MAK TECHNOLOGIES

Large Scale Simulation
Current Approaches and Future Challenges

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Scalability Requires System-wide Design

Simulate

A Simulation Engine that can efficiently **simulate** millions of entities all over the planet

Scalable “Power Plant”

Communicate

A Data Storage and Transmission Infrastructure that can **communicate** data about millions of entities

Scalable “Power Grid”

Visualize

Virtual Simulators that can connect to million-entity simulations, and efficiently **visualize** thousands of entities that are most relevant to the player

Smart and Efficient “Appliances”

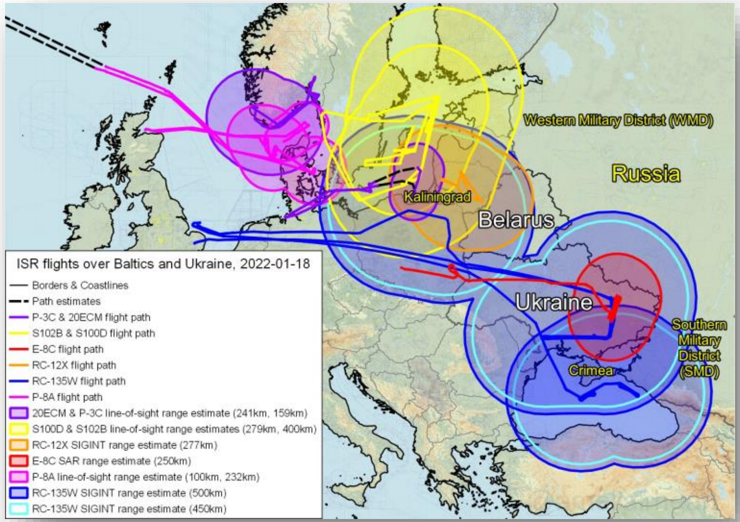
What is the Goal of Scalability?

Crowd Modeling
Football stadiums, concerts, threats to large civilian groups need to be modeled. How many people attend the Olympics? How many attend a US Presidential Inauguration?

Mega City
Large city modeling? The vehicles, people, and patterns of life of mega cities. What terrorism threats to people face in these cities?

The World
Shipping, smuggling, sanction busting ships. To protect our borders we need to think about things that can be very far away.

What is a Large-Scale Simulation?



World-Wide Logistics
NATO Partners face threats around the world. Modeling logistic supply chains in *contested* areas requires tools that span the planet and can model modern threats.

Large Area Exercises
Air and Maritime exercises cover large areas and involve diverse assets. Training for tomorrow's wars will not be done in a village in the Middle East.

Command Staff Training
NATOs current threats are large. Serious training will require serious simulation capabilities

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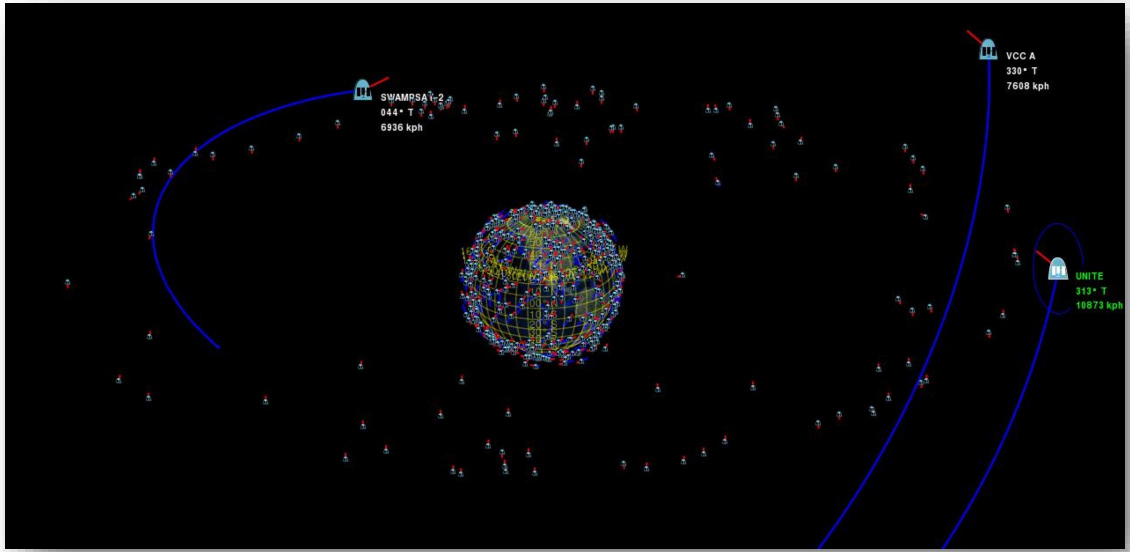
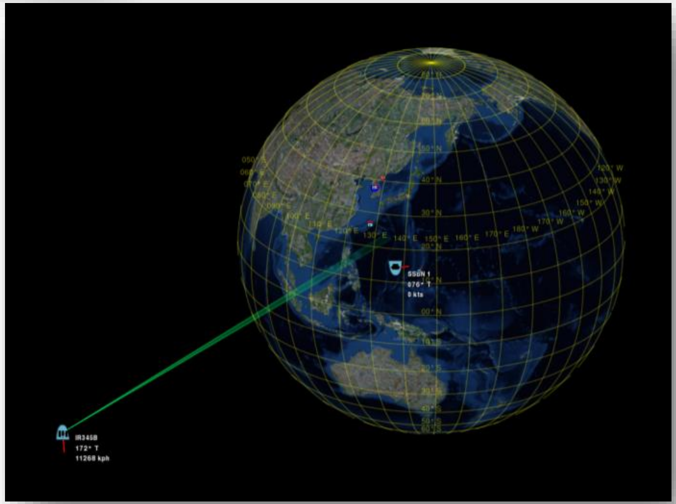


Space
Modern combat will include space modeling, for communications, early warning systems, and advanced weapons.



Synthetic Environment and the Architecture

The Synthetic Environment is a digital twin of planet Earth. It's the physical space where entities interact to address the purpose of our simulations.

The Architecture that enables a Synthetic Environment has three layers

The **Simulation Software Infrastructure** that runs the simulations that model: the platforms, weapons, weather, atmosphere, terrain, oceans, etc.

The **Compute Deployment Layer** that hosts the Simulation Infrastructure. This is the computers and graphics cards and storage that implements the system.

The **Network Infrastructure** that shares the state and interactions of all the simulation objects across the machines in the middle layer. Sometimes this gets lumped in with the Physical Layer

Network Infrastructure

Most of the focus so far has been on Network Infrastructure:

There are many proven examples of network interoperability architectures that can achieve scale. E.g. HLA, Legion (3.8million), Improbable, …

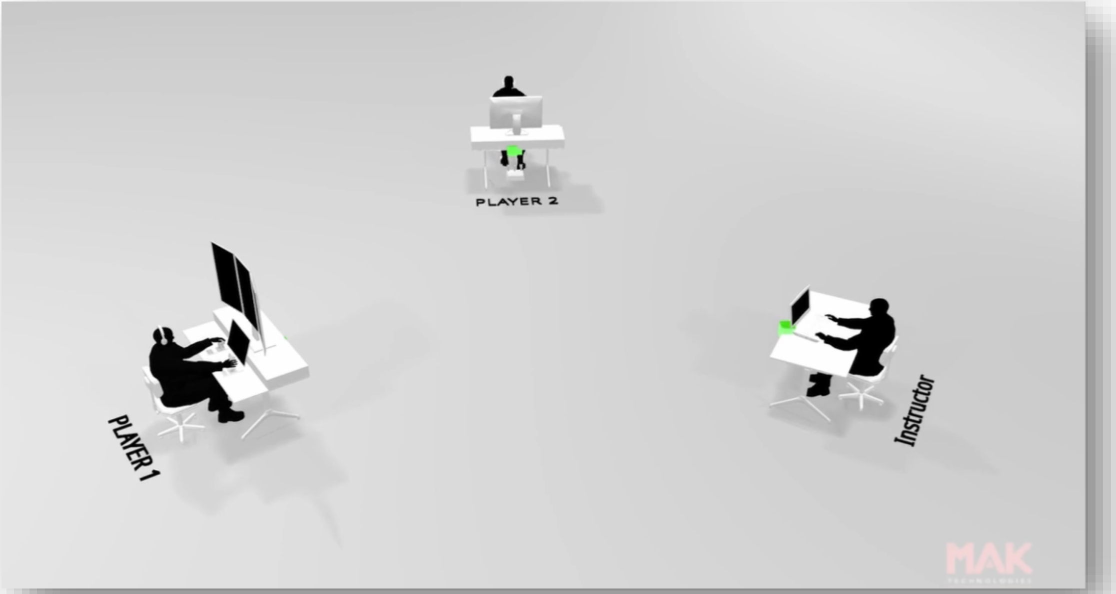
Combining data using a Cache Coherent Data Oriented Design means you can send a LOT more information between federates.

