

ASA: A Simulation Environment for Evaluating Military Operational Scenarios

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AGENDA

- Big Picture
- Related Work
- Definition
- Features
- Architecture
- Applications
- Summary



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BIG PICTURE

- Commanders: experience and intuition to make decisions
- The modern battlefield scenarios brought new challenges
- New technologies: **missiles, drones, RWR, air defense systems**
- **Simulation** and **Data Analysis** to support the decision-making process in the Theater of Operations
- Requiring more **integrated** and **flexible** solutions: **technical** and **organizational** aspects
- Establish **strategies, parameters**, and **command decisions** to the aerospace context for defense purposes



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RELATED WORK

- **[Clive et al, CSC 2015] The Advanced Framework for Simulation, Integration and Modeling (AFSIM)**
 - 2003-2013 Boeing
 - **\$50M** investment, **restricted to a few US partners**
 - Common modeling framework
 - AFRL has licensed it to over **275** government, industry, and academic organizations, and provided training to over **1200** users
- **[Hodson et al, CSC 2018] Mixed Reality Simulation Platform (MIXR)**
 - OpenEagles
 - Opensource
 - Construction of **virtual** (human-in-the-loop) and **constructive** simulation applications
 - Modern C++ object-oriented software design



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DEFINITION

- [2018] Institute for Advanced Studies
- The Aerospace Simulation Environment or *Ambiente de Simulação Aeroespacial -- ASA in Portuguese*
- Computational solution that enables the modeling and simulation of operational scenarios
 - Flexible solution that may be tailored to the user needs
 - Requirements: not attended by commercial off-the-shelf simulation software
- Use simulation to make decisions
 - Support Brazilian Air Force strategic planning
 - Meet operational analysis needs
 - Development and evaluation of new technologies to enhance military research



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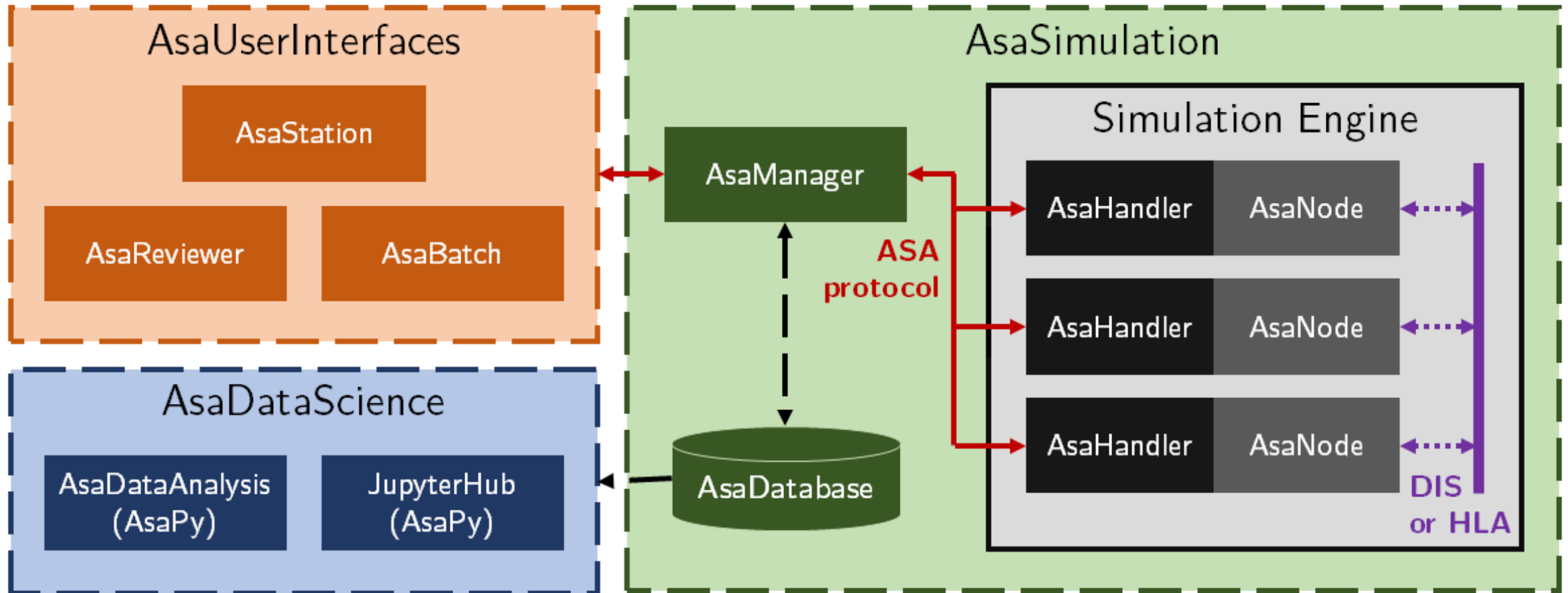
FEATURES

- ASA: extension of the MIXR's possibilities
 - We created a **manager application** with a distributed architecture for managing **multiple simulation machines**
 - The capability of **loading models at simulation runtime**
 - **Batch mode execution** to perform multiple executions using different initial parameters
 - A **visualization tool** that suits the Brazilian Air Force technical requirements
 - **Data analysis platform** for post-processing simulation data

