ray and the hit sphere has occurred. When there is no collision, then the method returns to step **29216**. When there is a collision, then the method proceeds to step **29238**.

At step **29238**, the shortest distance between the ray and the center of the hit sphere is determined, as previously described.

At step **29240**, the probability of hitting the digital bird object is determined according to the Gaussian Pellet Distribution, as previously described.

At step **29242**, a random number is generated for each dimension.

At step **29244**, a hit is recorded based on the Gaussian Pellet Distribution, as previously described.

At step **29246**, an animation graphic is triggered when the digital bird reaches the current position of the phantom target. In a preferred embodiment, the animation is provided by the animation array specific to the bird object chosen in the predefined set of attributes. In one preferred embodiment, the animation array shows bird activity terminating and the bird falling along a physically correct arc path for an inanimate object starting with the altitude, speed and trajectory of the digital bird when the hit activity occurred.

Referring to FIG. **30**, weapon movements can be used in the place of controller movements. In a preferred embodiment, the hardware used in a virtual reality simulation includes weapon **2200**, positioning detector **2204**, and a sensor thimble (not shown) worn by user **2201**. After a long press of the sensor thimble, directional movements of weapon **2200** are interpreted as controller commands or specific actions in the simulation, an example of which is shown in the table below.

| Direction | Action |
|---|---|
| Up 3002 | Launch target |
| Down 3004 | Laser toggle |
| Left 3006 | Turn point of view within simulation to the left |

-continued

| Direction | Action |
|---|---|
| Right 3008 | Turn point of view within simulation to the right |

In preferred embodiment, a long or slow press by the sensor thimble uses a threshold duration of 0.5 seconds and the movement has a minimum threshold of 0.5 inches. After holding the sensor thimble down for 0.5 seconds and moving the end of the barrel of the weapon up **3002** by at least 0.5 inches, the system registers a launch target command, e.g., launch signal **29112**, and will launch a target after a random delay of up to two seconds. A long press of the sensor thimble followed by a downward movement **3004** of the end of the barrel of weapon **2200** will toggle on or off the display of a laser that emanates from the end of weapon **2200** during the simulation and identifies the orientation of weapon **2200** in the simulation, such as one or more of beams **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** of FIG. **19**. Moving the barrel left **3006** or right **3008** after holding the sensor thimble for a long press rotates the point of view of the user within the simulation left or right until the sensor thimble is released. Different movements, different actions, and different mappings between movements and actions can be used.

In an alternative embodiment, voice commands are used to perform the actions listed in the table above. For example, when the user says "pull!", the system recognizes the word, identifies that the word is mapped to the launch target action, and initiates launching the target based on the recognized voice command by activating the launch signal, such as in step **29112** of FIG. **29**C. Additional voice commands can be mapped to the actions performed by the system and multiple voice commands can be mapped to the same action. The table below enumerates several voice commands that are mapped with system actions.

| Voice Command | Action |
|---|---|
| "Pull" or "Launch" | Launch target |
| "Toggle" | Laser toggle |
| "Turn left" or "Look left" | Turn point of view within simulation a fixed number of degrees to the left |
| "Turn right" or "Look right" | Turn point of view within simulation a fixed number of degrees to the right |

Referring to FIG. **31**, computer implemented method **3100** is a further description of step **29107** from FIG. **29**C for processing a control signal.

At step **3102**, the system receives a control signal from a peripheral attached to the weapon. In a preferred embodiment, the control signal is the press of a sensor thimble connected to a positioning detector.

At step **3104**, after receiving the control signal, the method determines the initial position of the weapon. In a preferred embodiment, the system stores the current position (location and orientation) of the weapon with the current time.

At step **3106**, it is determined whether or not the control signal has been active for longer than a threshold amount of time. In a preferred embodiment, the threshold amount of time is 0.5 seconds and is referred to as a "long press" or "long touch" of the sensor thimble. The current time is compared to the time stored at step **3104**. If the control signal has been active for longer than the threshold amount of time, then the method proceeds to step **3110**, otherwise the method proceeds to step **3134**, and ends.

At step **3110**, it is determined if the weapon has moved a threshold distance. In a preferred embodiment, the current position of the weapon is compared to the initial position stored at step **3104** and a difference is calculated. If the distance is greater than the threshold, then the method proceeds to step **3114**. If the difference is not greater than the threshold, then the method proceeds to step **3134**, and ends.

At step **3114**, it is determined if the movement of the weapon is in the up direction. If so, the method proceeds to step **3116**. If not, then the method proceeds to step **3118**.

At step **3116**, the method triggers the launch of a clay target in the simulation in response to the movement of the weapon by the user. Afterwards, the method for handling control signals ends at step **3134**.

At step **3118**, the method determines if the movement is in a "downward" direction. If so, then the method proceeds to step **3120**. If not, then the method proceeds to step **3122**.

At step **3120**, the method toggles on or off a "laser" image that emanates from the barrel of the weapon during the simulation, such as one or more of beam images **1906**, **1912**, **1916**, **1920**, **1924**, **1928**, **1932**, and **1936** of FIG. **19**. After toggling the laser image, the method moves to step **3134**, and ends.

At step **3122**, if the weapon was moved to the left, then the method proceeds to step **3124**. If not, then the method proceeds to step **3128**.

At step **3124**, the method rotates the point of view of the user within the simulation to the left.

At step **3126**, the method then checks to see whether or not the control signal is active. If so, then the method returns to step **3124**. If not, then the method moves to step **3134**, and ends.

At step **3128**, the method determines whether or not the movement of the weapon is to the right. If so, then the method moves to step **3130**.

At step **3130**, the method turns the point of view of the user to the right. The method then moves to step **3132**.

At step **3132**, a determination is made as to whether or not the control signal is active. If so, then the method returns to step **3130**. If not, then the method moves to step **3134**, and ends.

Referring then to FIG. **32**, an alternate embodiment of an augmented reality overlay of the simulation resulting from method **2900** is described.

Overlay **320**, is a mixed reality overlay that includes both images from stereo camera **925** and a rendering of simulation objects. In this example, a mixed reality overlay includes actual high house **324**, actual shooter **326** and an actual live target (such as a bird) **328**, all present in the background view of the augmented reality display. The actual high house, actual shooter and live target exist in cartesian coordinate system **322** including x-axis, y-axis and z-axis with an origin at the high house. The mixed reality overlay further includes phantom target **332** rendered by the simulation and displayed on display **958**. Actual live target **328** travels along actual path **330**. The simulation generates projected path **334**, as will be further described. Phantom target **332** leads actual live target **328** by a lead distance "l" as shown. Distance "d" is the distance between the shooter and the live target at a specific instance in time, "t". Live target **328** is flying altitude "y". The angle between the horizontal plane "h" and actual live target **328** at the position of actual shooter **326** is denoted by angle γ.

Referring to FIGS. **32** and **33**, method **3300** of generating a phantom target ahead of a live bird target will be described.

At step **3302**, pass through mode of mixed reality unit **950** is activated. In pass through mode, the images from stereo camera **925** are projected on display **958** with a delay of approximately 50 microseconds.

At step **3304**, the system identifies a spatial anchor. In one preferred embodiment, the spatial anchor is comprised of mapped environment stored in the Microsoft Point Cloud. Once identified, the spatial anchors are uploaded to the point cloud. In this example, spatial anchors comprise actual high house **324** and actual live target **328** in the background. At step **3305**, the spatial anchors are synchronized with the background so that movement of the images can be translated into movement of the position of the stereo camera. At step **3306**, the actual live target is recognized as a bird object is from the object classifications available from the point cloud. In a preferred embodiment, the bird object is recognized through an API call available from the Microsoft HoloLens system.

At step **3308**, the depth "d" for the bird object (the distance from the headset to the target bird object) is measured. In a preferred embodiment, the depth is obtained from API function call to processor **954**. In other embodiments, the distance to target information can be obtained from a LIDAR system, a US_RTLS system, a UWB system or a WLAN, WiFi system as previously described.

At step **3310**, actual path **330** is identified. In a preferred embodiment live target **328** travels from actual high house **324** to the position shown along actual path **330**. Actual path **330** is observed by stereo camera **925**. Velocity is recorded at each point along the path. A set of uniformly spaced points along the path is recognized as cartesian coordinates and stored in an array. A mathematical model of the path is then calculated using the points in the array by a spline function available in the Unity 3D engine. The points in the array are passed to the spline function. The spline function generates a continuous path by interpolating between known points on the path from the array. In this example, the continuous path is shown from point "A" to point "B". The spline function also allows the path to be extrapolated to point "C" as shown in FIG. **32**, within a certain predefined confidence interval.

At step **3312**, the depth is assumed to be the distance to target and is used to calculate the lead distance based on a ballistic table for the weapon, as previously described.

At step **3314**, the correct lead path is calculated. In one embodiment, the Unity 3D engine spline function is used to extrapolate the future path of the live bird up to the appropriate lead position. A set of uniformly spaced discrete points for the target in Cartesian coordinates is identified from the moving image of the bird from the stereo camera and recorded in a table. The discrete points are used by the spline function to interpolate the remaining points along the path and to project movement of the target a short distance into the future. The speed of the live bird is assumed to remain constant. In most cases, the lead distance will be about 2 feet. Because this distance is relatively short, the lead position extrapolated from the known position data using the spline function is usually sufficient accurate to be useful. The spline function takes the form of the spline interface ispline.cs in Unity 3D. The hermite spline interpolation function is employed to derive intermediate points between known points. In order to extrapolate the path, the ray function of Unity 3D is called and passed the last known point (in this case "B") as the origin. The direction for the ray function is taken as the direction defined by the last two known points along the path.

In another preferred embodiment, image processing from the stereo camera can be used to determine the position, direction, and speed of the live bird in order to determine the correct lead path. In this case, the speed of the live bird is determined by reviewing a constantly updating moving window of the sixty most recent video frames in time. The average speed of the live bird determined from the moving window and is assumed to be constant for the entirety of the lead path. The position of the bird is determined by the most recent video frame analyzed. The direction of the live bird is determined by processing the video image to determine where the bird is "looking." In a preferred embodiment, image processing can determine the relative positions of the head of the bird relative to the body of the bird over any number of video frames. The direction of the bird is taken as the vector direction from the centroid of the body of the bird and the centroid of the head of the bird. The vector is recorded and averaged for each frame of the sixty-frame moving window. The vector average is taken as the direction.

A ray function is used through the centroid of the body of the bird and the centroid of the head of the bird to determine the direction for the lead path.

In an alternate embodiment, the lead path is calculated using a neural network as will be further described.

At step **3316**, the image of the live target available from the stereo camera is copied into memory. At step **3317**, the system compensates for movement of the position of the shooter and the orientation of the cameras by adjusting the simulation to change the position of the data, the lead path and the lead distance to account for the movement, as previously described. In this way, the images of the bird at the lead position will appear normal to the shooter.

At step **3318** the copy of the bird image is rendered on the lead path at the lead distance on the lead path ahead of the live target position.

Referring then to FIG. **35**, a preferred neural network **349** for use at step **3314** will be further described.

In a preferred embodiment, the neural network is a recurrent neural network (RNN) applying long short term memory (LSTM) modules. In general, recurrent networks accept as input current data and data from previous node states. In this way the RNN projection of future target paths is more accurate than other more simple feed forward neural networks. Each LSTM module implements a set of gates. The gates propagate data by using the Sigmoid function, σ, as will be further described.