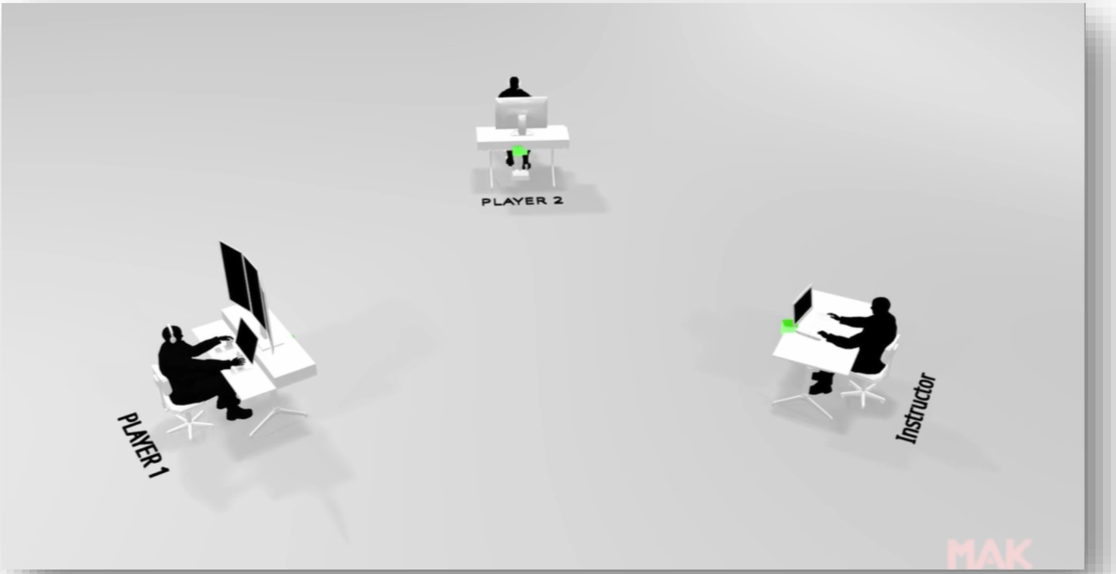
3 Million entities have been achieved; many more are possible.

The Journey
Legion

Legion focuses on Communication:

- Sending fewer data packets with large blocks of information allows for higher throughput than sending many smaller packets with less data
- Having a central server with accurate data allows for no late joiner penalty
- Keeping the data in a decoded contiguous block allows for faster processing and updating of the data






VR-Forces

Network Infrastructure

Key takeaways:

- Focus on the ability to standardize
- Remember existing standards – HLA still solves 99% of the problems.
  - Most performance limitations simulators face these days are all related to the SIM, not the network.
- Make sure you don't get locked into an environment that requires specific physical infrastructure or a specific Orchestration Layer.

Orchestration Layer

There are many proven deployment architectures that can achieve scale. E.g. computers in peer-to-peer networks, virtualized servers, clouds, etc.

Key Takeaways:

- Prefer commercial solutions
- Make sure this layer remains optional
- Don't get overly tied up with the Network/Physical Layer
- Don't be tricked into believing that the orchestration layer can overcome shortcomings in the SIM and offer much of anything for scale

Simulation Software Infrastructure

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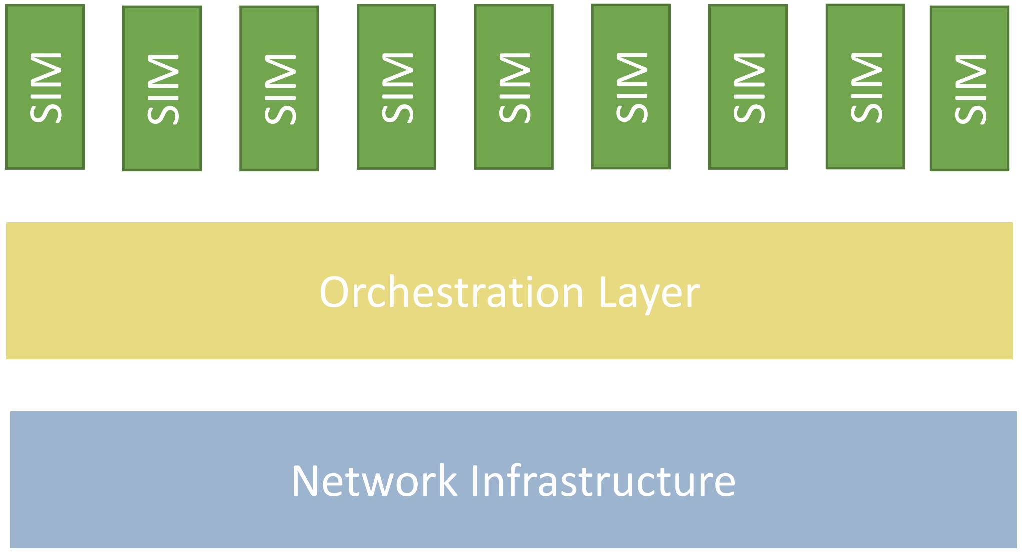
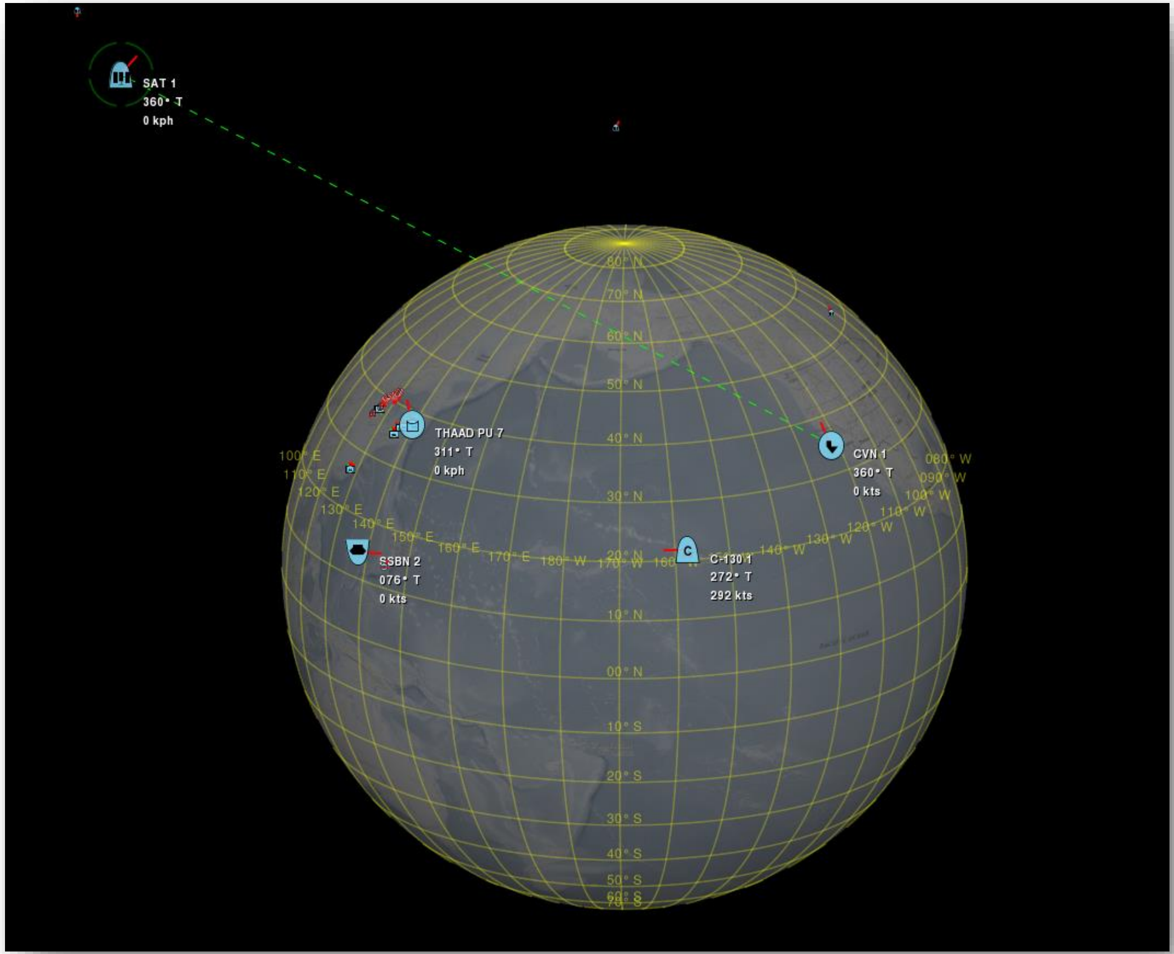