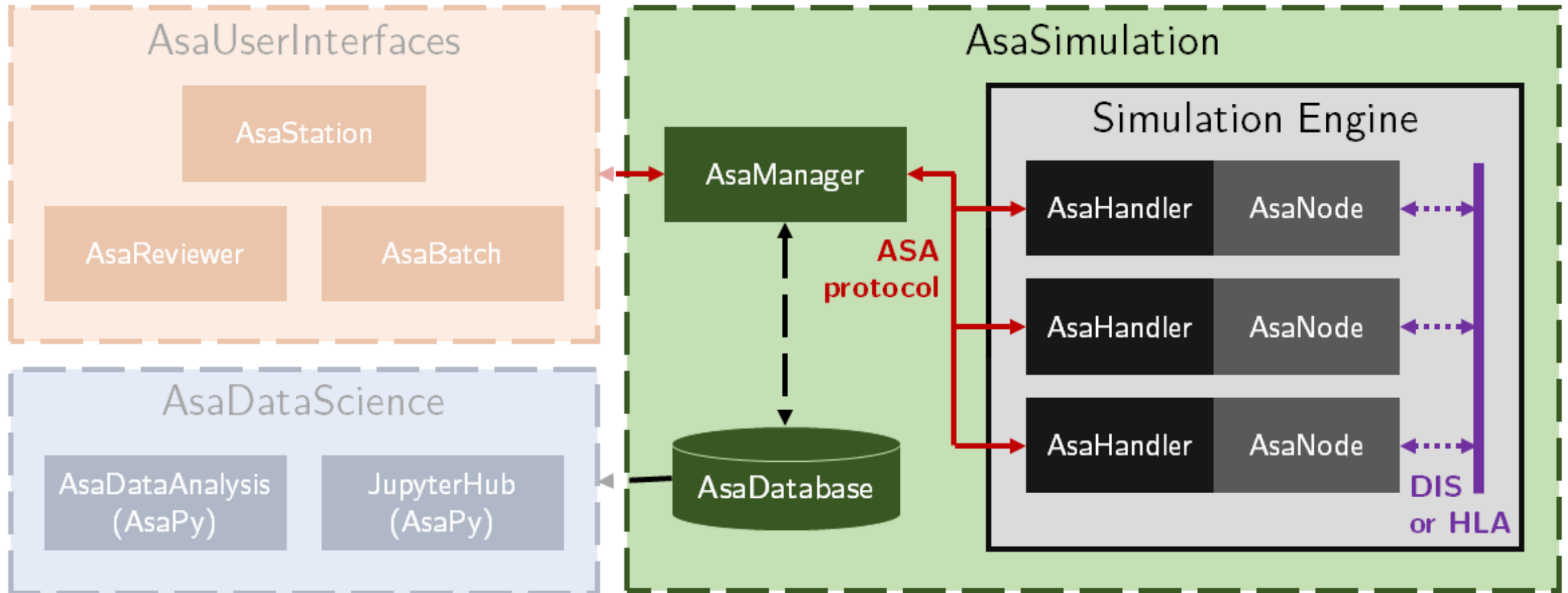


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ARCHITECTURE



ARCHITECTURE: AsaSimulation



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- **AsaDatabase**

- Keeps agent metadata, simulation scenarios, execution data, and analysis results

- **AsaManager**

- Responsible for coordinating and synchronizing the processes in a distributed manner.
- Controlling the simulation processing nodes
- Receives control commands (play, pause, resume, and stop) and transmits them to the simulation engine
- CRUD methods: responsible for accessing the AsaDatabase and updating it
- Tasks imperceptible for the user:
 - Loading extensions metadata
 - Converting the JSON scenario specification to a compatible format (MIXR initialization scheme)
 - Interpreting commands to control the execution progress on the simulation machine
 - Changing orders in agents' behaviors during real-time simulation



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ARCHITECTURE: AsaSimulation

- **AsaNode**

- The simulation engine: process the simulation itself
- Estimates how the scenario will evolve, considering the models incorporated in each agent present in the simulation
- Executable file compiled from the MIXR's code and features developed by the ASA team:
 - Dynamically loading extensions
 - Controlling the execution of the simulation (pause, resume, stop, execution speed, etc.)
- Run on the same machine as the AsaManager or in a clustered computing environment (batch execution)

