A New Simulation Infrastructure

supporting the Next Generation of Simulation-based Testing and Training Applications

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Approved for Public Release; Distribution Unlimited. Case Number 19-01906-5

Why Yet Another Simulation Infrastructure?

- **IEEE 1278 Distributed Interactive Simulation (DIS) and IEEE 1516 High Level Architecture (HLA), are updated on a regular basis by standardization bodies**
- **Concepts behind these standards are several years old**
- **New developments in the IT world shaped the recent years**
  - Significant increase in data utilized by the systems
    - Internet of Things (IoT) and Industry 4.0
    - Smart cars, houses, and cities
    - Cyber-physical systems
  - Multi-modality of the systems
    - Multiple sensors that all perceive a different facet of the environment
    - Large variety of different channels with different formats, resolution, etc.

New Generation of Systems: It all began at the end of WW II

Courtesy of Wikimedia Commons

Generation 0:
The **Messerschmitt Me 262**, nicknamed ***Schwalbe*** in fighter versions, or ***Sturmvogel*** in fighter-bomber versions, was the world's first operational jet-powered fighter aircraft.

Jet-powered fighters changed warfare – and the need for testing and training – significantly.

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1st to 4th Generation Weapon Systems

- **1st Generation:**
  US F-86 Sabre/Soviet MiG-15 Fagot
  - They are the first jets emerging after the end of WW II

- **2nd Generation:**
  US F-104 Starfighter/Soviet MiG-21 Fishbed
  - higher speed (up to Mach 2)
  - weapons (air-to-air guided missiles)
  - sensors (enhanced nighttime and bad weather capabilities)

- **3rd Generation:**
  US F-4 Phantom/Soviet MiG-23 Flogger
  - beyond visual range engagements

- **4th Generation:**
  US F-15 Eagle/Soviet MiG-29 Fulcrum
  - digital datalinks to exchange and share information automatically
  - Increased effectiveness against ground targets with new radars
  - highly accurate air-to-surface munitions

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5th and Higher Generation

- **US F-35 Lightning II / Russian Sukhoi Su-57**
  - Very low observable (VLO) stealth capability
  - Next-generation avionics and integrated on board sensor fusion
  - Fully embedded, network-enabled on-board capability
  - Multiple role aircraft

More Battle Management
More sensors and data feeds
More avionics

Data intensive and multi-modal

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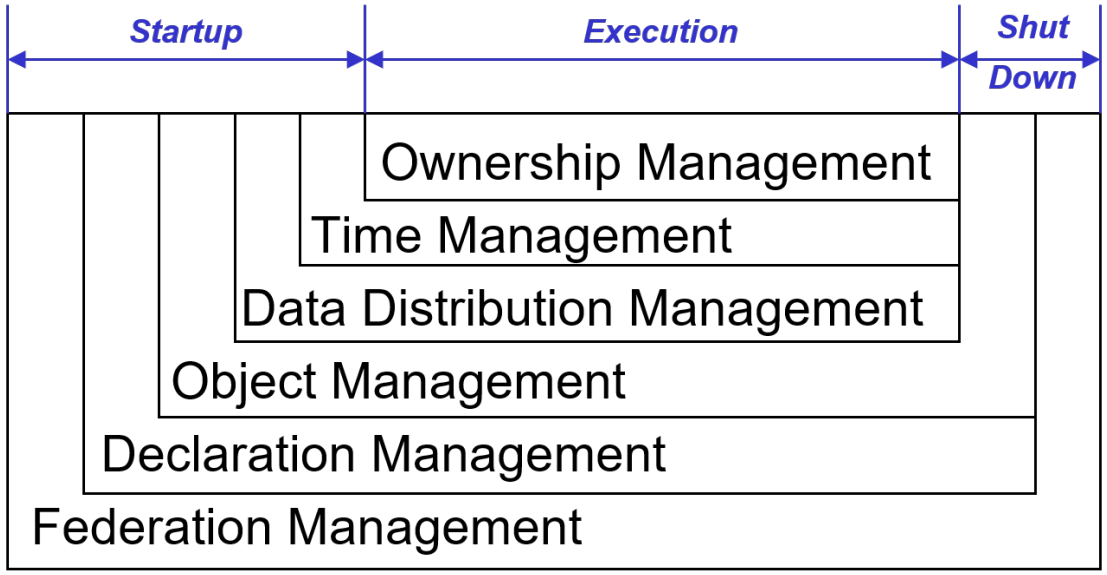
Current Solution: Runtime Infrastructure



- **Federation Management** determines the federation. Federates join and leave the federation using the functions defined in this group.