Neural network **349** includes input layer **351**, node layer **353** and output layer **355**. Node layer **353** further comprises nodes N**1**, N**2** and N**3**. In this example, the input layer includes the positional data $x_t$, $y_t$ and $z_t$ at time "t". The output layer comprises a predicted position, $x_{t+1}$, $y_{t+1}$ and $z_{t+1}$, at time t+1.

In use, the network is trained by the positional data available in the path array. The positional data is the actual string of points in cartesian coordinates at each time "t" observed by stereo camera **925** for many thousands of separate target flights, each originating from the same point, in this case the high house. The lead path is calculated by submitting the actual path **330** of the actual live target **328** at point "B," at time "t", into input layer **351** and extracting from the output layer the appropriate future position of the target at point C, at time t+1. The time step t+1 is the lead time required for the target to reach the lead distance based on a ballistic table for the weapon, as previously described.

Referring then to FIG. **36**, a preferred embodiment of the LSTM network node structure **360** will be described. Each of nodes N**1**, N**2** and N**3** comprises a separate instance of the LSTM network node structure **360**.

LSTM network node structure **360** comprises module **357**, module **382**, and module **356**, operatively connected by signal flow **371**, **372**, **373** and **374**. Signal flow **372** comprises previous cell state **358**, denoted in the Figure as $C_{t+1}$. Signal flow **371** comprises previous cell value **380**, denoted in the drawing as $h_{t-1}$. Signal flow **373** comprises current cell value **359**, denoted as $h_t$. Signal flow **374** comprises current cell state **375**, denoted in the drawing as C.

Module **357** further comprises input data **361**, $x_{t-1}$, previous cell state **358**, $C_{t-1}$, and an output of previous cell value **380**, or output value $h_{t-1}$.

Module **382** likewise comprises input data **381**, $x_t$, current cell state **375**, C, and an output of current cell value **359**, or output value $h_t$.

Likewise, module **356** comprises input data **362**, $x_{t+1}$, future cell state **377**, $C_{t+1}$, and an output of future cell value **376**, or output value $h_{t+1}$.

Each of the modules functions in a similar way. Therefore, as an example, module **382** will be described.

Generally, the LSTM network node will output a new value "$h_t$" based on an previous cell value "$h_{t-1}$" and a new signal "$x_t$". To prevent information overflow, gates which are comprised of Sigmoid functions and hyperbolic tangent functions are employed. The Sigmoid functions assign weights that vary between 0 and 1. A value of 1 will allow the data to flow through the gate unimpeded while a value of 0 will stop the data from exiting the gate. The hyperbolic tangent functions filter the data between −1 and 1.

For example, module **382** includes forget gate **364** and input gate **366**.

The value $f_t$, the output of forget gate **364**, can be described as

$$f_t=\sigma(W_f[h_{t-1},x_t]+b_f) \qquad \text{Eq. 34}$$

where $W_f$ is a gate weight and $b_f$ is a bias.

Input gate **366** determines the next values that will be stored in the new state value $C_t$. $C_t$ is multiplied a scaling factor, $i_t$. The factor $i_t$ can be described as

$$i_t=\sigma(W_i[h_{t-1},x_t]+b_i) \qquad \text{Eq. 35}$$

where $W_i$ is a weight and $b_i$ is a bias.

A new vector of cell "candidates" is described as $\tilde{C}_t$ and can be described as.

$$\tilde{C}_t=\tan h(W_c[h_{t-1},x_t]+b_c) \qquad \text{Eq. 36}$$

where $W_c$ is a weight and $b_c$ is a bias.

The new cell value $C_t$ is described as

$$C_t=f_t*[C_{t-1}+i_t]*\tilde{C}_t \qquad \text{Eq. 37}$$

The current cell value $h_t$, **359** is given as

$$h_t=\sigma_t*\tan h(C_t) \qquad \text{Eq. 38}$$

Where:

$$o_f=\sigma(W_o[h_{t-1},x_t]+b_o) \qquad \text{Eq. 39}$$

$W_f$, $W_i$, $W_C$ and $W_o$ form a coefficient matrix and, $b_f$, $b_i$, $b_C$ and $b_o$ form a bias matrix. σ is the Sigmoid function. Likewise, tan h denotes the hyperbolic tangent function.

Normalization of the path data is necessary before using it to train the LSTM network. Min-Max normalization is a linear strategy. It transforms the features of the data to values between 0 and 1.

In a preferred embodiment the RNN is written with Keras, an open source neural network library written in Python. Preferably, Keras is run on top of the Microsoft Cognitive Toolkit and CNTK, available from Microsoft of Redmond, Wash.

Referring to FIG. **37**A, the architecture of an exemplary embodiment of tactical unit **3710** will be described. Exemplary tactical unit **3710** is comprised of headset module **3810**, weapon module **3820** and targeting module **3830**.

The three modules each have their own processor and communicate via a combination of local area networks. The headset module communicates with the targeting module through a hardwired bus. The weapon module communicates with the targeting module through a wireless connection. All wireless communication in the system is encrypted, in a preferred embodiment. In a preferred embodiment, a symmetric cypher is used to promote rapid data transfer rates.

In general, headset module **3810** is responsible for gathering visual information from internal facing and external facing cameras and information from the targeting module, and then processing and displaying that information to the user, on a dedicated augmented reality display, as will be further described.

In general, weapon module **3820** is responsible for gathering positional, ranging and firing data from the weapon and communicating it to the targeting module, as will be further described.

In general, targeting module **3830** is responsible for gathering data from a GPS transceiver, an IMU, a laser range finder and a compass and then calculating and communicating target paths and the relative positions of the weapon, headset and other remote units, as will be further described.

Referring to FIG. **37**B, an overview of the operation of system **3700** will be described. System **3700** includes a single tactical unit **3721**, including weapon **3722**, operating in a tactical theatre. Tactical unit **3721** operates in a cartesian coordinate system **3701** having origin **3702** and three axes, x, y and z. The x axis is aligned with the west east cardinal directions of windrose **3722**. The y axis is aligned with the north to south cardinal directions of windrose **3722**. The z axis is vertical.

Target **3719** moves in the coordinate system along path **3711**. While traveling on the path, target **3719** traverses positions **3712**, **3713**, **3714** and **3715**.

Weapon **3722** is shown in two positions, **3722***a* and **3722***b*. In both positions the weapon is trained on the target. In position **3722***a*, the range to target between tactical unit **3721** and position **3712** of target **3719** is shown as **3704**. In position **3722***b*, the range to target between target **3719** at position **3713** is shown as **3706**.

Virtual laser **3707** is shown projected from weapon **3722** to target **3719** at position **3714**. The virtual laser is displayed and pointed at the target.

The movement of the weapon is used to determine the trajectory of the target. The trajectory of the target is then reduced to a target path equation. The target path equation is used to predict the position of phantom **3715** which is then translated and rotated to account for changes in position of the unit which take place after the path equation is calculated but before the shot is fired.

In a preferred embodiment, the shooter aims virtual laser **3707** at the phantom target as it moves from position **3714** to position **3715** in front of the target before triggering the shot.

Virtual tracer **3708** is shown between weapon **3722** and target **3719** at position **3715**. The virtual tracer is displayed after the shot is fired and before the target is hit or missed.

Referring to FIG. **38**A, system **3701** architecture will be described. System **3701** includes a plurality of remote units, **3710**, **3720**, **3730** and **3740**. Each of the remote units supports a fast, bidirectional wireless data connection with each of the other remote units via a local area network or a wide area network, as will be further described. The number of remote units can be different than shown. In a preferred embodiment, the number of remote units is best suited to a squad or section of between 4 and 10 participants. However, other embodiments, the number of remote units can accommodate a platoon of between 16 and 40 participants. Each remote unit in the system of remote units is of identical architecture in these embodiments. However, in other embodiments the architecture of the remote units can differ to accommodate specialization for different tactical assignments.

A remote unit can also serve as a sentinel and spotter for other remote units, tracking the target from a concealed location, but not firing on it.

Multiple remote units in a tactical theatre is important because when any one remote unit triggers a shot, the user at that remote unit loses track of the target when he shoots. However, the other remote units do not loose track of the target. Hence, the other remote units can be essential in reacquiring a target track after it has been obscured from the shooters vantage point.

Referring to FIG. **38**B an overview of the operation of system **3750** will be described.

As can be seen from the drawing, remote unit **1** and remote unit **2** are positioned in a cartesian coordinate system having an origin **3790** an x and pitch axis, a y and roll axis, and a z and yaw axis, as shown. As shown in windrose **3791**, the x axis lies west to east and the y axis lies north to south. The z axis is vertical.

Remote unit **1** moves from position **3752** to position **3754** along path **3751**. At position **3752**, remote unit **1** has weapon position **3753**. At position **3754**, remote unit **1** has weapon position **3755**.

Remote unit **2** moves from position **3756** to position **3758** along path **3760**. At position **3756**, remote unit **2** has weapon position **3757**. At position **3758**, remote unit **2** has weapon position **3759**.

Target **3769** moves along target path **3770** from position **3772** to position **3774**. At position **3772**, the target has a range **3784** from remote unit **1**. At position **3774**, the target has a range **3782** from remote unit **1**.

Remote unit **1** derives a target path from its relative positions **3752** and **3754**, weapon positions **3753** and **3755** and ranges **3784** and **3782**, as will be further described. Remote unit **1** projects phantom target **3776** ahead of the target at lead distance **3778** along target path **3770**, on its display as seen from its perspective.

Remote unit **1** displays virtual tracer **3790** on its display based on its position and the position of the weapon. The virtual tracer follows the path that a round of known caliber would assume given the launch angle of the weapon in position **3755**.

Target path **3769** is transmitted to remote unit **2** by remote unit **1**. The target path is translated by remote unit **2** into a proper display format, for remote unit **2**. Remote unit **2** generates and displays virtual tracer **3786** and phantom position **3776** on its display, as seen from its perspective.

Either or both of remote unit **1** and remote unit **2** can trigger a directed shot along the virtual tracer once the virtual tracer and the phantom position are coincident on their respective displays.

Referring to FIG. **39**, an exemplary embodiment of headset module **3900** will be described. The architecture of headset module **3900** comprises display processor **3912**, strategically located in a tactical helmet shell, as will be further described. In a preferred embodiment, display processor **3912** is a Qualcomm Snapdragon 850 processor in combination with a companion holographic processing unit as found in the Microsoft HoloLens 2 headset. Other processors known in the art of similar capability will suffice. The display processor includes local internal memory sufficient to store and execute required display information, boot code and operational instructions.

Headset module **3900** further comprises targeting processor **3911**. Targeting processor **3911** is preferably implemented by the AMD Radeon RX 5500M mobile graphics chip. The targeting processor is capable of accelerated geometric calculations such rotation and translation of vertices into different quadrant system including oversampling and interpolation techniques to produce high precision positional calculations. Targeting processor is further capable of high speed matrix and vector operations which accommodate the neural network aspect of the invention, as will be later described. Targeting processor **3900** is operably connected to memory **3919**. Memory **3919** is of sufficient size to store boot code, positioning information and operational code required to implement the functions of the targeting processor. In a preferred embodiment, a 120 gigabyte memory card has been found to be sufficient. Targeting processor **3900** is connected to the display processor **3912** through a hardwired internal high speed bus embedded in the tactical helmet (not shown).