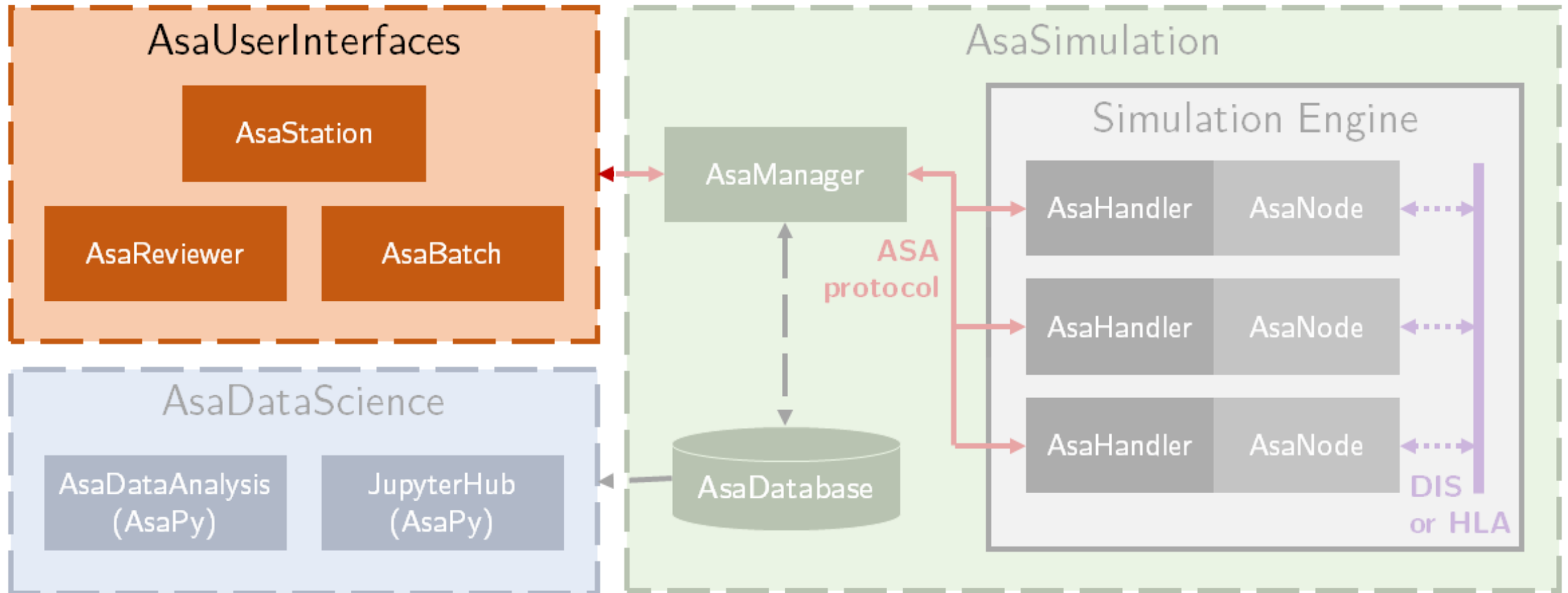
- **AsaHandler**

- Make the bridge between AsaNode and AsaManager
- Informes AsaManager which computers on a network are available to execute simulations
- Receives the properly formatted specifications from AsaManager and runs an instance of AsaNode dedicated to processing them
- Transmits simulation commands based on the orders received from AsaManager, obtained from the user interface



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ARCHITECTURE: AsaUserInterfaces



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- **AsaStation**

- Graphical User Interface
- AEROGRAF [Petersen et al, 2008]
- Create a scenario: military symbols, geometric drawings, aeronautical charts, and digital terrain models
- Visualize how a scenario will evolve
- Create, delete, or modify simulations
- Change the simulation components, agents or the execution view

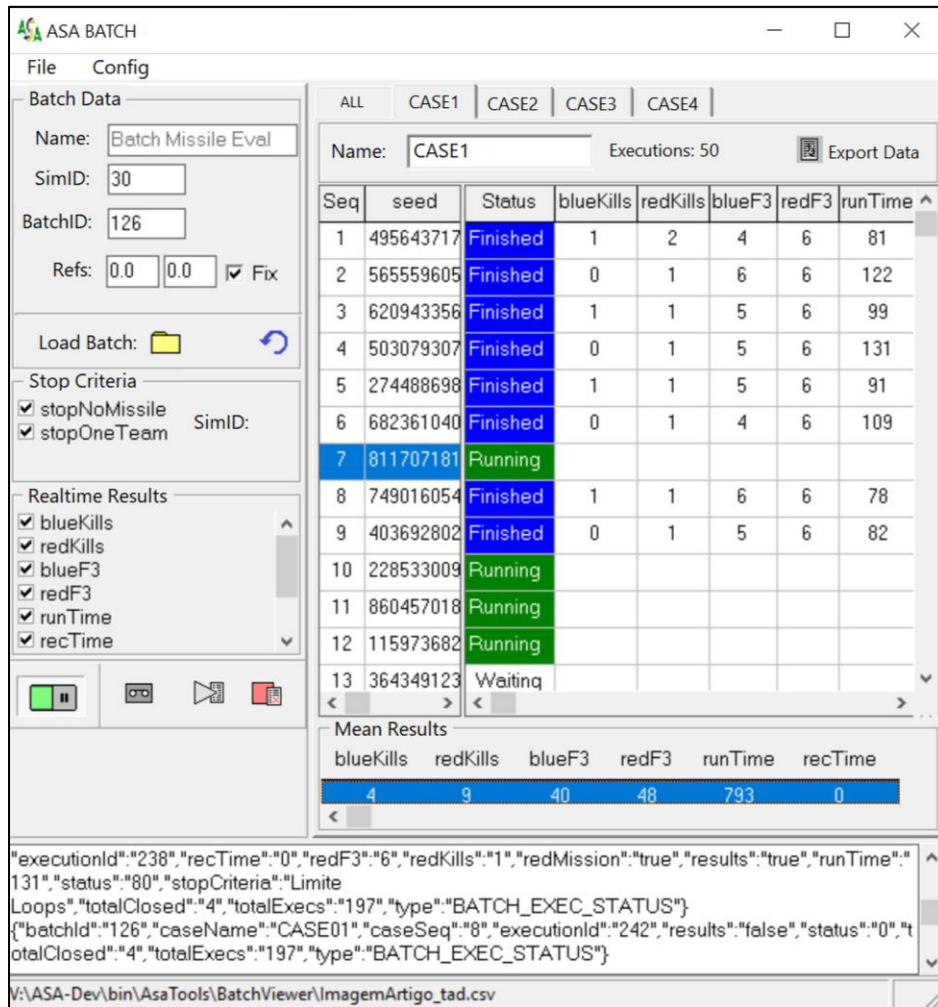
- **AsaReviewer**

- Revisualize simulations from the AsaDatabase
- Support the decision-maker



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ARCHITECTURE: AsaUserInterfaces