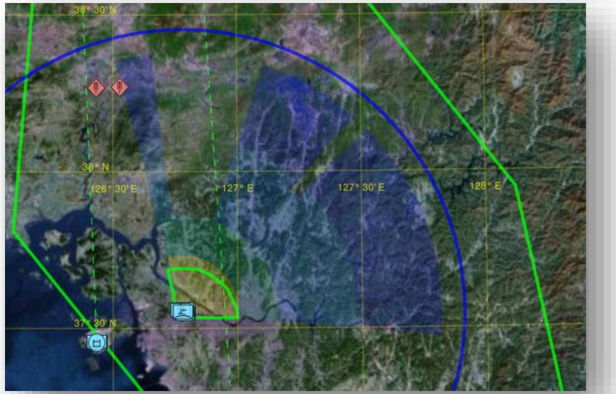
Planetary Digital Twin

Round Earth Everywhere

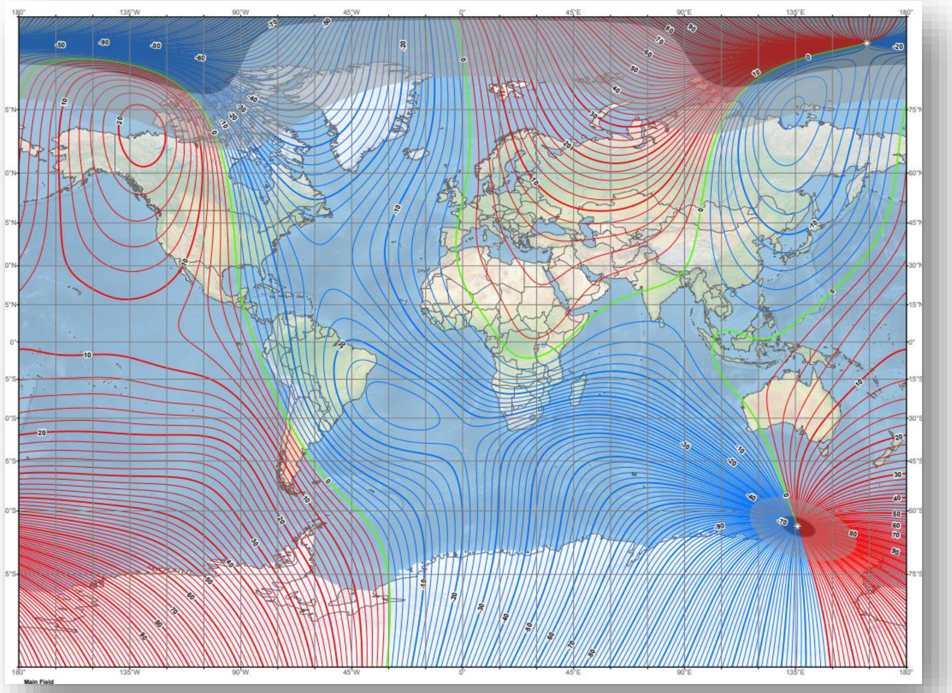


A Round Earth

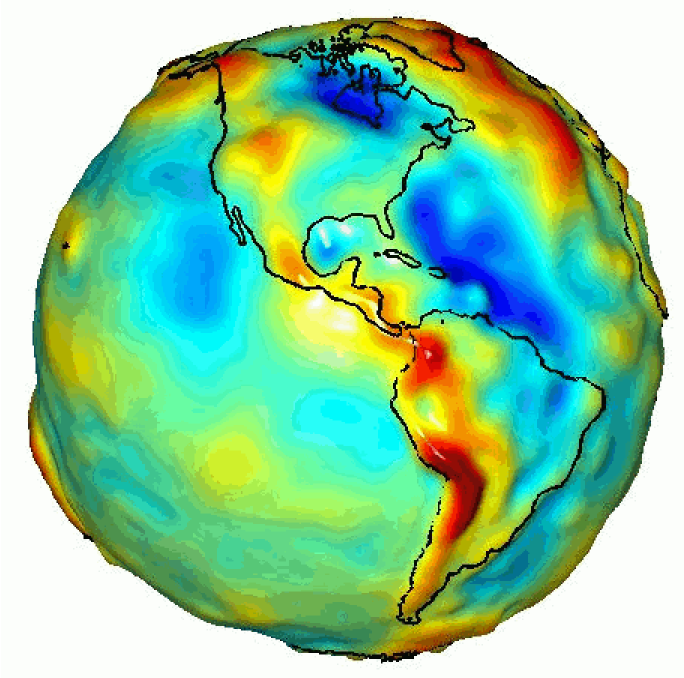
- Always assume a round earth, no cheating
- All calculations need to be done in 64 bits
- This is often contrary to what Game Engines need



Planetary Digital Twin
Magnetic Model and EGC 84



Wikicommons

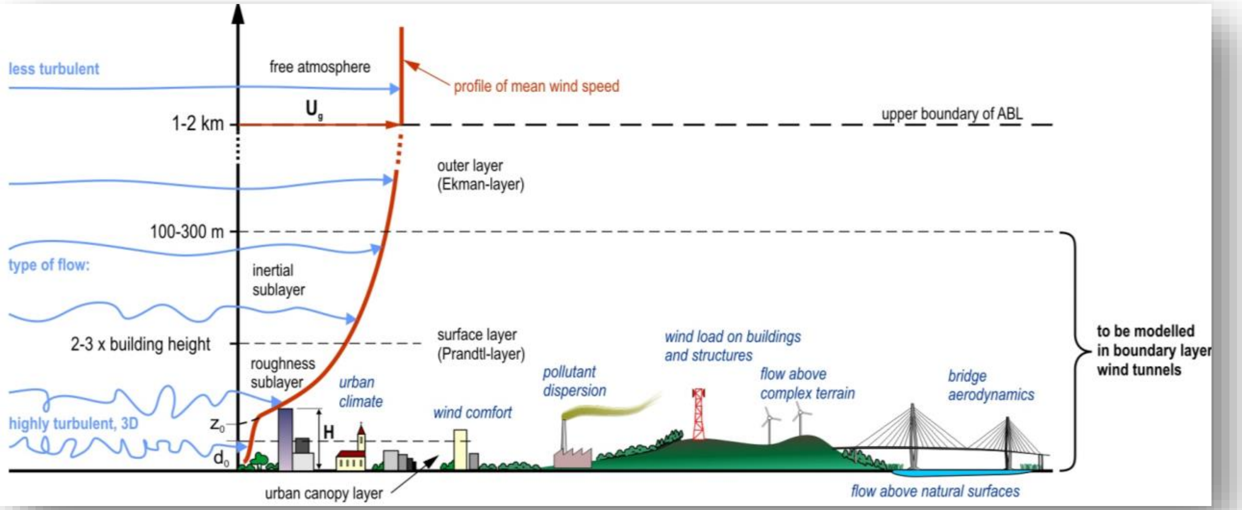


NASA/JPL/UT Center for space research

Earth Magnetic Model
- Flight planning and tasking in large areas require a whole Earth Magnetic model
- This has to be fully integrated into tasking and planning

Earth Gravitation Model
- The Earth isn't round, and the ocean isn't flat
- Correct modeling of the EGC is needed for large area maritime environments, especially as we deal with LVC environments