Communications interface **3934** is operatively connected to targeting processor **3911**. In a preferred embodiment, the communications interface can comprise a Bluetooth module, available from Intel, Part No. Intel 9260NGW IEEE 802.11ac Bluetooth 5.0—Wi-Fi/Bluetooth Combo Adapter. Communications interface **3934** can also include a wide area communication interface such as a cellular transceiver or a satellite radio transceiver. In a preferred embodiment, the cellular transceiver module is a TP-Link AC1300 PCIe wireless 2.4G/5G dual band wireless PCI express adapter. In a preferred embodiment, the satellite radio transceiver is an Iridium **9603** Two Way Satellite Data Transceiver. In a preferred embodiment, the communications interface is capable of encrypting and decrypting data sent and received. Encryption keys are stored in and deployed by the targeting processor for each new tactical theatre after an origin reset. In this way, data integrity and security is maintained between tactical operations.

Communications interface **3934** is operatively connected to antenna stack **3914**. Antenna stack **3914** is strategically placed atop the tactical helmet, as will be further described. In a preferred embodiment, antenna stack **3914** includes, WiFi, Bluetooth, satellite and cellular antennas in a single removable module. Antenna stack **3914** also preferably comprises GPS transponder antenna such as the Symbol GPS Antenna 8508851K59 including a low noise amplifier.

Headset module **3900** further comprises stereoscopic camera **3916** operatively connected to targeting processor **3914**. In a preferred embodiment, stereoscopic camera **3916** is the Mynt Eye S stereoscopic camera flat board module available from Slightech, Inc. of Beijing, China. The stereoscopic camera is capable of 60 frames per second depth map resolution of 752×480 pixels. Accurate depth sensing is provided between about 0.5 and about 20 meters. In a preferred embodiment, stereoscopic camera **3916** also provides infrared capability with a field of view of 120° horizontal by 75° vertical. The unit provides frame synchronization accuracy of less than 1 millisecond.

Display processor **3912** is operatively connected to internal camera **3917**. The internal camera is focused on and constantly records movements of the eyes of the user during tactical operations after shouldering of the weapon.

Targeting processor **3914** is further connected to range finder **3918**. In a preferred embodiment, range finder **3918** is forward mounted on the tactical helmet, as will be further described. In a preferred embodiment, the laser range finder is the LRF 3013 available from Safran Vectronix AG of Heerbrugg, Switzerland. The laser range finder includes a range capability of up to 3 kilometers with a typical accuracy of about 0.75 meters.

Tactical processor **3911** is further operatively connected to GPS transceiver **3920**. In a preferred embodiment, GPS module **3920** is Part No. 511-TESEO-LIV3F available from STMicroelectronics.

Tactical processor **3911** is further operatively connected to altimeter **3922**, compass **3924**, accelerometer **3926** and gyroscope **3925**. In a preferred embodiment, the altimeter, compass, accelerometer and gyroscope are all provided in an onboard IMU module available from Vectornav Part No. VN-100IMU/AHRS which comprises an attitude and heading reference system including a 3-axis accelerometer, a 3-axis gyro, a 3-axis magnetic sensor, and a barometric pressure sensor. In use, real time 3-D orientation positions of the remote unit are continually transmitted to tactical processor **3911**, when the unit is activated, at approximately 800 Hz. A 0.5° static pitch/roll capability is provided, as well as a 1° dynamic pitch/roll capability. The internal gyro provides a 5° per hour in run bias. Data is transmitted to the processor at approximately 800 Hz. The accelerometer provides a range of ±16 grams. The gyroscope provides a tolerance of ±2000° per second.

Display processor **3912** is operatively connected to display **3928**. In a preferred embodiment, the display is a pair of see through holographic lenses, positioned in front of the users eyes, providing 2.3 megapixel widescreen capability. The preferred display is provided in the Microsoft HoloLens 2 system and Integrated Visual Augmentation System ("IVAS"), both available from Microsoft.

Microphone **3930** is operatively connected to display processor **3912** for input of voice commands.

The headset module is powered by onboard power supply **3932**. In a preferred embodiment, the onboard power supply is portable lithium ion battery pack attached to the headset module or carried by the user.

Referring to FIGS. **40**A and **40**B, a preferred embodiment of the tactical helmet unit will be further described. Headset module **3810** and targeting module **3830** are resident on carbon fiber tactical helmet shell **4000** worn by user **4020**. In a preferred embodiment, the carbon fiber helmet shell is available as the EXFIL Carbon Helmet, Zorbium Liner, Part No. 71-Z41S-B31, available from Opticsplanet.com. In another preferred embodiment, the carbon fiber helmet shell is Team Wendy EXFIL Ballistic Helmet, Rail, Part No. 73-R3-41S-E31 available from Opticsplanet.com.

Targeting module **3830** is mounted at the rear of the tactical helmet and is removable. The removable nature of the targeting module is important to support quick correction of malfunctions in the field. Further, the targeting module includes watertight seal **4012**, which allows the unit to be completely submersible without effecting operation.

In a preferred embodiment, the targeting processor, display processor, GPS transponder, altimeter, compass, accelerometer, gyroscope and communications interface are all hermetically sealed in targeting module **3830**. In a preferred embodiment, the targeting module is encapsulated in epoxy resin and is removably attached to the tactical helmet by a single mechanical toggle (not shown).

Antenna stack **3914** is optimally positioned on top of the tactical helmet. In a preferred embodiment the antenna stack is removable and is encased by a rearward sloping attachment shroud **4014**, which provides for deflection of debris and brush during tactical operations. The removable nature of the antenna stack is important to allow quick reconfiguration of the helmet and correction of antenna malfunctions in the field.

Range finder **3918** is forward mounted on the tactical helmet and protect by rearward sloping shroud **4016**.

Stereoscopic camera **3916** is forward mounted on the tactical helmet above display **3928** and is positioned to view an outward facing direction generally parallel with line of sight **4010**. Forward shroud **4018** is permanently affixed to the tactical helmet positioned in front of the user's eyes along line of sight **4010**. Line of sight **4010** is centrally positioned to enable a view of external environment and a target through display **3928** by the user. Display **3928** observes a local coordinate system **3929** of "x" in the horizontal direction relative to the display and "y" in the vertical direction relative to the display. Internal facing camera **4011** is affixed inside the forward shroud positioned to view each of the users eyes to readily identify the gaze ray of the line of sight.

Referring to then FIG. **41**A, an example of weapon module **3820** will be described.

Weapon module **3820** includes processor card **4112**. In a preferred embodiment, processor card **4112** is a Raspberry Pi 3, Model B available from Digikey. Processor card **4112** is operatively connected to memory **4113**.

Antenna stack **4114** is operatively connected to processor card **4112**. Processor card **4112** is further connected to laser range finder **4116**. In a preferred embodiment, the laser range finder is the LRF 3013 available from Safran Vectronix AG of Heerbrugg, Switzerland. The laser range finder includes a range capability of up to 3 kilometers with a typical accuracy of about 0.75 meters.

Weapon module **3820** further comprises communications interface **4122**. The communications interface allows encrypted communication between the targeting module and the weapon module during tactical operations. In a preferred embodiment, the communications interface can comprise a Bluetooth module, available from Intel, Part No. Intel 9260NGW IEEE 802.11ac Bluetooth 5.0—Wi-Fi/Bluetooth Combo Adapter. Communications interface **3934** can also include a wide area communication interface such as a cellular transceiver or a satellite radio transceiver. In a preferred embodiment, the cellular transceiver module is a TP-Link AC1300 PCIe wireless 2.4G/5G dual band wireless PCI express adapter. In a preferred embodiment, the satellite communications interface is an Iridium **9603** Two Way Satellite Data Transceiver.

Weapon module **3820** further comprises power supply **4124**. In a preferred embodiment, power supply **4124** is a lithium ion battery located in the stock of the weapon, as will be further described.

Weapon module **3820** further comprises forward IMU **4126** operatively connected to processor card **4112**. Processor card **4112** is further connected to rear IMU **4128** and compass **4130**. In a preferred embodiment, forward IMU **4126** and rearward IMU **4128** are each an IMU module available from Vectornav Part No. VN-100IMU/AHRS which comprises an attitude and heading reference system including a 3-axis accelerometer, a 3-axis gyro, a 3-axis magnetic sensor, and a barometric pressure sensor. The compass function of rear IMU can be used by the system to provide the direction orientation of the weapon in the x, z plane of the cartesian coordinate system.

Referring then to FIG. **41**B, a preferred embodiment of processor card **4112** and memory **4113** are described. Processor card **4112** includes processor **4153**. In a preferred embodiment, processor **4153** is a Broadcom BCM2837 1.2 GHz Quad-Core processor.

Two USB ports **4154** and **4155** are operatively connected to processor **4153**. USB port **4154** is connected to Bluetooth module **4156** which provides a short-range wireless networking connection for the communications interface. The Bluetooth module in a preferred embodiment is Bluetooth 4.0 USB Module (v2.1 Back-Compatible), Product ID 1327, available from Ada Fruit at adafruit.com. The Bluetooth module includes antenna **4159**, Positioned in antenna stack **4114**. USB port **4155** is operatively connected to laser range finder **4116**.

Processor **4153** is connected to general purpose input output pins **4160**. In a preferred embodiment, data from IMU **4126** and IMU **4128** is received through these pins.

Processor **4153** is connected to memory card **4158** via access slot **4161**. Code resident on the memory card is used to boot the processor and perform the operations necessary to control its operation, as will be further described.

Referring then to FIG. **42**A, a preferred implementation of weapon **4200** will be described. Antenna stack **4114** can be seen to be positioned atop the picatinny rail of the weapon adjacent stock **4202**. The position atop the rail allows for reliable wireless communication with the targeting processor of the headset module through the communications interface.

Communications interface **4122** is located remotely from the antenna stack in stock **4202** and is connected to the antenna stack by a coaxial bundle (not shown). Stock **4202** also houses processor **4112**, power supply **4124** and rear IMU **4128**. In a preferred embodiment, the stock is sealed in epoxy resin to protect the components from shock and moisture.

Forward IMU **4126** is positioned in forearm **4204** adjacent barrel **4206** and iron sights **4208**. Laser range finder **4116** is positioned atop the weapon on the picatinny rail as shown. In a preferred embodiment, laser range finder **4116** is side mounted thereby avoiding interference with a line of sight through iron sights **4208**. These components are connected to processor card **4112** by a hard-wired ribbon cable bus (not shown).

Referring then to FIG. **42**B, a top view of weapon **4200** will be described. Weapon **4200** includes forward visual sight marker **4250** positioned adjacent iron sights **4208** of barrel **4206**. Weapon **4200** further includes rearward visual sight marker **4252** positioned adjacent antenna stack **4114**. Both visual sight markers are in the visual line of sight of stereoscopic camera **3916** and the view of the display of the headset module, when the weapon is shouldered. In an alternate embodiment, the orientation of the barrel can be determined and tracked from the IR sensors and forward facing cameras of the HoloLens 2 headset.

Referring to FIG. **43**A, the functions of a single tactical unit operating in a preferred embodiment of system **4300**, will be described. In this preferred embodiment, a single tactical unit is identified as an example and operates alone in the tactical theatre. A spotter (not shown) may also be provided.

At step **4374**, the weapon module senses a shouldering event. In this embodiment, the forward IMU sends a signal to the targeting module indicating a rapid succession of position changes of the weapon in the vertical direction, which is interpreted to be a shouldering event.