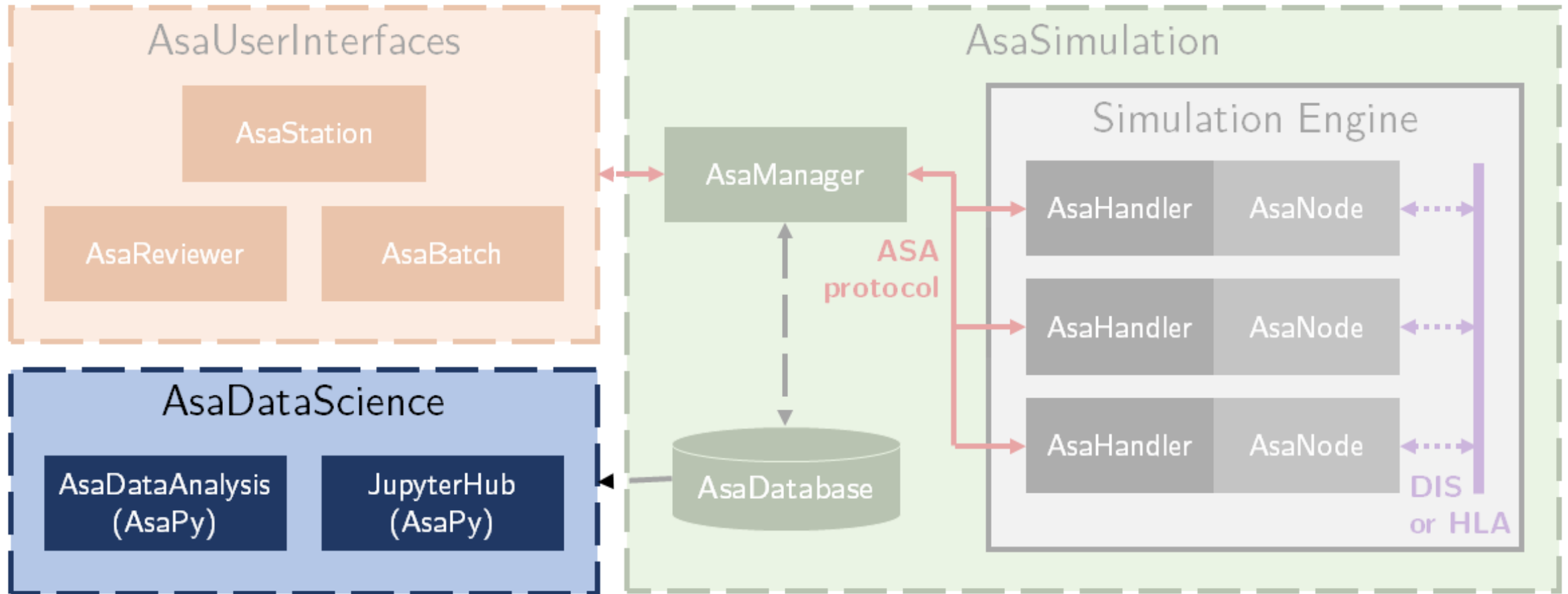
- **AsaBatch**

- Run multiple simulations at the same time
- Analyze scenarios with stochastic factors: change the initialization parameters (seed)
 - Starting positions of each component
 - Weapon performance factors
 - Agents' Behaviors
- Check preliminary results in real-time



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ARCHITECTURE: AsaDataScience



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- **Jupyter Hub**
 - **Cloud-computational environment** that includes **high-performance hardware**
 - Interactive programming environment to optimize the batch execution of simulations and data analysis
- **AsaPy**
 - Python analysis library
 - 4 packages



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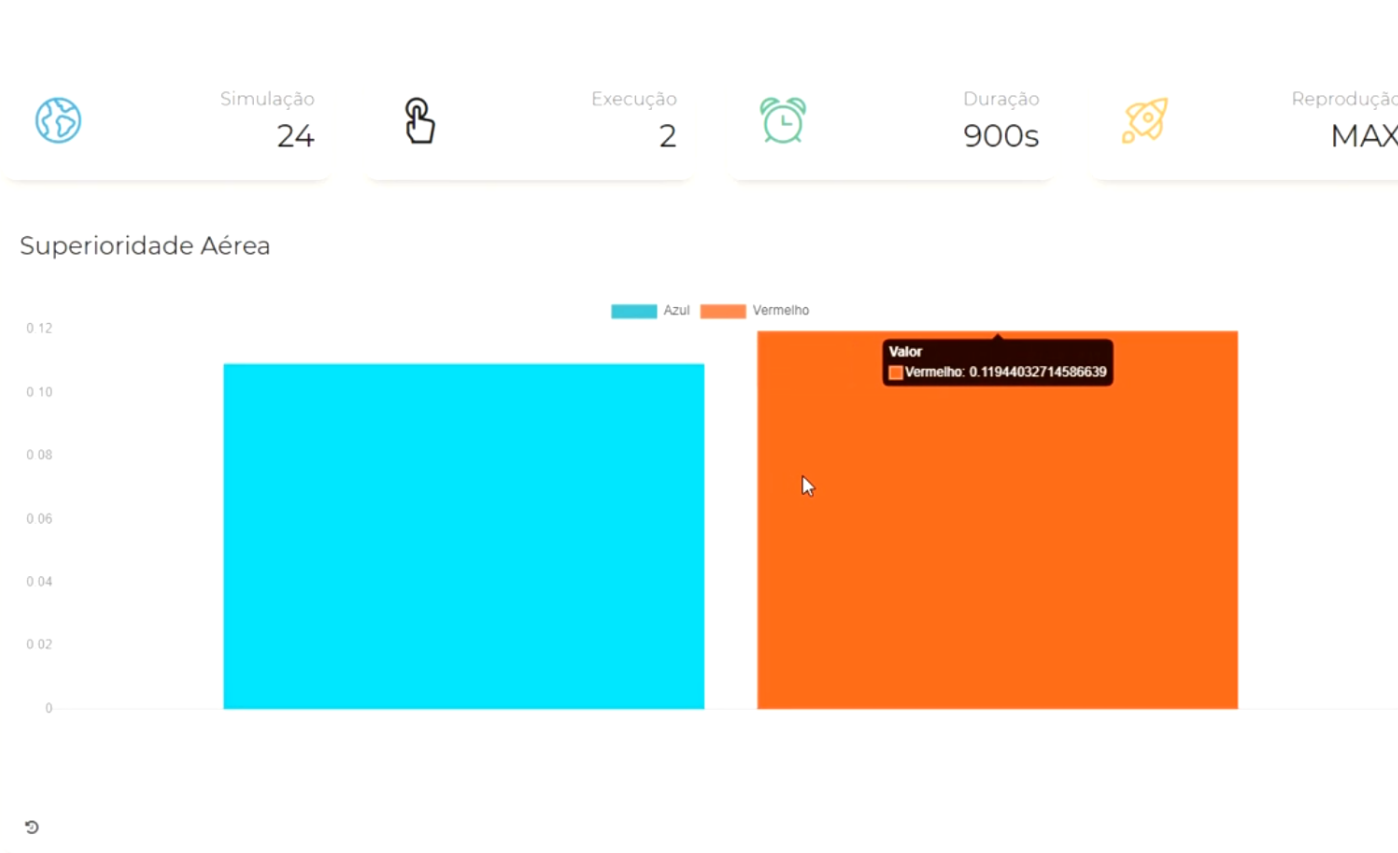
ARCHITECTURE: AsaDataScience