Planetary Digital Twin
Complex Weather Environments



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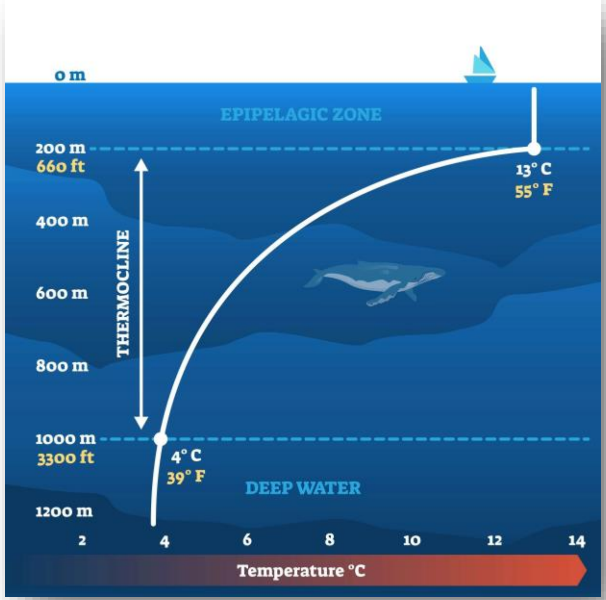
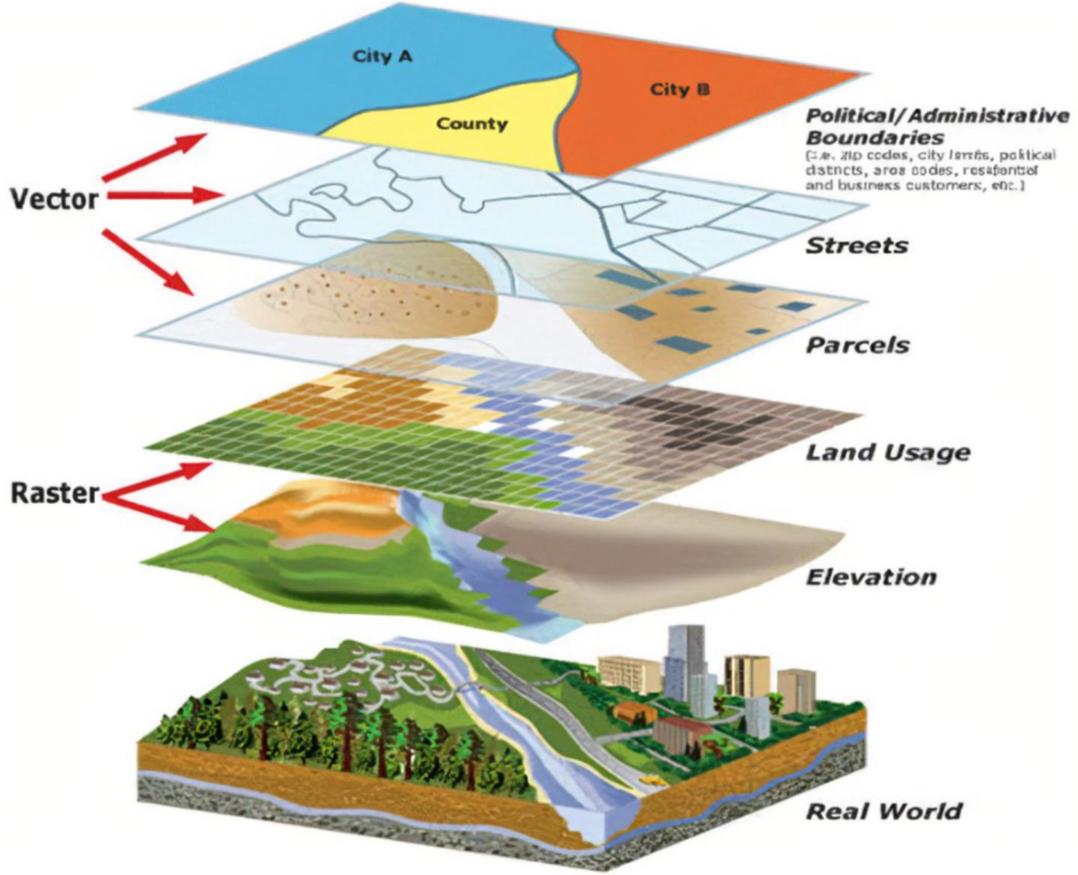


The Complex Atmosphere
The atmosphere varies significantly from the ground to space. Modeling wind speeds and pressure changes greatly impact aircraft speeds and fuel consumption.

The Complex Ocean
The Ocean is as complex as the atmosphere, changes to salinity and pressure effect sensors and movement under the sea

Planetary Digital Twin

Open GIS Standards

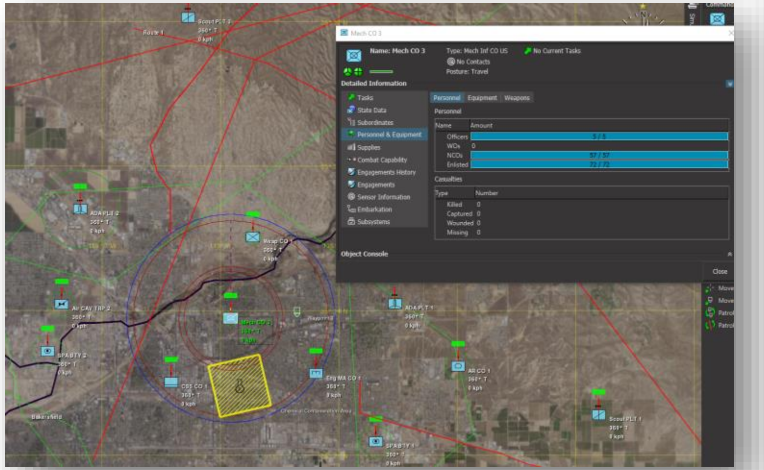


The Data You Need

- Build terrains using common GIS tools. The less M&S specific processing the better.
- Support Legacy terrain formats, but don't buy into an M&S mind set here.

Simulating all that Data

Common Simulation Infrastructure
Aggregate and Entity Level Simulation



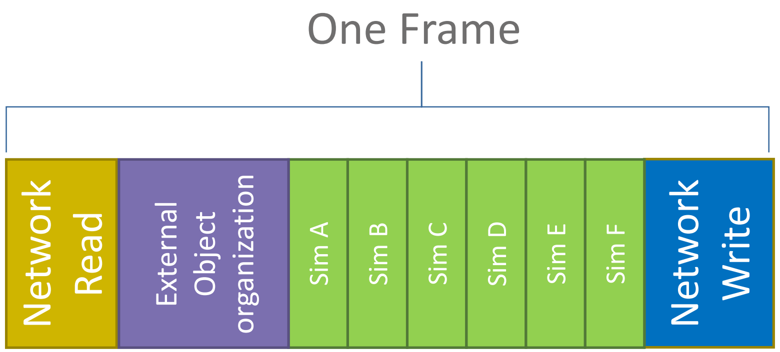
Aggregate Level Modeling
Simulates at the unit level, allowing for very large entity count simulation without the details of individual objects

Entity Level Modeling
Simulates every object, allowing for ideal 3d placement and visualization via ISR

Common Simulation Infrastructure
- Allows for common terrains
- Consistent UX
- Integrated scenario configuration
- Efficient Plugin development

Unsolved Problems
- Still no good object Model adopted by the community. Some FOMs for WARSIM, but no open standards.
- There is talk about even dropping the Aggregate PDUs in DIS.
- Need general strategies for mixing the two concepts.

What Limits Large Entity Counts



The Frame

- Every non-deterministic simulator works with frames.
- You can only do so many things each frame.
- The longer the frame, the less time things have to react, the less time things have to behave in a reasonable way.

Components of a Frame

- Read in from the network
- Do some spatial organization to allow for fast look up of things.
- Write the data out to the network.

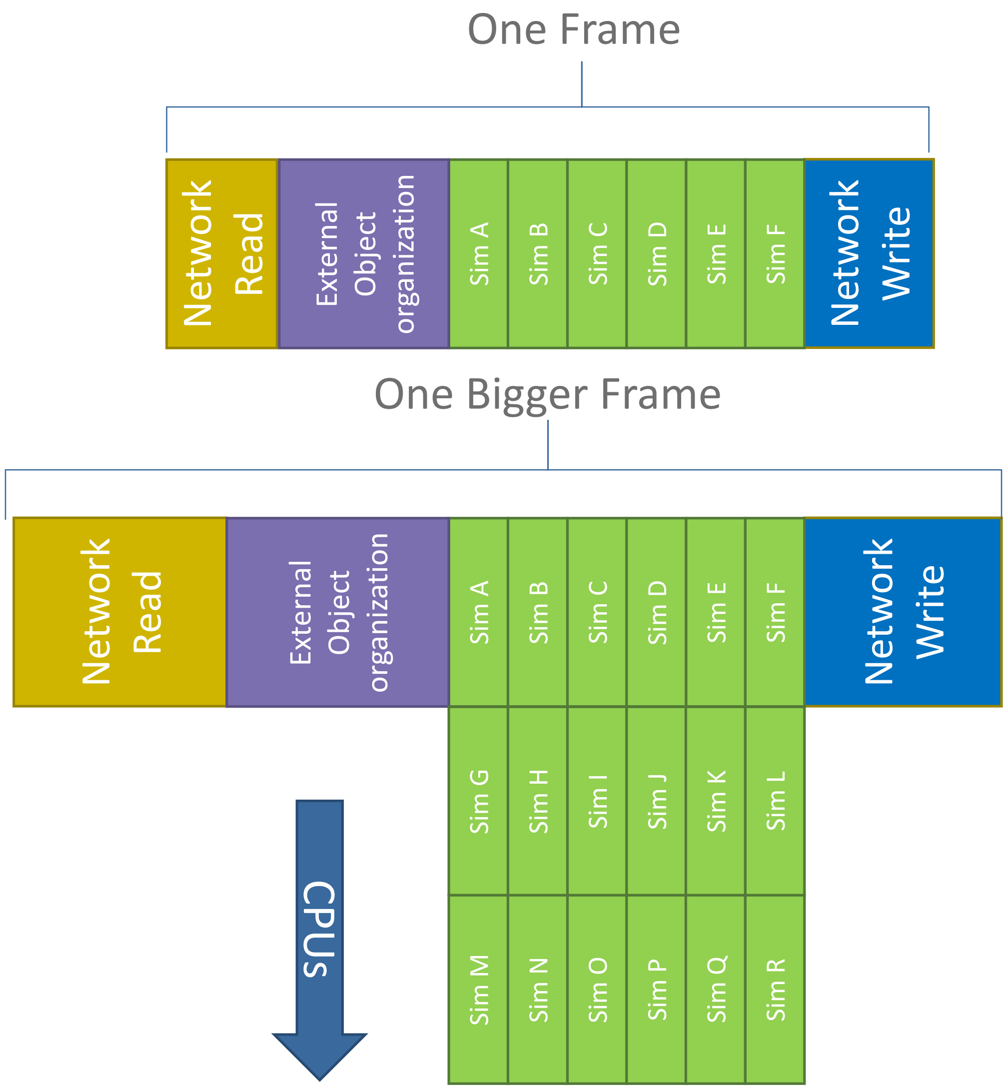
What Limits Large Entity Counts

Multi-Threading

- Multi-Threading allows you to add more entities, but usually at the cost of increasing the header and footers

