



Game Engine-based Agent Simulator (GEAS)

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Why use a simulator?

- Autonomous Vehicles (AVs) require control software
- Control software requires a testing environment
 - Ideally, the vehicle itself
- However, this might not be best
 - There may be limited quantity of vehicles
 - May require additional knowledge to operate
 - Possibly slow iteration time
 - May take vehicle away from more productive work
 - Experimental work could possibly damage vehicle

Existing simulators

- CADCON^[Chappell et al.], SMART^[Turner et al.],
DIS-Java-VRML^[Brutzman et al.]
- However, these have their own problems
 - Typically highly specialized for their vehicle
 - Control software likely unique to the vehicle
 - Typically built from ground up
 - Rendering, physics, etc.
 - Often under-maintained; can quickly become obsolete

Alternative?

- Game Engines
 - CryEngine, Unity3D, Unreal, Polycode, Torque3D
 - Small to large-scale game development
- Eliminate need to “reinvent the wheel”
 - Rendering
 - Physics
 - Content creation tools
- Consistently maintained and updated
- Free (or reasonable commercial licenses)

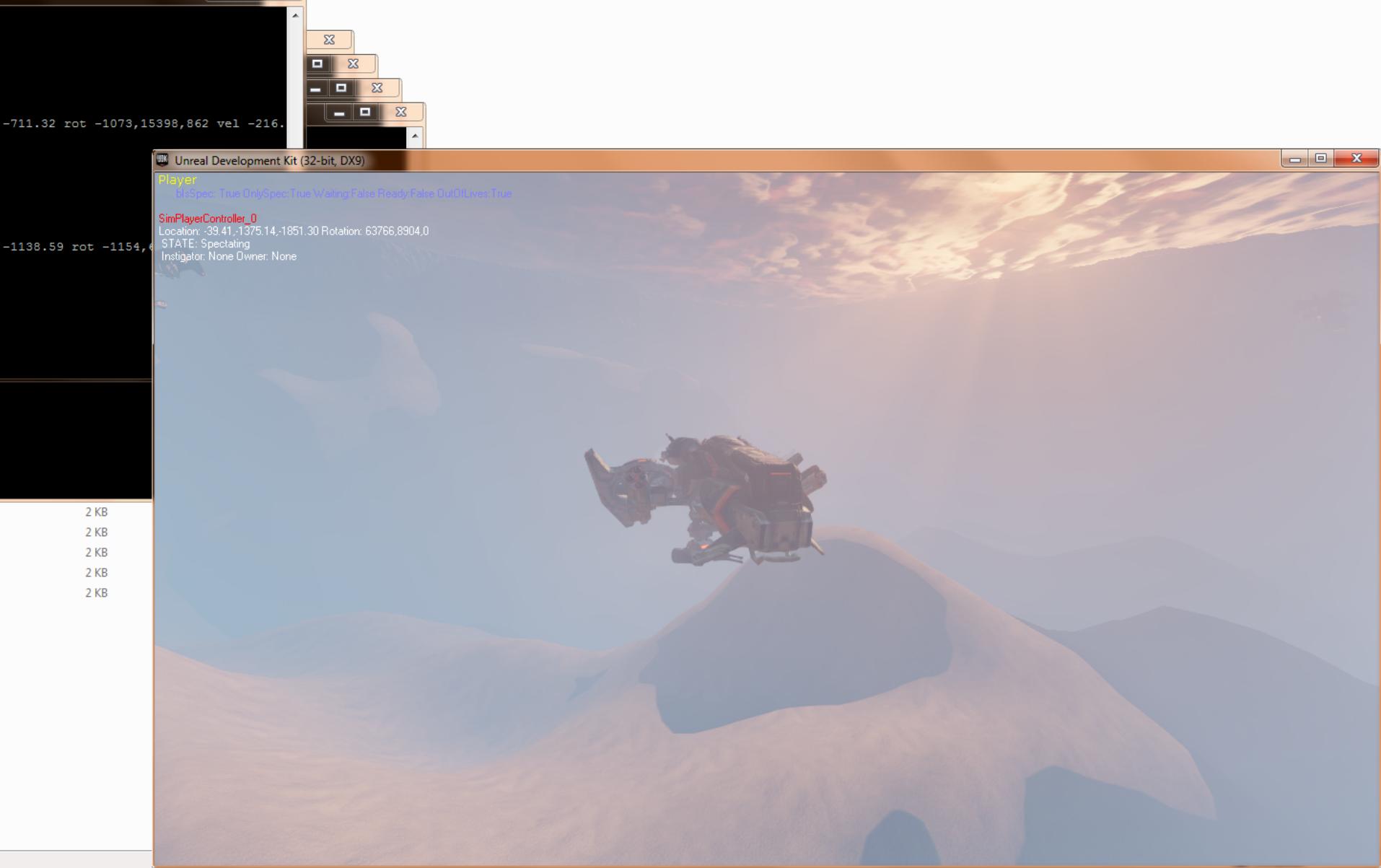
“Serious Games”