At step **4376**, the unit sets an origin of the tactical theatre in cartesian coordinates. In this embodiment, the origin is set at the current location of the rear IMU of the unit. Other origin points may be used, so long as the origin remains fixed during the tactical maneuver. All positional changes are sensed from this origin by the IMU of the tactical processor and/or the forward IMU and rear IMU of the weapon module.

At step **4378**, the compass is read to determine the cardinal directions in order to set the cartesian axes. The x axis is assigned east west. The y axis is assigned north south. The z axis is assumed vertical.

At step **4380**, the unit determines range to target distance. In this embodiment, the target is assumed to be a physical entity on which the weapon is trained. The range to target distance is read from the laser range finder of the weapon while the weapon is trained on the target. In an alternate embodiment, the range to target distance is read from the stereoscopic camera. In another preferred embodiment, the range to target distance is read from the laser range finder of the tactical helmet.

At step **4381**, the weapon position is determined, as will be further described.

At step **4382**, the virtual laser position is calculated. The virtual laser moves with the weapon as the weapon moves, in order to mimic the appearance of a real world targeting laser. The position of the virtual laser must account for shot drop at range in order to accurately predict the position of the round after any period of time after launch. The virtual laser is projected as a straight line from the barrel of the weapon extending to the shot drop position, for a distance equal to or surpassing the range to target distance. The position of the weapon is used to determine the correct orientation of the virtual laser with respect to the weapon, as will be further described. In a preferred embodiment, the virtual laser position is calculated and animated by the display processor by making a function call to the Microsoft HoloLens 2, Integrated Visual Augmentation System ("IVAS"), available from Microsoft, or Unity 3D gaming engine.

At step **4383**, the display processor of the remote unit displays the virtual laser entity on the augmented reality display.

At step **4384**, target path is calculated. The flight path of a moving object can be segmented into discrete pieces by using the range finder, the tracked movement of the gun barrel and the displays frame rate acting as a clock. Each frame defines a discrete time period and a distance along the path. With a change in distance over time, speed can be derived as can rate of change, acceleration and deceleration. Since images are typically generated at 60 or 90 frames per second, the trajectory can be segmented at the same rate, and used to predict and display the aim point in terms of "frames" ahead.

In general, the target path is derived from the position, velocity and acceleration of the weapon, evaluated as a rigid body, relative to the origin. The position, velocity and acceleration of the weapon as a rigid body are calculated by recording the positions of the forward IMU and the rear IMU at discrete time intervals, called "frames." A virtual ray object is then calculated as a "projection" coaxial with the axis of the barrel. The axis of the barrel is approximated from the positions of the rear IMU and the forward IMU. The virtual ray object is then extended mathematically from the position of the forward IMU away from the rear IMU, by a distance equivalent to the range to target to a termination point. The termination point is assumed to be the target position. The termination point moves as the weapon moves and, at the distance of range to target, is assumed to be the target path. An equation of the target path may be derived for use in predicting future movements of the target.

In a preferred embodiment, the target path equation is derived path in spherical coordinates from changes of the weapon position over time, for at least two time periods, and the range to target data. In a simplified example, where the range to target is constant, the following equations of motion are employed to derive r, v and a in spherical coordinates:

$$r = r(t) = r\hat{e}_r \qquad \text{Eq. 40}$$

$$v = v\hat{e}_r + r\frac{d\theta}{dt}\hat{e}_\theta + r\frac{d\varphi}{dt}\sin\theta\hat{e}_\varphi \qquad \text{Eq. 41}$$

$$a = \left(a - r\left(\frac{d\theta}{dt}\right)^2 - r\left(\frac{d\varphi}{dt}\right)^2\sin^2\theta\right)\hat{e}_r + \left(r\frac{d^2\theta}{dt^2} + 2v\frac{d\theta}{dt} - r\left(\frac{d\varphi}{dt}\right)^2\sin\theta\cos\theta\right)\hat{e}_\theta + \left(r\frac{d^2\varphi}{dt^2}\sin\theta + 2v\frac{d\varphi}{dt}\sin\theta + 2r\frac{d\theta}{dt}\frac{d\varphi}{dt}\cos\theta\right)\hat{e}_\varphi \qquad \text{Eq. 42}$$

Where:

r is the range to target taken along the axis of the weapon from the forward IMU position;

v =target velocity;

a=target acceleration;

θ is the angle of the weapon from the z axis;

φ is the angle of the weapon from the x axis;

ê=vector notation.

$$\frac{d\theta}{dt} = \frac{\theta_1 - \theta_2}{t_1 - t_2} \qquad \text{Eq. 43}$$

$$\frac{d\varphi}{dt} = \frac{\varphi_1 - \varphi_2}{t_1 - t_2} \qquad \text{Eq. 44}$$

Where:

$\theta_1$ and $\varphi_1$ are taken at $t_1$;

$\theta_2$ and $\varphi_2$ are taken at $t_2$.

The target path between time t and $t_2$ may be considered a "segment." The time between $t_1$ and $t_2$ may be considered a "frame."

The target position, velocity and acceleration of the weapon may then be derived for successive segments in successive frames.

In a preferred embodiment, the mathematical projection of the virtual ray object takes the form of a function call from the targeting processor to the Microsoft HoloLens 2 or the Unity 3D gaming engine, available from Unity Labs or similar.

At step **4386**, lead distance is calculated. The lead position must account for the distance that the target will move during a period of time between the trigger event and the arrival of the round at the target position. The lead must also account for the shot drop in the round between the triggering event and arrival of the round at the position of the target.

In a preferred embodiment, to accurately represent correct lead on real targets in an AR headset, the aim point is animated at a frame rate, the gun barrel is motion-tracked and the range is updated on the target at approximately the same rate as the frame rate of the animation.

Once the correct lead is established, the system ceases updating the target path from the weapon position and animation of the phantom proceeds using only the target path equation, which is translated and rotated to account for changes in the position of the unit. In one embodiment, the position of the unit is drawn from the IMU of the targeting module.

In another preferred embodiment, lead is calculated by consulting a ballistics table stored in memory of the targeting processor of the unit. The ballistics table provides the shot drop for each range and for each potential type of weapon and round used by the unit. The velocity of each potential round used by the unit is also provided in the ballistics table. Given the velocity of the round and the range to target, the elapsed time between a trigger event and arrival of the round at the target can be calculated as follows:

$$t = \frac{r}{v} \qquad \text{Eq. 45}$$

Where:

t=time to target

r=range

v=velocity

The time to target is then substituted into the target path equation, which is solved for the position of the target at the ballistic intercept point. The lead distance is the difference between the position of the target at the time the shot is fired to the position of the target at the time of ballistic intercept. Once the target path and the lead distance are derived, the use of current weapon position data to update the target path equation ceases, and the display relies on the then calculated target path equation for animation of the phantom target image. The display of the virtual laser and the virtual tracer remain dependent on weapon tracking data, to determine their positions in the display.

At step **4391**, a phantom target is displayed at the lead position.

At step **4392**, the display processor compares the phantom target position to the virtual laser position to determine a coincidence event. A "coincidence event" is an overlap between the graphic displays of the virtual laser and the phantom target.

At step **4393**, the display processor receives a coincidence event signal and sends it to the targeting processor.

At step **4394**, the display processor generates and displays a fire alert. A shot is assumed to be triggered at or near the time of the display of the fire alert.

At step **4395**, a virtual tracer path is calculated. In a preferred embodiment, the virtual tracer path is determined by calculating a predicted shot trajectory given the current position and launch angle of the weapon, translated and rotated to account for the position, velocity and acceleration of the unit. The virtual laser path is stored as an equation which is sent to the display processor of the unit. The virtual tracer path remains dependent on constantly updated weapon position data.

Upon indication of a shot being fired, at step **4396**, the virtual tracer is displayed by the display processor. The virtual tracer is displayed along its path as a generally hyperbolic broken bright line.

At step **4397**, the display processor monitors the display for a hit condition. A "hit condition" is defined for the display processor as a presumed hit of the target being tracked. A "hit condition" event in one embodiment occurs when the laser range finder of the weapon reports an infinity value for the range to target distance or the IVAS or similar camera records the reflection of a spotter round or incendiary round hitting the target or a spotter verifies a hit. A hit condition is logged upon occurrence. If a hit condition event is not reported within a shot predetermined time frame, the shot is logged as a "miss."

At step **4398**, the display processor records a hit (or miss) incident and transmits it to the targeting processor.

At step **4399**, the origin point is cleared.

Referring to FIG. **43**B, the functions of a plurality of remote units operating in a preferred embodiment of system **4301**, will be described. In this preferred embodiment, two remote units are identified as examples and operate in the tactical theatre. However, in other embodiments communications and functions such as those described can occur between a larger number of remote units, all in communication with each other through the local area network or a wide area network. In this example, remote unit **4390** initially acts as a "spotter" for remote unit **4395**.

At step **4302**, remote unit **4390** sets an origin of the tactical theatre in the cartesian coordinates. In this embodiment, the origin is taken at the GPS location and elevation of the tactical processor of remote unit **4390**. At step **4303**, the compass is read to determine the cardinal directions. The x axis is assigned east west. The y axis is assigned north south. The z axis is assumed vertical.

At step **4304**, the origin position is sent to remote unit **4395** through the local area network. At step **4305**, remote unit **4395** stores the origin and adopts it as the origin of the tactical theatre. In a preferred embodiment, the GPS location of remote unit **4395** is read and the origin is translated and rotated to account for the difference in position between remote unit **4390** and remote unit **4395**. At step **4306**, remote unit **4395** reads its internal compass for cardinal directions and assigns them to the x and y axes, as described. The vertical direction is assigned the z axis. In one preferred embodiment, the cardinal directions are synchronized and matched as between the remote units.

At step **4307**, remote unit **4390** identifies a target to track. The target is "identified" by the system when the user shoulders the weapon and assumes a stable pattern of weapon movement. In a preferred embodiment, a stable pattern of weapon movement occurs when the weapon is directed along a continuous path for greater than about 750 milliseconds.

At step **4308**, remote unit **4390** initiates a target tracking routine. The target tracking routine implements a sequential sampling of range to target distance, weapon position and unit position. Each sampling of data points is taken simultaneously from the range finder of the weapon and the forward IMU and rear IMU, repeatedly at discrete time intervals or frames. The data is stored in a table for later use, indexed by time or frame rate. In a preferred embodiment, the discrete steps are about 25 milliseconds apart. In other embodiments, a 60 to 90 second frame rate is used. The frame rate may be synchronized to that of the display processor.

At step **4309**, range to target is read from the laser range finder of remote unit **4390**. At step **4311**, the weapon position is read, as will be further described. At step **4313**, remote unit **4390** determines its own current position in the operating theatre, relative to the origin and the cartesian coordinate system, using repeated calls to the onboard IMU.

At step **4315**, the target path equation relative to the origin is calculated, as previously described. In this embodiment, the apparent target path as seen from the position of remote unit **4390** must be appropriately translated and rotated by remote unit **4390** to derive the target path relative to the origin.

At step **4317**, the target path equation derived by remote unit **4390** is transmitted to remote unit **4395** via the wireless network.

At step **4323**, the targeting processor of remote unit **4395** polls the laser range finder attached to its weapon and calculates the distance to target as if it were a stand-alone unit, as previously described.

At step **4324**, the targeting processor of remote unit **4395** calculates the time to target given the distance to target. At step **4325**, shot drop at range is determined. The shot drop is derived for the particular weapon and round being used, from the ballistic table.

