Modeling *Space Fortress*

Marc Destefano
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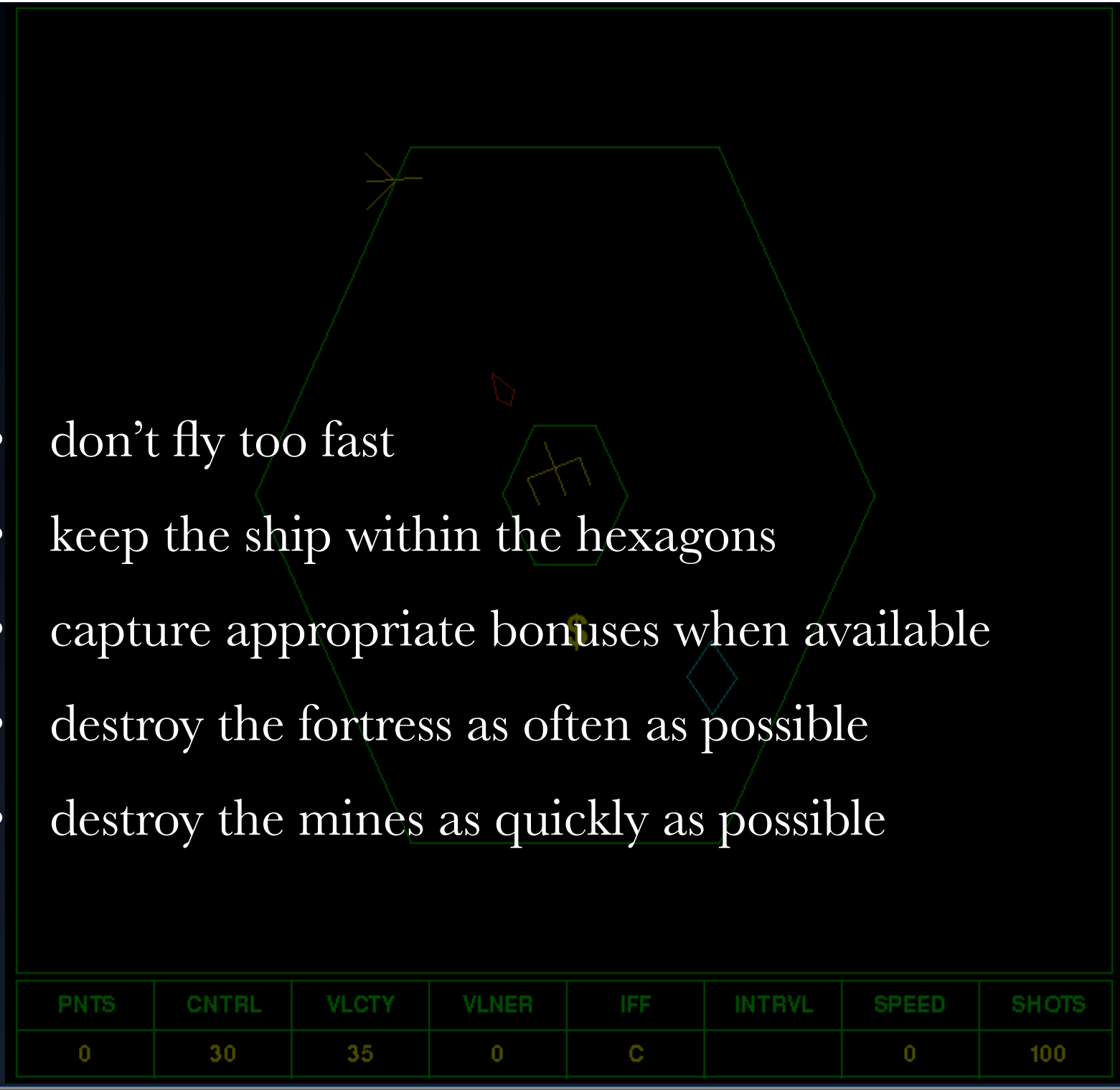
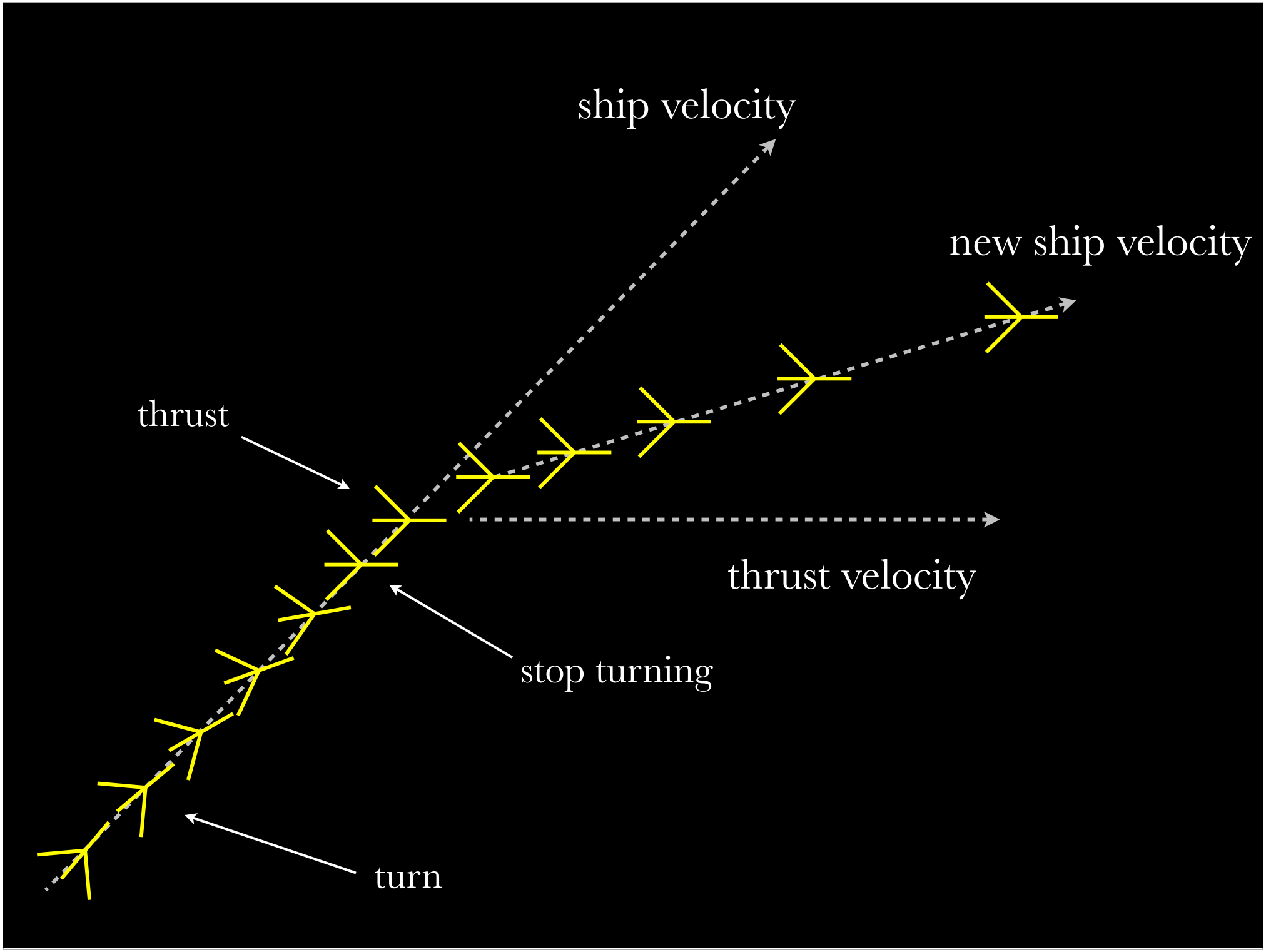


- don’t fly too fast
- keep the ship within the hexagons
- capture appropriate bonuses when available
- destroy the fortress as often as possible
- destroy the mines as quickly as possible

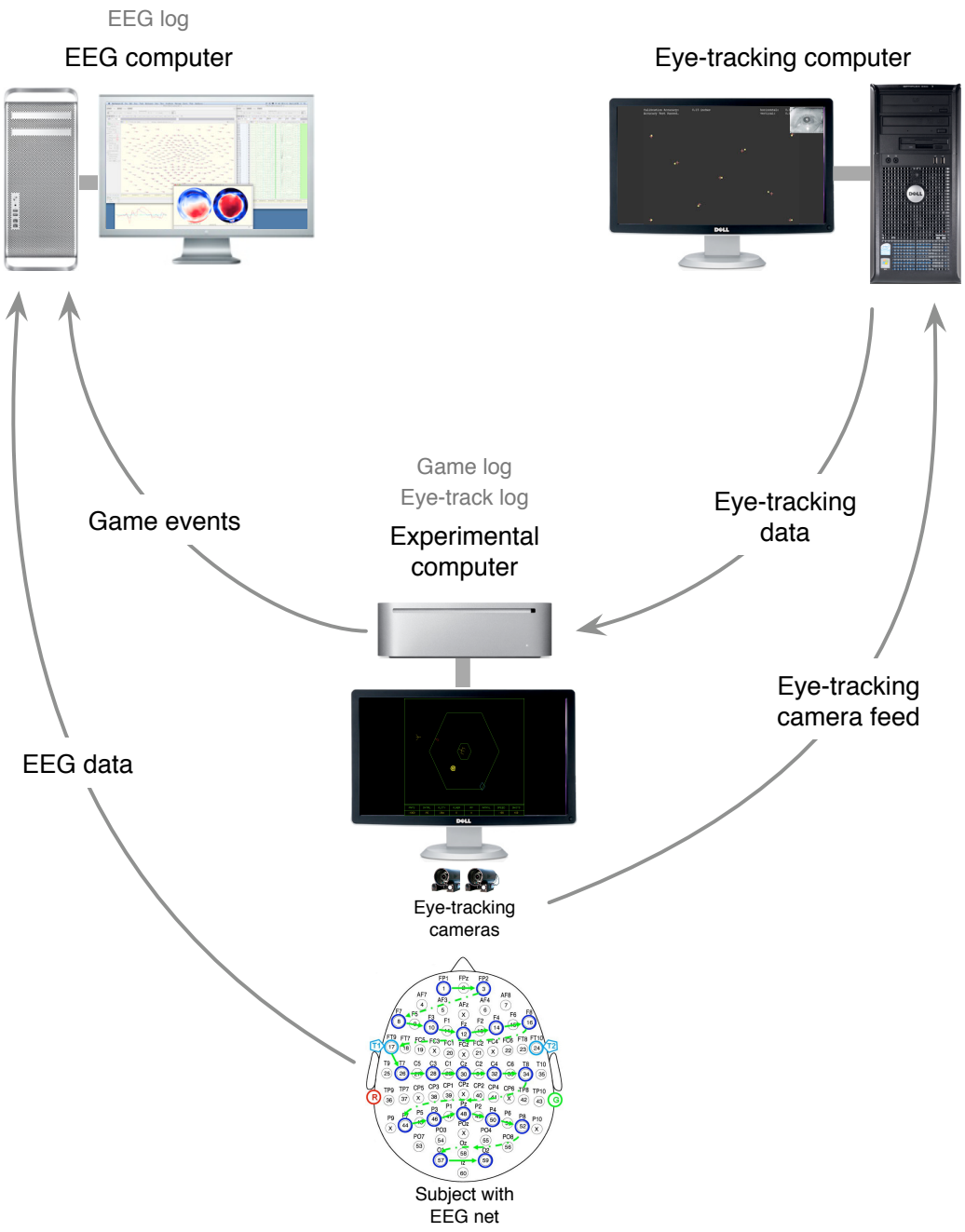
Ship Flight

- Thrust is acceleration-based
- Space is frictionless
- Orientation and motion are decoupled

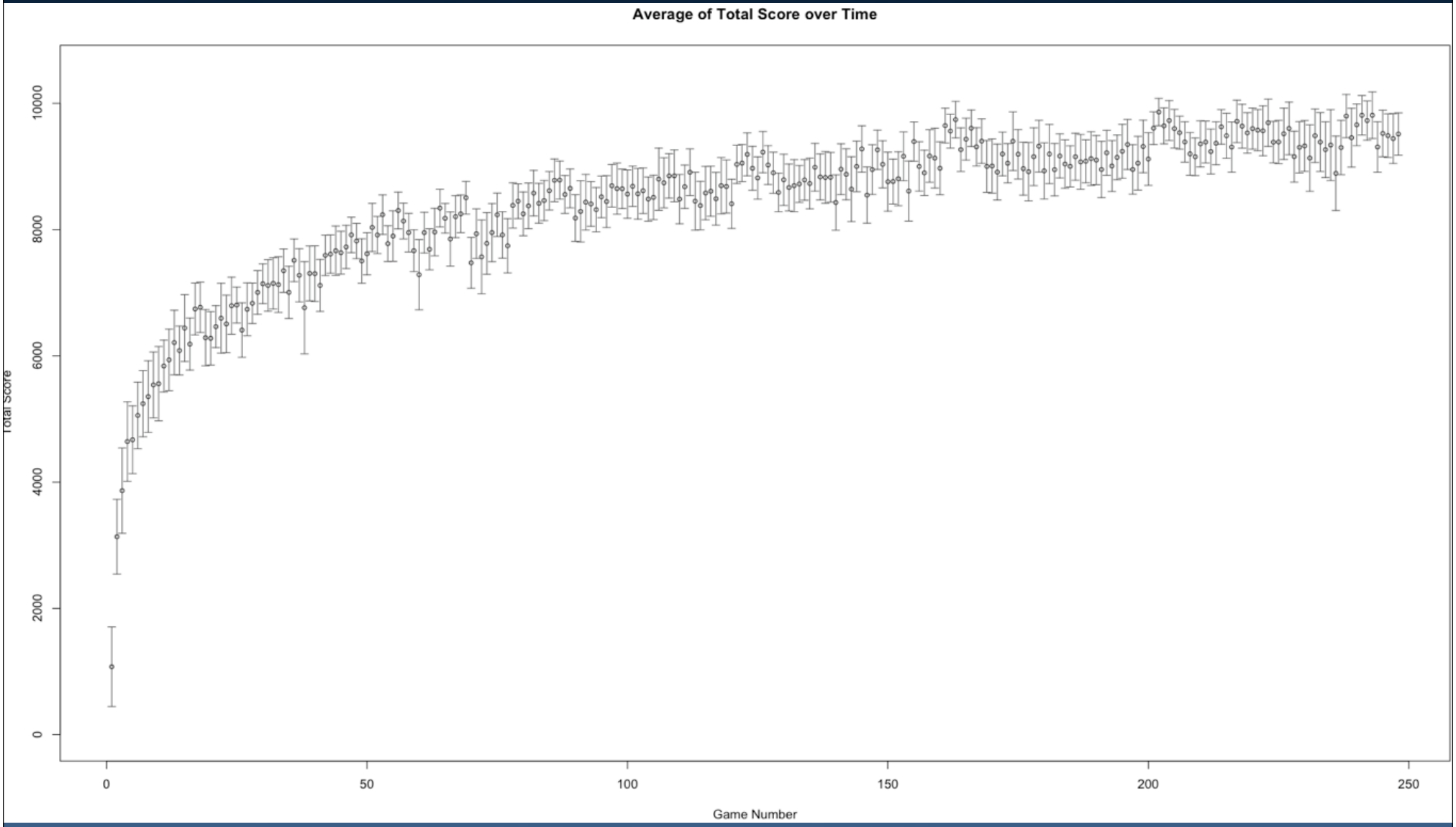

ship velocity
new ship velocity
thrust
thrust velocity
stop turning
turn

Experiment


1
6
11
16
21
26
31
Eye tracking
Eye tracking
Eye tracking
Eye tracking
Eye tracking
Eye tracking
Eye tracking
EEG
EEG
EEG
EEG