- **Declaration Management** identifies which federate can publish and/or subscribe to which information exchange elements. This defines the type of information that can be shared.
- **Object Management** manages the instances of shareable objects that are shared in the federation. Sending, receiving, and updating belong in this group.
- **Data Distribution Management** ensures the efficiency of information exchange. Adding additional filters ensures that only data of interest are broadcast.
- **Time Management** synchronizes the execution of the participation federates.
- **Ownership Management** enables the transfer of responsibility for instances or attributes between federates.

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Future Solution: Tenets for a Modern Simulation Infrastructure

Scalability
Change with the size, scale, or number of simulated entities, participating services, or the amount of exchange data

Flexibility
Support domain services with different resolution/scope, time management methods, and simulation paradigms

Adaptability
Ability to adjust to new conditions, including unforeseen ones

Modularity
Degree to which the services and components of the simulation infrastructure can be separated and recombined

Configurability
Purposefully utilize the other characteristics of the new simulation infrastructure to maximize the benefits for a new infrastructure based experiment

The Infrastructure must ensure that

1. All information needed by the simulation services is provided
2. Only the information needed will be provided
3. The information is provided in a secure and timely manner

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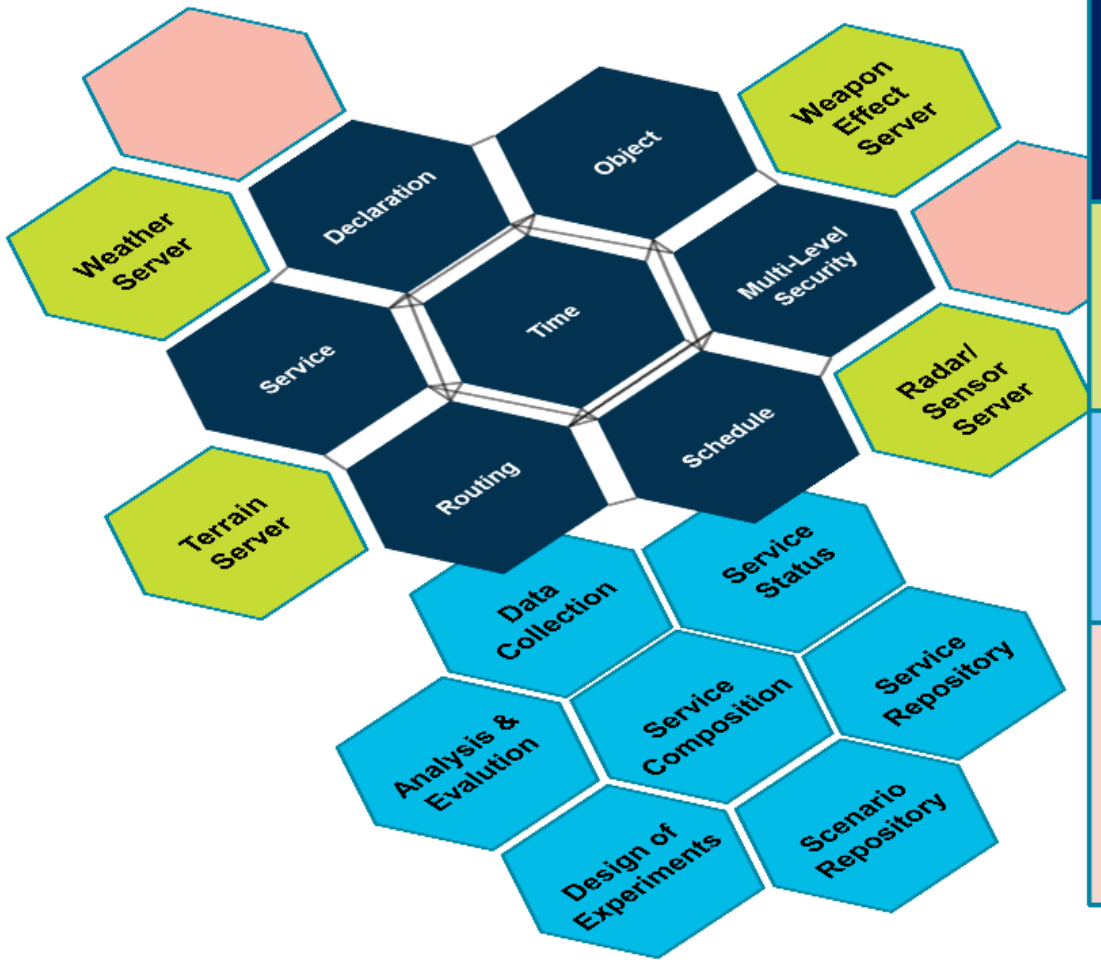
Recommended Foundation: Composable Services