- Already used for military, educational, training or medical purposes
 - VBS^[BI Studios], DARWARS^[BBN]
 - Flight Simulator^[Microsoft]
 - Re-Mission^[HopeLab]
- But very little for AV development
 - IAAVS^[Periera, Rossetti] - but geared toward traffic simulation
- Need some way to work with control software

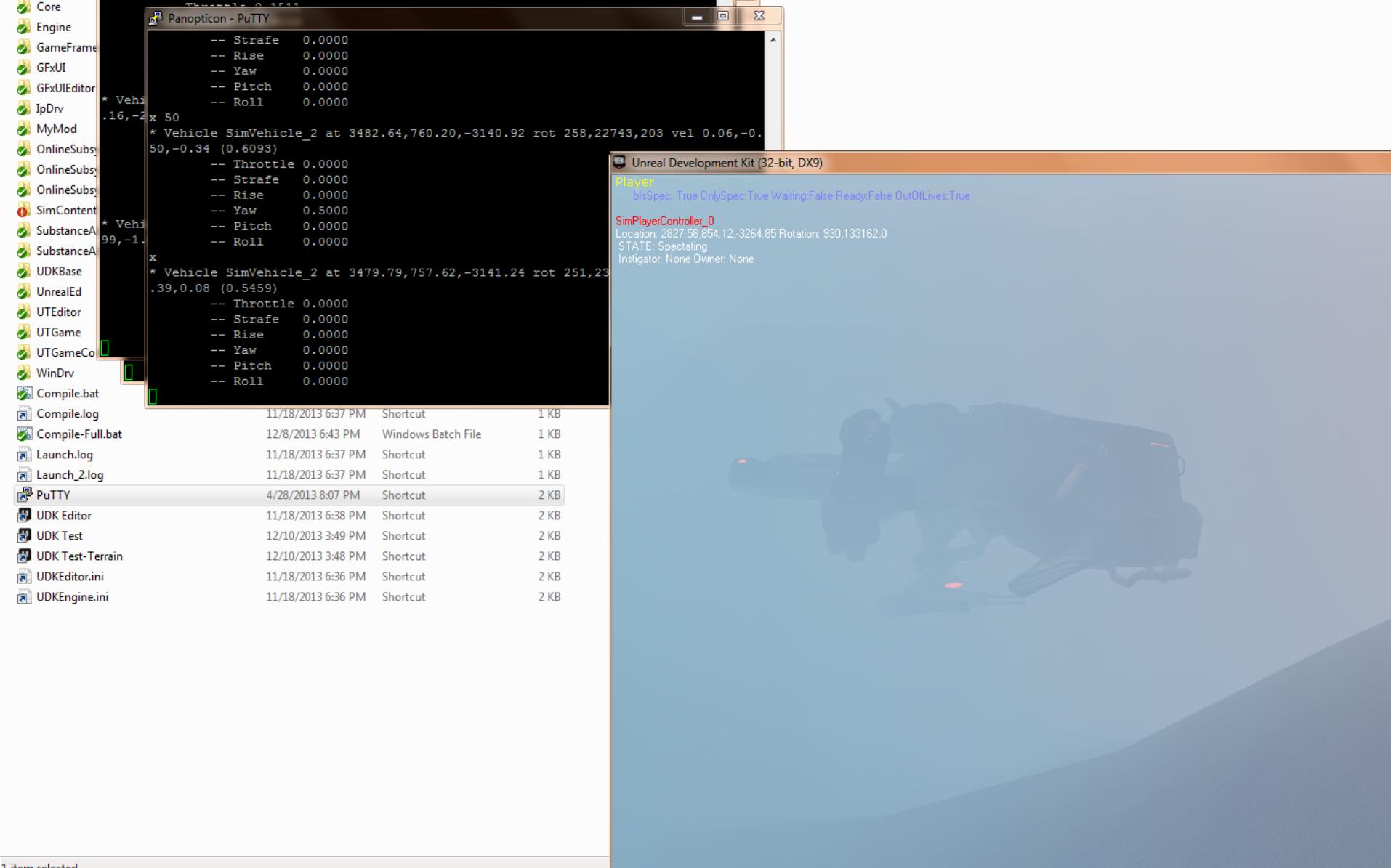
Game Engine-based Agent Simulator (GEAS)