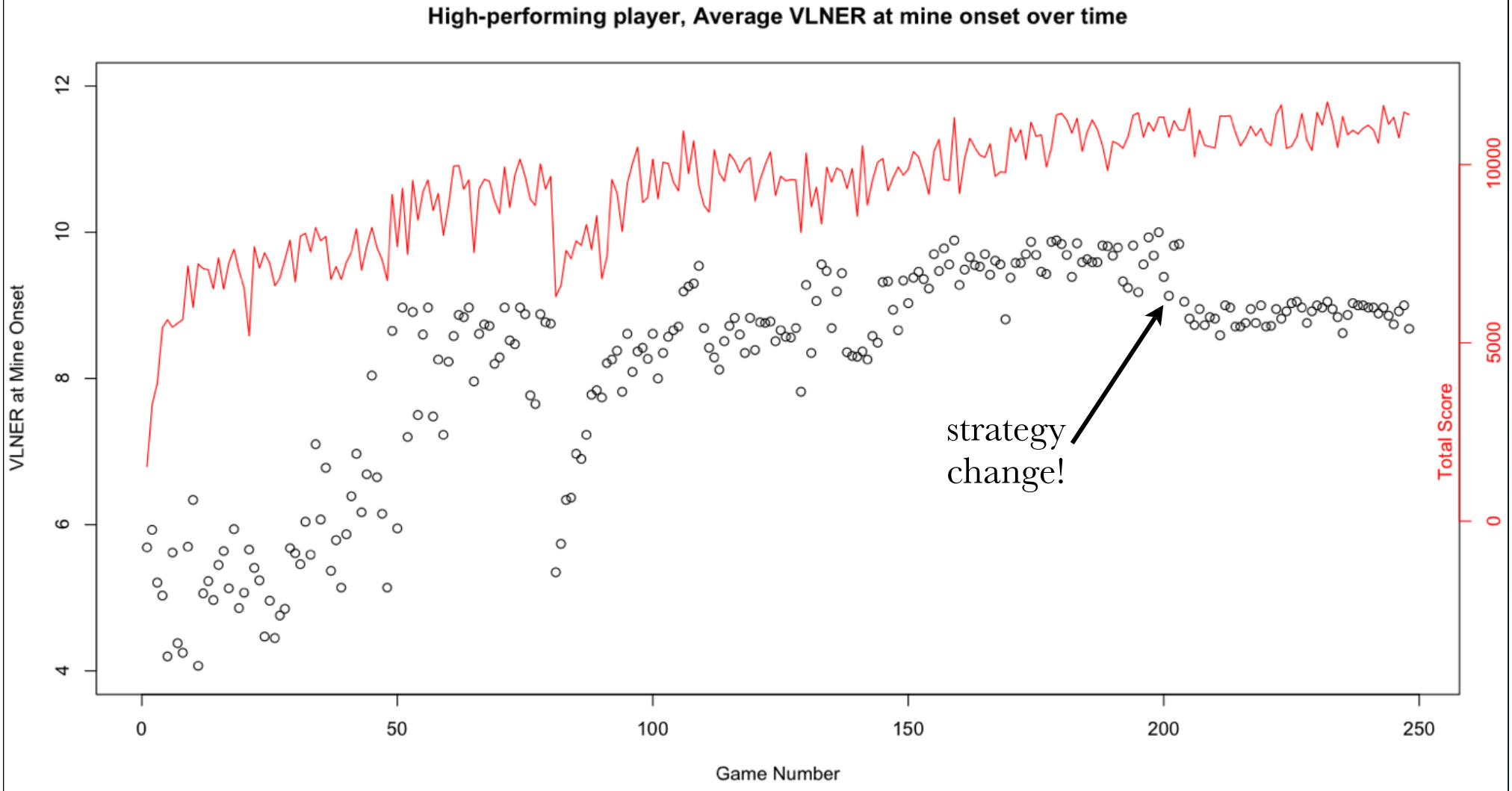

EEG log
EEG computer
Eye-tracking computer
Game log
Eye-track log
Game events
Experimental computer
Eye-tracking data
Eye-tracking camera feed
EEG data
Eye-tracking cameras
Subject with EEG net

Results


Average of Total Score over Time
Total Score
0
2000
4000
6000
8000
10000
0
50
100
150
200
250
Game Number

Strategies Learned

- Waiting for the mine
- Using VLCTY as a counter
- Increased capture of PNTS bonuses


High-performing player, Average VLNER at mine onset over time
VLNER at Mine Onset
Total Score
Game Number
strategy change!
4
6
8
10
12
0
50
100
150
200
250
0
5000
10000