Package	Description
DoE	Design of experiments methods for planning the input parameters.
API	Access to the functionalities provided by the AsaSimulation elements, especially those related to the execution and management of simulations.
Data	Access data present in the AsaDatabase and contains the methods necessary for handling the data and metadata simulation.
Analysis	Machine learning and statistical methods for analyzing output data.



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ARCHITECTURE: AsaDataScience



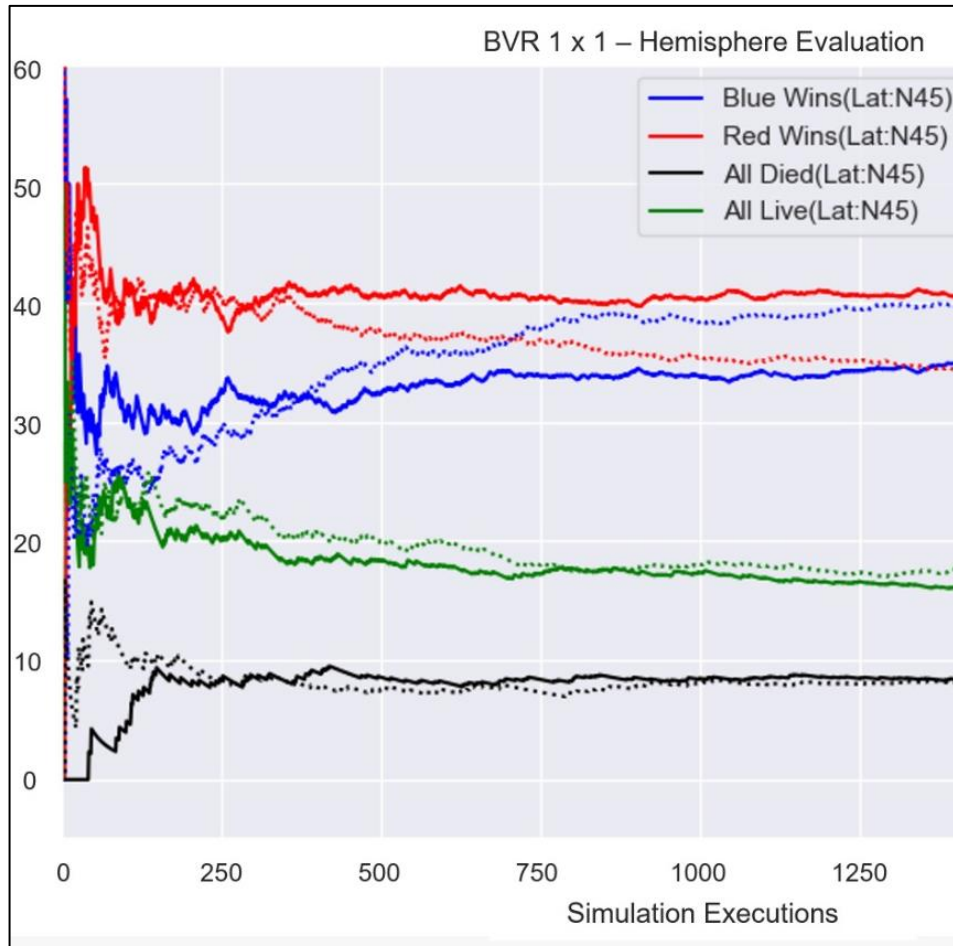
• Web Dashboard

- Visualize **indices** and **metrics**
 - Agents' Measure of performance
 - Cost of operation
 - How many missiles were launched
 - How many aircraft were destroyed