- Unreal and Java
- High-level AV simulation
- Flexible
- Extendible
- Portable





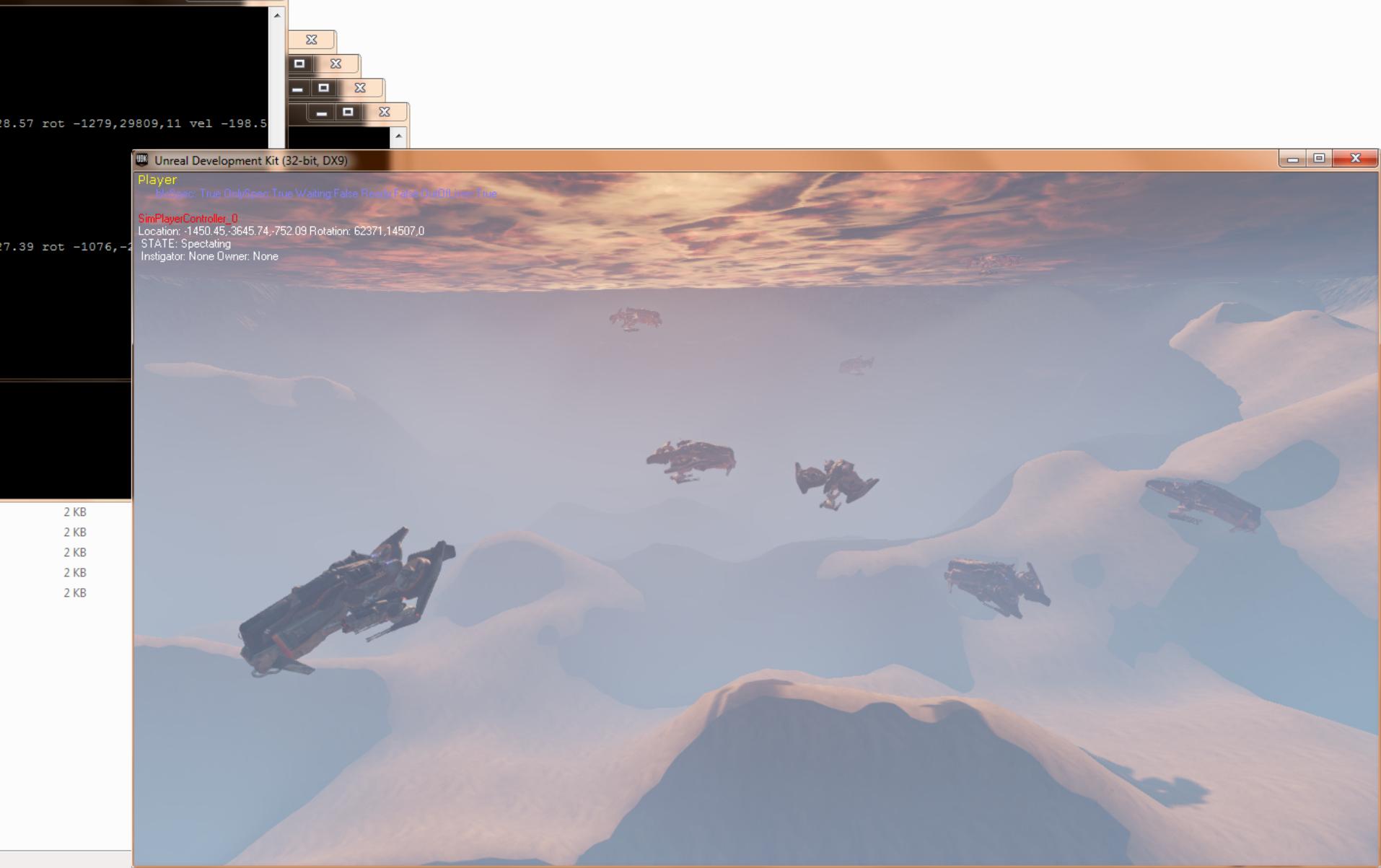
- Autonomous Underwater Vehicles (AUVs)
 - But designed to be flexible for any type of vehicle!