Final Bonus Capture

No bonus captured SHOTS bonus captured PNTS bonus captured

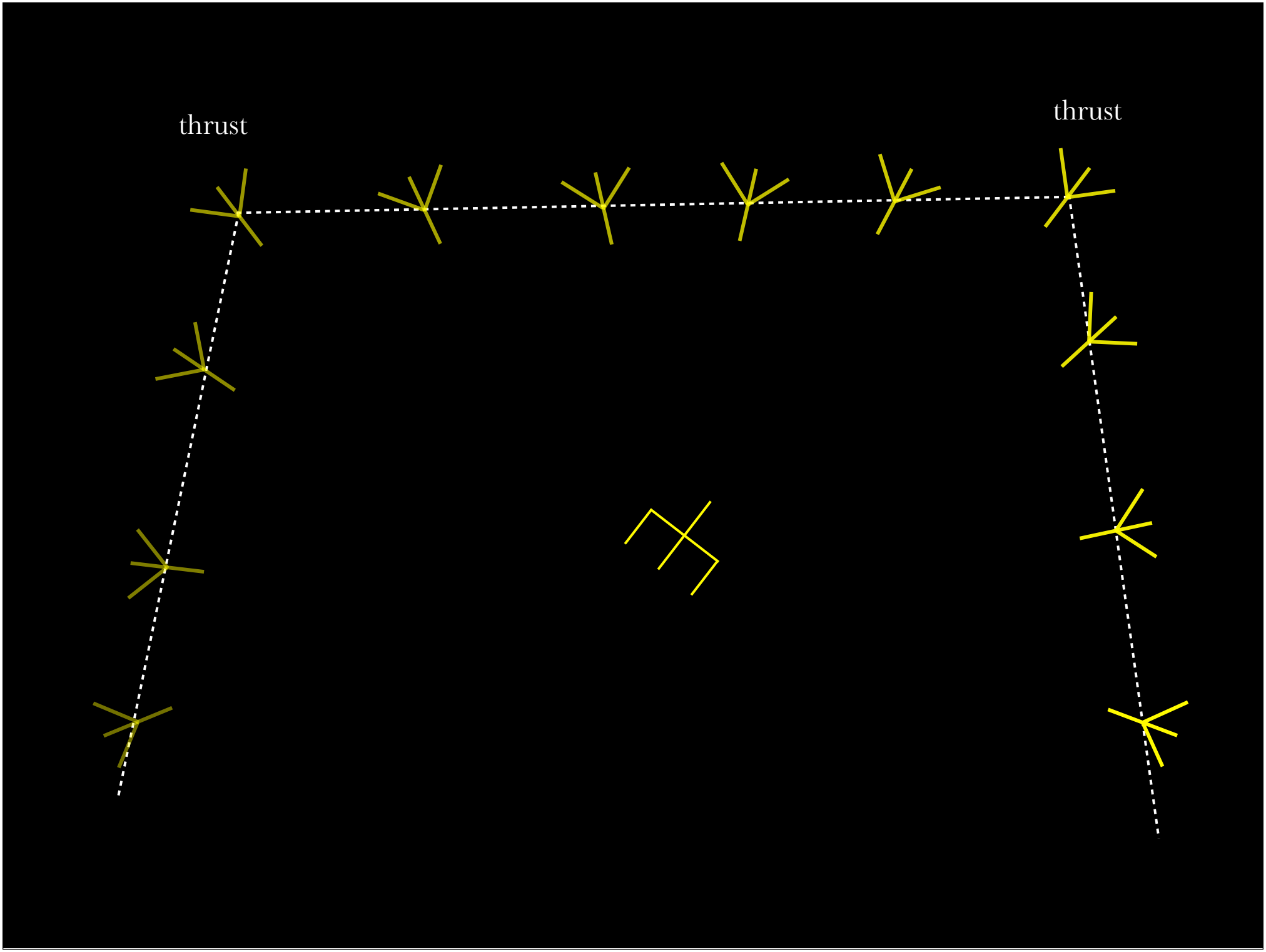
Low-performing player

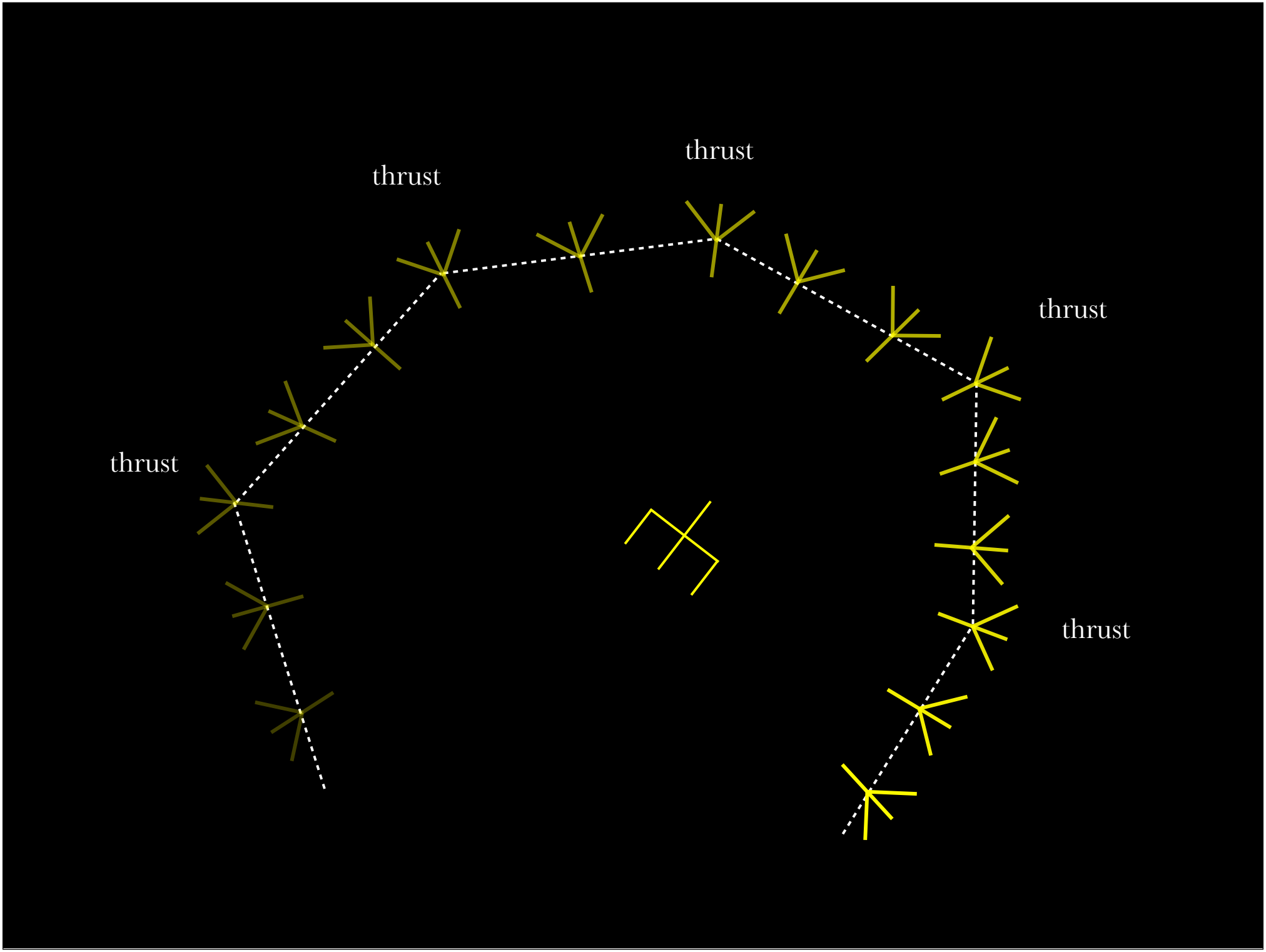
Medium-performing player

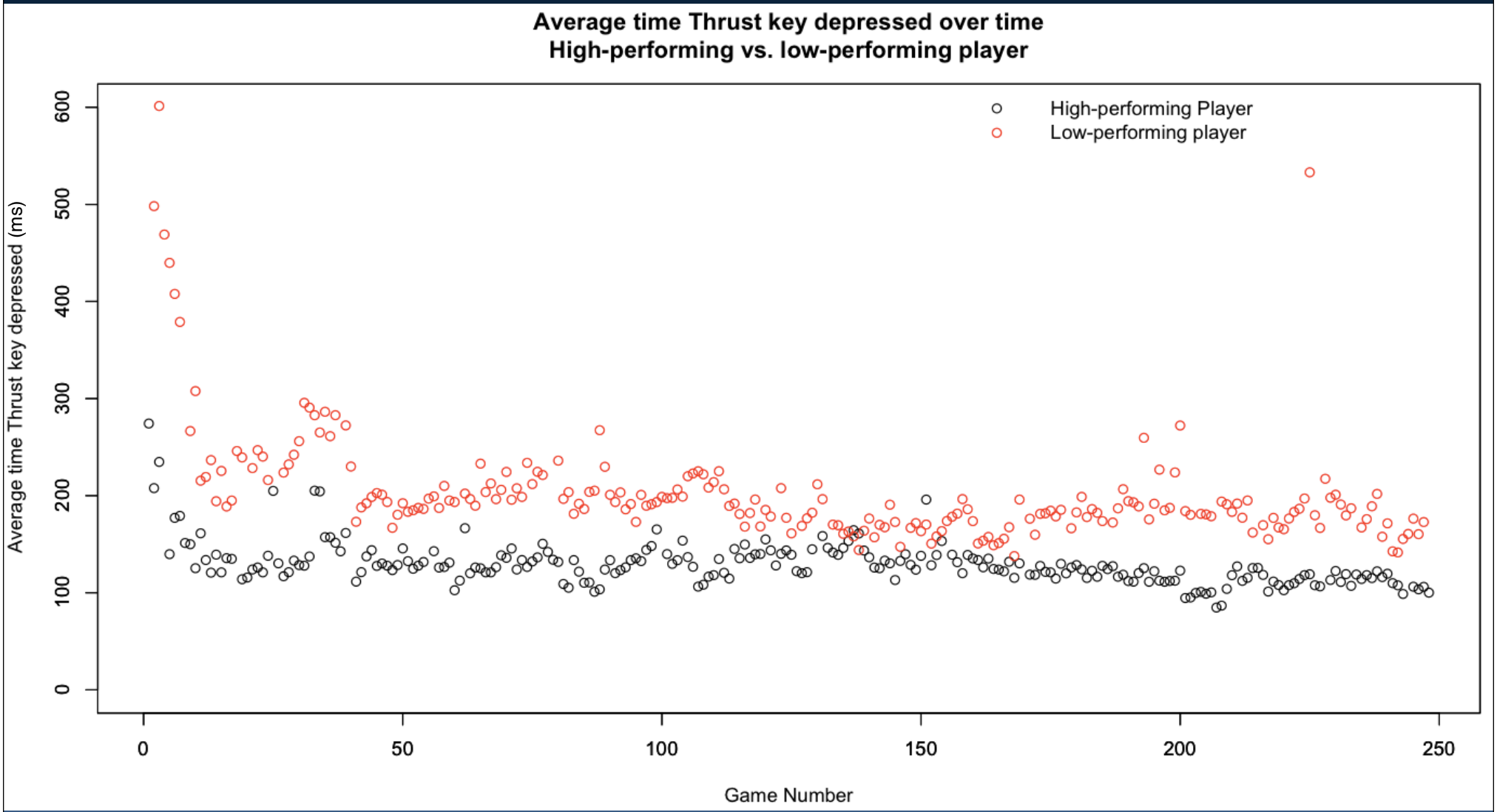
High-performing player

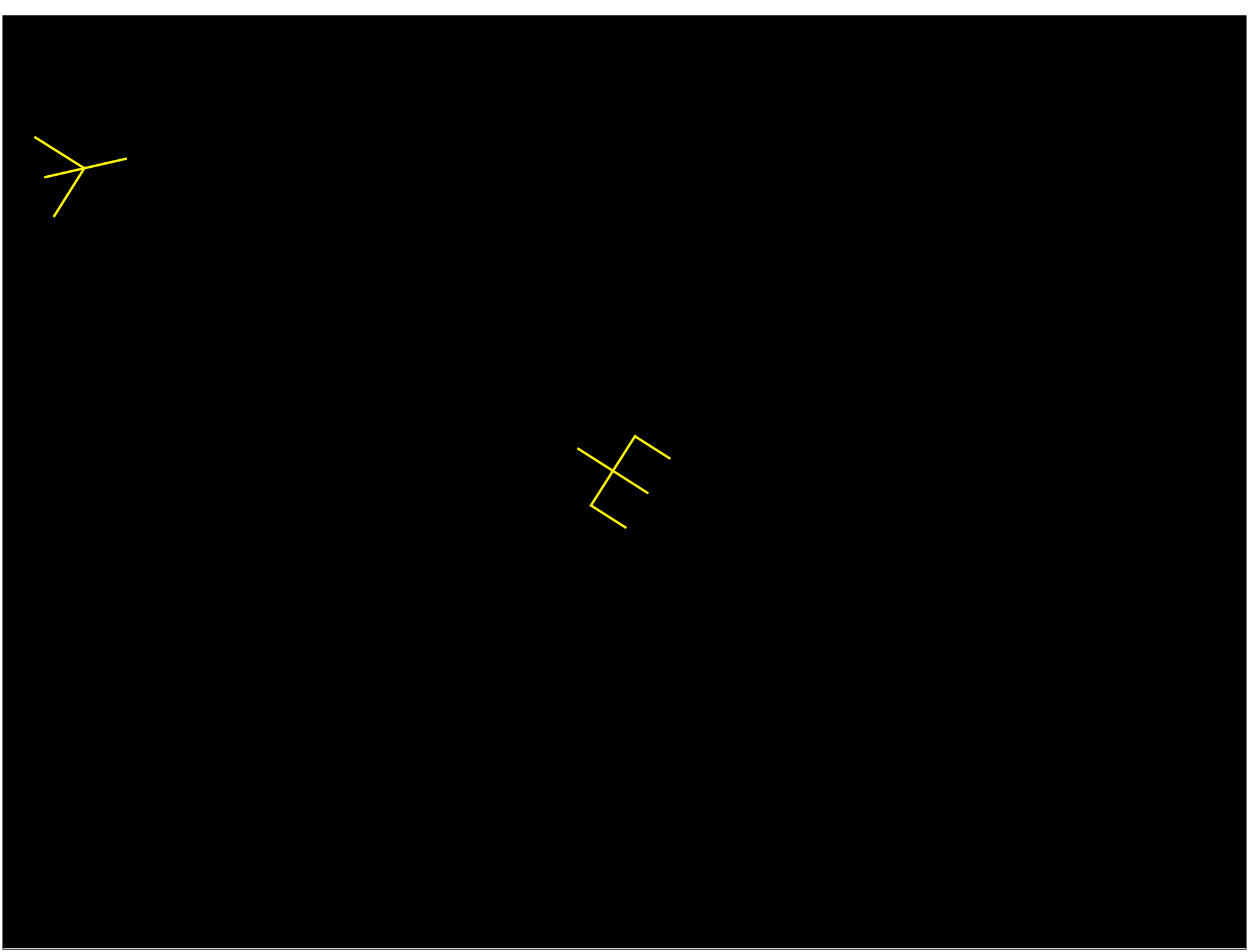
Tactics

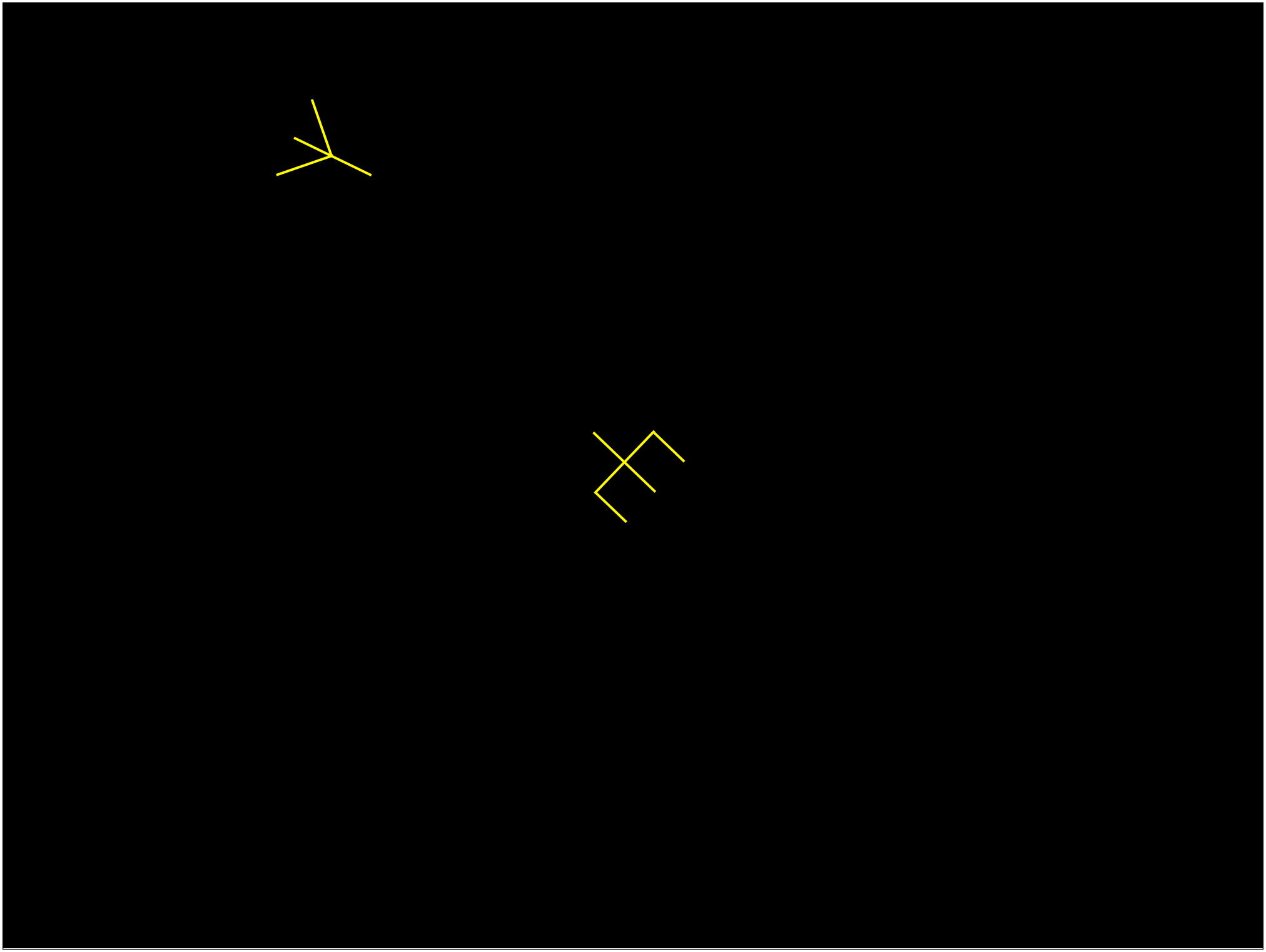
- Stay close to inner hexagon, moving slowly, but fast enough to prevent fortress from firing
- Keep movement perpendicular to fortress as often as possible
- Aim ship to face fortress as often as possible
- Small movements, rapid keypresses

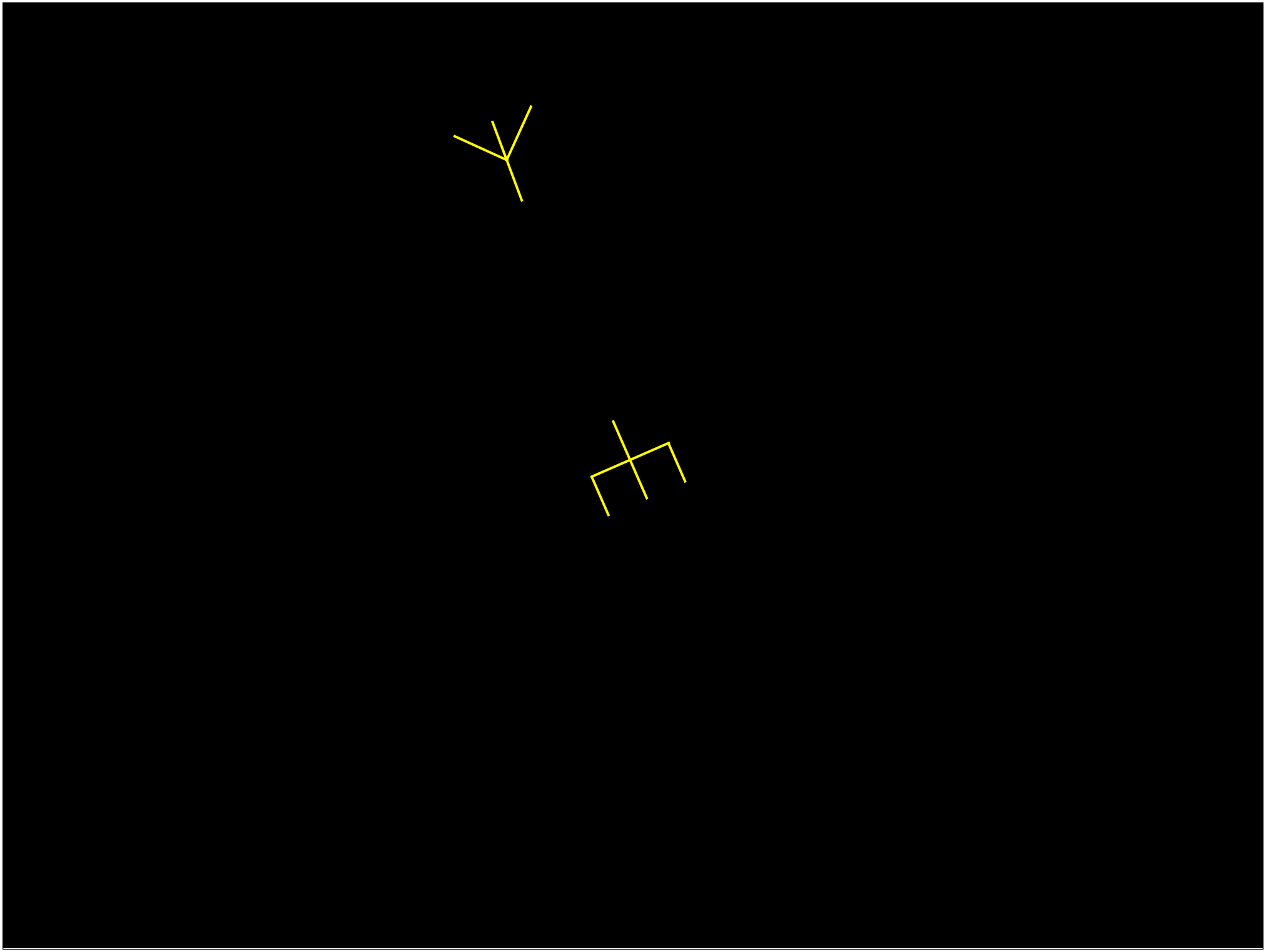

thrust
thrust

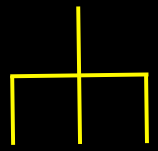

thrust
thrust
thrust
thrust
thrust
thrust

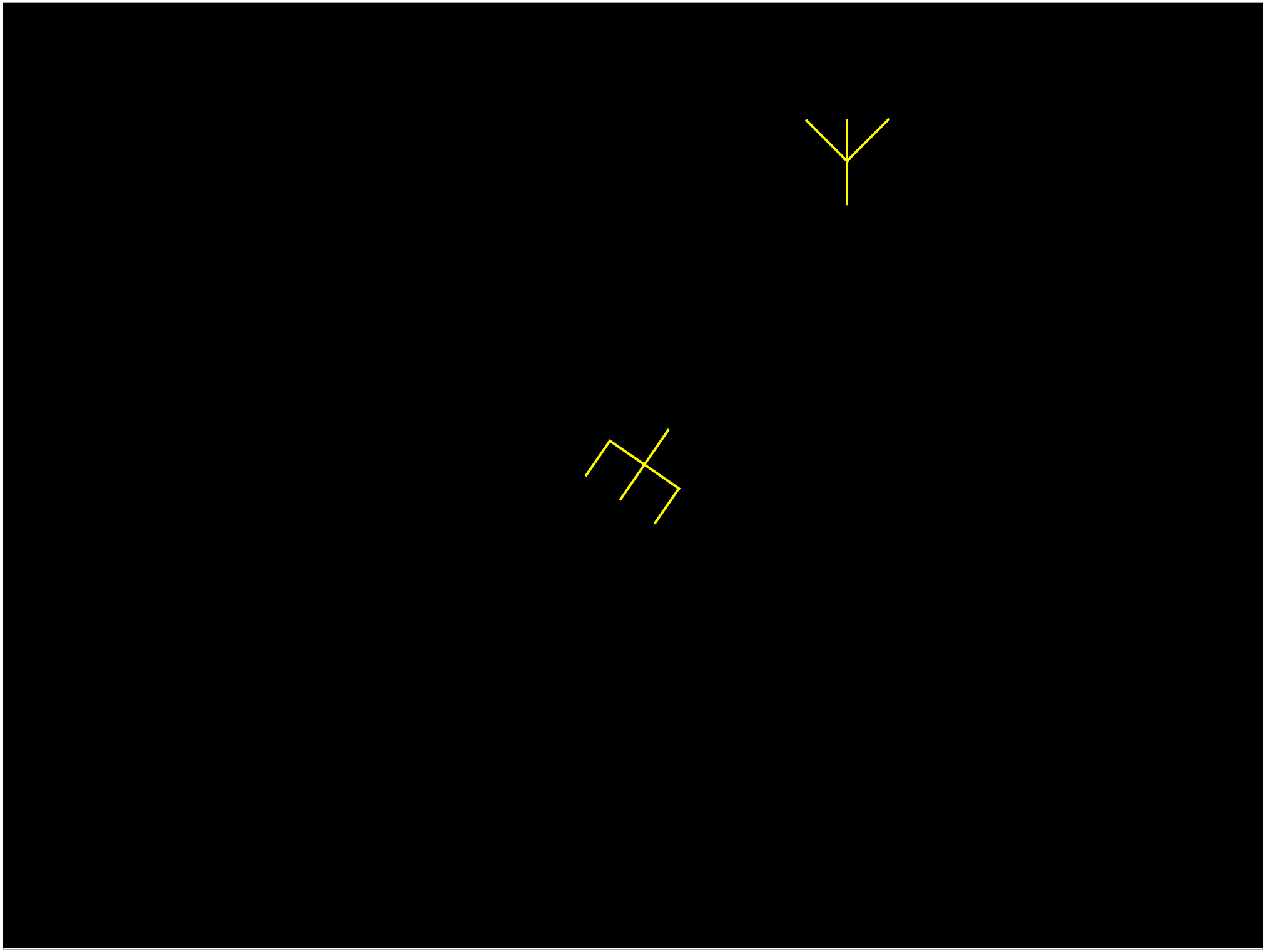

Average time Thrust key depressed over time
High-performing vs. low-performing player
High-performing Player
Low-performing player
Average time Thrust key depressed (ms)
0
100
200
300
400
500
600
0
50
100
150
200
250
Game Number