At step **4326**, remote unit **4395** determines its weapon position, as will be further described.

At step **4327**, the display processor of remote unit **4395** displays a virtual laser image on the augmented reality display. The virtual laser image is displayed as a straight bright line.

At step **4329**, remote unit **4395** determines its position, velocity and acceleration. In a preferred embodiment, the targeting processor of remote unit **4395** polls the onboard IMU to determine instantaneous position, velocity and acceleration with respect to the origin. In an alternate embodiment, the targeting processor polls the onboard GPS transceiver to determine position at least several points in order to obtain position and vector values for velocity and acceleration.

At step **4331**, the targeting processor of remote unit **4395** translates and rotates the target path equation received from remote unit **4390** for proper display from the perspective of remote unit **4395**.

At step **4335**, the targeting processor of remote unit **4395** calculates the lead distance for the particular round in the weapon, based on the round velocity, shot drop, range to target, translated target path, and target position, velocity and acceleration and sends it to the display processor. In a preferred embodiment, the lead position is calculated by determining the time that the round will take to reach the target, and then extrapolating the path of the target from the target path equation ahead of the target for this period of time. The phantom target position is raised in the z direction by the shot drop distance to more precisely indicate the ballistic interrupt point.

In another embodiment, the phantom is advanced along the path, in predicted segments, at the same frame rate as the display is sampled, for the number of frames as would be required for the round to travel from the weapon to the target.

At step **4339**, the display processor of remote unit **4395** displays a phantom image ahead of the target along the target path at the lead distance and accounting for shot drop.

At step **4341**, the display processor compares the phantom position to the position of the virtual laser. In a preferred embodiment, a "coincident" function call is made to the HoloLens 2 system to compare for overlap between the two visual elements of the virtual laser and the phantom image.

At step **4345**, when the images of the phantom target and the virtual laser are coincident, the display processor reports a coincidence event at step **4343** to the targeting processor.

At step **4345**, the targeting processor generates a fire alert message. At step **4347**, remote unit **4395** displays a fire alert message on the display of the headset module. At step **4348**, the forward IMU senses a shot signal and transmits it to the targeting module. A shot is assumed to be triggered at or near the time of the display of the fire alert message.

At step **4349**, remote unit **4395** sends the shot signal message to remote unit **4390** via the local area network. At step **4351**, the display processor of remote unit **4390** displays the shot signal message and an indicator of which remote unit sent the message for the user on the augmented reality display of remote unit **4390**.

At step **4352**, remote unit **4395** generates and displays a virtual tracer image along the shot path, as previously described.

At step **4353**, remote unit **4395** monitors for and records a hit or miss condition.

Optionally, at step **4354**, remote unit **4390** resets the origin.

At step **4355**, the targeting processor of remote unit **4390** calculates time to target, as previously described. At step **4356**, remote unit **4390** calculates the shot position at range by consulting a ballistics table to determine shot drop at range for the particular round being fired.

At step **4357**, remote unit **4390** calculates the shot path based on the weapon position, velocity and acceleration, as previously described.

At step **4359**, the display processor of remote unit **4390** displays a virtual laser the display of remote unit **4390**, as previously described.

At step **4361**, targeting processor of remote unit **4390** calculates a lead distance along the target path, relative to the display of remote unit **4390**, as previously described.

At step **4363**, the display processor of remote unit **4390** displays a phantom target, at the lead distance, along the target path, and accounting for shot drop as previously described.

At step **4365**, the display processor of remote unit **4390** compares the displayed phantom position to the virtual laser position, as previously described. At step **4367**, the display processor of remote unit **4390** records a coincidence between the displayed phantom and the virtual laser.

At step **4368**, upon receiving a coincidence condition, the targeting processor of remote unit **4390** generates a fire alert message. At step **4369**, the display processor of remote unit **4390** displays the fire alert message on the display to the user. At step **4370**, remote unit senses a shot signal. At step **4371**, remote unit **4390** generates a shot signal message. At step **4372**, remote unit **4390** sends the shot signal message to remote unit **4395**, through the local area network. At step **4373**, remote unit **4395** displays the shot signal message, along with an indicator that remote unit **4390** has fired.

At step **4373**, remote unit **4390** generates and displays a virtual tracer, as previously described.

At step **4374**, remote unit **4395** displays the shot signal.

At step **4375**, remote unit **4390** records a hit or miss condition.

At step **4376**, remote unit **4390** resets the origin.

Referring then to FIG. **44**, method of determining weapon position for a remote unit **4400** will be described.

At step **4415**, weapon processor **4409** polls the forward IMU sensor to derive forward IMU data. In a preferred embodiment, the forward IMU data comprises a position, velocity and acceleration of the forward end of the weapon relative to the origin.

At step **4417**, weapon processor **4409** polls the rear IMU sensor to derive rear IMU data. In a preferred embodiment, the rear IMU data comprises a position, velocity and acceleration of the rear end of the weapon relative to the origin.

The forward IMU and rear IMU data pairs are taken repeatedly so that a weapon position may be accurately derived. The forward IMU and the rear IMU data pairs are individually time stamped so that they can be associated together for later use.

At step **4418**, the data pairs are time stamped by appending a clock field to each data set including the current time. At step **4419**, weapon processor **4409** sends the time stamped forward IMU and rear IMU data pairs to the targeting processor over the local area network.

At step **4420**, targeting processor **4407** stores the forward IMU and the rear IMU data pairs.

At step **4425**, display processor **4405** reads the position of the forward visual sight marker position, velocity and acceleration and stores then in memory. At step **4427**, the display processor reads the position of the rear visual sight marker position, velocity and acceleration and stores then in memory. The process is repeated creating data pairs. The forward and rear visual sight marker data pairs are time stamped for later use.

At step **4428**, the data sets are time stamped.

At step **4433**, display processor **4405** sends the forward visual sight marker position data, and the rear visual sight marker position data pairs to targeting processor **4407**. At step **4434**, the data sets are stored.

At step **4435**, the targeting processor determines the weapon position, velocity and acceleration from the IMU data. In a preferred embodiment, the processor determines the weapon position from the IMU data by establishing a vector between the rearward IMU position and the forward IMU position for each pairing of the standard data. The two positions are assumed to be separate positions on the same rigid body. A weapon path equation is derived using kinematic equations, as will be further described.

At step **4437**, targeting processor **4407** derives weapon position, velocity and acceleration from the visual sight marker data. In a preferred embodiment, a path is derived for the first position of the forward visual sight marker and the second position of the forward visual sight marker. Similarly, a rear visual sight marker path is derived between the first position of the rear visual sight marker and a second position of the rear visual sight marker. A vector is established between the rear visual sight marker position to the forward visual sight marker position for each pairing of time stamped data. The two positions are assumed to be separate positions on the same rigid body. A weapon path equation is derived.

In general, the weapon path equation is derived from the following kinematics equations:

The angular velocity of a rigid body B in a reference frame N is equal to the sum of the angular velocity of a rigid body D in N and the angular velocity of B with respect to D:

$$ {}^{N}\omega^{B} = {}^{N}\omega^{D} + {}^{D}\omega^{B} \qquad \text{Eq. 46}$$

For any set of three points P, Q, and R, the position vector from P to R is the sum of the position vector from P to Q and the position vector from Q to R:

$$ r^{PR} = r^{PQ} + r^{QR} \qquad \text{Eq. 47}$$

The velocity of point P in reference frame N is defined as the time derivative in N of the position vector from O to P:

$$ N_{V} P = \frac{N_{d}}{dt}(r^{OP}) \qquad \text{Eq. 48}$$

Where:

O=the origin;

N=indicates that the derivative is taken in reference frame N.

The acceleration of point P in reference frame N is defined as the time derivative in N of its velocity:

$$N_a P = \frac{N_d}{dt}(N_V P) \qquad \text{Eq. 49}$$

For two points P and Q that are fixed on a rigid body B, where B has an angular velocity ${}^N\omega^B$ in the reference frame N, the velocity of Q in N can be expressed as a function of the velocity of P in N:

$${}^N\mathrm{v}^Q = {}^N\mathrm{v}^P + {}^N\omega^B \times r^{PQ} \qquad \text{Eq. 50}$$

By differentiating the equation for the Velocity of two points fixed on a rigid body in N with respect to time, the acceleration in reference frame N of a point Q fixed on a rigid body B can be expressed as:

$${}^N a^Q = {}^N a^P + {}^N\omega^B \times ({}^N\omega^B \times r^{PQ}) + {}^N\alpha^B \times r^{PQ} \qquad \text{Eq. 51}$$

Where:

${}^N\alpha^B$ is the angular acceleration of B in the reference frame N.

In a specific case of these equations, the 3 reference points on the rigid body are assumed to be collinear, along the weapon barrel between the rear IMU position and the forward IMU position.

In another embodiment, recognition of barrel orientation and motion can be done by the HoloLens 2, Integrated Visual Augmentation System ("IVAS") or Leap Motion tool available from the developer archive of Leap Motion of San Francisco, Calif.

In optional step **4439**, the final weapon position, velocity and acceleration is determined by averaging the vector coordinates of the weapon position derived from IMU data and the vector coordinates of weapon position derived from the visual sight marker data.

At step **4440**, the final weapon position, velocity, acceleration and the weapon path equation are reported for later use.

In an alternate preferred embodiment, steps **4415**, **4417**, **4419**, and **4437** are optional. In an alternate preferred embodiment, steps **4425**, **4427**, **4428**, **4433** and **4437** are optional.

Referring to FIGS. **45**A, **45**B and **45**C, an example of the display of a single unit showing a phantom and a pull-away lead will be described.

Referring to FIG. **45**A, display **4560** can view weapon **4598** trained on target **4597** moving along path **4596**. Virtual laser **4599** can be seen directed to target **4597**.

Phantom image **4592** is shown traversing path **4596** to an anticipated position ahead of the target by lead distance **4591**.

Referring to FIG. **45**B, display **4560** can now visualize weapon **4598** having "pulled-away" from target **4597** along direction **4593**. Virtual laser **4599** can now be seen directed toward a coincident position with phantom display **4592**. At this point, a fire signal is sent and shown in the display at **4594**. When the shot is fired, virtual laser **4599** disappears and a virtual tracer is displayed, as will be further described.

Referring to FIG. **45**C, a display of a virtual tracer and ballistic intercept display will be described.

Display **4560** shows weapon **4598** trained on target **4597**. Target **4597** travels along path **4596**. Virtual tracer **4593** is shown displayed from weapon **4598** along a generally hyperbolic path to a ballistic intercept of target **4597**. The virtual tracer is activated upon a shot being triggered and disappears upon recording of a hit or miss incident.

Referring to FIGS. **45**D and **45**E, exemplary displays of remote unit **4390** and remote unit **4395**, respectively, operating in the same tactical theatre, will be described.

Referring to FIG. **45**D, display **4391** of remote unit **4390**, as seen from the perspective of the user is shown. Weapon **4505** is shown directed toward phantom target **4509**. Target **4507** proceeds along path **4502**. Phantom target **4509** is shown at lead distance **4510** ahead actual target **4507**. Virtual laser **4511** is shown coincident with phantom target **4509**.

Referring to FIG. **45**E, display **4396** of remote unit **4395**, as seen from the perspective of the user, is shown. Weapon **4555** is shown directed at phantom target **4559**. Target **4507** is shown proceeding along path **4503**. Phantom target **4559** is shown leading actual target **4507** at distance **4560**. Virtual laser **4561** is shown coincident with phantom target **4559**.