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APPLICATIONS

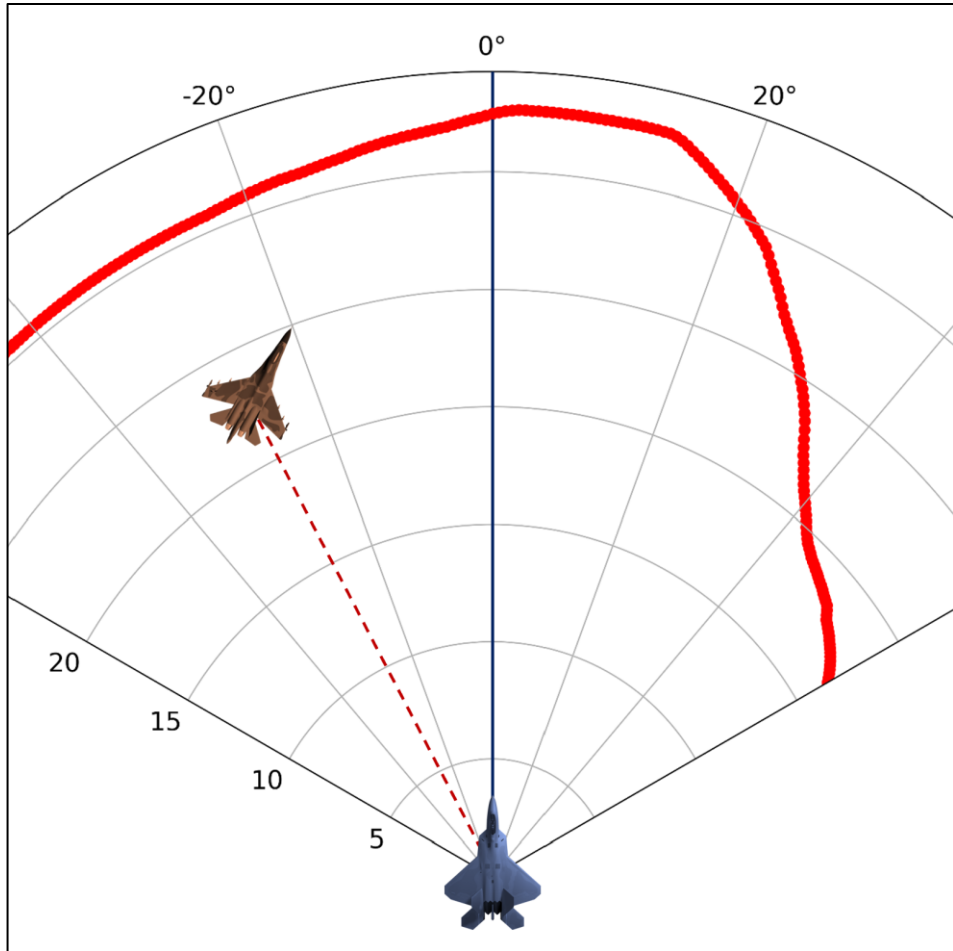


[Kuroswiski, 2020] Agent-Based Modeling and Simulation as a Support Tool for Air Defense Capabilities Assessment

Master's Thesis -- Aeronautics Institute of Technology (ITA)

The author analyzed the feasibility of using **Agent-based Modeling and Simulation (ABMS)** to assess **air defense capabilities** in the context of strategic planning, presenting a case study based on simulations of BVR air combat scenarios at the engagement level