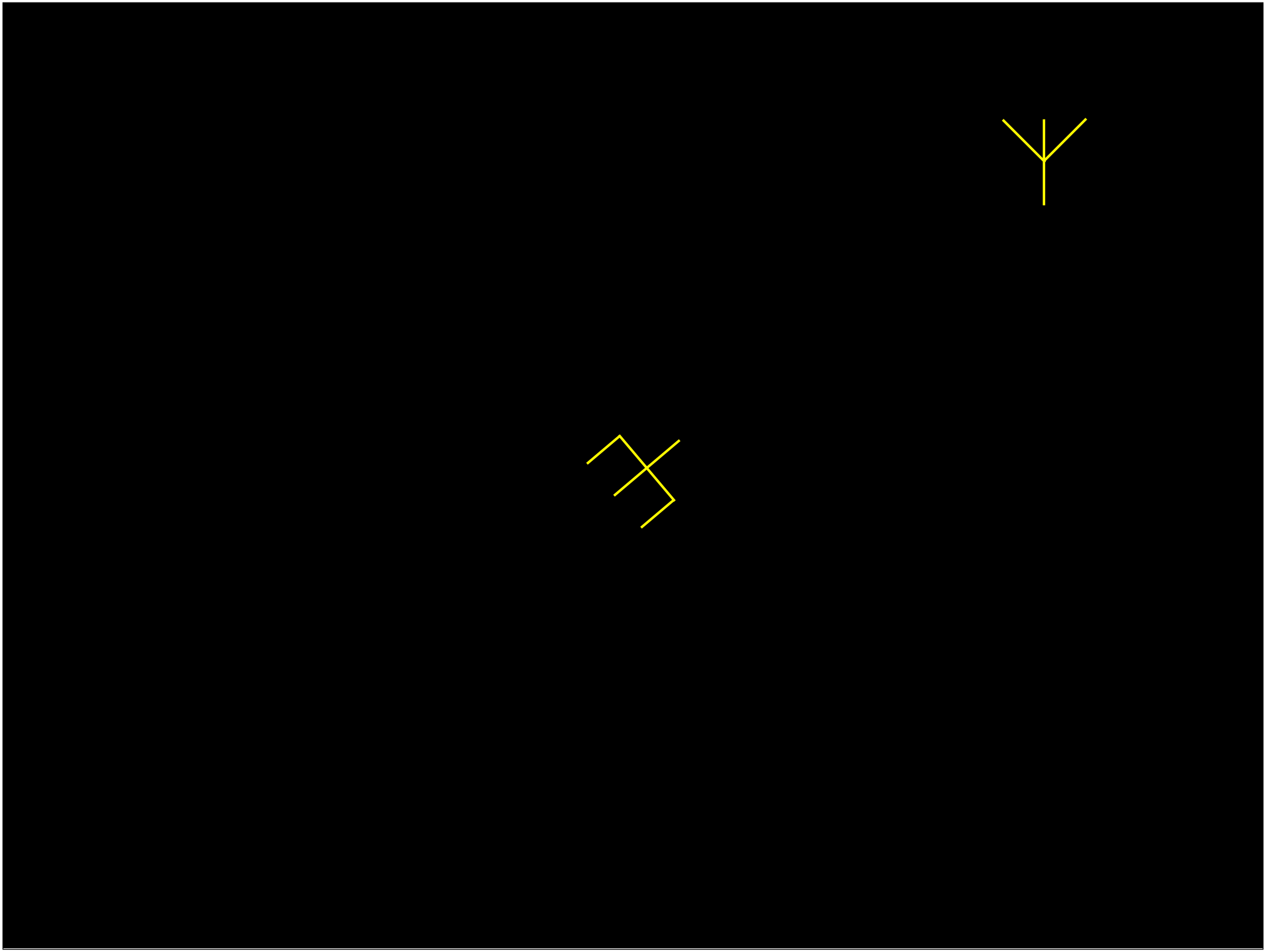


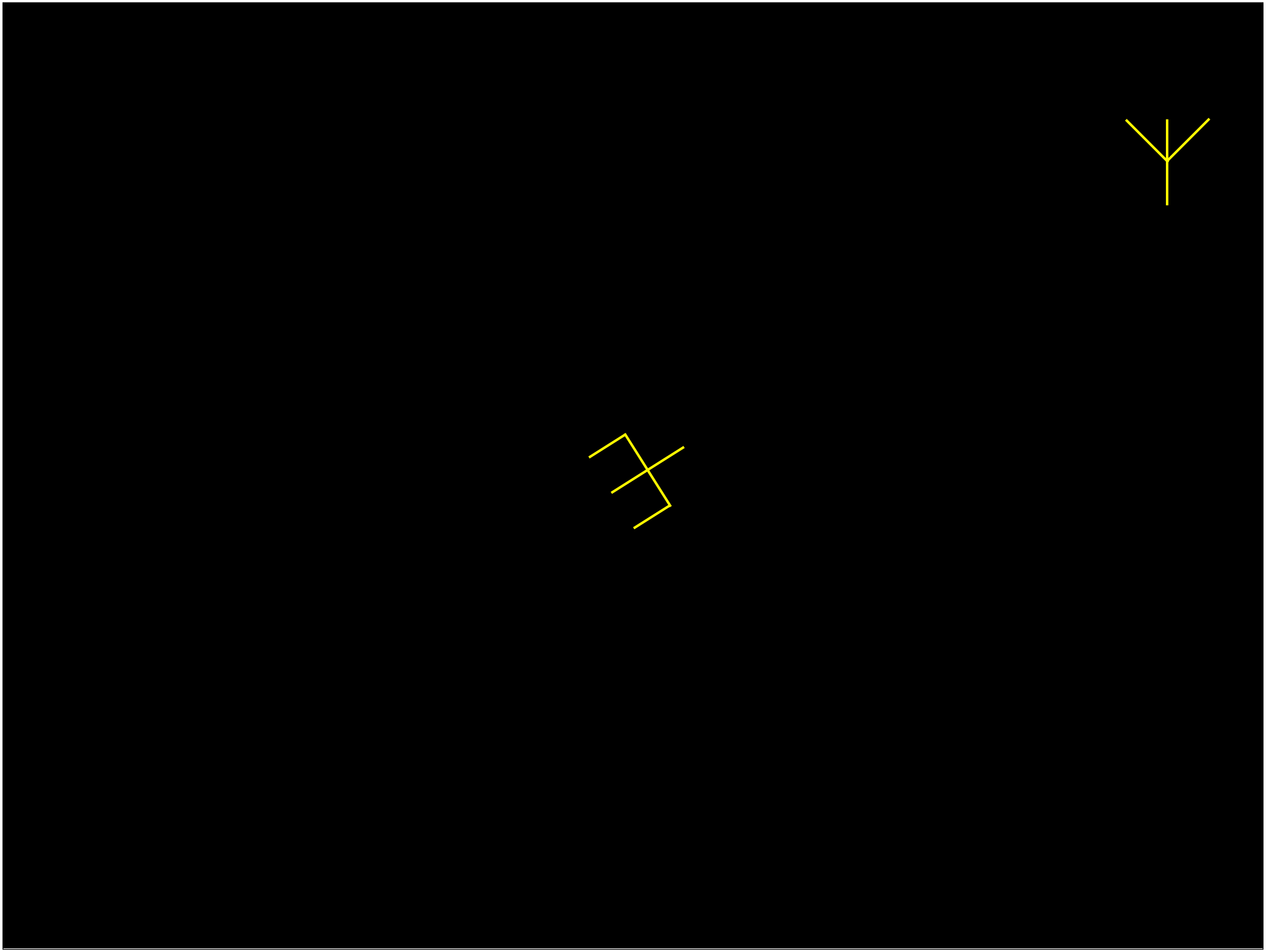


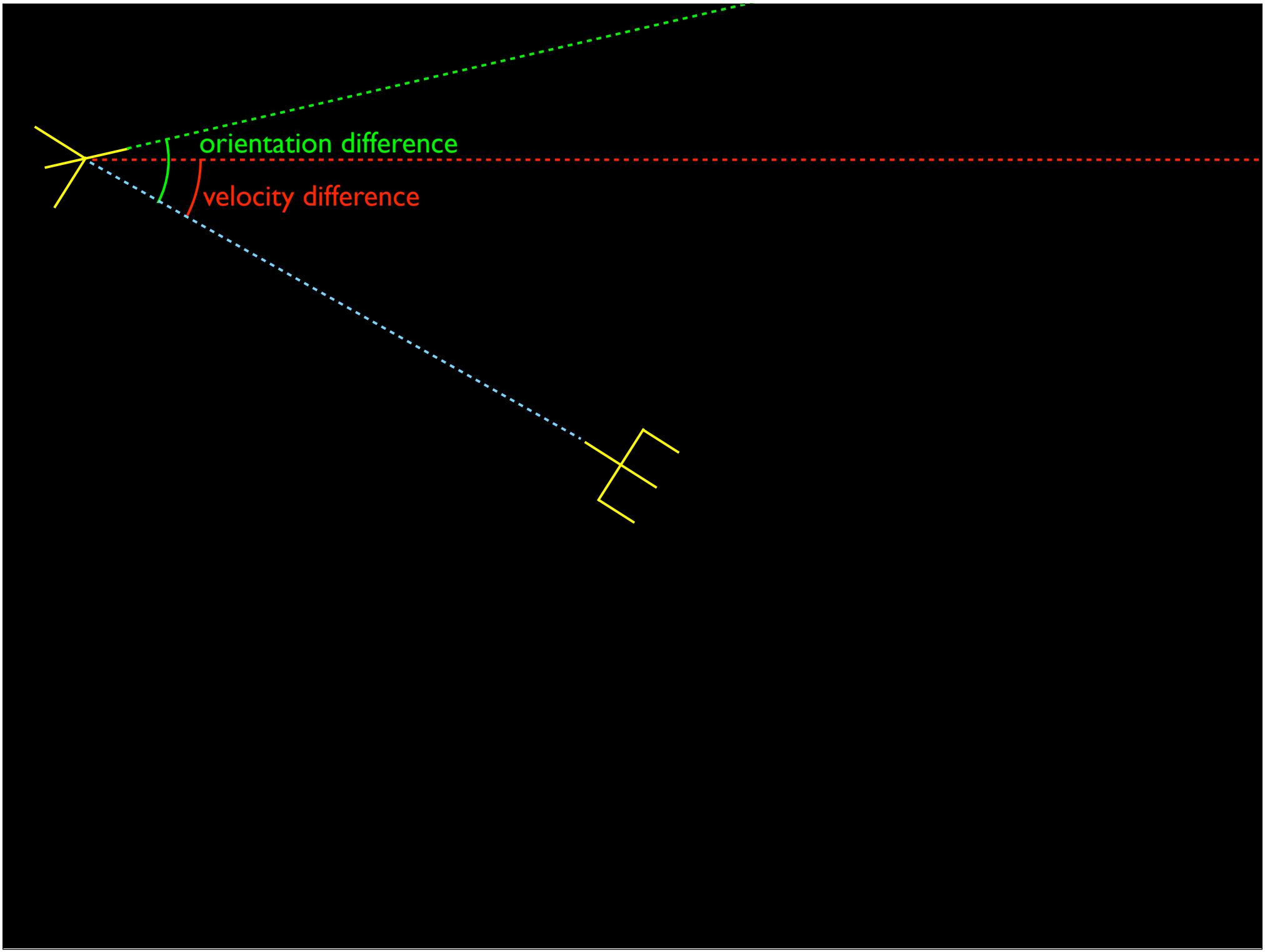


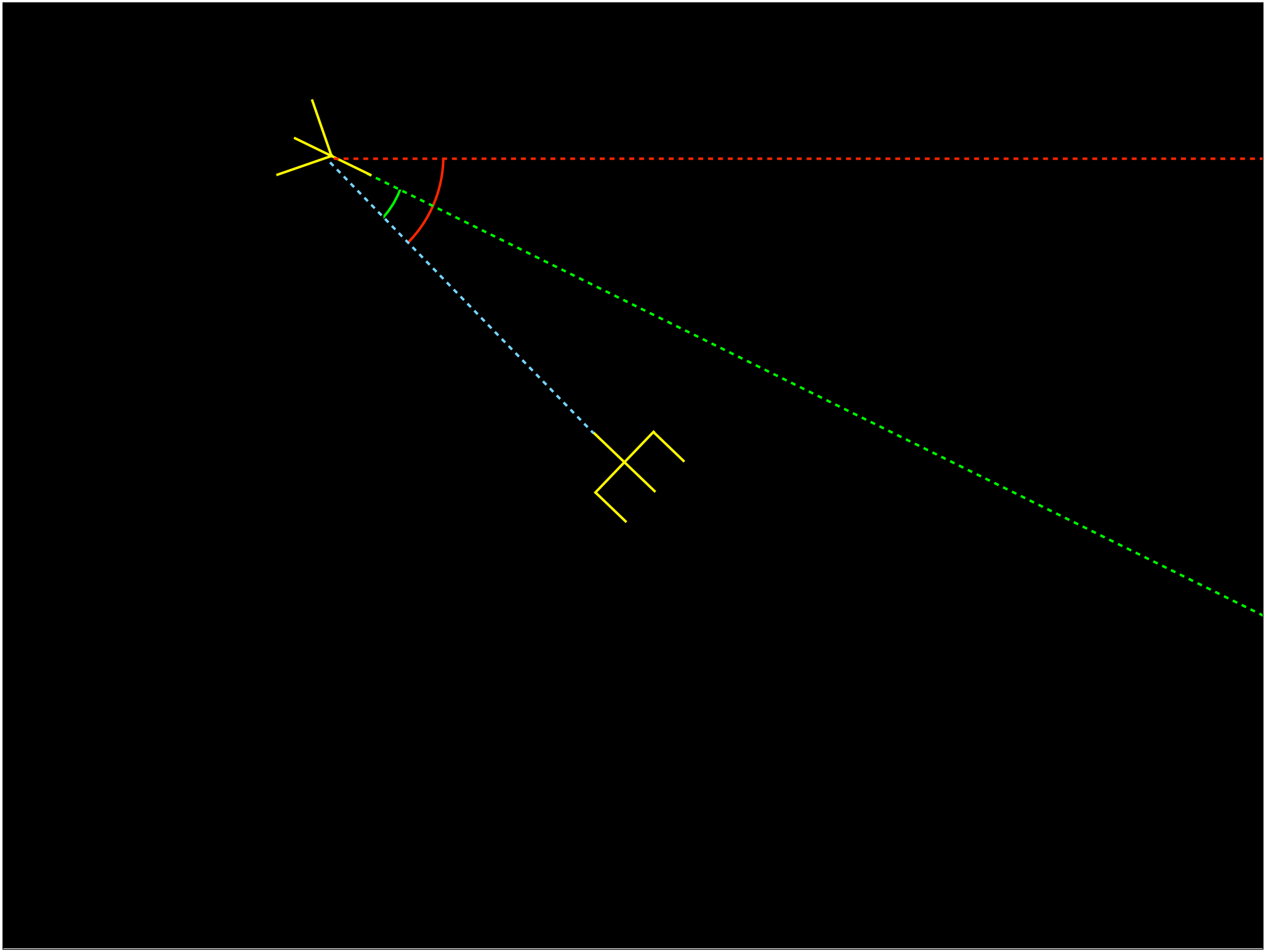


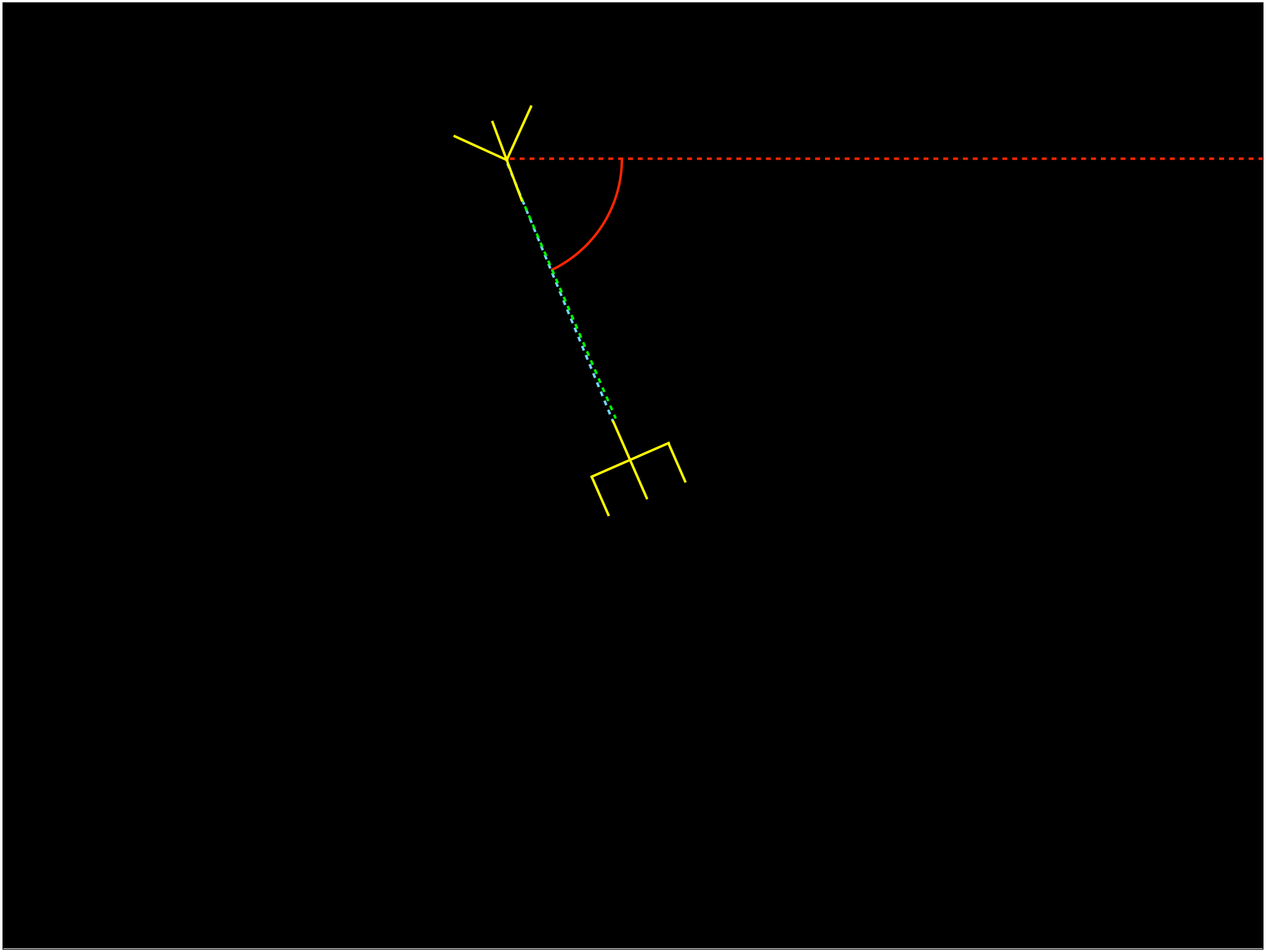


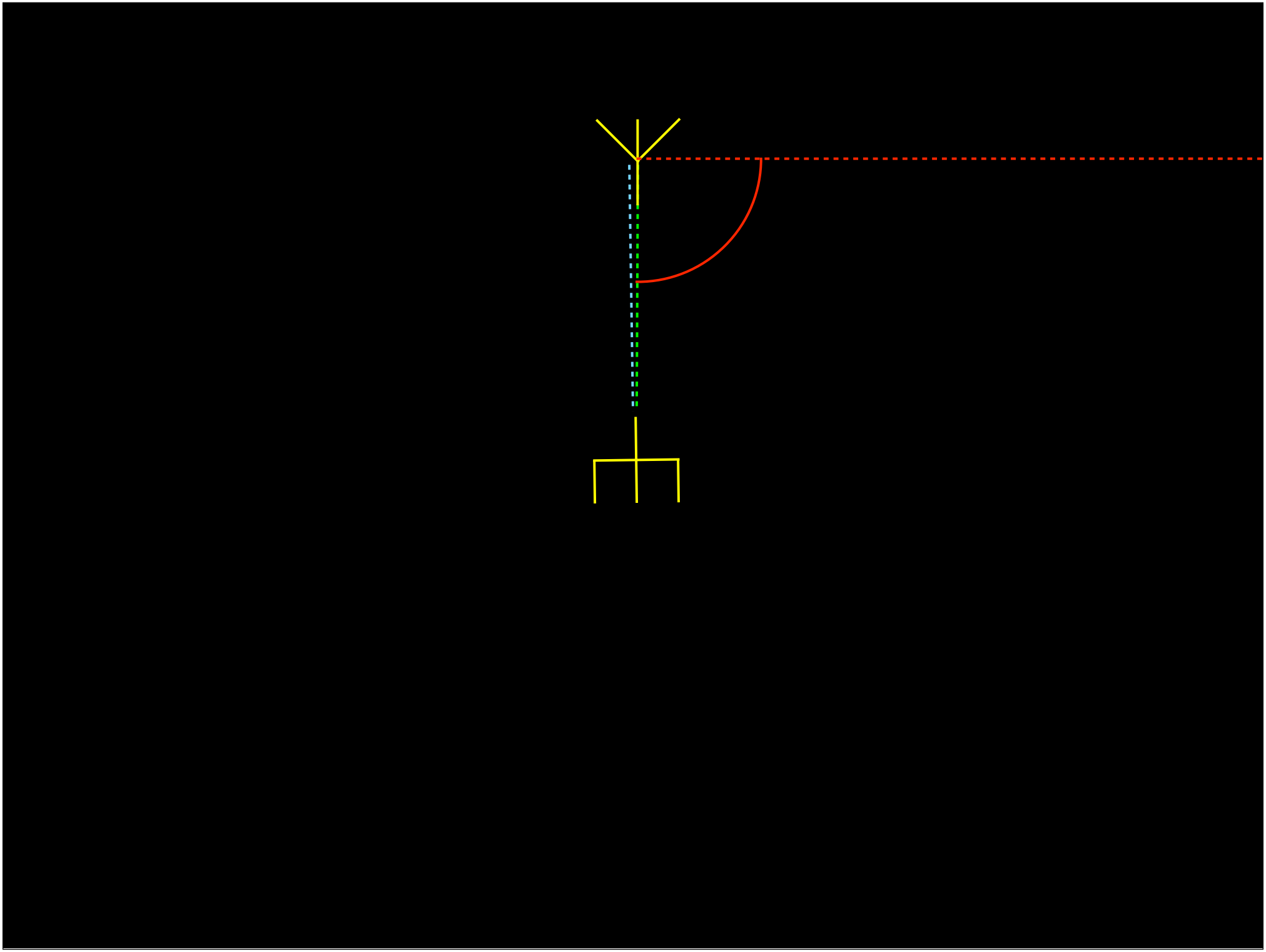


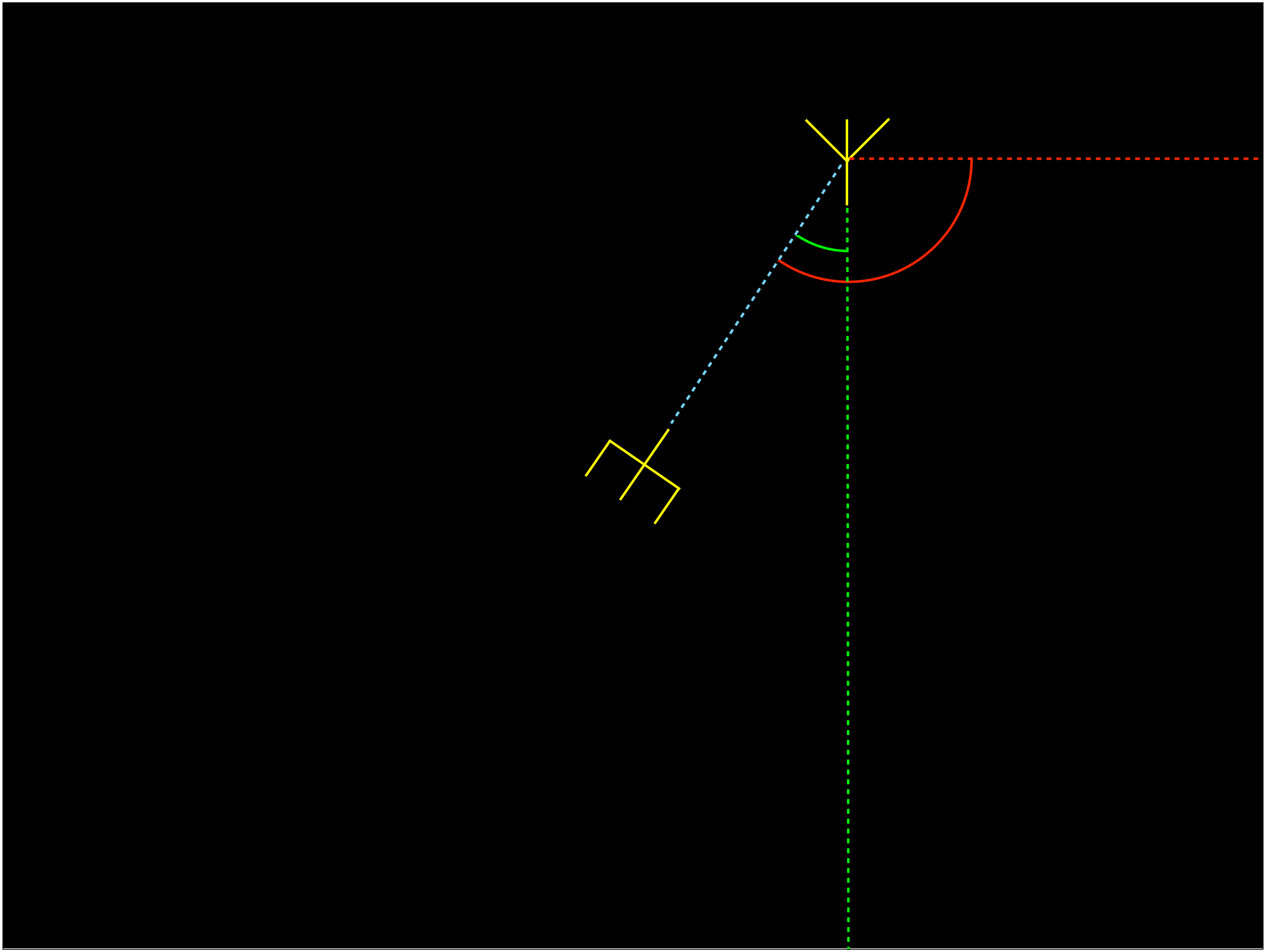


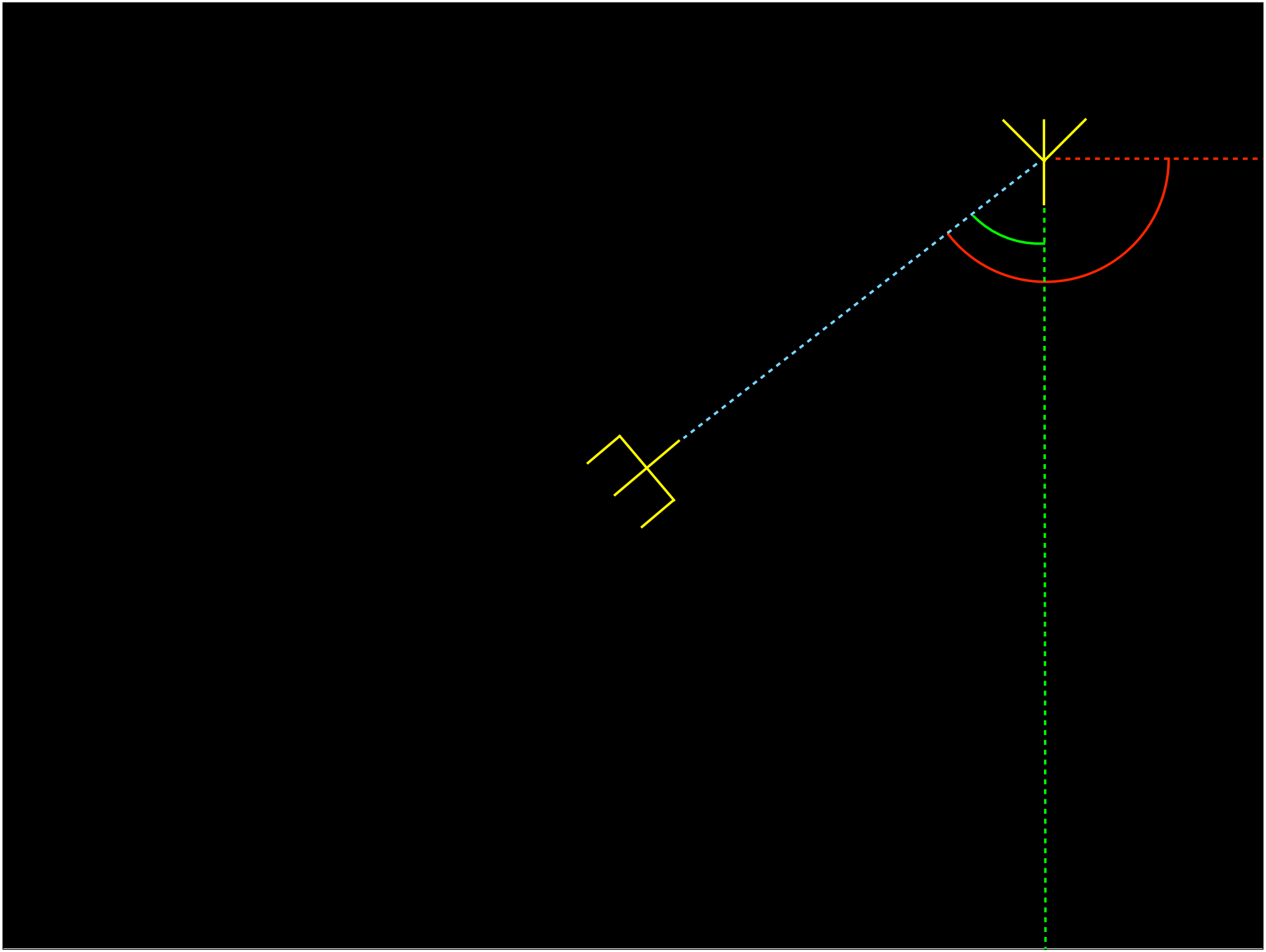

orientation difference
velocity difference



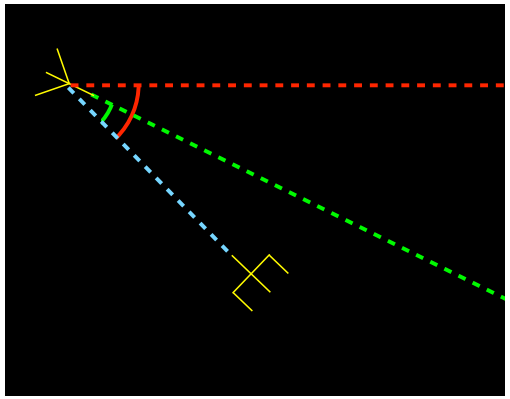




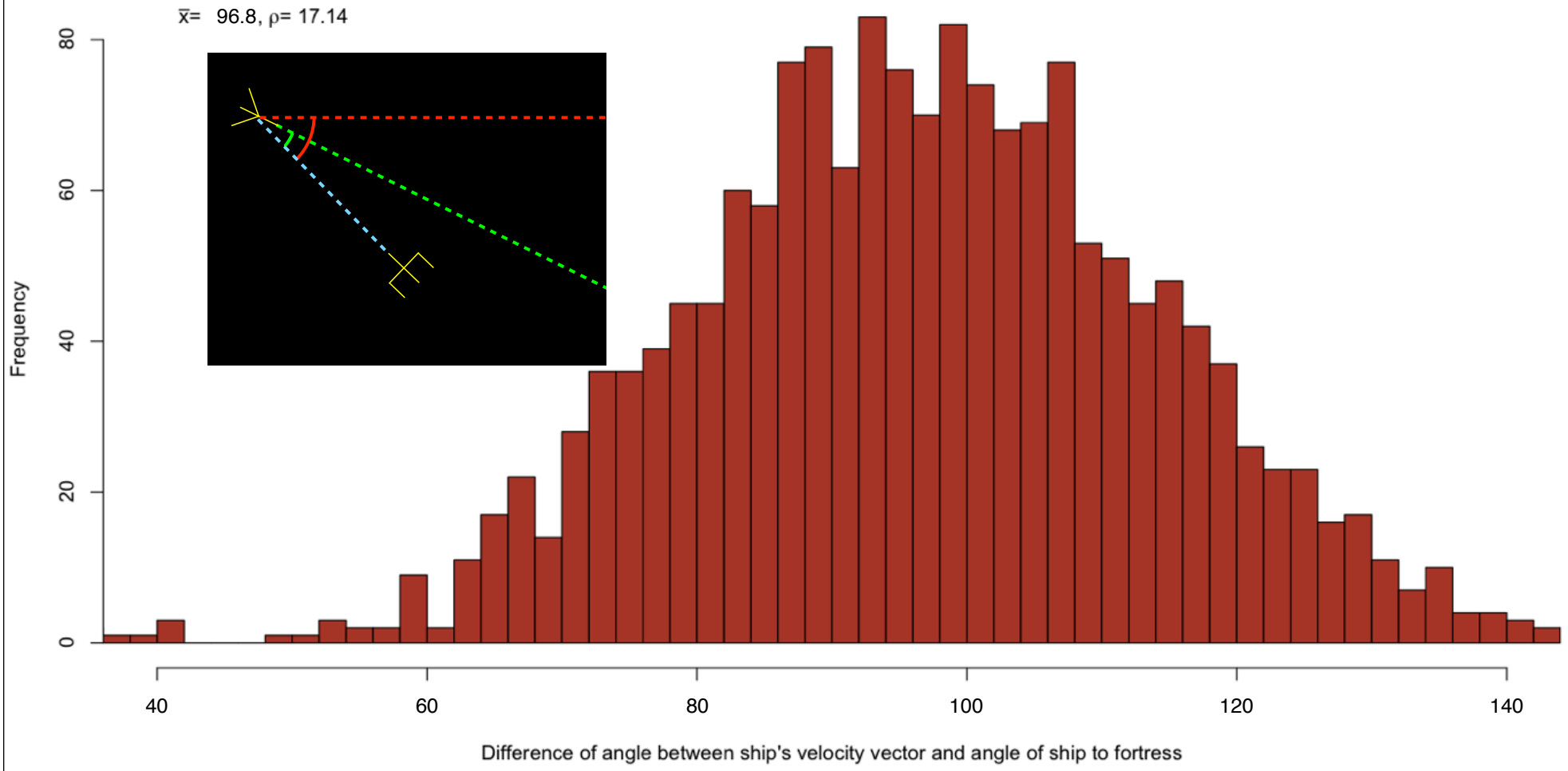




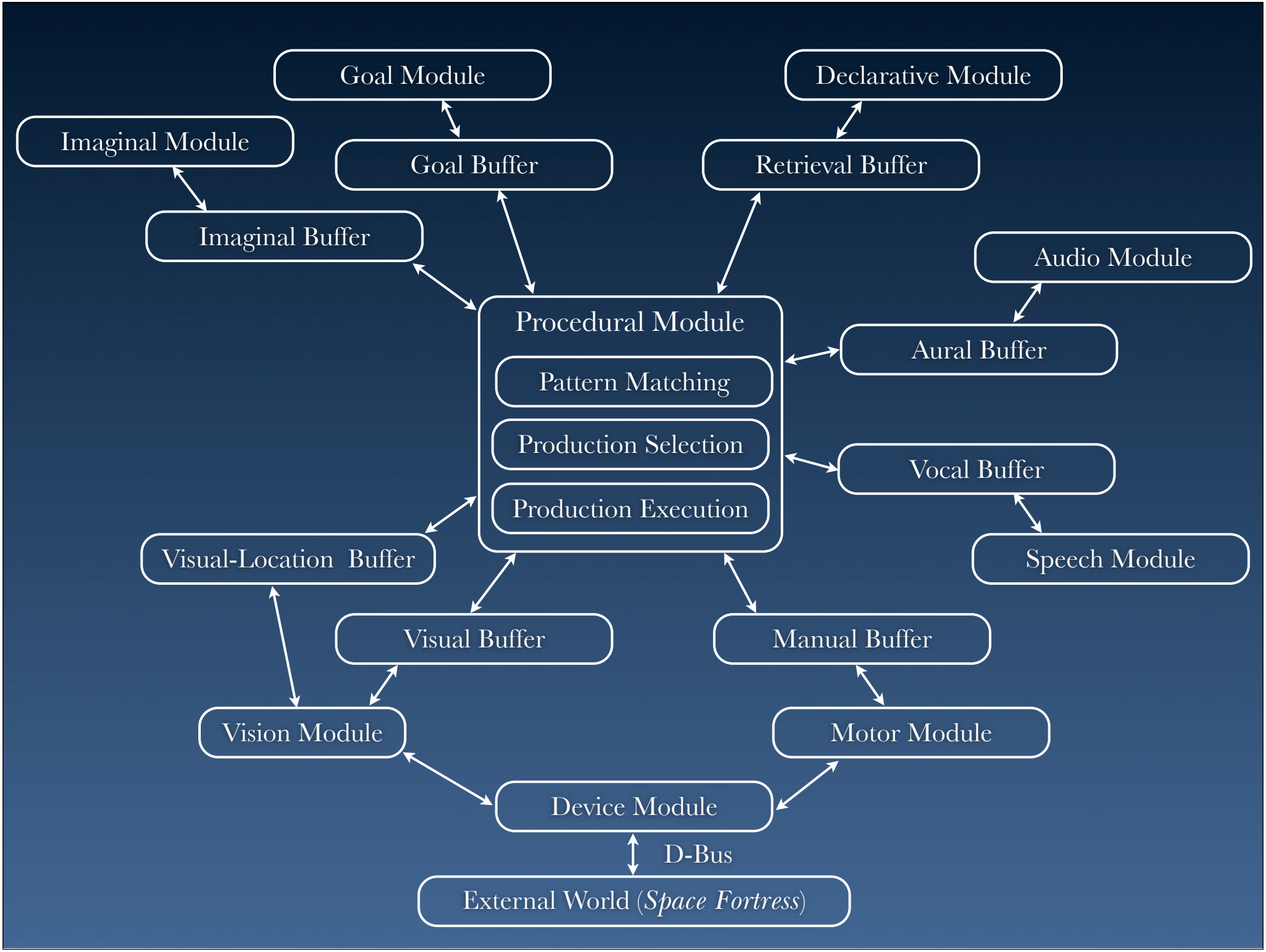
Most common orientation angle differences for starting ship turning

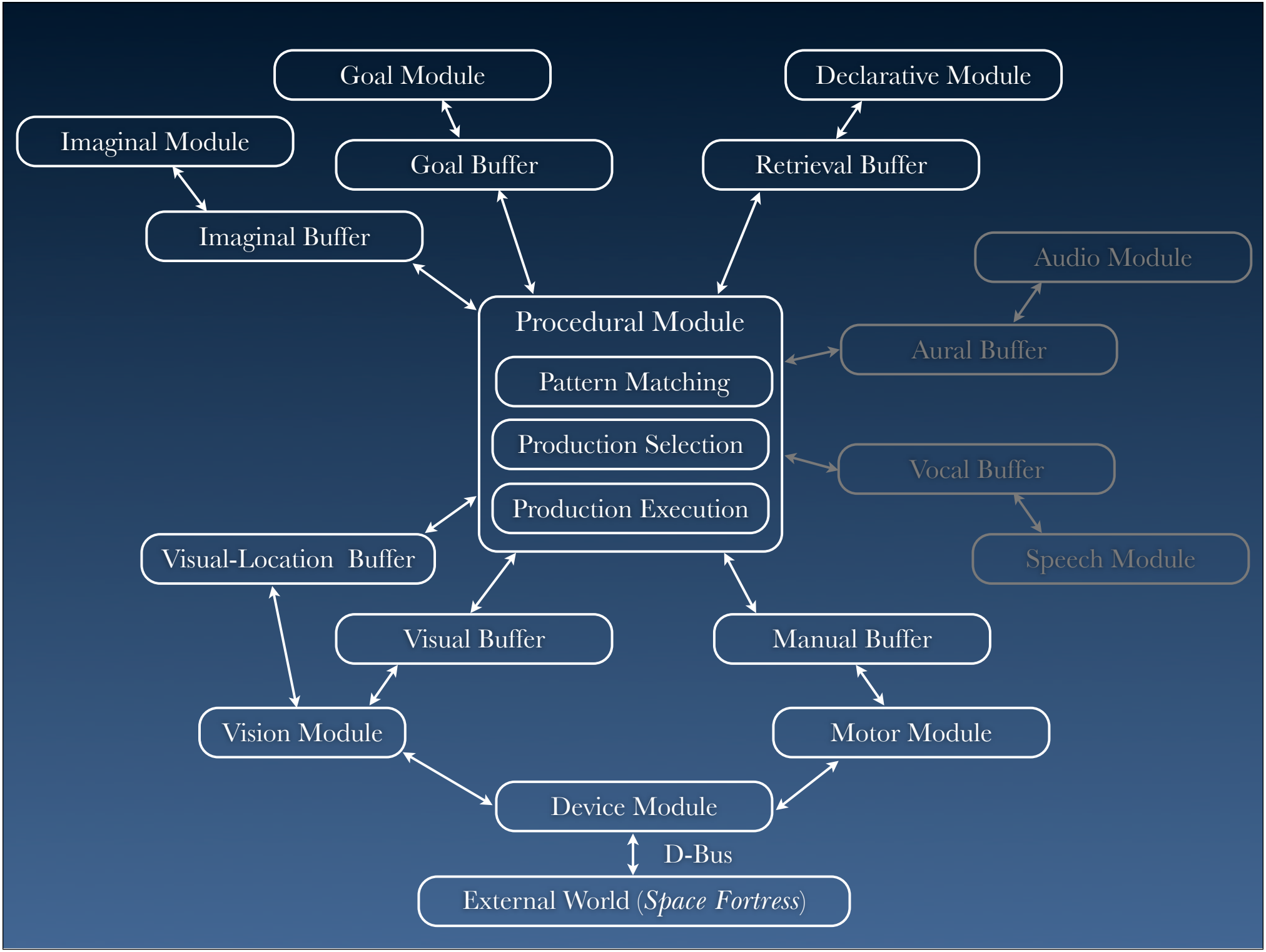


Most common velocity angle differences for starting to thrust



Model


Goal Module
Declarative Module
Imaginal Module
Goal Buffer
Retrieval Buffer
Imaginal Buffer
Audio Module
Procedural Module
Aural Buffer
Pattern Matching