As can be seen, although the actual real-world trajectory of target **4507** in the cartesian coordinates is the same, that the display of the trajectory to remote unit **4390** differs from the display of the trajectory to remote unit **4395**. Similarly, there is a difference between lead distance **4510** and lead distance **4560** as seen from the perspective of remote unit **4390** and remote unit **4395**, respectively.

Referring to FIG. **46**A, the architecture of an alternate system embodiment **4600** will be described.

System **4600** comprises a plurality of remote units. In this example, the architecture shows remote units **4610**, **4620**, **4630** and **4640**. In other embodiments, there may be a greater or smaller number of remote units. Each of the remote units is configured as previously described. Each of the remote units communicates wirelessly with each of the other remote units through a local wireless network, as will be further described. All communications conducted wirelessly are encrypted in a preferred embodiment. A symmetric cypher is preferred to maximize encryption and decryption speed.

The addition of drones, spotters, remote and fixed cameras is important because when any one shooter or any plurality of shooters triggers a shot, they lose track of the target when the weapon is fired. However, the spotters, drones and fixed cameras will not lose track of the target that is otherwise obscured from one or more shooters vantage points.

Each of the remote units also communicates with tactical monitor **4645** through the wireless network. Tactical monitor **4645** further communicates with drone **4660** and fixed camera **4670** through a wireless network. In a preferred embodiment, drone **4660** and fixed camera **4670** operate in the same tactical theatre as the remote units. In other embodiments, a plurality of fixed cameras and a plurality of drones, all in communication with the tactical monitor are provided and are operational in the tactical theatre.

Tactical monitor **4645** is operatively connected to local database **4655** and neural network pattern processor **4650**.

Referring to FIG. **46**B, an overview of a preferred embodiment will be described.

The tactical theatre is defined by a cartesian axis with origin **4672** and axes defined by windrose **4673**. In the operational theatre, remote unit **4674** and remote unit **4676** are free to move in the x, y plane. Fixed camera **4678** maintains a fixed position in the cartesian system. Drone **4680** is free to move is three dimensions in the cartesian system.

Target **4682** moves from target position **4684** to target position **4685** along target path **4683**.

Remote unit **4674** has a range to target of **4690**. Remote unit **4676** has a range to target of **4691**. Fixed camera **4678** has a range to target of **4689**. Drone **4680** has a range to target of **4693**.

Remote unit **4676** displays virtual laser **4688** and a phantom **4686**. Phantom **4686** is displayed at lead distance **4692** ahead of target **4682** along target path **4683**.

Referring to FIG. **47**, drone **4660** will be further described.

Drone **4660** includes processor **4705**. Processor **4705** includes three concurrently running modules including navigation module **4707**, flight management module **4709** and data communication management module **4711**. Processor **4705** also includes memory sufficient to store and process flight and positional instructions necessary to carry out its functions.

Navigation module **4707** is responsible for executing a predetermined flight path, according to a flight schedule in the tactical theatre. In an alternate embodiment, the navigation module receives flight path corrections from the processor responsive to a remote set of commands from the tactical monitor. Flight management module **4709** is responsible for activation and maintenance of motor speed, collision avoidance and in-flight stability. Data communication module is responsible for gathering, formatting and transmitting data from the IMU, GPS transponder, camera and range finder to the tactical monitor through the communication interface. The data communication module is also responsible for receiving and distributing course correction instructions and camera positioning instructions from the tactical monitor.

Processor **4705** is operatively connected to GPS transceiver **4720**.

Drone **4660** further comprises altimeter **4722**, compass **4724**, gyroscope **4726** and accelerometer **4728**. In a preferred embodiment, the altimeter, compass, gyroscope and accelerometer are contained in an internal IMU unit which communicates directly with the processor.

Drone **4660** further comprises communication interface **4730**. In a preferred embodiment, communications interface **4730** accommodates a wireless local area network and a wireless wide area network such as the Internet.

Drone **4660** is powered by power supply **4732**. In a preferred embodiment, power supply **4732** is a lithium ion battery power source capable of supplying approximately about 30 minutes flying time.

Processor **4705** is further connected to stereo camera **4734**. In a preferred embodiment, the stereo camera is mounted on a pan, tilt and zoom platform which communicates directly to the processor and can be remotely positioned by the tactical monitor, as will be further described.

Processor **4705** is further connected to laser range finder **4736**. In a preferred embodiment, the laser range finder is physically attached to the pan, tilt, zoom platform of the camera and is moved with the camera. The processor and communications interface are operatively connected to antenna stack **4738**, which is externally mounted on the drone airframe (not shown).

In a preferred embodiment, drone **4660** is the Yuneec H520-E90 Configurable Bundle available from Vertigo Drones of Webster, N.Y. In this embodiment, the drone is a six rotor configuration airframe, including direct communication with tactical monitor **4645** through mission control software, as will be further described. Drone **4660** is capable of carrying out predetermined flight plans, including both positional, rotation and altitude maneuvers. Live feed video transmissions, including position data, range data and GPS data are communicated directly and constantly to the tactical monitor via the communications interface, as will be further described.

Referring to FIG. **48**, fixed camera **4670** will be further described.

In a preferred embodiment, fixed camera **4670** includes processor **4805**. Processor **4805** is operatively connected to camera **4810**. Camera **4670** further is positioned on a motorized platform **4815** capable of pan, tilt and zoom functions, positioned locally by the processor according to commands from the tactical monitor.

Fixed camera **4670** further comprises communications interface **4820** operatively connected to processor **4805**. GPS transponder **4825** is optionally included in the fixed camera and is operatively connected to the processor and required antennas. If included, the GPS transponder communicates with the processor and the tactical monitor through the communications interface. The GPS transponder is included to allow periodic repositioning of the camera unit. In a preferred embodiment, fixed camera **4670** further comprises range finder **4830**, operatively connected to processor **4805**, and movable with the camera by the pan, tilt, zoom platform.

The communications interface is capable of communication with the tactical monitor through either or both a wireless local area network or wireless wide area network, such as the Internet.

In a preferred embodiment, the fixed camera is the military grade MX6 FLIR PTZ thermal imaging long range multi sensor pant tilt MWIR camera system, available from Sierra Pacific Innovations Corp. of Las Vegas, Nev. The camera is capable of LFIR thermal imaging at up to 55 kilometers distance. The fixed camera is further capable of laser range finding to approximately 50 millimeter tolerance.

Referring to FIG. **49**, a preferred method of operation of preferred system **4900**, will be described. In a preferred embodiment, tactical processor **4906**, display processor **4908** and weapon processor **4910** are all connected through a local area network. In a preferred embodiment, targeting processor **4906** is connected to tactical processor **4904** and AI processor **4902** through a wide area network. In this embodiment, the targeting processor, display processor and weapon processor are resident on a single remote unit.

At step **4911**, targeting processor **4906** sets the cartesian origin of the tactical theatre. In a preferred embodiment, the origin is set via GPS coordinates. At step **4916**, the origin coordinates are sent to the tactical processor.

At step **4912**, the tactical processor launches and positions the drone along a predetermined flight path. The drone processor coordinates local flight operations of the drone along the predetermined flight path.

At step **4913**, weapon processor **4910** reads the forward weapon IMU to determine movement. The movement is interpreted as a shoulder signal. At step **4914**, weapon processor **4910** sends the shoulder signal to targeting processor **4906**. At step **4915**, weapon processor **4910** forwards the shoulder signal to the display processor **4908**. At step **4917**, targeting processor **4906** forwards the shoulder signal to tactical processor **4904**.

At step **4918**, tactical processor **4904** registers the cartesian origin in GPS coordinates and determines cardinal axes. At step **4919**, the tactical processor publishes the origin position, in GPS coordinates, to all the nodes of the network. In a preferred embodiment, the nodes of the network include a plurality of remote units, a drone and a fixed camera. In other embodiments, a greater or fewer number of remote units, drones and fixed cameras may be employed.

At step **4922**, weapon processor **4910** identifies the weapon position, as previously described.

At step **4921**, display processor **4908** identifies a gaze ray position. In a preferred embodiment, the gaze ray position is determined by a function call to the Microsoft HoloLens 2 system. The gaze ray function call returns the line of site of the users eyes relative to the display of the remote unit. The gaze ray is assumed to identify a target of preference moving along a target path. At step **4923**, a series of gaze ray positions is tracked by sequential gaze ray function calls to track the target. The gaze ray positions are translated to account for the relative changes in the headset module as recorded by the headset IMU, relative to the origin to derive a set of gaze ray track data. The gaze ray track data is interpreted as the target track. At step **4924**, the gaze ray track data is sent to targeting processor **4906**. At step **4925**, targeting processor **4906** forwards the gaze ray track data to AI processor to **4902**.

At step **4926**, weapon processor **4910** sends the weapon position data to targeting processor **4906**. At step **4927**, targeting processor **4906** forwards weapon position data to AI processor **4902**. At step **4928**, AI processor adds the weapon position data and the gaze ray track data to a training table, as will be further described.

At step **4929**, targeting processor **4906** determines the path of the remote unit. In a preferred embodiment, the path of the remote unit is tracked based on the series of polls of the IMU by the targeting processor. The IMU presents a position of the targeting processor and the remote unit relative to the origin at any point in time. Instantaneous velocity, position, velocity and acceleration are taken from the IMU at this step.

At step **4930**, weapon processor **4910** determines a range to target by polling the laser range finder attached to the weapon. At step **4931**, targeting processor **4906** determines a range to target by the polling laser range finder attached to the tactical helmet. In another preferred embodiment, targeting processor **4906** determines range to target by polling the stereoscopic camera attached to the tactical helmet.

At step **4932**, targeting processor **4906** calculates the virtual laser position from the weapon position based on its position, velocity and acceleration.

At step **4933**, targeting processor **4906** sends the virtual laser position to display processor **4908**. At step **4934**, display processor **4908** displays the virtual laser position.

At step **4935**, targeting processor **4906** and weapon processor **4910** calibrate to determine a "true" range to target. In a preferred embodiment, the true range to target is determined by the targeting processor by averaging the ranges reported by the weapon processor, and by the targeting processor by both the stereo cameras and the laser range finder.

At step **4936**, the targeting processor **4906** calculates a target path. In a preferred embodiment, the target path is calculated using true range from the remote unit to the target, the path of the remote unit (if moving) and the weapon position data, as previously described.

Alternatively, the step of calculating the target path uses the path of the remote unit, the true range, and the gaze ray track data according to the following equation:

$$\frac{d\theta}{dt} = \frac{\theta \text{ gaze ray } 1 - \theta \text{ gaze ray } 2}{t_1 - t_0} \qquad \text{Eq. 52}$$

-continued

$$\frac{d\phi}{dt} = \frac{\varphi \text{ gaze ray } 1 - \varphi \text{ gaze ray } 2}{t_1 - t_0} = r_0 + vt - \frac{1}{2}at^2 \qquad \text{Eq. 53}$$

At step **4937**, targeting processor **4906** sends the target path data to tactical processor **4904**. In a preferred embodiment, the target path data is sent in spherical coordinates. At step **4938**, tactical processor **4904** receives external target path data relative to the origin from other nodes of the network.