APPLICATIONS

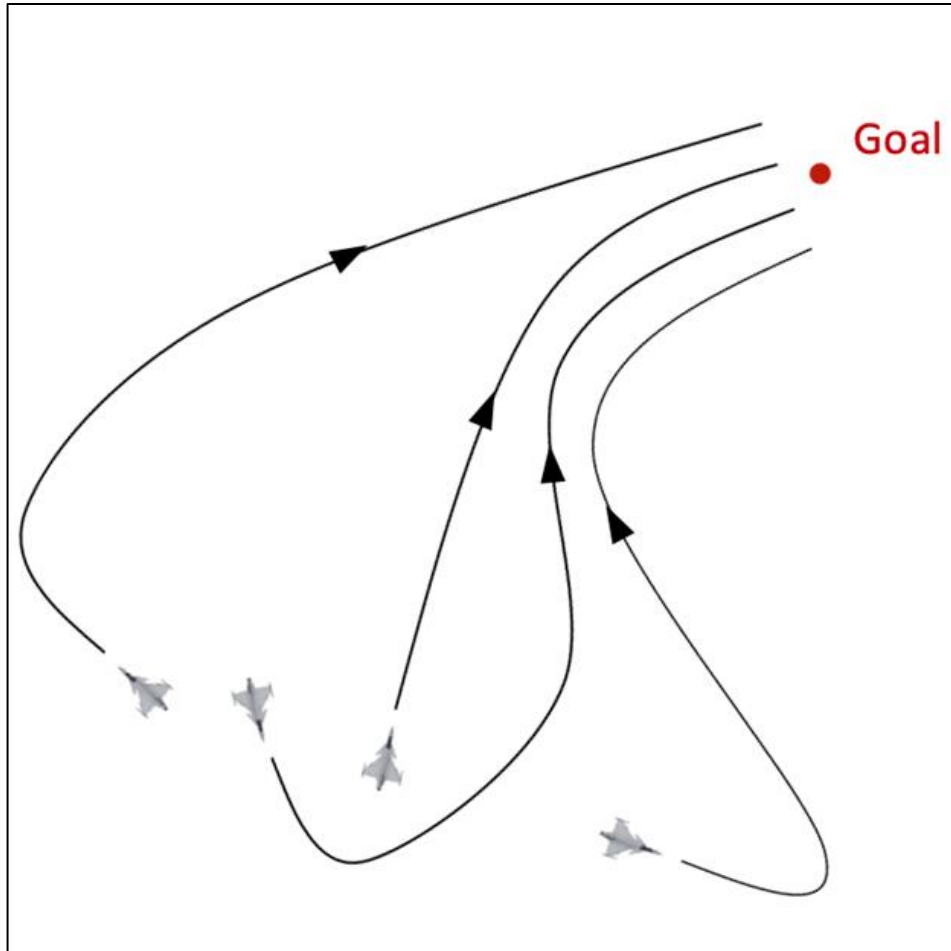


[Dantas et al, 2021] Weapon Engagement Zone Maximum Launch Range Estimation Using a Deep Neural Network

Brazilian Conference on Intelligent Systems

A **Deep Neural Network** estimates the **Weapon Engagement Zone maximum launch range**, allowing pilots to identify the airspace in which the missile has the highest probability of success in hitting a target

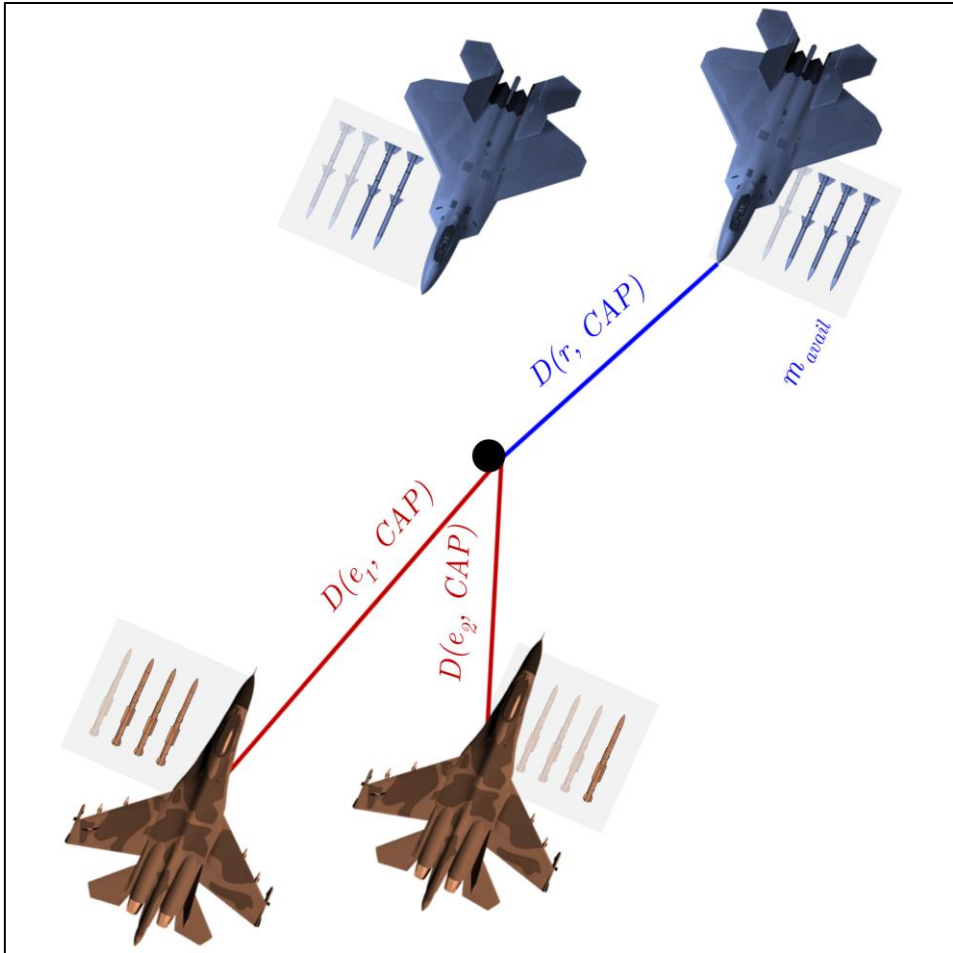
APPLICATIONS



[Costa et al, 2021] Formation control method based on artificial potential fields for aircraft flight simulation
SIMULATION SAGE

Use of both **artificial potential fields** and **simulation optimization** to achieve more robust results for **simulated military aircraft to fly in formation**, using a large set of scenarios for the optimization process, which evaluates its objective function through the simulations