Production Selection
Vocal Buffer
Production Execution
Visual-Location Buffer
Speech Module
Visual Buffer
Manual Buffer
Vision Module
Motor Module
Device Module
D-Bus
External World (*Space Fortress*)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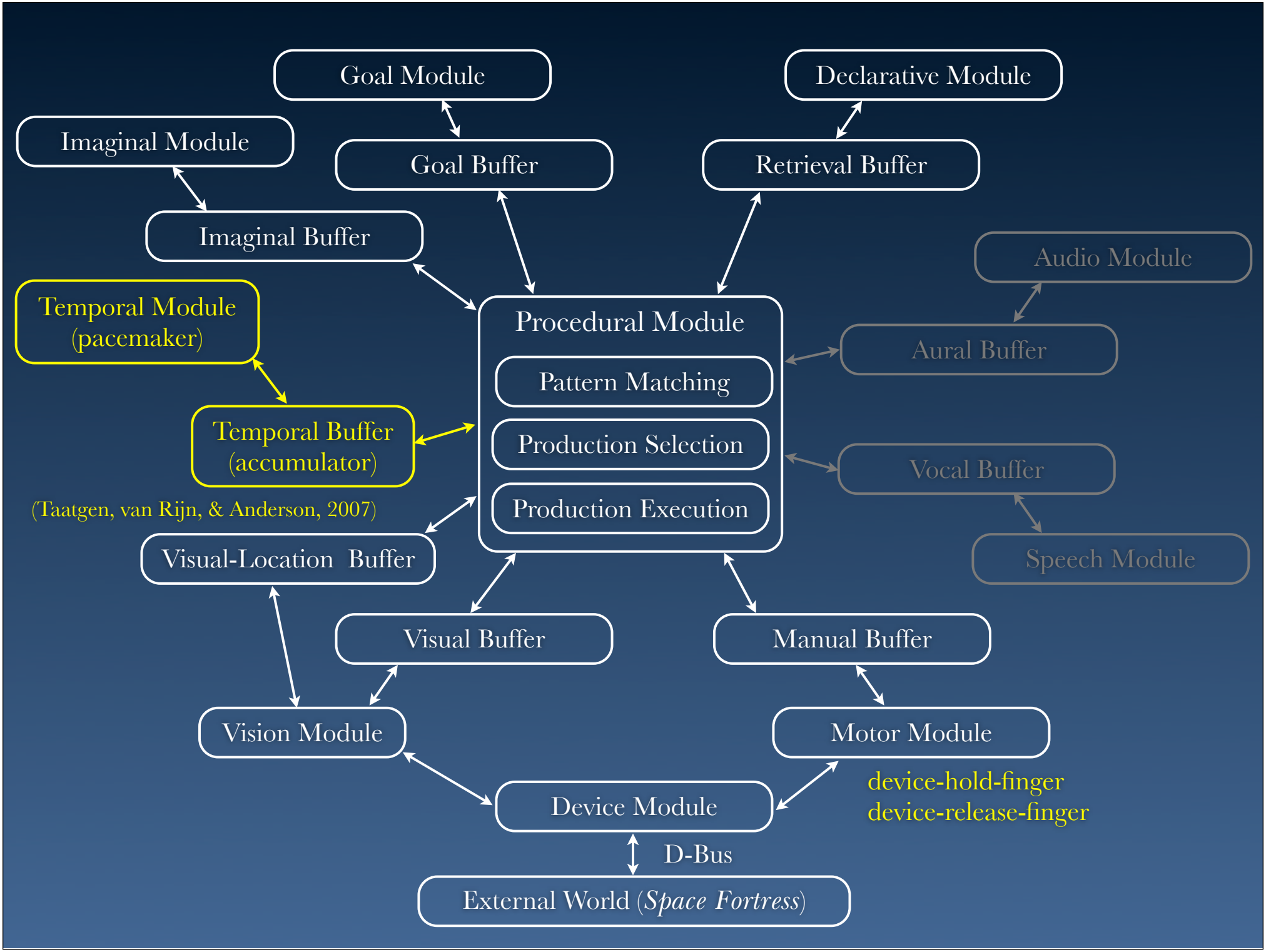
Goal Module
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Imaginal Module
Goal Buffer
Retrieval Buffer
Imaginal Buffer
Audio Module
Temporal Module
(pacemaker)
Procedural Module
Aural Buffer
Pattern Matching
Temporal Buffer
(accumulator)
Production Selection
Vocal Buffer
(Taatgen, van Rijn, & Anderson, 2007)
Production Execution
Visual-Location Buffer
Speech Module
Visual Buffer
Manual Buffer
Vision Module
Motor Module
device-hold-finger
device-release-finger
Device Module
D-Bus
External World (*Space Fortress*)

Global Parameters

```
(sgp :esc t :er t :v t :mas 1
:bll 0.5 :ans 0.25 :lf 0.5
:visual-movement-tolerance 40.0
:trace-detail high :test-feats nil
:motor-feature-prep-time 0
:default-punch-delay 0.06
:visual-attention-latency 0.05
:do-not-harvest imaginal)
```

Global Parameters

visual movement tolerance set to 40 degrees (!)

```
(sgp :esc t :er t :v t :mas 1
:bll 0.5 :ans 0.25 :lf 0.5
:visual-movement-tolerance 40.0
:trace-detail high :test-feats nil
:motor-feature-prep-time 0
:default-punch-delay 0.06
:visual-attention-latency 0.05
:do-not-harvest imaginal)
```

Global Parameters

Set instant motor feature preparation (Kieras, 2009)

```
(sgp :esc t :er t :v t :mas 1
:bll 0.5 :ans 0.25 :lf 0.5
:visual-movement-tolerance 40.0
:trace-detail high :test-feats nil
:motor-feature-prep-time 0
:default-punch-delay 0.06
:visual-attention-latency 0.05
:do-not-harvest imaginal)
```