Legacy Systems and Amdahl's Law

- The biggest bottleneck in most simulations isn't the network read/write. It's the actual simulation of the entity.
- HLA networks will not get bogged down until you have added a lot more entities.
- Even as HLA networks get bogged down, most of the bogging often happens around late joiners, and how the FOM data is structured



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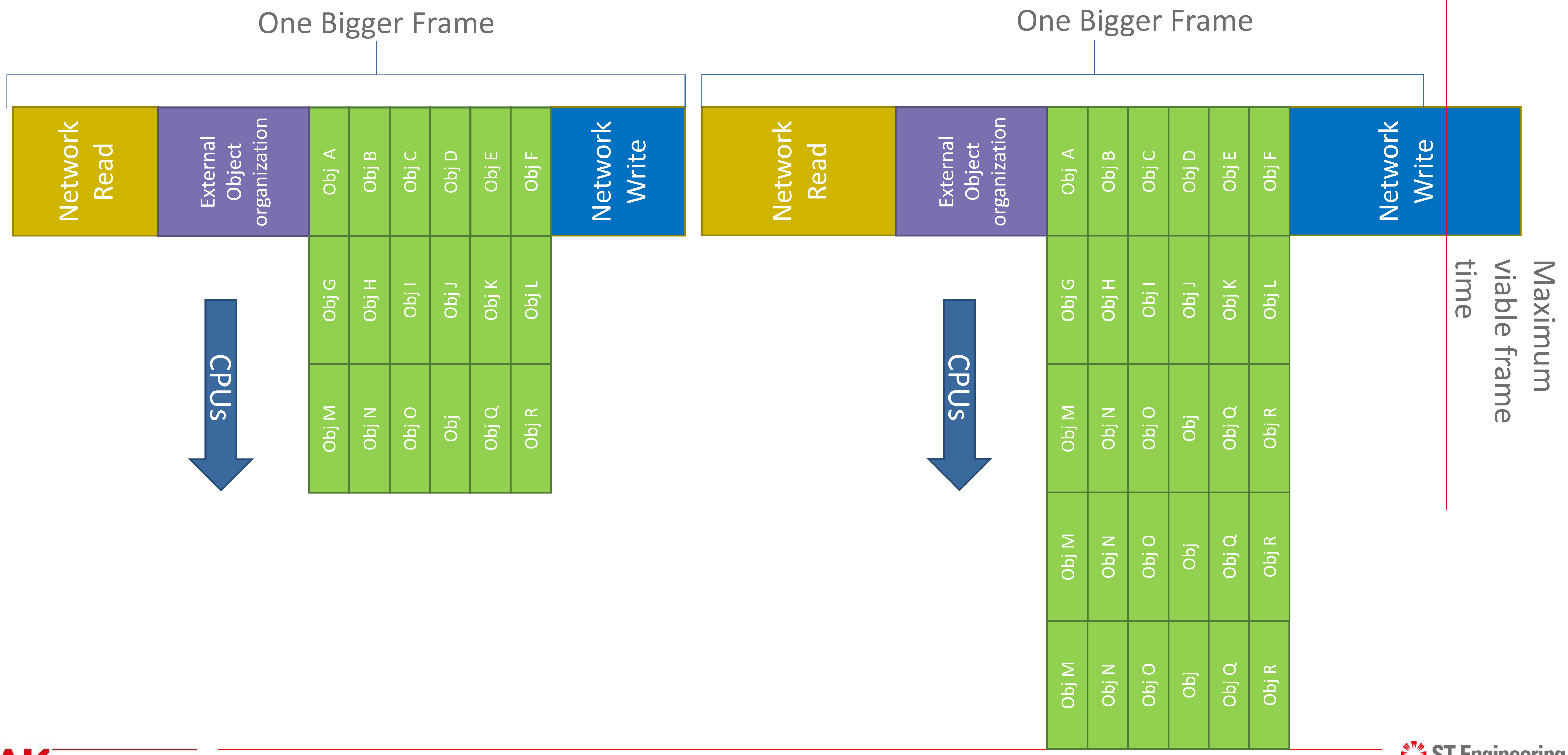

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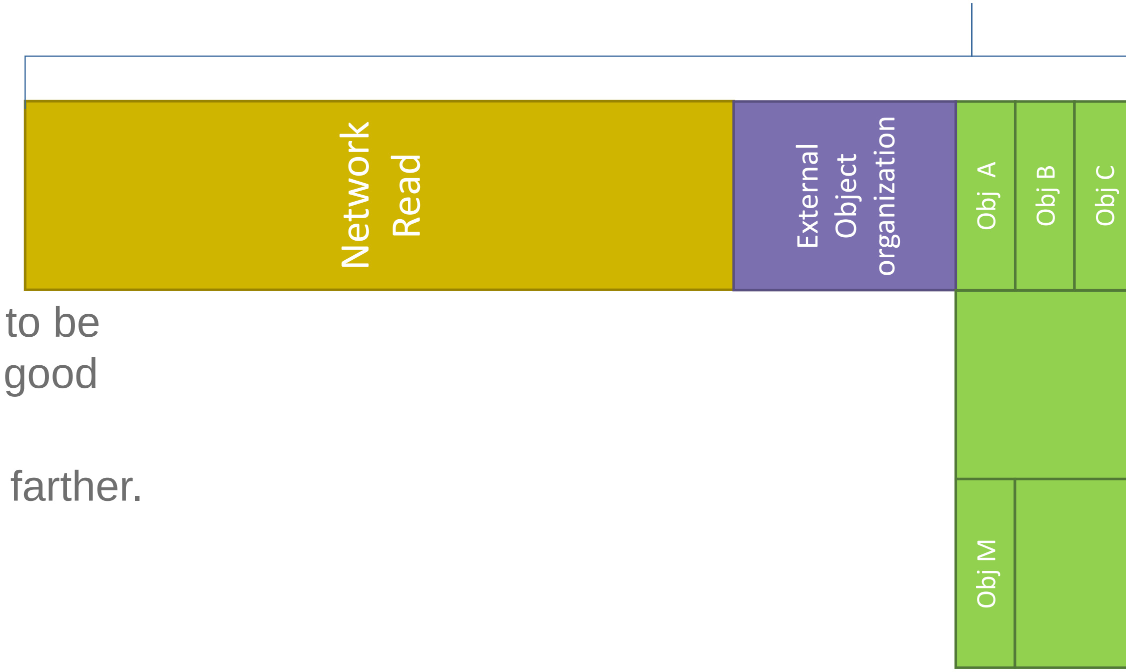