At step **4939**, tactical processor **4904** derives an equation for the true target path. In a preferred embodiment, the "true" target path is resolved by averaging the path data received from each of the nodes on the network. However, the true target path may be based on just one of the range reported by the weapon processor, the range reported by the laser range finder of the tactical helmet, or the range reported by the stereoscopic camera. Once an equation is derived for the true target path, the target path is decoupled from the current weapon position data and is not updated with new weapon position data until after a hit or miss condition is received.

At step **4940**, the true path data is sent from the tactical processor to targeting processor **4906**. At step **4941**, targeting processor **4906** calculates a lead position. Time to target is derived from the ballistic table given the true range. The shot drop is then determined by consulting the ballistic table at the true range. The true path is then projected forward in time by the time to target for the ballistic round at the current range. In a preferred embodiment, the path is projected forward by the display processor in a segmented fashion for an appropriate number of frames to match the time of flight of the round to the target at range.

At step **4942**, tactical processor **4904** sends the resolved path data to AI processor **4902**. At step **4943**, AI processor **4902** determines lead position from the neural network using the true target path data, as will be further described.

At step **4944**, AI processor **4902** sends the lead predicted by the neural network to targeting processor **4906**.

At step **4945**, optionally, targeting processor **4906** compares the lead calculated from the ballistic table to the lead predicted by the neural network. In a preferred embodiment, the total number of recorded hits based on shots on the lead calculated from the ballistic table and the total number of recorded hits based on shots taken according to the neural network recommendation are compared. The lead associated with the highest number of recorded hits is taken as true. "Hits" can also be determined by the use of spotter rounds, which mark where they hit. Such markings can be recognized by the fixed camera or the drone. Hits can also be determined by the use of conventional tracer rounds.

At step **4946**, optionally, targeting processor **4906** chooses the lead associated the highest number of recorded hits. At step **4947**, targeting processor **4906** sends the chosen lead distance to display processor **4908**. At step **4948**, the targeting processor translates the lead coordinates to match the position, velocity and acceleration of the remote unit. At step **4949**, the translated lead coordinates are transmitted from the targeting processor to the display processor.

At step **4950**, display processor **4908** displays a phantom target at the lead coordinates.

At step **4951**, the display processor compares the virtual laser position to the phantom position to determine coincidence.

Upon occurrence of coincidence, at step **4952**, display processor **4908** displays a fire alert on the display and sends a “fire alert” signal to targeting processor **4906**. At step **4953**, targeting processor **4906** forwards the fire alert signal to tactical processor **4904**. At step **4954**, tactical processor **4904** publishes the fire alert signal, and the identity of the remote unit that triggered the shot, to all nodes on the network.

At step **4955**, weapon processor **4910** registers a shot signal. In a preferred embodiment, the forward IMU of the weapon registers a “shot signal” upon firing of the weapon. The shot signal is sent from the forward IMU to the targeting processor.

At step **4956**, the display processor calculates and displays a virtual tracer, as previously described. At step **4957**, weapon processor **4910** forwards the shot signal to targeting processor **4906**. At step **4958**, targeting processor **4906** forwards the shot signal to tactical processor **4904**. At step **4959**, tactical processor **4904** forwards the shot signal to AI processor **4902**. At step **4960**, AI processor adds the shot signal to a training table, as will be further described.

At step **4961**, display processor **4908** identifies a hit or miss condition. In a preferred embodiment, the display processor monitors the image of the identified target with the stereoscopic camera for disappearance. Upon disappearance, a “hit” signal is generated. If no hit signal is generated within a predetermined period of time, a “miss” signal is generated. Spotter rounds and tracers can also be used to validate a hit, as previously described.

At step **4962**, display processor **4908** sends the hit or miss signal to targeting processor **4906**. At step **4963**, targeting processor **4906** forwards the hit or miss signal to tactical processor **4904**. At step **4964**, tactical processor **4904** forwards the hit or miss signal to AI processor to **4902**. At step **4965**, AI processor **4902** adds the hit or miss signal a training table, as will be further described.

At step **4971**, targeting processor **4906** clears the cartesian origin. At step **4972**, targeting processor **4906** sends a clear origin signal to tactical processor **4904**. At step **4973**, tactical processor **4904** resets the cartesian origin of all nodes in the tactical theatre.

Referring then to FIG. **50**, method **5000** of target path resolution will be described.

In a preferred embodiment, fixed camera **5002**, drone **5004**, tactical processor **5006** and remote unit **5008** are all connected through a wireless local area network. In another preferred embodiment, fixed camera, drone, tactical processor unit are connected through a wireless wide area network.

At step S**020**, tactical processor **5006** sets the cartesian origin. In a preferred embodiment, the cartesian origin is set at the location of a remote unit upon instance of a shouldering signal. In one embodiment, the “x” direction is north to south, as registered by the onboard compass. The “y” direction is east to west. The “z” direction is straight up.

At step S**022**, tactical processor **5006** sends the cartesian origin to drone **5004**. Similarly, at step S**024** tactical processor **5006** sends the cartesian origin to remote unit **5008**. At step S**026**, tactical processor **5006** sends the cartesian origin to fixed camera **5002**.

At step S**028**, drone **5004** initiates a preset flight path recorded in memory. In another preferred embodiment, the flight path may be controlled manually by the tactical processor through a separate set of flight controls.

At step S**030**, tactical processor **5006** receives a target identification signal, as previously described. At step S**032**, tactical processor **5006** positions the target in the coordinate system relative to the origin. At step S**034**, tactical processor **5006** sends the position of the target to drone **5004**. At step S**036**, tactical processor **5006** sends the target position to fixed camera **5002**. At step S**038**, tactical processor **5006** sends the target position to remote unit **5008**.

At step S**040**, remote unit **5008** trains the weapon on the target position. At step S**041**, remote unit **5008** gets range data from the weapon as previously described. At step S**042**, remote unit **5008** calculates a path for the target, including position, velocity, acceleration and a target path equation, as previously described. At step S**058**, remote unit **5008** sends the target path to tactical processor **5006**.

At step S**043**, drone **5004** trains its camera on the target position. The camera may be trained alternatively by automatically maintaining a constant range to target or manually by instructions from the tactical monitor. At step S**044**, drone **5004** suspends the flight path and holds position. At step S**046**, drone **5004** gets range data from the onboard laser range finder. At step S**047**, drone **5004** tracks the target by monitoring its change in location, velocity and acceleration. At step S**048**, drone **5004** calculates the target path relative to the origin. In this embodiment, the camera position tracks the target, the range data and the PTZ control instructions are used to derive the target path equation. At step S**056**, drone **5004** sends the calculated target path to tactical processor **5006**.

At step S**050**, fixed camera **5002** trains its camera on the target position, as previously described. At step S**052**, fixed camera **5002** obtains range data from its onboard laser range finder. At step S**054**, fixed camera **5002** tracks the target to obtain relative positions over time. At step S**055**, fixed camera **5002** calculates the target path from the target track and from the range data and the PTZ movement instructions required to track the target. At step S**060**, camera **5002** sends the target path to tactical processor **5006**.

At step S**062**, tactical processor **5006** resolves the target path relative to the origin. In general, the target path is resolved by averaging the perceived target positions, velocities and accelerations reported from each node reporting on the network. In this embodiment, the target path is resolved relying on a data from the drone, the remote unit and the fixed camera are relative to the same set of cartesian coordinates. In a simplified example, assuming linear motion, the following equations are used.

$$r_1=r_{01}+v_1t-\tfrac{1}{2}a_1t^2 \qquad \text{Eq. 54}$$

$$r_2=r_{02}+v_2t-\tfrac{1}{2}a_2t^2 \qquad \text{Eq. 55}$$

$$r_3=r_{03}+v_3t-\tfrac{1}{2}a_3t^2 \qquad \text{Eq. 56}$$

Where:

$r_1$=position from drone perspective;
$r_{01}$=drone initial position;
$v_1$=velocity from drone perspective;
$a_1$=acceleration from drone perspective;
$r_2$=position from fixed camera perspective;
$r_{02}$=fixed camera initial position;
$v_2$=velocity from fixed camera perspective;
$a_2$=acceleration from fixed camera perspective;
$r_3$=position from fixed camera perspective;
$r_{03}$=fixed camera initial position;
$v_3$=velocity from fixed camera perspective;
$a_3$=acceleration from fixed camera perspective;

Where:

$$r_{resolved}=\frac{(r_{01}+r_{02}+r_{03})}{3}+\frac{(v_1+v_2+v_3)t}{3}-\frac{(a_1+a_2+a_3)t^2}{6} \qquad \text{Eq. 57}$$

The target path appears differently to each of fixed camera **4678**, remote unit **4674**, remote unit **4676** and drone **4680**. The target path is translated for proper display of remote unit **2** whereupon phantom position **4686** is calculated and displayed. At lead distance **4692**, virtual tracer **4688** is displayed on remote unit **4676** and a shot signal is generated when virtual tracer **4688** is coincident with phantom position **4686**.

As shown in FIG. **51**, in a preferred embodiment, the AI processor maintains a separate running artificial neural network for each cardinal direction x, y and z in the tactical theatre for each participant. In a preferred embodiment, each of these neural networks is the same, as will be further described. The input for each artificial neural network is the position, velocity, acceleration and true range of the target for each of the cardinal x, y and z directions in the tactical theatre for its particular participant. Each artificial neural network then predicts the vector component of the distance of the lead ahead of the target position, provided the input of the position, velocity, acceleration and range in each of the cardinal directions.

A preferred embodiment of a single, artificial neural network for predicting a vector component, x, y or z, of the lead distance for one participant is shown in FIG. **52**. Neural network **5200** includes input layer **5205**, weighting layer **5210**, and output layer **5215**. The inputs are weighted and processed through input function **5220** and activation function **5225** for reaching an output value. Back propagation is provided by the activation function applied to the weighted neurons. In a preferred embodiment, input function **5120** is a weighted sum of the inputs. In a preferred embodiment, activation function **5125** is the Sigmoid function, as will be further described. One of skill in the art will recognize that other arrangements, numbers and layers of neurons are possible that may provide the desire predictive features of the invention.

The Sigmoid function is preferred for the activation function because its output can be conveniently used to generate its derivative. For example, if the output variable is "x" then its derivative will be x(x−1). The Sigmoid function is shown below:

$$S(x) = \frac{1}{1+e^{-x}} = \frac{e^x}{e^x+1} \qquad \text{Eq. 58}$$

In a preferred embodiment, output layer **5215** assumes a value between 0 and 1 and is appropriately scaled to match the coordinates of the tactical theatre. The output value "h" is the predicted vector component of the lead ahead of the target in one cardinal direction "h" at the position, vector, acceleration and range data is input. With each of three neural networks providing a single component of the lead position, processing is extremely fast. The lead ahead of the target at any given position, velocity, acceleration and range can be predicted to assist in targeting the weapon.