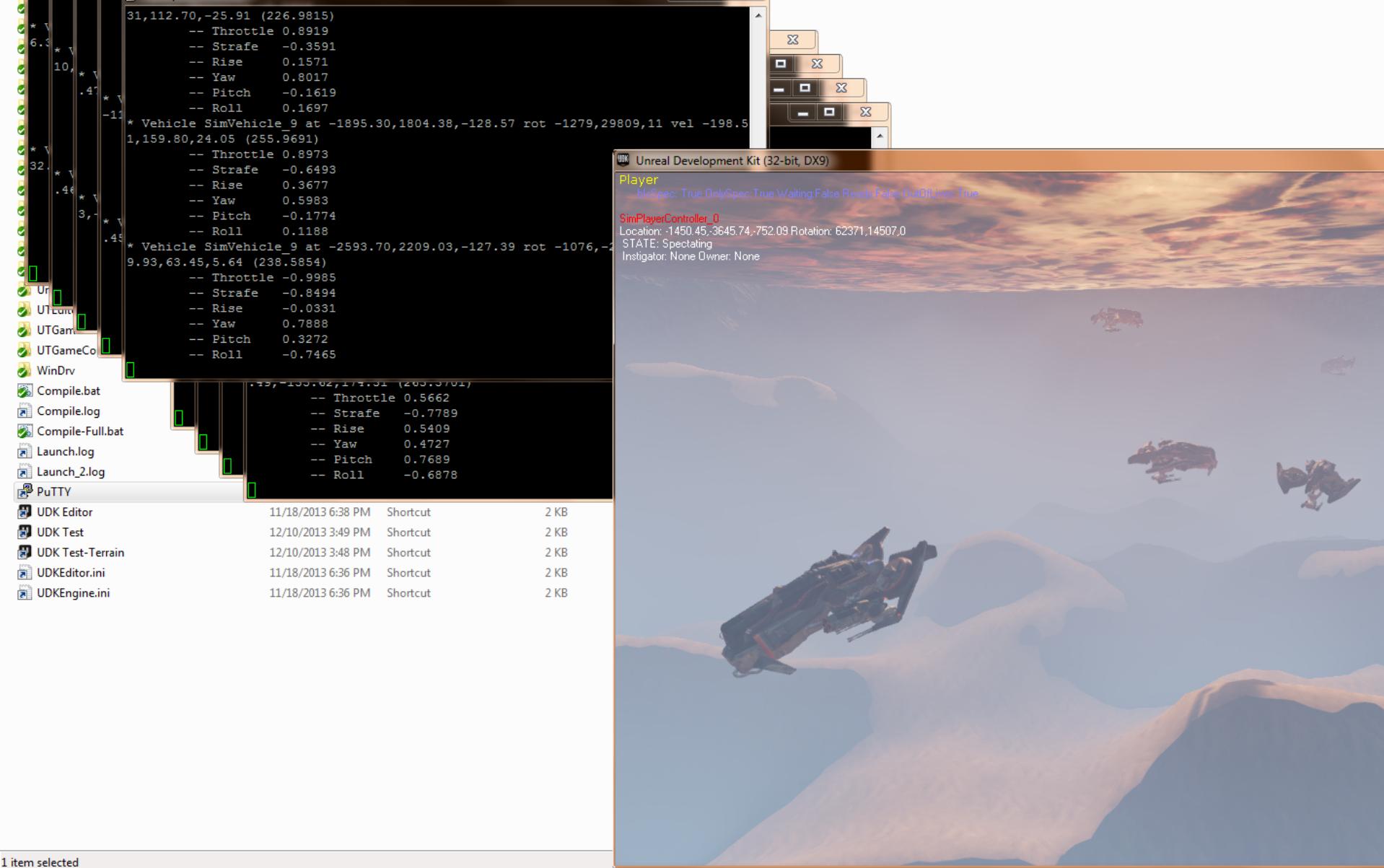
- Simulated vehicle *not* controlled in-game, but instead by external controller via socket connection

```
Panopticon - PuTTY
-- Strafe   -1.0000
-- Rise     0.0000
-- X Turn   0.0000
-- Y Turn   0.0000
x 20
* Vehicle UTVehicle_Manta_Content_0 at 1785.14,-1552.61,-38.56 rot -679,8136,-12
86 vel 1814.83,-6.43,0.12 (1814.8381)
    -- Throttle 1.0000
    -- Strafe   -1.0000
    -- Rise     0.0000
    -- X Turn   0.2000
    -- Y Turn   0.0000
i
    Vehicle UTVehicle_Manta_Content_4 at 1930.38,3405.05,-37.44 rot -1066,27392,-2
vel -49.41,25.81,0.35 (55.7489)
    Vehicle UTVehicle_Manta_Content_3 at 1700.24,3481.64,-38.06 rot -923,8442,-236
vel -48.62,27.07,0.76 (55.6551)
    Vehicle UTVehicle_Manta_Content_2 at 4213.34,3818.94,-37.46 rot -864,36,-19 ve
l -0.62,0.04,-0.56 (0.8390)
    Vehicle UTVehicle_Manta_Content_1 at 4811.75,3837.80,-37.47 rot -863,29924,-15
vel 0.29,-0.89,-0.20 (0.9555)
* Vehicle UTVehicle_Manta_Content_0 at 6164.69,727.05,-37.85 rot -795,23593,-847
vel 654.54,1652.86,-0.57 (1777.7393)
```