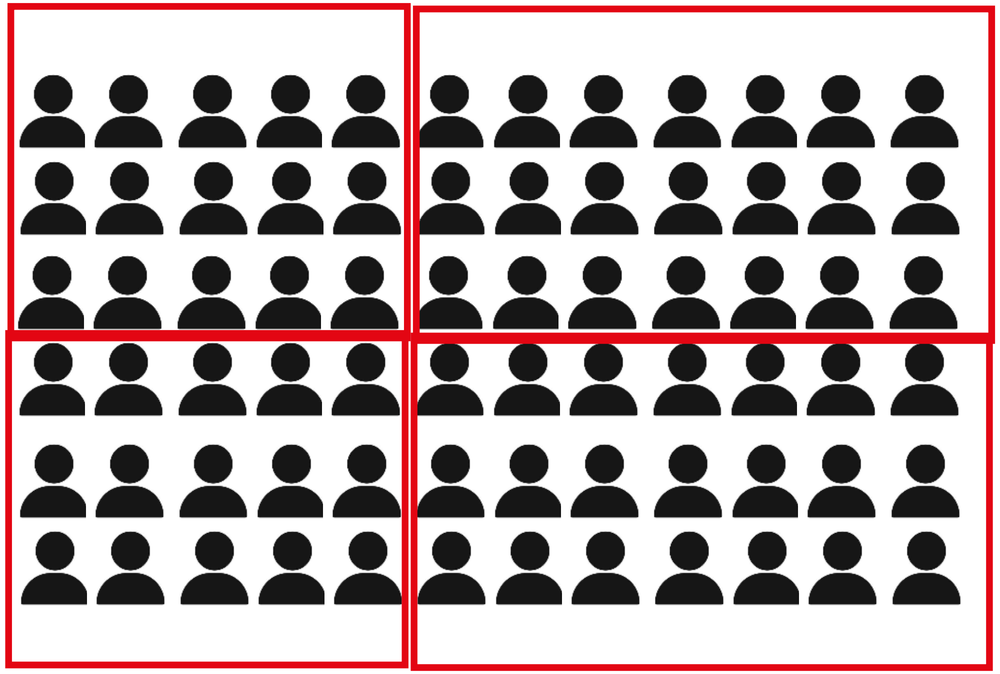
Network Read

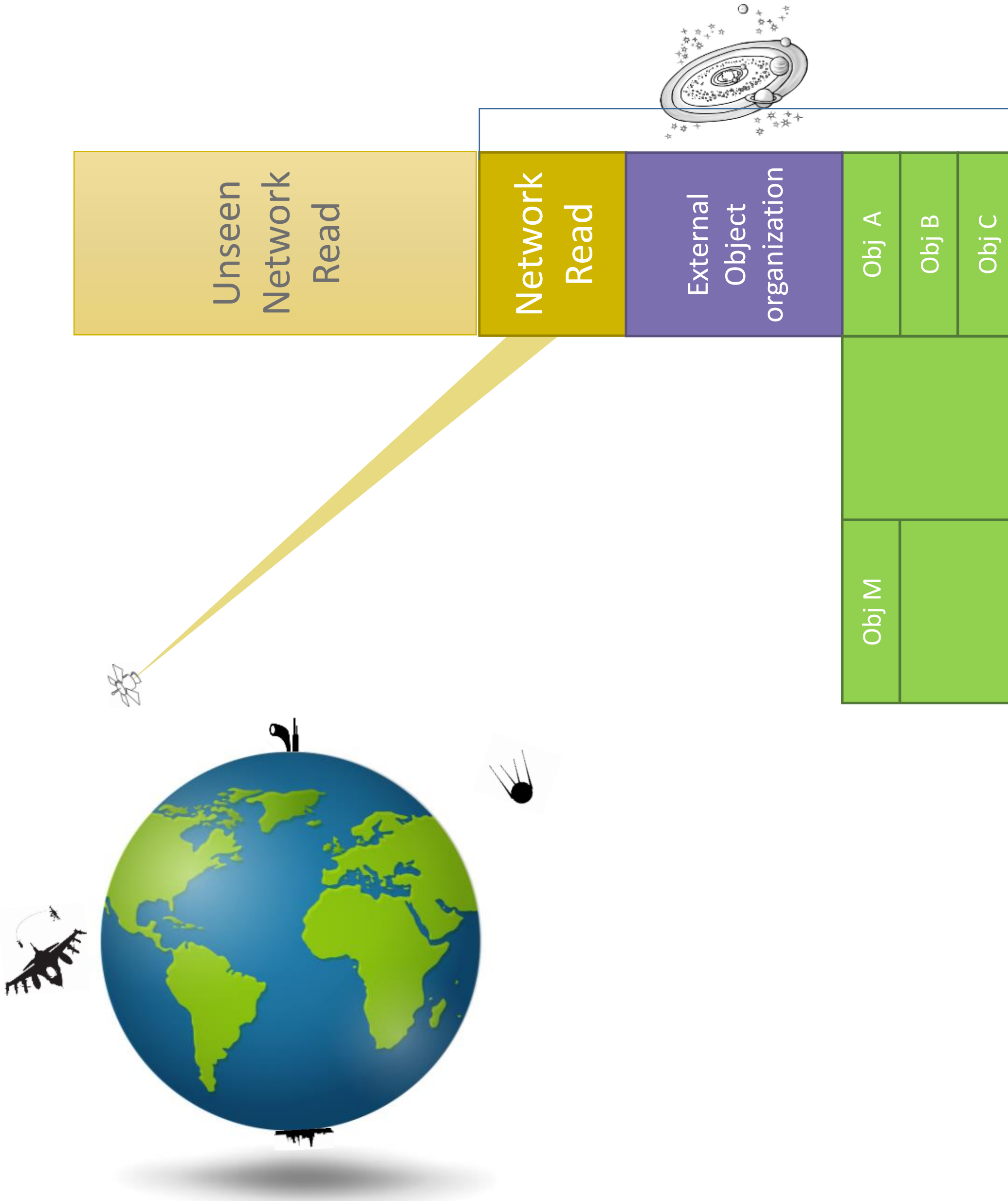
- The network read problem is structural in HLA, things have to be encoded/decoded for the network, and data is (when using good FOM design) not tightly packed.
- Legion alleviates this, at least pushes it down the road a lot farther.

External Objects

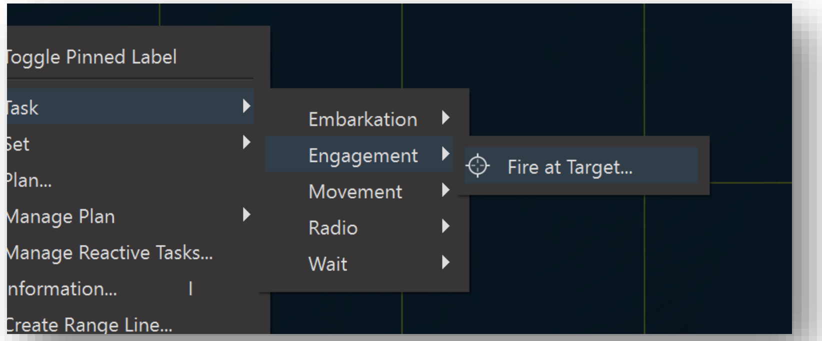
- Data Segmentation is the standard answer, but it’s a highly incomplete one.

Understanding all the Data





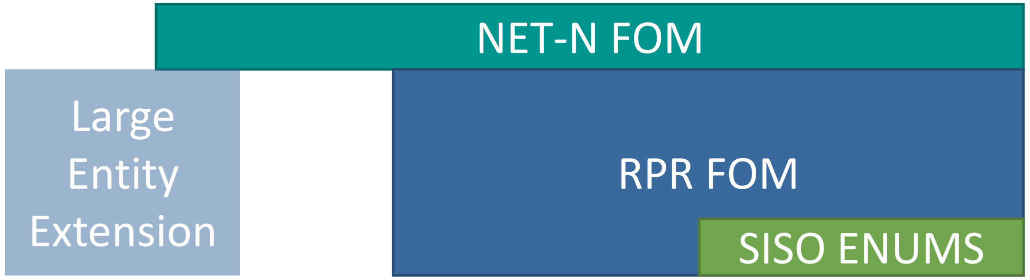
An Object Model for Scalability



Breaking up Large (Millions) of entities into areas or force type (Air/Ground/Civilian etc.) helps with high quality visualization systems.

It doesn't work for IOSs which often need to see and understand the whole scenario. Tasks require addressable objects for planning and interaction. If you cannot see it, and cannot know about it, then you cannot task it or work it into your plans.

For realistic tasking, the entire object list needs to be known and "searchable." This can be solved with low fidelity object lists with generalized locations and low update rates.



City Scalability

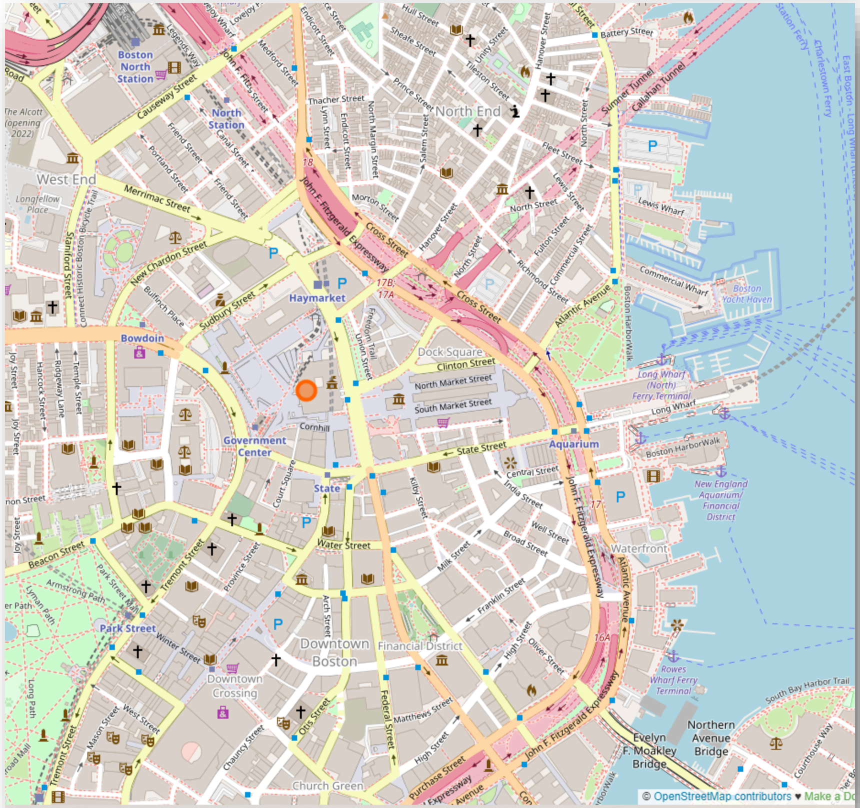
How do you define a city simulation?