Training for each artificial neural network requires a training input and a training output. The training input for each neural network is provided by a path table for each direction maintained in database **4655** by tactical monitor **4645** from position, velocity and acceleration of the target. Acceleration and range data is received from the remote units, the drone and the fixed camera. The data can be appropriately scaled. In a preferred embodiment, the distance component of the data is scaled by simply dividing each distance by the maximum distance in the tactical theatre. In another embodiment, the data is scaled by dividing each entry by the largest whole number in the data set. Other scaling methods may be used. In a preferred embodiment, the lead distance entered in the table is characterized by a lead "hit" distance and a lead "miss" distance. In this way, the lead is characterized as a "successful" lead or a "failure" lead. An example table is shown below:

TABLE 3

| Time | $P_x$ | $P_y$ | $P_z$ | $v_x$ | $v_y$ | $v_z$ | $a_x$ | $a_y$ | $a_z$ | $L_h$ | $L_m$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $t_0$ | $P_{x0}$ | $P_{y0}$ | $P_{z0}$ | $v_{x0}$ | $v_{y0}$ | $v_{z0}$ | $a_{x0}$ | $a_{y0}$ | $a_{z0}$ | $L_h$ | |
| $t_1$ | $P_{x1}$ | $P_{y1}$ | $P_{z1}$ | $v_{x1}$ | $v_{y1}$ | $v_{z1}$ | $a_{x1}$ | $a_{y1}$ | $a_{z1}$ | | $L_m$ |
| $t_2$ | $P_{x2}$ | $P_{y2}$ | $P_{z2}$ | $v_{x2}$ | $v_{y2}$ | $v_{z2}$ | $a_{x2}$ | $a_{y2}$ | $a_{z2}$ | $L_h$ | |
| $t_3$ | $P_{x3}$ | $P_{y3}$ | $P_{z3}$ | $v_{x3}$ | $v_{y3}$ | $v_{z3}$ | $a_{x3}$ | $a_{y3}$ | $a_{z3}$ | | $L_m$ |
| . | . | . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . | . | . | . | . |
| $T_n$ | $P_{xn}$ | $P_{yn}$ | $P_{zn}$ | $v_{xn}$ | $v_{yn}$ | $v_{zn}$ | $a_{xn}$ | $a_{yn}$ | $a_{zn}$ | $L_{hn}$ | $L_{mn}$ |

As can be seen from the table, in this example, each line contains only a single entry for either the lead hit designation or the lead miss designation. In a preferred embodiment, the only lines from the table used for training include only those which include "a lead hit" designation and distance. In this way, the neural network is trained to more accurately predict the lead distance based only on successful hit training data.

Referring to FIG. **53**, a flow chart of method **5300** for training and using each of the artificial neural networks for each of the lead vectors will be described.

At step S**305**, each neuron of the weighted layer is assigned a random number between −1 and 1, having a mean value of zero, as initial weight (w).

At step S**310**, for each ANN, the training input array is multiplied by the weight array and is summed in a matrix operation. The input data must be appropriately scaled. In a preferred embodiment, the inputs are supplied to the algorithm as a "4×n" matrix, where "n" is the number of time periods where path data is available.

At step S**315**, for each iteration, the sigmoid function is applied to derive a calculated output. At step S**317**, for each iteration, the calculated output is subtracted from the training output to determine an error.

At step S**320**, for each iteration, the error is multiplied by the derivative of the sigmoid function of the calculated output. At step S**325** the result is multiplied by the training inputs in a matrix operation, to derive an adjustment which complies with the error weighted derivative formula. In a preferred embodiment, the error weighted derivative formula is an algorithm based on gradient descent. In this case, the derivative of the sigmoid function guarantees that the adjustment to each weight changes in a way that always decreases the error for the weight of each neuron.

At step S**327**, the adjustment for each neuron is added to the current weight for that neuron.

At step S**330**, the process is repeated for a preset number of iterations. In a preferred embodiment, the preset number of iterations is anywhere from **20**,**000** to **100**,**000**. Other iterations counts can be used. A higher iteration count increases the accuracy of the node weights.

Once step S**330** is complete, the neural network is "trained."

At step S**340**, live target path and range data from the tactical theatre from the remote units, the drone and the fixed camera is scaled and input into the trained neural network by the remote AI data acquisition pattern processor **4650**. At step S**347**, the output for the predictive lead values is read.

In a preferred embodiment, the predictive lead values are then transmitted from the pattern processor to the tactical monitor for the distribution to nodes active in the tactical theatre.

An example of computer code written Python to perform one example of the method is shown in FIG. **54**. Of course, other code may be used to implement this and other embodiments of the neural network described.

It will be appreciated by those skilled in the art that the described embodiments disclose significantly more than an abstract idea including technical advancements in the field of data processing and a transformation of data which is directly related to real-world objects and situations in that the disclosed embodiments enable a computer to operate more efficiently. For example, the disclosed embodiments transform positions, orientations, and movements of a user device and a weapon into a graphical representations of the user and the weapon in a simulation environment.

It will be appreciated by those skilled in the art that modifications can be made to the embodiments disclosed and remain within the inventive concept, such as by omitting various described features, rearranging features, and using features from one embodiment in another embodiment. Therefore, this invention is not limited to the specific embodiments disclosed, but is intended to cover changes within the scope and spirit of the claims.

The invention claimed is:

**1**. An augmented reality ranging and lead determination system comprising:

a set of processors, operatively connected to a set of memories;

an augmented reality display, connected to the set of processors;

the set of memories further comprising instructions that when executed by the set of processors cause the system to:

derive a weapon path, from a movement of a weapon trained on a target;

derive a range distance from the weapon to the target;

extend a ray object, from the weapon to the range distance, based on the weapon path;

derive a target trajectory from the ray object;

derive a lead position from the range and the target trajectory; and,

render a phantom, at lead position, on the augmented reality display.

**2**. The system of claim **1** further comprising instructions that when executed by the set of processors cause the system to:

calculate a virtual laser position from the weapon path; and,

render a virtual laser, at the virtual laser position, on the augmented reality display.

**3**. The system of claim **2** wherein the virtual laser position is generally coaxial with a barrel of the weapon.

**4**. The system of claim **2** further comprising instructions that when executed by the set of processors cause the system to:

compare the phantom and the virtual laser for a coincident condition; and,

send an alert signal upon the coincident condition.

**5**. The system of claim **1** further comprising instructions that when executed by the set of processors cause the system to:

calculate a virtual tracer path from the weapon position; and,

render a virtual tracer, at the virtual tracer path, on the augmented reality display.

**6**. The system of claim **1** further comprising instructions that when executed by the set of processors cause the system to:

monitor the target for a hit event; and,

record the hit event in the memory.

**7**. The system of claim **1** wherein the weapon further comprises:

a forward motion sensor, positioned adjacent a barrel of the weapon, operatively connected to the set of processors;

a rear motion sensor, positioned adjacent a stock of the weapon, operatively connected to the set of processors; and,

wherein the movement of the weapon is derived from the forward motion sensor and the rear motion sensor.

**8**. The system of claim **1** further comprising a laser range finder, attached to the weapon, operatively connected to the set of processors; and,

wherein the range distance is derived from the laser range finder.

**9**. The system of claim **1** further comprising a stereoscopic camera, operatively connected to the set of processors; and,

wherein the range distance is derived from the stereoscopic camera.

**10**. An augmented reality ranging and lead determination system for a target comprising:

a first remote unit, having a first processor, and a first memory and a first augmented reality display, operatively connected to the first processor;

a second remote unit, having a second processor, and a second memory, and a second augmented reality display, operatively connected to the second processor;

the first memory and the second memory including a set of instructions that, when executed, cause the system to perform the steps of:

initiating, by the first remote unit, a track of the target;

determining, by the first remote unit, a first range to the target;

determining, by the first remote unit, a first weapon position;

determining, by the first remote unit, a first remote unit position;

calculating, by the first remote unit, a target path based on the first weapon position, the first remote unit position and the first range to target;

sending, from the first remote unit to the second remote unit, the target path;

determining, by the second remote unit, a second range to target;

calculating, by the second remote unit, a first time to target;

determining, by the second remote unit, a second weapon position;

displaying, on the second augmented reality display, a first virtual laser based on the second weapon position;

calculating, by the second remote unit, a first lead distance based on the first time to target;

displaying, on the second augmented reality display, a first phantom target at the first lead distance;

comparing, by the second remote unit, the first phantom target to the first virtual laser to determine a first coincidence condition; and, generating a fire alert message, by the second remote unit, upon receipt of the first coincidence condition.

**11**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

displaying, at the second remote unit, the fire alert message, on the second augmented reality display.

**12**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

sensing, at the second remote unit, a shot signal;

generating, by the second remote unit, a virtual tracer path upon receipt of the shot signal; and,

displaying, on the second augmented reality display, a virtual tracer on the virtual tracer path.

**13**. The system of claim **12** further comprising instructions that, when executed, cause the system to perform the steps of:

sending, from the second remote unit to the first remote unit, the shot signal; and,

displaying, on the first augmented reality display, the shot signal.

**14**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

recording, at the second remote unit, one of a target hit condition and a target miss condition.

**15**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

determining, by the second remote unit, a shot drop based on the first time to target; and,

translating the target path based on the shot drop.

**16**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

determining, by the second remote unit, a change in position of the second remote unit; and,

translating and rotating the target path based on the change in position.

**17**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

setting, by the first remote unit, an origin position; and,

sending, by the first remote unit to the second remote unit, the origin position.

**18**. The system of claim **10** further comprising instructions that, when executed, cause the system to perform the steps of:

receiving, by the first remote unit, a set of cardinal directions; and,

setting, by the first remote unit, a set of cartesian coordinates based on the origin and the set of cardinal directions.

**19**. An augmented reality ranging and lead determination system for a target comprising:

a tactical computer, having a first processor and a first memory;

a spotter unit, having a second processor, a second memory, and a camera, operatively connected to the tactical computer;

a remote unit, having a third processor, a third memory, and an augmented reality display, operatively connected to the tactical computer;

the first memory, the second memory and the third memory including a set of instructions, that when executed, cause the system to perform the steps of:

deriving a weapon path from a movement of a weapon trained on the target;

deriving a first range to target from the remote unit;

deriving a first target trajectory from the weapon path and the first range to target;

deriving a camera path from a movement of the camera trained on the target;

deriving a second range to target from the spotter unit;

deriving a second target trajectory from the camera path and the second range to target;

deriving a third target trajectory from the first target trajectory and the second target trajectory;

calculating a lead from the third target trajectory; and,

displaying a phantom target, on the third target trajectory, at the first lead, on the augmented reality display.

**20**. The system of claim **19** wherein the spotter unit further comprises an airborne platform and the set of instructions include further instructions that, when executed, cause the system to perform the steps of:

moving the airborne platform on a flight path; and,

the step of deriving the second trajectory further comprises the step of correcting the second trajectory for the flight path.

**21**. The system of claim **20** wherein and the set of instructions include further instructions that, when executed, cause the system to perform the step of:

controlling the flight path by the tactical computer.

**22**. The system of claim **19** wherein the spotter unit further comprises a fixed platform, supporting the camera.

**23**. The system of claim **22** wherein and the set of instructions include further instructions that, when executed, cause the system to perform the step of:

controlling the camera path by the tactical computer.

**24**. An augmented reality ranging and lead determination system for a target comprising:

a tactical computer, having a first processor and a first memory;

a neural network, having an input layer and an output layer, operatively connected to the tactical computer and the first memory;

a remote unit, having a second processor and a second memory, and an augmented reality display, operatively connected to the tactical computer;

the first memory and the second memory including a set of instructions, that when executed, cause the system to perform the steps of:

deriving a weapon path from a movement of a weapon trained on the target;

deriving a range to target from the remote unit;

deriving a target trajectory from the weapon path and the range to target;

training the neural network with the target trajectory and the range to target;

submitting a current set of target path data to the input layer; and,

reading a predictive set of lead data from the output layer.

**25**. The system of claim **24** wherein the step of training further comprises training the neural network with a set of successful lead data.

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