- Simulated sensor data to external controller
 - “GPS”, Depth, Lidar, etc.



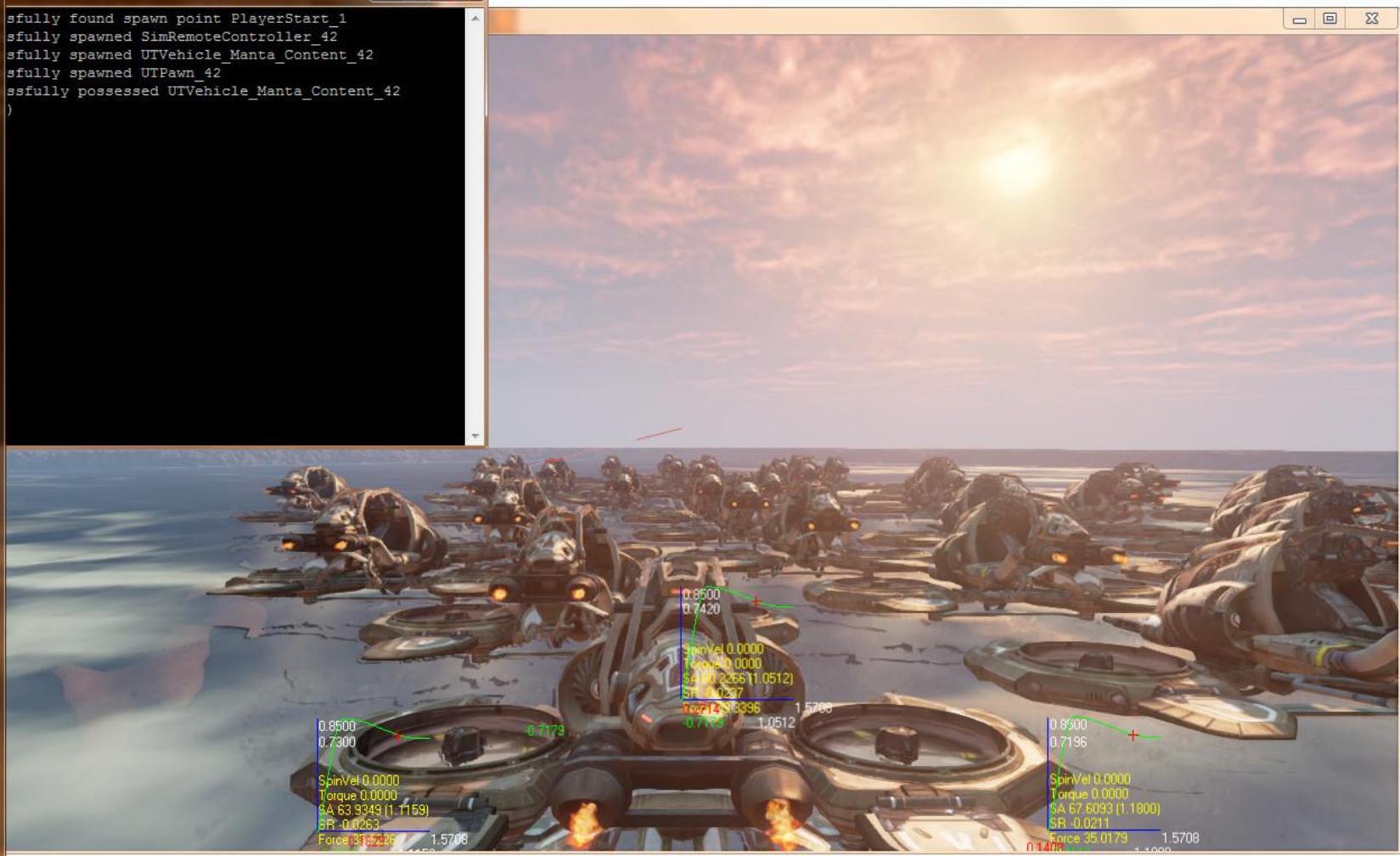
- Supports simulation of multiple agents...