Global Parameters

do not automatically harvest the imaginal buffer

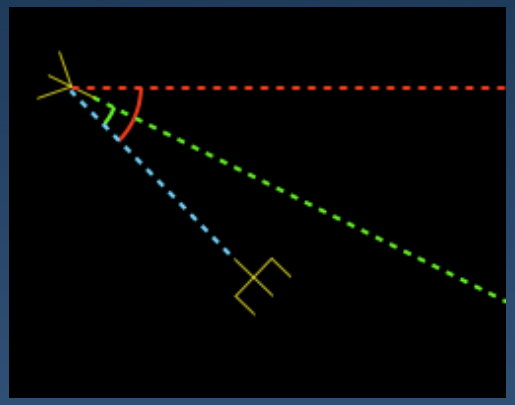
```
(sgp :esc t :er t :v t :mas 1
:bll 0.5 :ans 0.25 :lf 0.5
:visual-movement-tolerance 40.0
:trace-detail high :test-feats nil
:motor-feature-prep-time 0
:default-punch-delay 0.06
:visual-attention-latency 0.05
:do-not-harvest imaginal)
```

Implementation Details

- Imaginal buffer used as a non-harvested "scratchpad" to manage issue of interruptible tracking
- Device module modifies a fixed list of location and object chunks that represent the visicon
- Visual object chunks contain slots that assume ability to determine orientation, etc.
- ACT-R drives the simulation by stepping a frame every 33ms in the event scheduler

Flight Pattern Productions

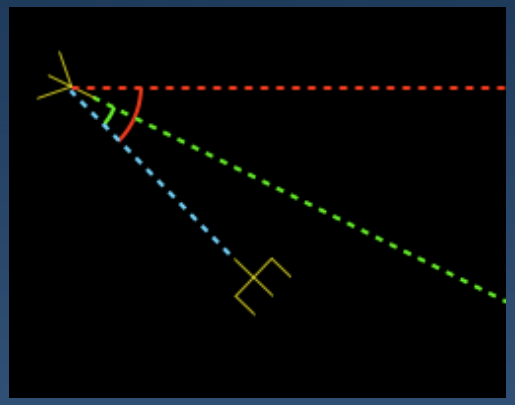
```
(p turn-right-in-circle
   =goal>
      ISA         fly-ship
      state       standard-flight-
pattern
   =visual>
      ISA         ship
      > orient-diff   2
      - vel     0
      > fortress-distance 95
      < fortress-distance 190
    ?manual>
      processor       free
==>
   +manual>
      ISA         press-key
      key         d
)
```



```
(p thrust-in-circle
   =goal>
      ISA         fly-ship
      state       standard-flight-
pattern
   =visual>
      ISA         ship
      - vel       0
      > vel-diff  95
      > fortress-distance 95
      < fortress-distance 175
      < orient-diff  5
   ?manual>
       processor  free
==>
   +manual>
      ISA         press-key
      key         w
)
```

"Butter Zone" Productions

```
(p turn-right-in-circle
   =goal>
      ISA         fly-ship
      state       standard-flight-
pattern
   =visual>
      ISA         ship
      > orient-diff   2
      - vel     0
      > fortress-distance 95
      < fortress-distance 190
    ?manual>
      processor       free
==>
   +manual>
      ISA         press-key
      key         d
)
```



```
(p thrust-in-circle
   =goal>
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   =visual>
      ISA         ship
      - vel       0
      > vel-diff  95
      > fortress-distance 95
      < fortress-distance 175
      < orient-diff  5
   ?manual>
       processor  free
==>
   +manual>
      ISA         press-key
      key         w
)
```
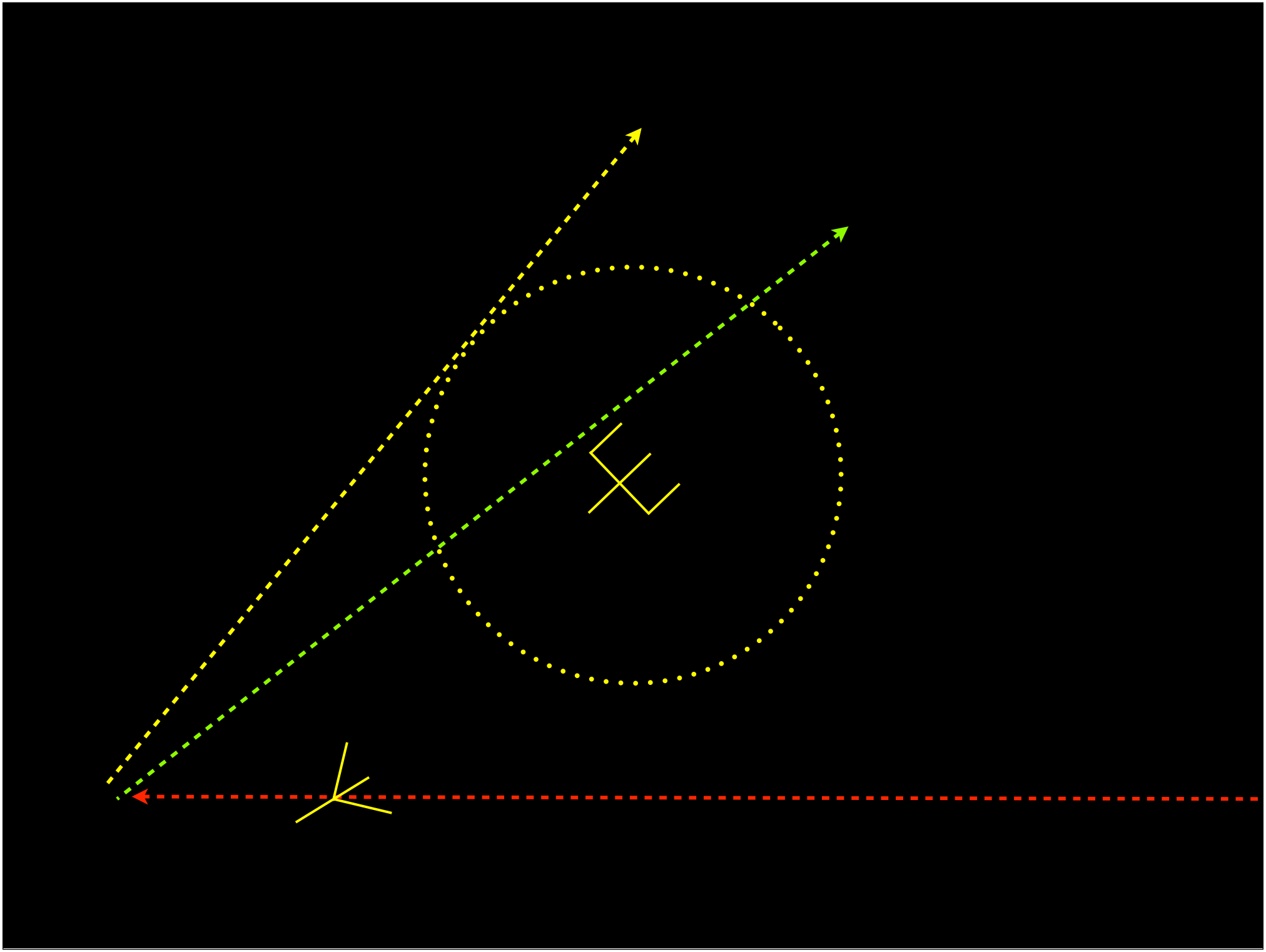
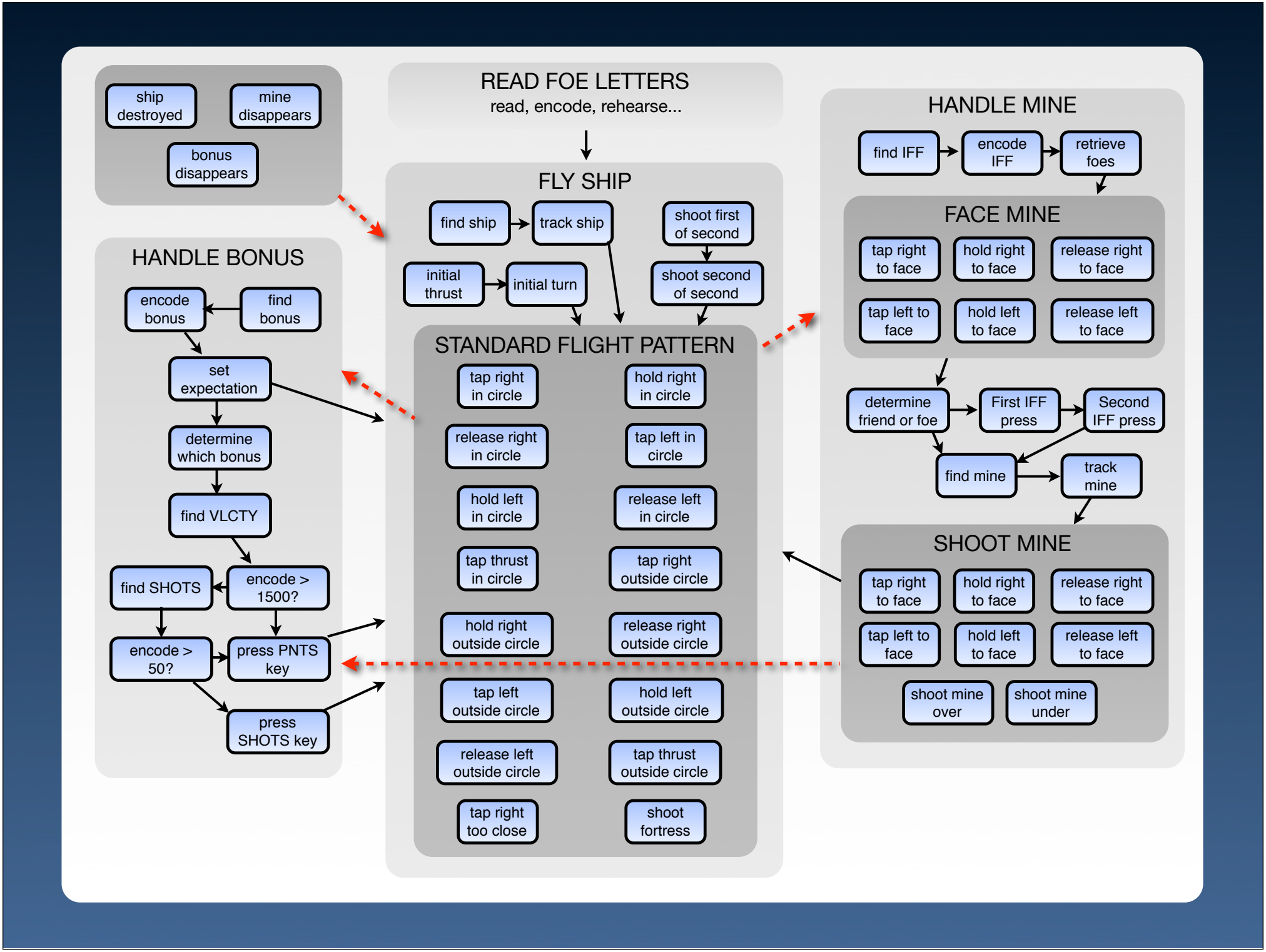

Outside the "Butter Zone"

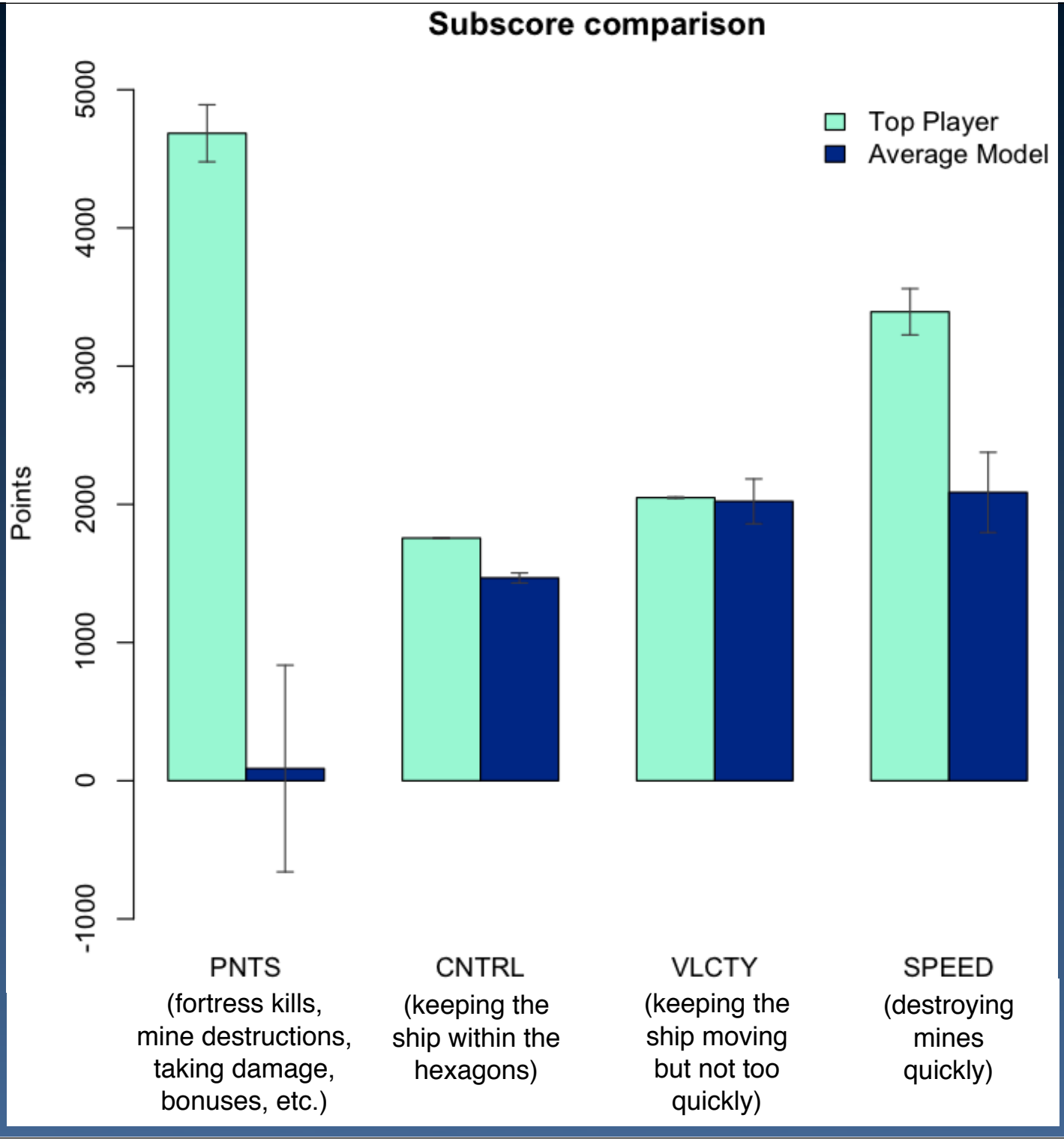
- Very difficult to pull patterns out of the data
- Most common expert subject claim: "I tried to get to a tangent"