- **Composable services are a good practice to implement a scalable, flexible, adaptable, modular, and configurable simulation infrastructure:**
  - Depending on the size, scale, or number of simulated entities and participating services, or the amount of data to be exchanged, the number of services providing the needed functionality can vary. **Composable services allow engineers to add, modify or remove services as needed.**
  - Different service instantiations can provide similar functionality to services that have different resolution/scope, time management needs, and supported simulation paradigms.
  - Should new or unforeseen conditions occur, only those services affected by those conditions need to be updated, allowing rapid and efficient adaptation of the solution to the new environment, tasks, missions, or threats.
  - Services are modular by design, allowing them to be separated and recombined by engineers, based on the principles of loose coupling in the technical domain and composability in the conceptual domain.
  - All properties captured so far are leading to a fully configurable solution that provides all needed functionality in an efficient way.

Information Exchange Services Matrix (IESM) and supporting Services



- **Core Services** provide functionality to execute composed services
- **Common Services** provide functionality to ensure fair fight/ fair analysis (common effects)
- **Exercise Services** provide functionality to set up, run, and analyze the experiment
- **Edge Services** provide the operational functionality needed (missions, systems, special effects)

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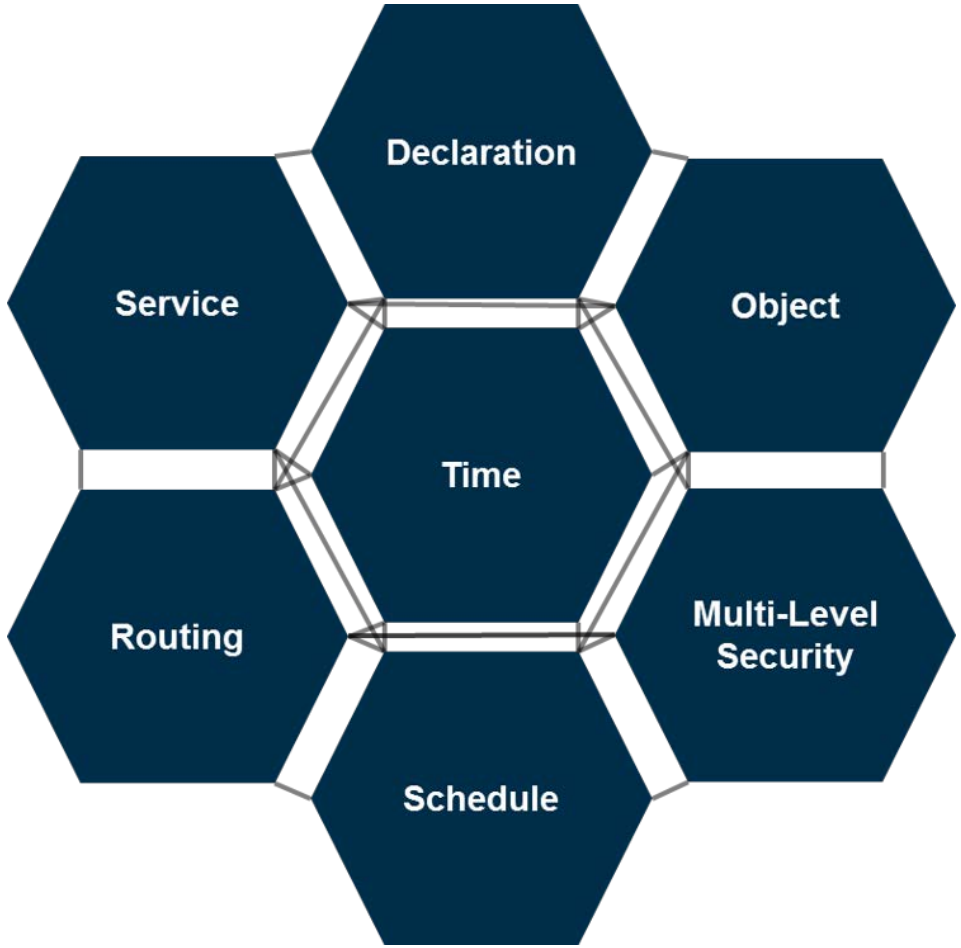
Core Services



- **HLA RTI, TENA, and CPS Influence**
  - Services Management for all four categories of services
  - Declaration Management for types of information exchange
  - Object Management for instances of IE
  - Time Management for synchronization
  - Routing to support consistent multi-modality transfer of information
  - Scheduling to support flexible computation (order of services based on need and importance)
  - Multilevel security ensuring safe need-to-know distribution

Timely and secure information exchange

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Common and Edge Services

- **Common and Edge Service provide the application specific functionality**
  - Simulators
  - Simulation systems
  - Services for terrain, weather, weapon effects, etc.