- ... each bound to their own controller

The screenshot shows a Star Citizen flight simulation. A sleek, futuristic ship is flying over a body of water under a clear blue sky. In the bottom right corner, a green rectangular heads-up display (HUD) box provides real-time data:

- SpinVel 0.000
- Torque 0.0000
- SA 63.9349 (1)
- BR -0.0263
- Force 31.5226



- Highly scalable...

```
SimRemoteController_89: Successfully possessed UTVehicle_Manta_Content_89  
Awaiting input... (? for help)
```

Unreal Development Kit (32-bit, DX9)

Player

SimPlayerController_0

STATE: Spectating

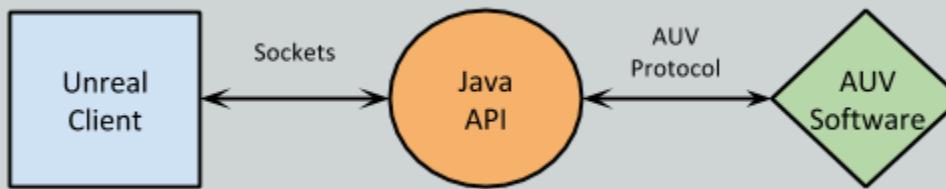
29.40
34.01



CPU Usage: 73.00% Commit Charge

- ... up through dozens, hundreds, or possibly thousands of simultaneous agents

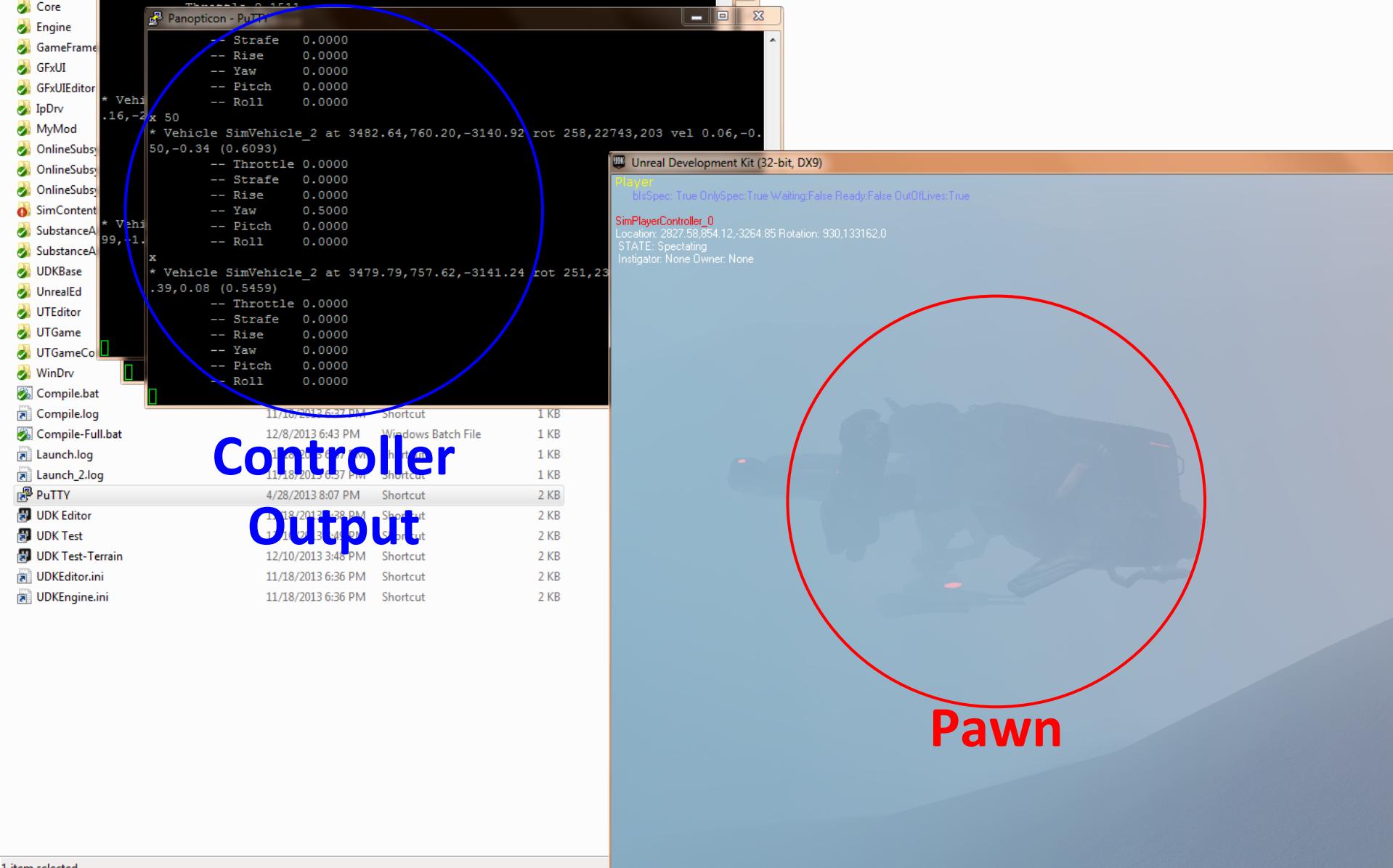
GEAS Structure



- **Unreal Client**
 - Game world, on-screen objects
- **Java API**
 - Optional interface to help AUV software utilize I/O
- **AUV Software**
 - Controls in-game objects based on perceived data

GEAS: Unreal - Structure

- UnrealScript
 - Object-oriented
 - Used for game logic (vs. underlying engine logic)
- ❖ Object
 - Actor
 - Pawn
 - “Physical” properties - movement, collision
 - Controller
 - “Drives” pawn



- **Pawn:** AUV
- **Controller:** Output over socket

GEAS: Unreal - Input

- Input over socket maps directly to in-game input
- Movement
 - Throttle
 - Strafe
 - Rise (Elevation)
- Rotation
 - Pitch
 - Yaw
 - Roll

GEAS: Unreal - Sensor Emulation

- “GPS”
 - Position
 - Velocity
- Depth
 - Distance from water surface
- Lidar
 - Situational awareness
 - Tracking other objects

GEAS: Unreal - Sensor Emulation - “GPS”