Emergent Behaviors

- Define needs and wants: Need religion, get angry at soldiers, need food, need schooling etc.
- Behaviors emerge, but do you get what you want? Does it help with training? What is your goal?

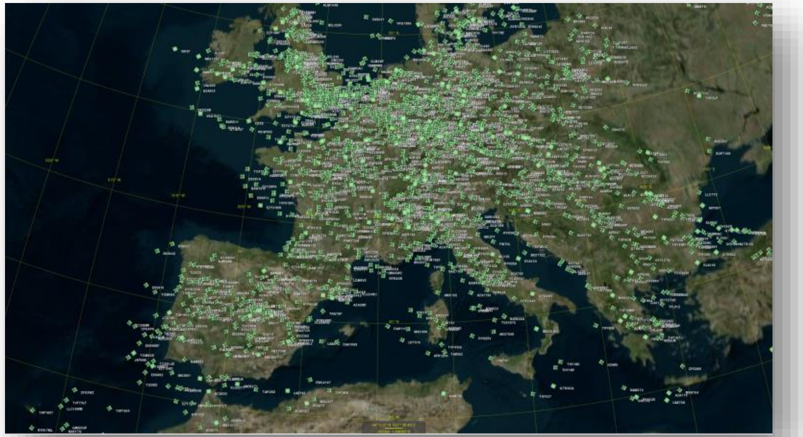
Predefined

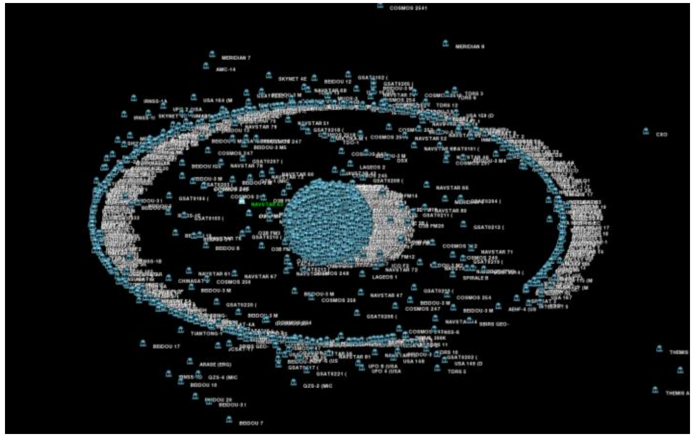
- Define flows and expected behaviors: Rush hour at X time, prayers at Y time, children to school at various times.
- Behaviors are predetermined and defined, helps with training but is it real?



openstreetmap.org

Simulating Real Entities





Clement Iphar

Populate the simulated world with real world data (either historical or live)

- Air Traffic from ADS-B streams
- Shipping traffic from AIS transponder data
- Satellite data from TLEs

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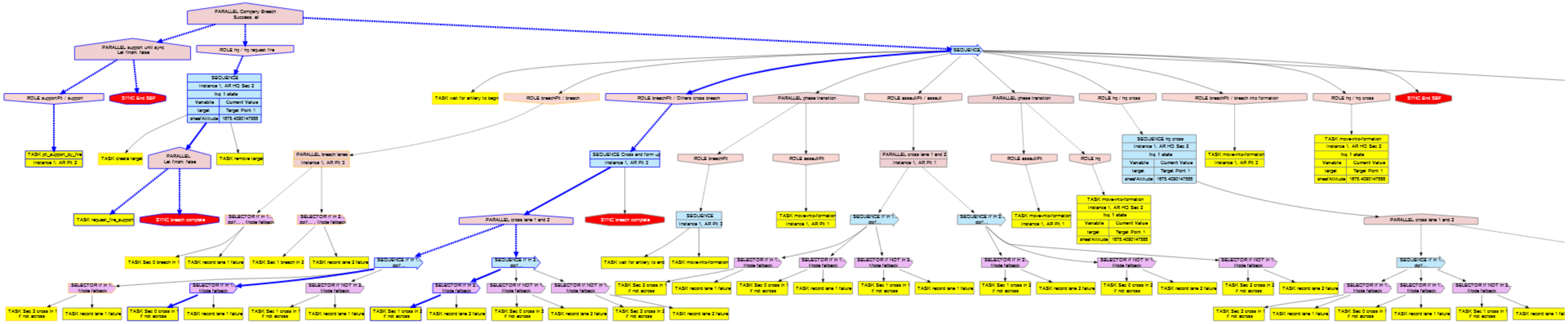
Complex Coordinated Behaviors



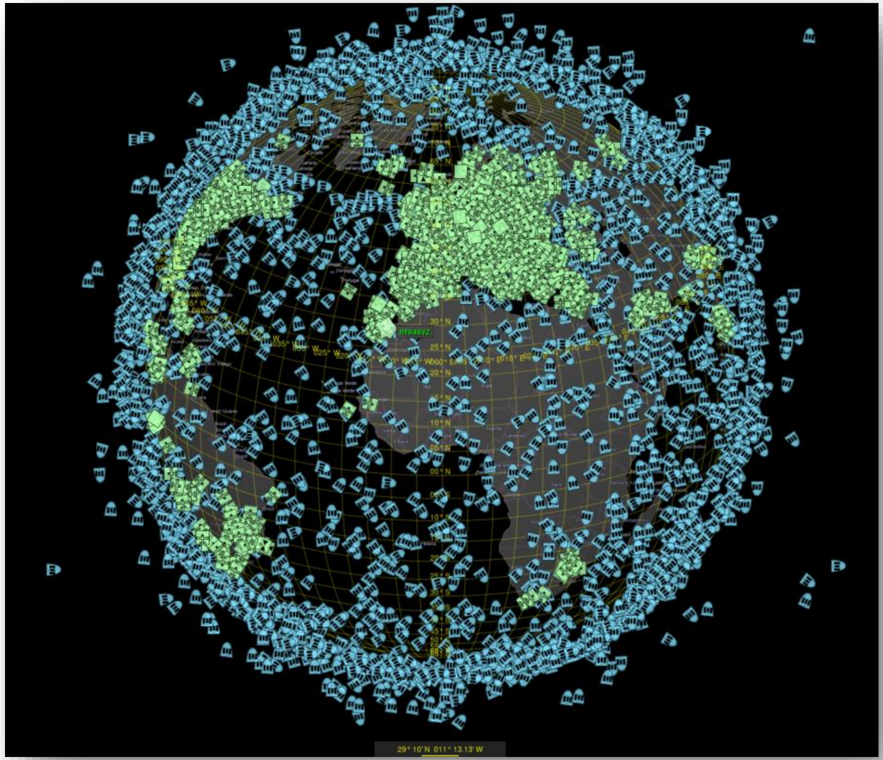
Large scenarios require complicated coordinated behaviors that are:

- Bi-directional communication chains -> information needs to pass up, and orders need to flow down
- Simulations need to understand entity roles and relationships

And don’t forget:

- Any complex behavior needs detailed terrain access and coordination (of course weather too)
- A framework for easy modification to support different doctrines