Common services ensure fair fights between simulated entities in different participating simulation systems by consistent computational representation of effects .

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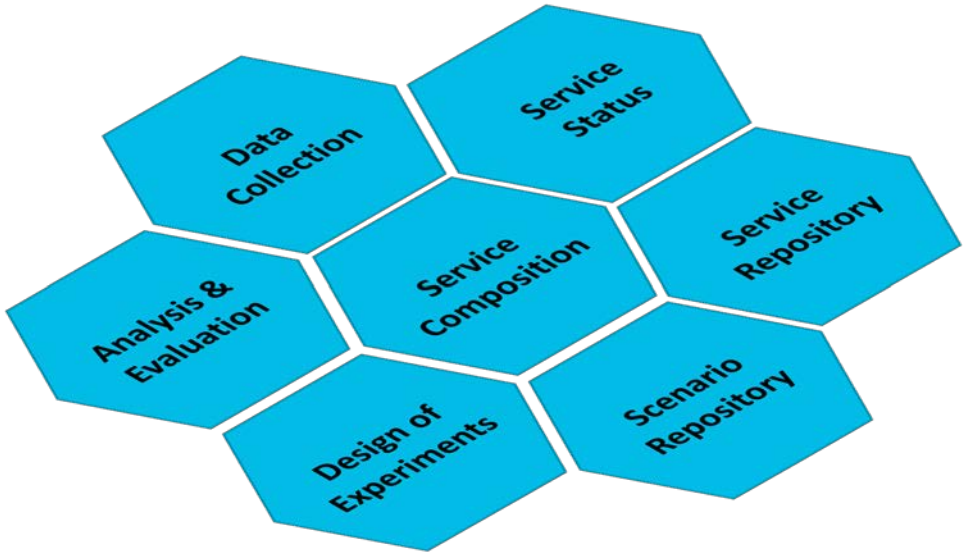
Exercise Services

- **Exercise services are “custodian” services needed to set up, run, and evaluate the simulation event**



- Services to plan the exercise, including operation planning tools
- Data collection tools
- Analysis and evaluation
- Services to observe load of computers and the network status
- Repositories
- …

Which and how many exercises services are needed depends on the supported event.