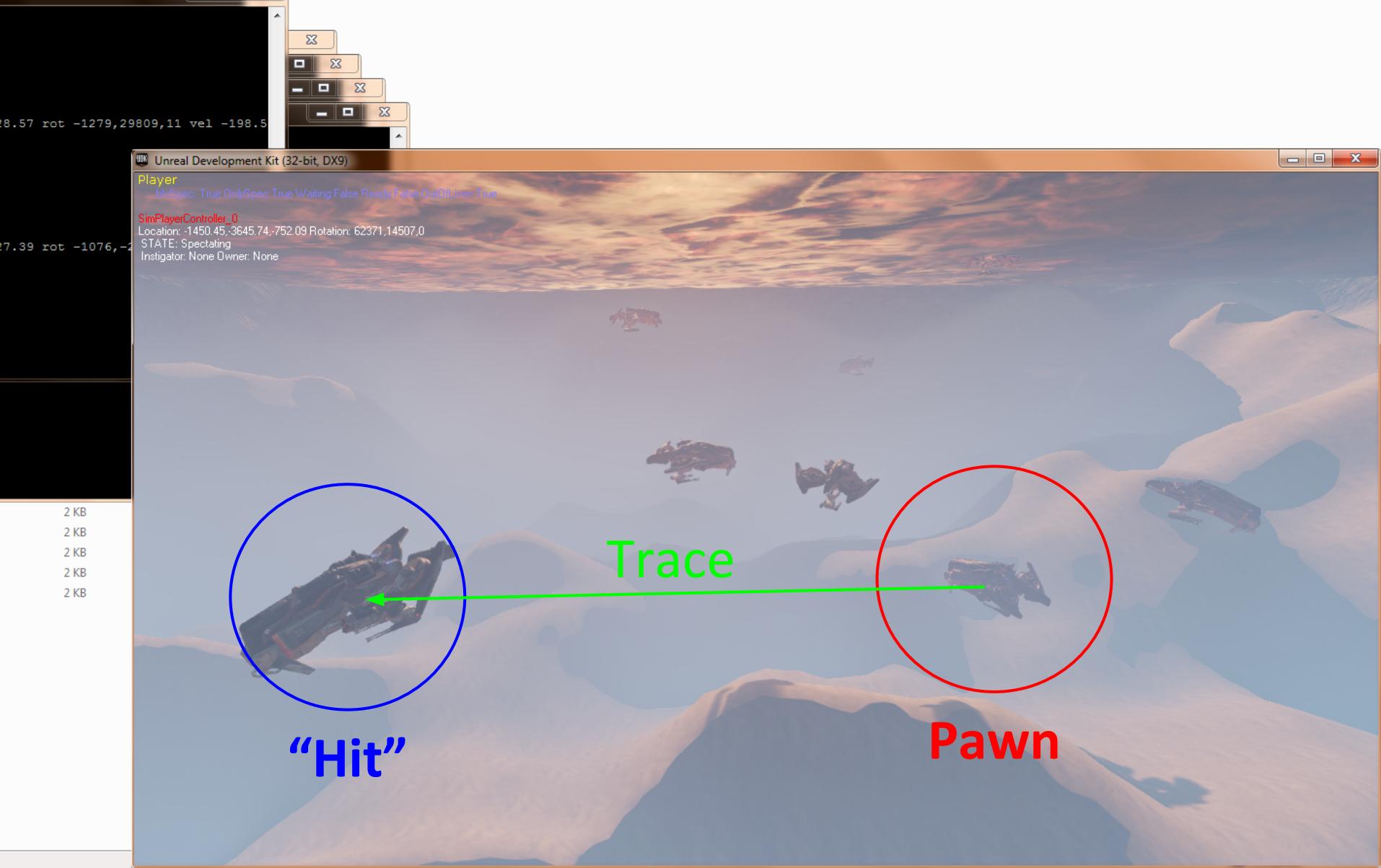
- Position and Velocity as Euclidean vectors
 - <X, Y, Z> world coordinates
 - e.g. 127, -34, -5816
 - <X, Y, Z> velocity
 - Can resolve X, Y, Z components into actual velocity
- In “Unreal Units”
 - no relation to real-world units - virtual world!

GEAS: Unreal - Sensor Emulation - Depth

- Water surface at elevation “0”, so...
- Simply Z-component of world position

GEAS: Unreal - Sensor Emulation - Lidar

- Traces from AUV Pawn
 - Fire “bullet”, see what it “hits”
- Returns $\langle X, Y, Z \rangle$ “hit” position
 - Distance by comparing to AUV Pawn position
- Also returns “hit” object, if any
 - Can examine object velocity, orientation, etc.



- Trace from **AUV** that “hits” another **AUV**

Future Work

- Fleshed out simulation
 - More accurate hydrodynamics
 - Temperature, pressure, currents, etc.
 - Interactive objects (fish, coral reefs, seaweed, etc.)
 - Additional sensor modules (Sonar etc.)
 - Sensor noise models
- Extended Java API
 - Built-in protocol support, etc.
- Distribution to research community as extendible framework

Conclusion

- Three-part autonomous vehicle simulation
 - In-game 3D simulation
 - Game <-> Controller interface
 - External AI controller
- Scalable and portable
 - Unreal and Java for a variety of hardware
- Extendible
 - Decoupled systems easy to repurpose

More Info

Strout, Alexander B., Turner, Roy M. (2013).
A Game Engine-based Simulator for Autonomous Underwater Vehicles,
18th International Symposium on Unmanned Untethered Submersible Technology (UUST),
Portsmouth, NH, August 11--14, 2013