Screen Decluttering



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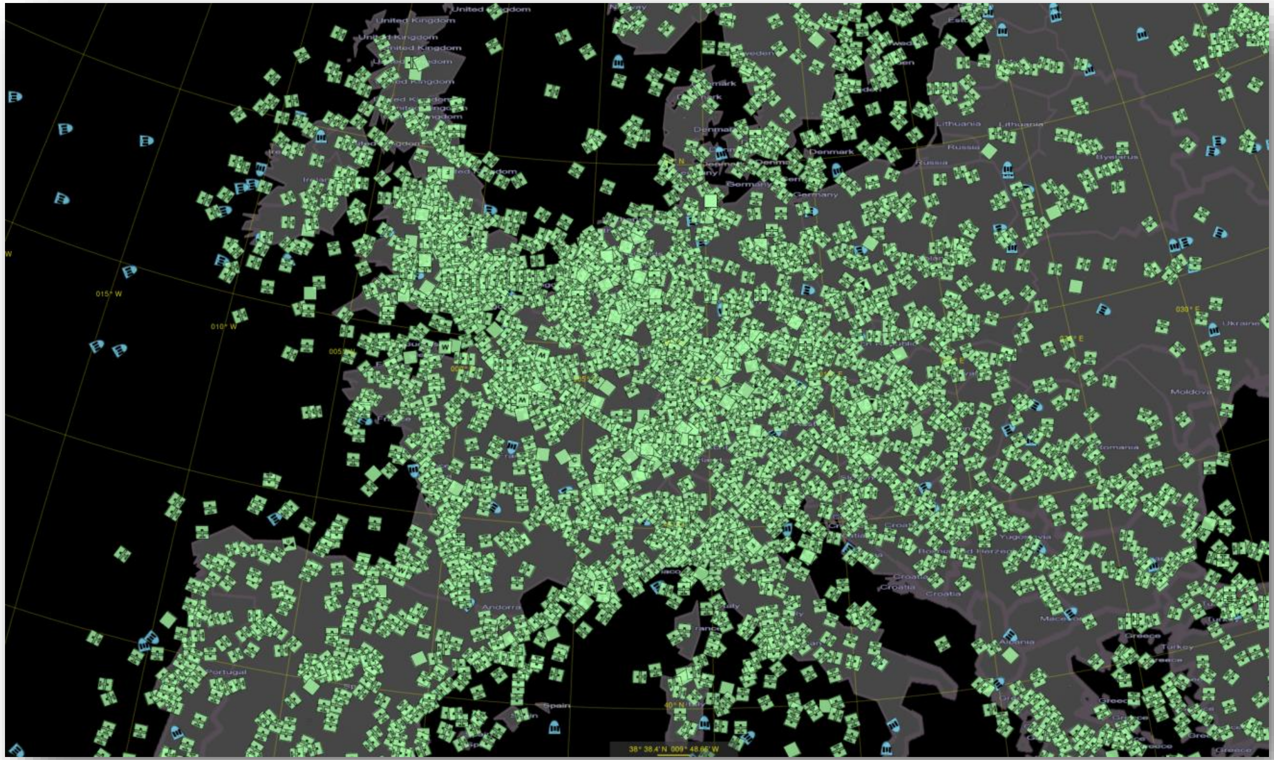

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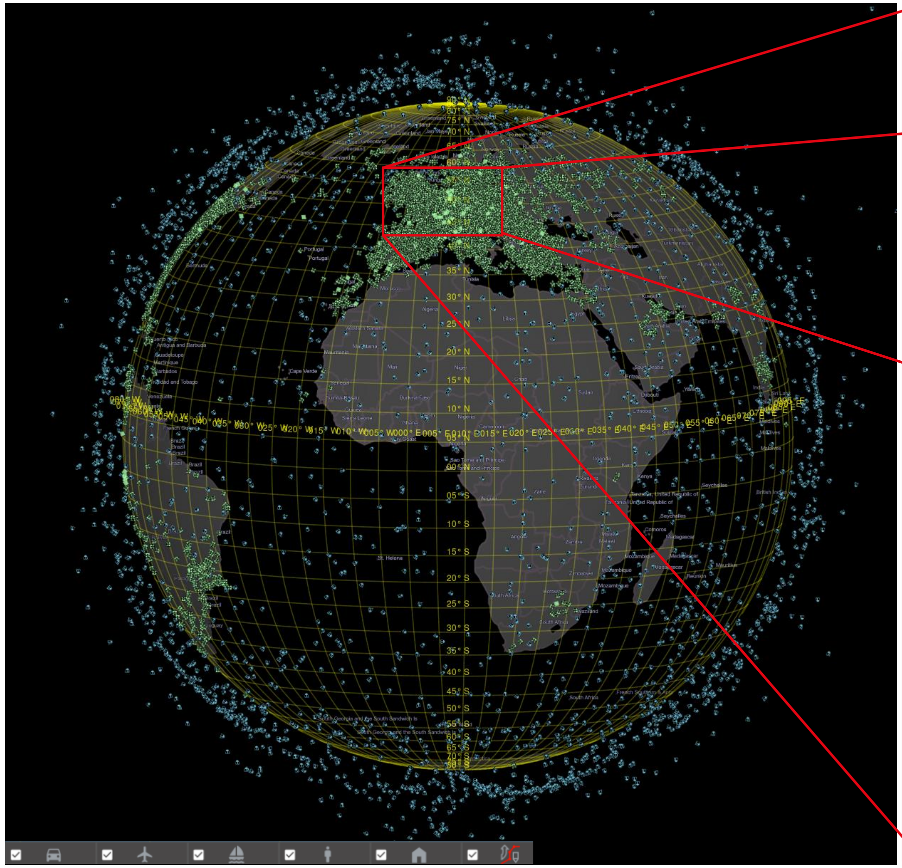

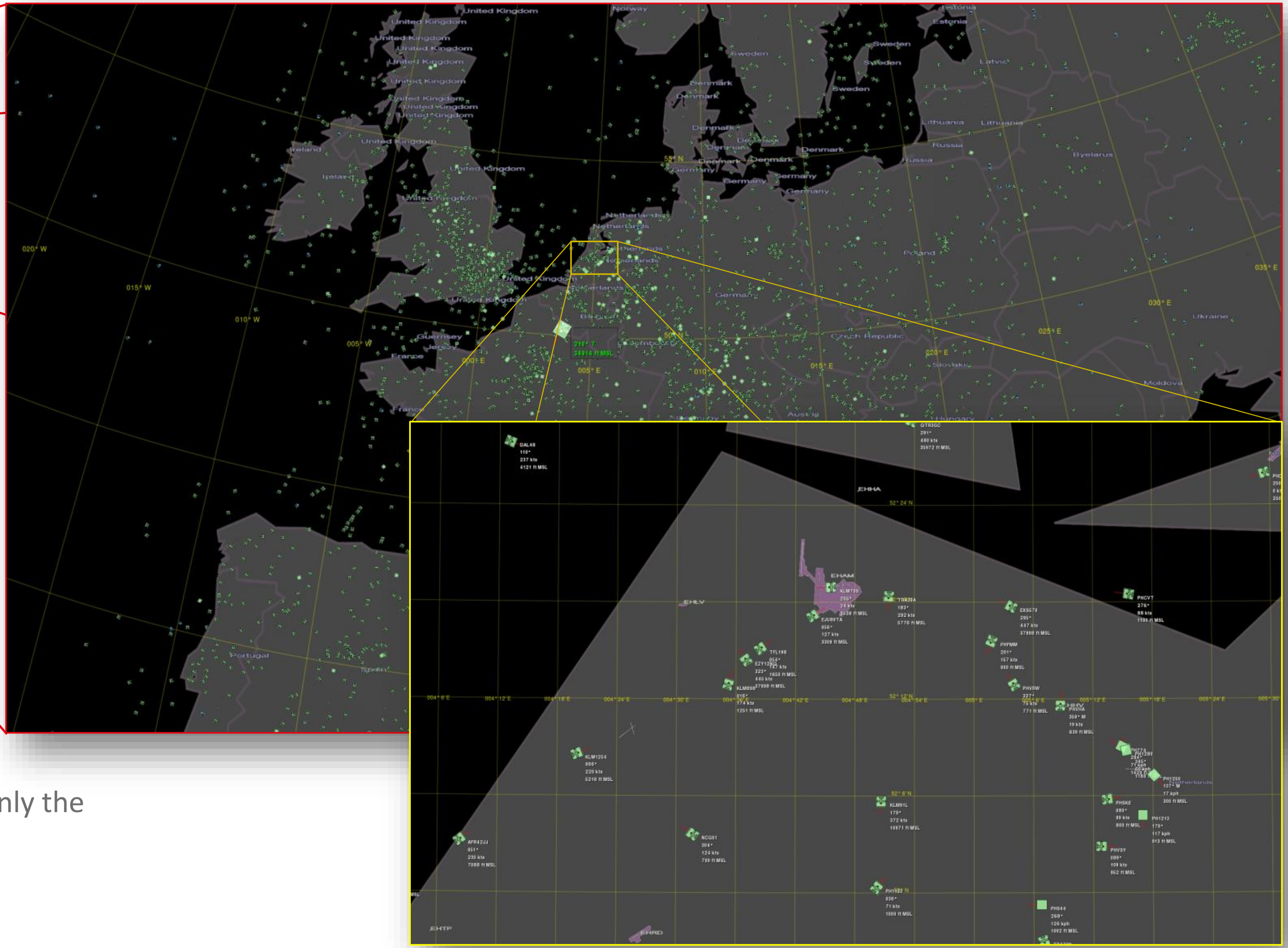

VR-Forces

Use dynamic sizing, coloring and labeling to show only the information needed for the task at hand.


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