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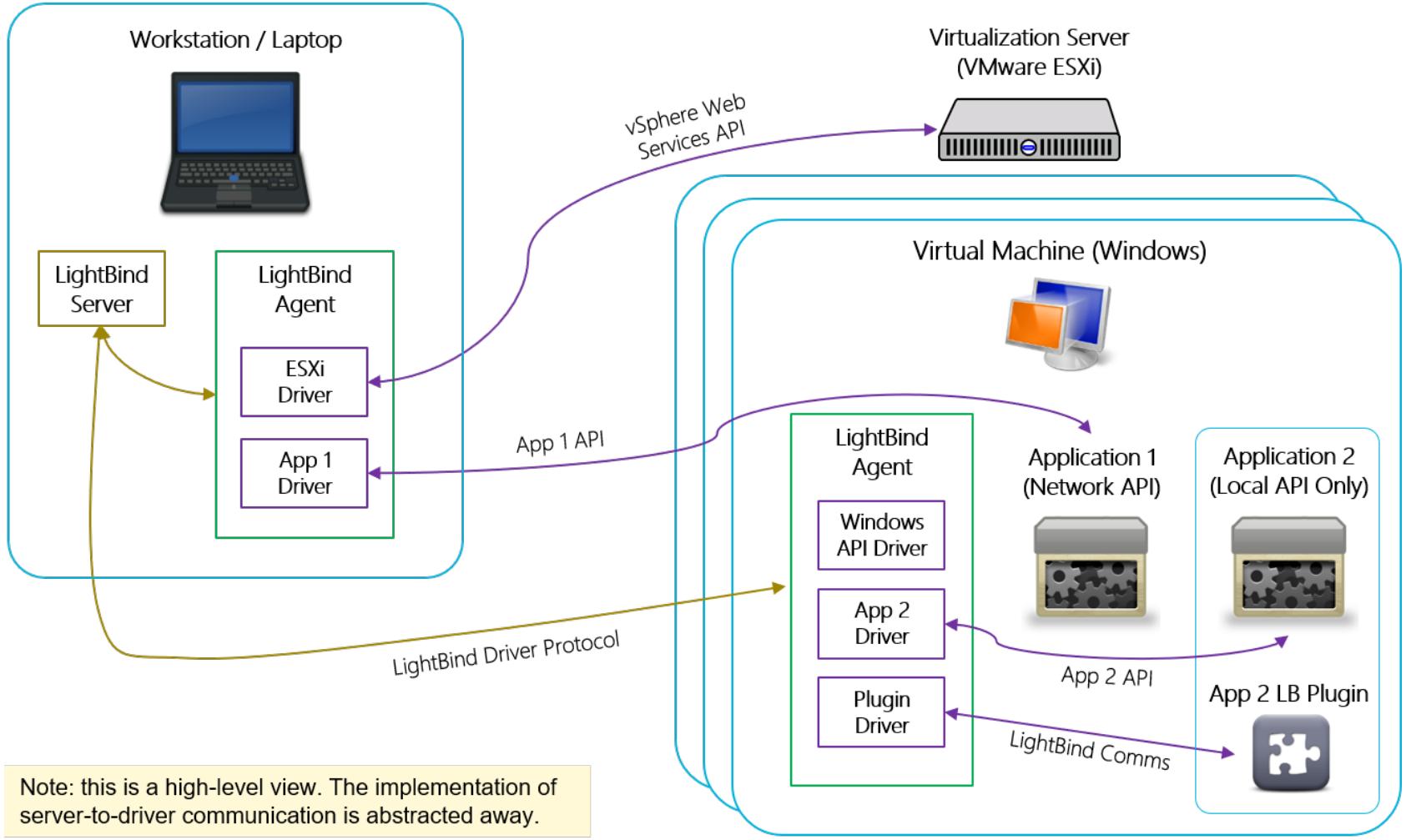
Service Coupling using *LightBind*



Note: this is a high-level view. The implementation of server-to-driver communication is abstracted away.

- **LightBind Drivers**
  - Wrap original software
  - Map interface to common representation
- **LightBind Server**
  - Central control and monitoring application
- **LightBind Agent**
  - Gateway into the LightBind composition

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Conceptual alignment using MBSE principles

Conceptual Planning Phase

Mission model

The **Military User** plans the mission to which the training or testing event will contribute, including metrics for the success.

What is simulated?

Why is it simulated?

Defining the event.

Composition Phase

Blueprint

The **Engineer** constructs the **Simulation Blueprint,** mapping applicable and available edge and common services needed to execute the mission.

Who is simulating?

Selecting the providers.

Operations Phase

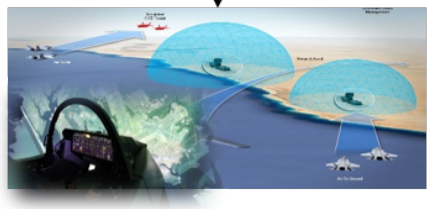
Composition

The **Engineer** configures, scales, and adapts the IESM and the selected edge services and composes them to provide all functions needed for the event.

Where is the simulation?

When is the simulation?

Configuration, scaling, and adapting the services.



The **Military User** starts, stops, resumes, and resets the simulation composition as needed to conduct the training or testing event.

How is it simulated?

Conducting and evaluating the event.

Conform with IEEE 1730-2010 - IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)

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Summary and Conclusion

- **We propose a scalable, flexible, adaptable, modular, and configurable simulation infrastructure**
  - based on common, core, and exercise services,
  - comprised in an IESM as a central piece of a possible Joint Simulation Environment
- **Maximize reuse of existing solution as a service**
  - If functionality is needed in the context
  - If services are not too tightly coupled
- **Use of latest IT Technology**
  - Cloud and Fog computing; cyber physical systems
  - Complex adaptive systems and complex systems engineering
  - Application of solutions useful in the battle management environment as well

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The slide set directly presents the research published in the paper "A New Simulation Infrastructure supporting the Next Generation of Simulation-based Testing ang Training Applications," Approved for Public Release; Distribution Unlimited. Case Number 19-1089.

Slides 3, 4, and 5 are based on the article by J. Hood, 2017. "Defining the 5th Generation Fighter Jet". http://www.jble.af.mil/News/Commentaries/Display/Article/1112351/, accessed August 20, 2018, Approved for Public Release; Distribution Unlimited. Case Number 18-2167-8