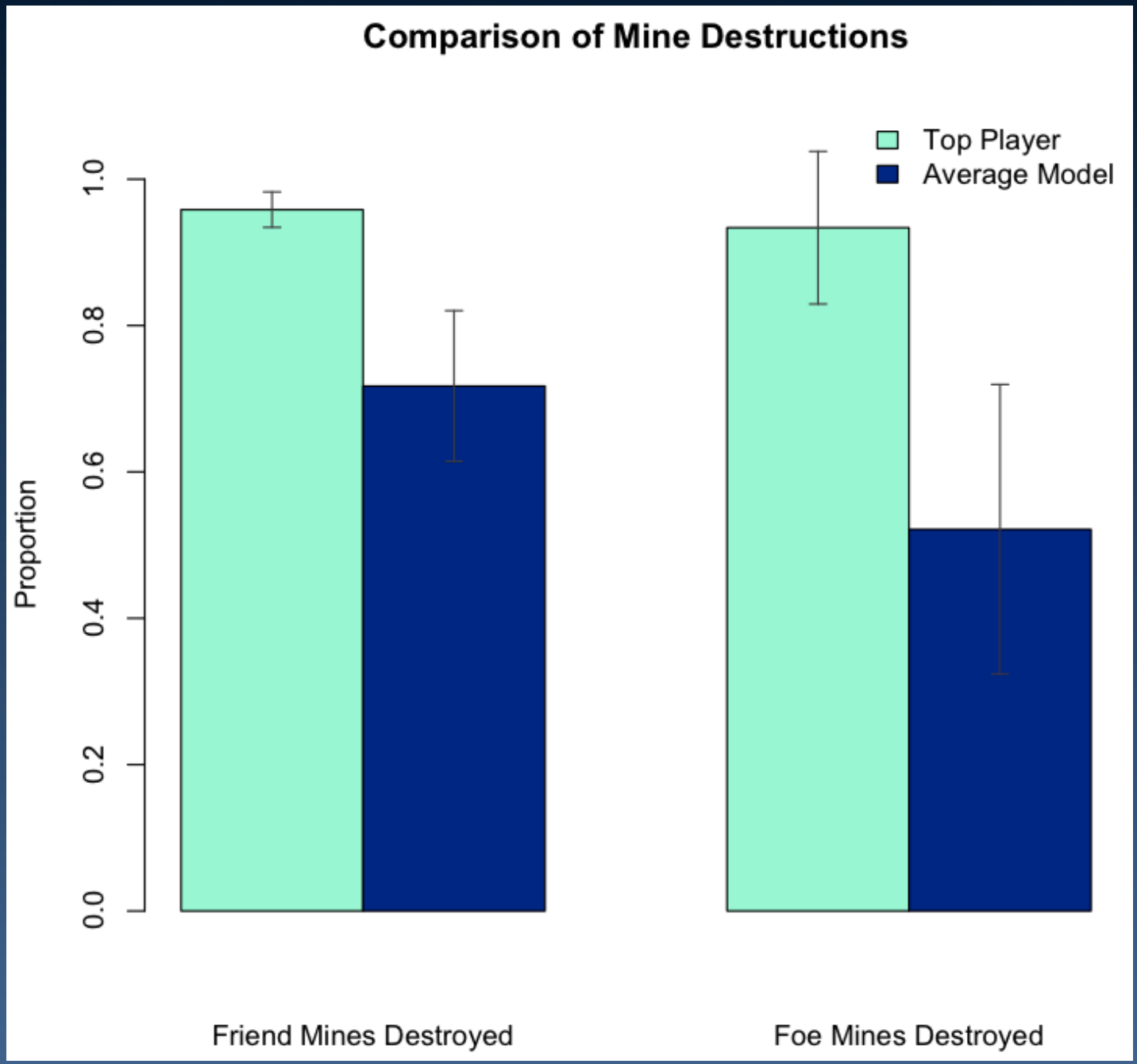


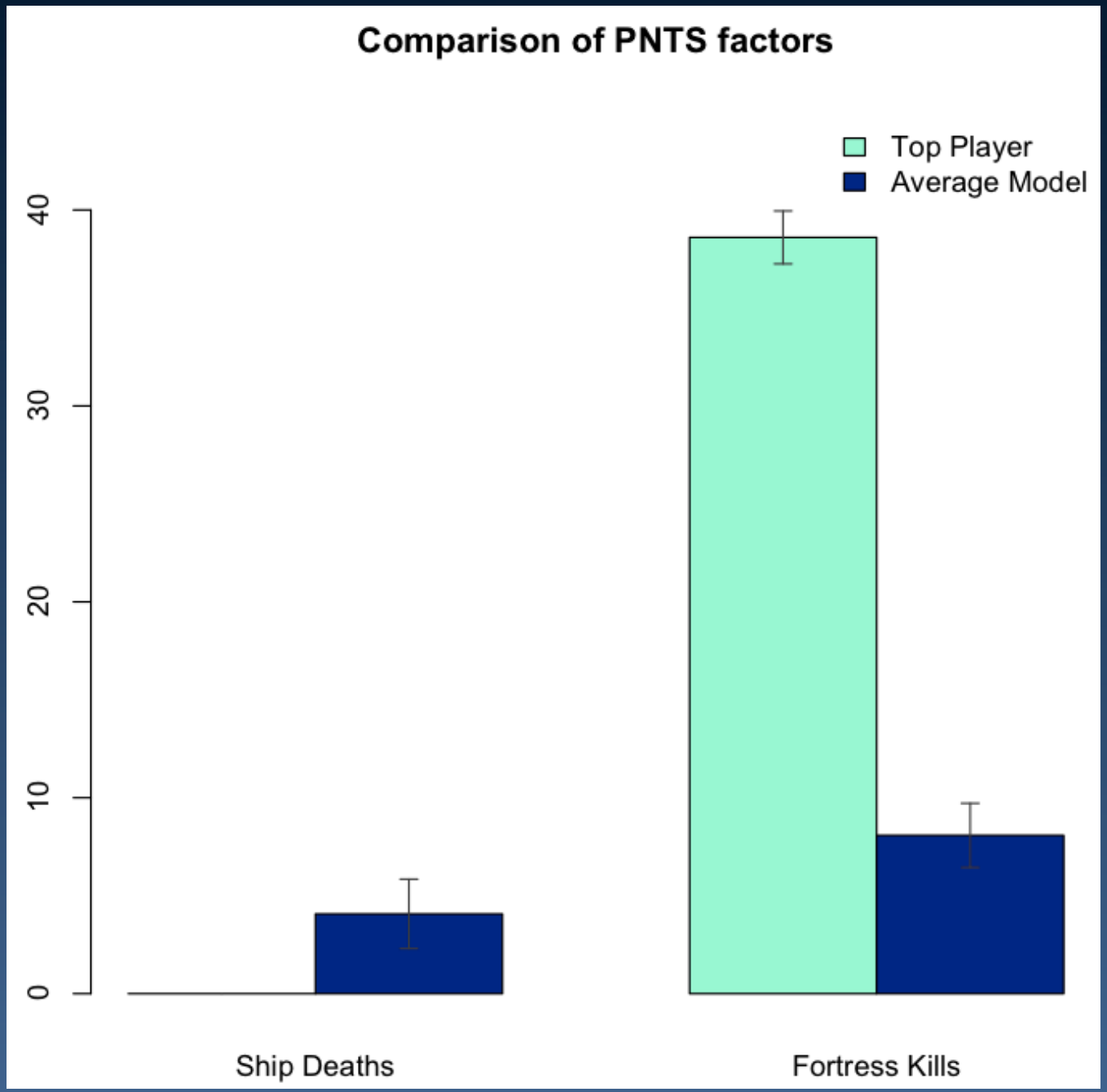

ship destroyed
mine disappears
bonus disappears
READ FOE LETTERS
read, encode, rehearse...
FLY SHIP
find ship
track ship
shoot first of second
initial thrust
initial turn
shoot second of second
STANDARD FLIGHT PATTERN
tap right in circle
hold right in circle
release right in circle
tap left in circle
hold left in circle
release left in circle
tap thrust in circle
tap right outside circle
hold right outside circle
release right outside circle
tap left outside circle
hold left outside circle
release left outside circle
tap thrust outside circle
tap right too close
shoot fortress
HANDLE BONUS
encode bonus
find bonus
set expectation
determine which bonus
find VLCTY
find SHOTS
encode > 1500?
encode > 50?
press PNTS key
press SHOTS key
HANDLE MINE
find IFF
encode IFF
retrieve foes
FACE MINE
tap right to face
hold right to face
release right to face
tap left to face
hold left to face
release left to face
determine friend or foe
First IFF press
Second IFF press
find mine
track mine
SHOOT MINE
tap right to face
hold right to face
release right to face
tap left to face
hold left to face
release left to face
shoot mine over
shoot mine under

Model Evaluation

- don't fly too fast ✓
- keep the ship within the hexagons ✓
- capture appropriate bonuses when available ✓
- destroy the fortress as often as possible ✗
- destroy the mines as quickly as possible ✗


Subscore comparison
Top Player
Average Model
Points
5000
4000
3000
2000
1000
0
-1000
PNTS
(fortress kills, mine destructions, taking damage, bonuses, etc.)
CNTRL
(keeping the ship within the hexagons)
VLCTY
(keeping the ship moving but not too quickly)
SPEED
(destroying mines quickly)

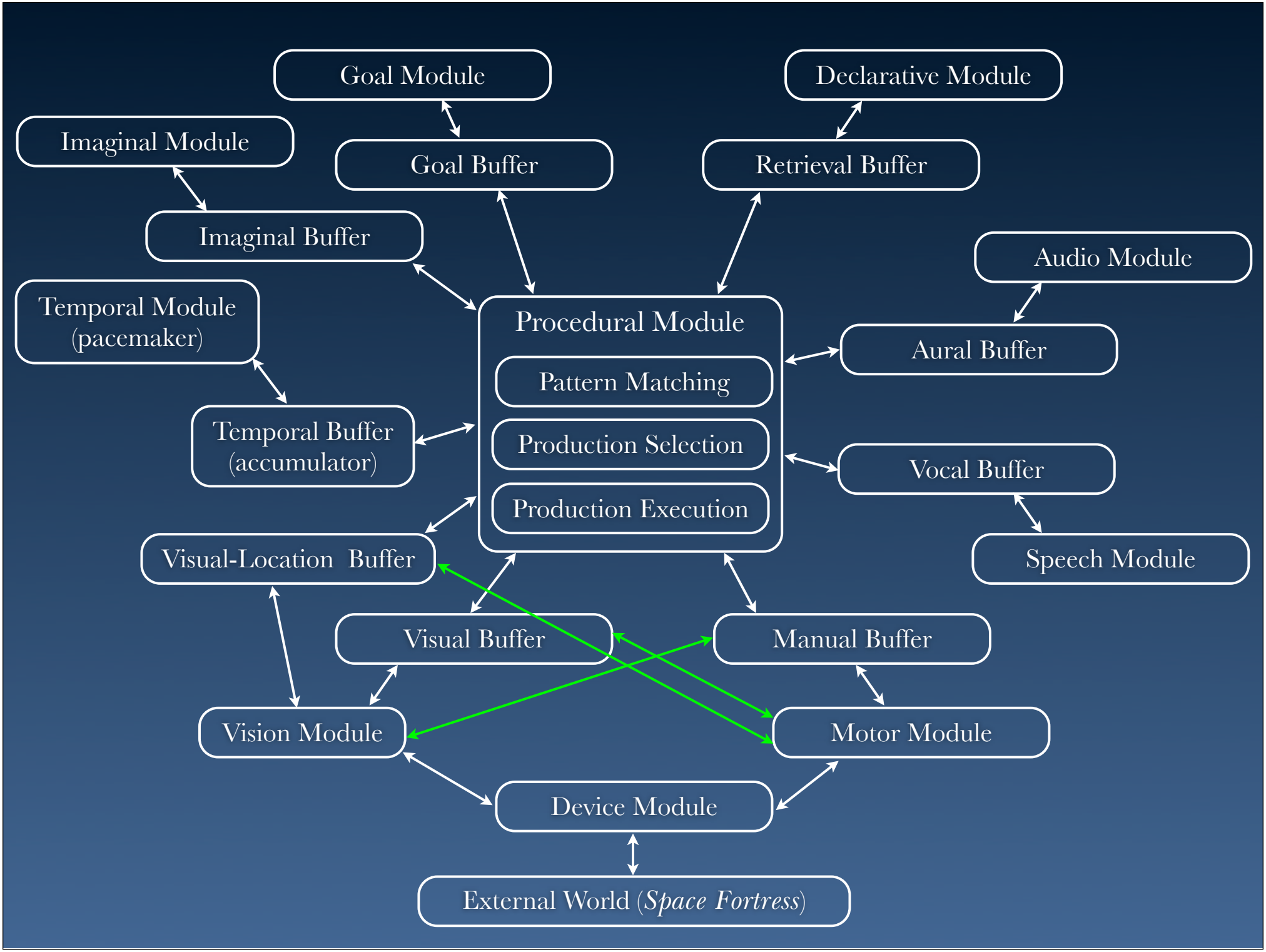

Comparison of Mine Destructions
Top Player
Average Model
Proportion
0.0
0.2
0.4
0.6
0.8
1.0
Friend Mines Destroyed
Foe Mines Destroyed


Comparison of PNTS factors
Top Player
Average Model
0
10
20
30
40
Ship Deaths
Fortress Kills

Discussion

Challenges for ACT-R

- More sophisticated motor control
- Disappearing objects
- Closed-loop control with continuous feedback
- Interruptible tracking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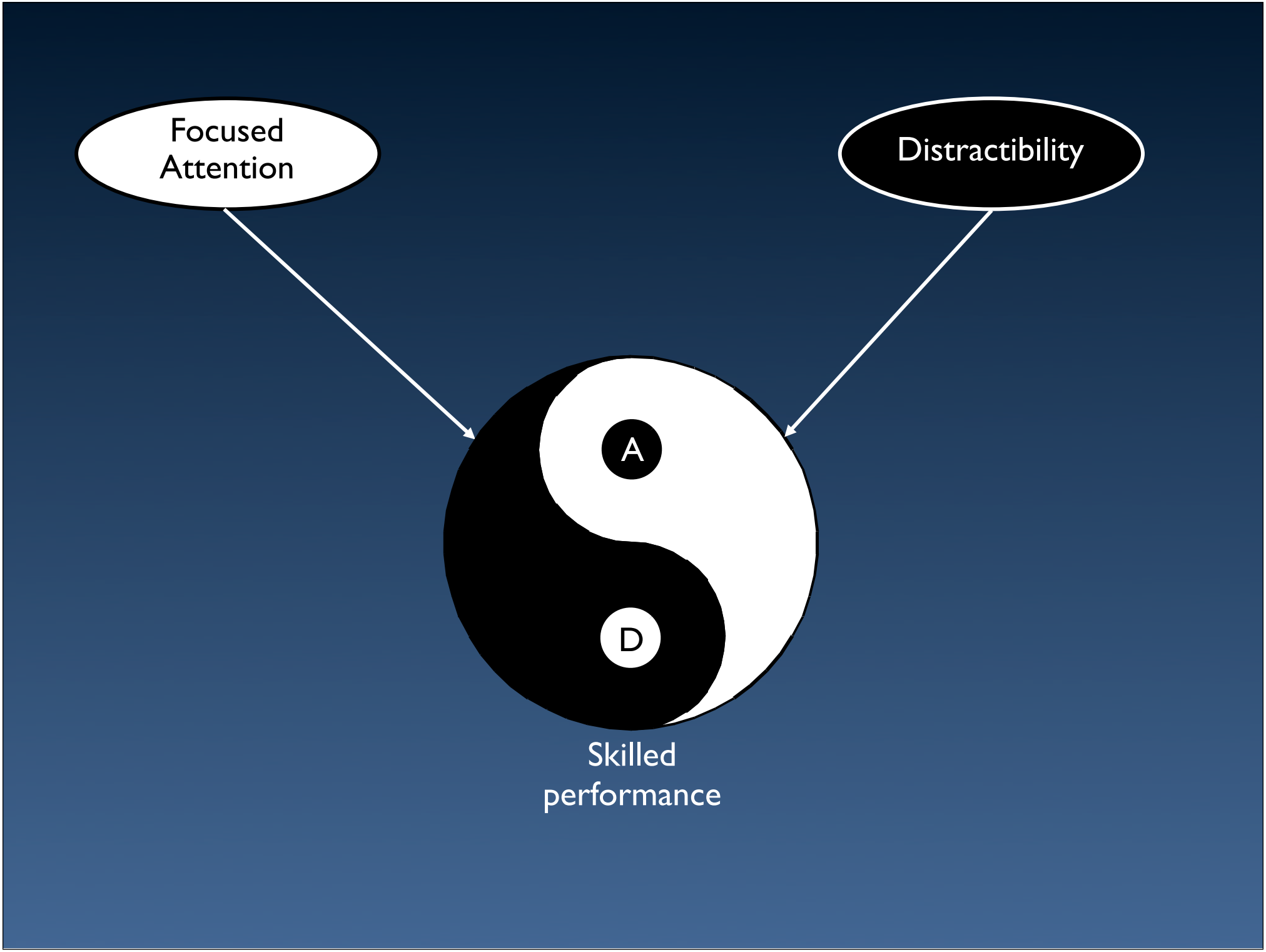
Focused Attention
Distractibility
A
D
Skilled performance