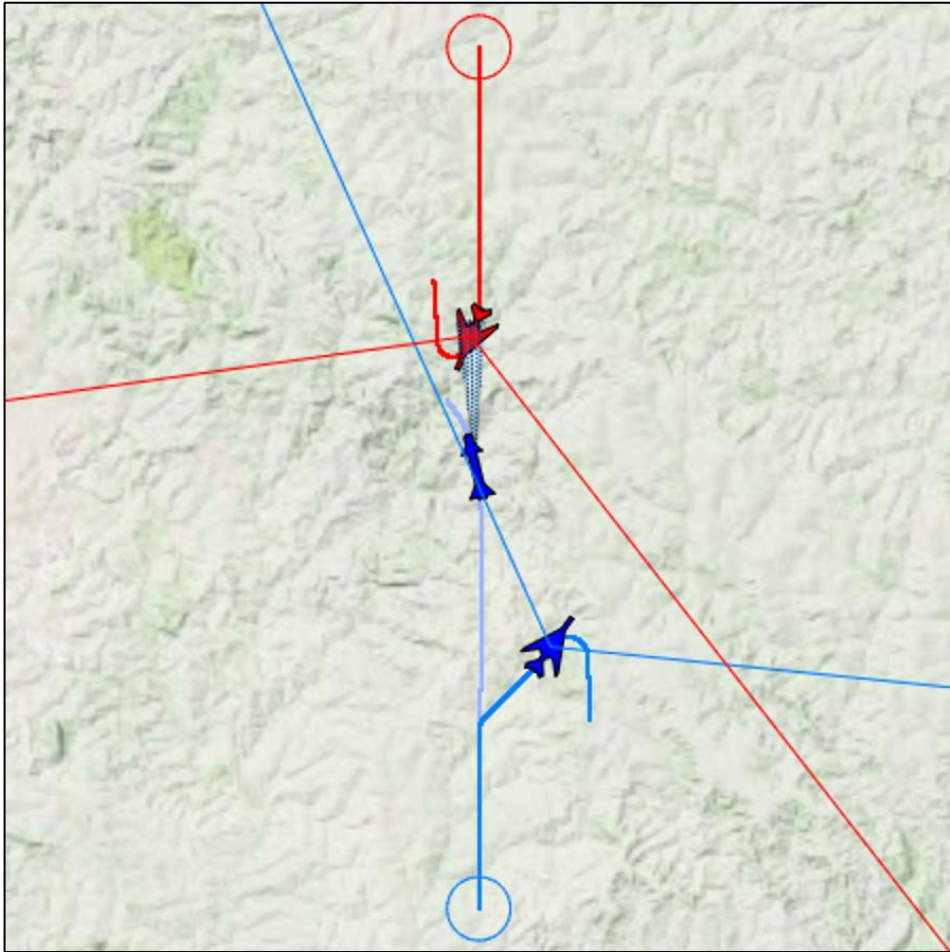
APPLICATIONS



[Dantas et al, 2021] Engagement decision support for beyond visual range air combat
Latin American Robotics Symposium

This work proposes an **engagement decision support tool for BVR air combat**, using a supervised learning model based on decision trees **to measure the quality of a new engagement**, which is the moment the pilot engages a target assuming an offensive stance and executing corresponding maneuvers.

APPLICATIONS



[Dantas et al, 2022] Machine Learning to Improve Situational Awareness in Beyond Visual Range Air Combat

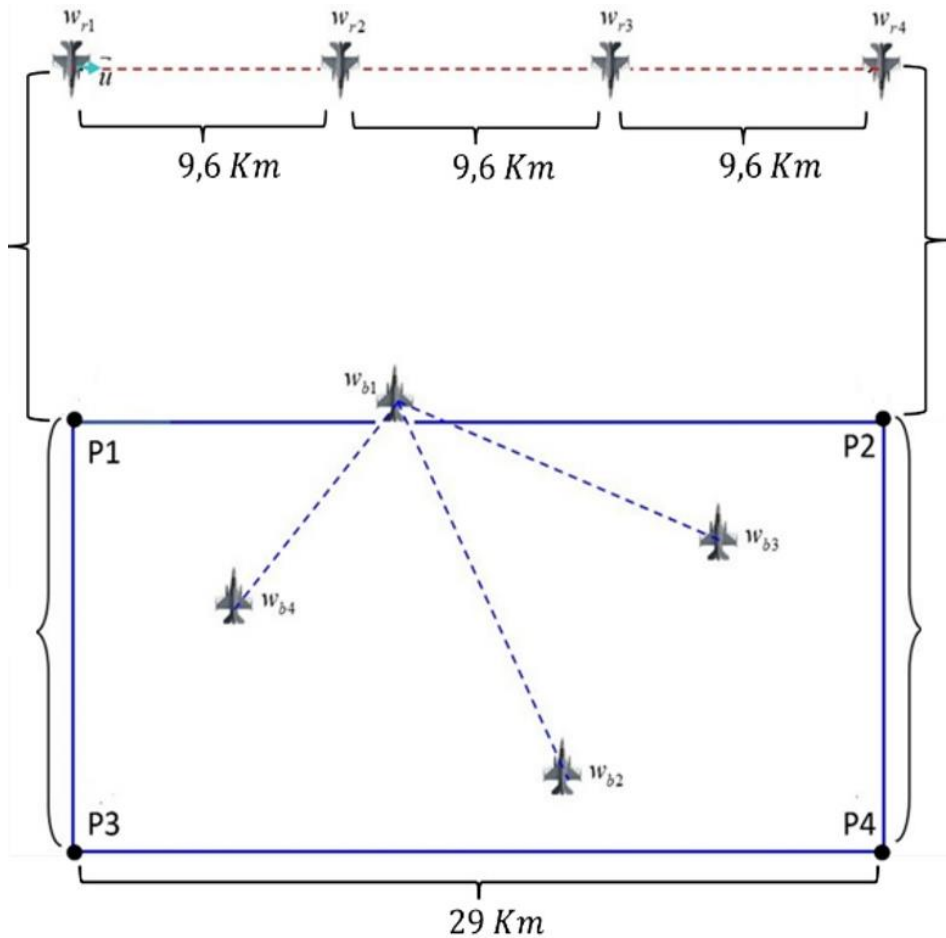
IEEE Latin America Transactions

The authors designed a **multilayer perceptron neural network** using data from constructive simulations to be employed in an embedded device to enhance the **pilot's situational awareness** in the in-flight decision-making process



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APPLICATIONS

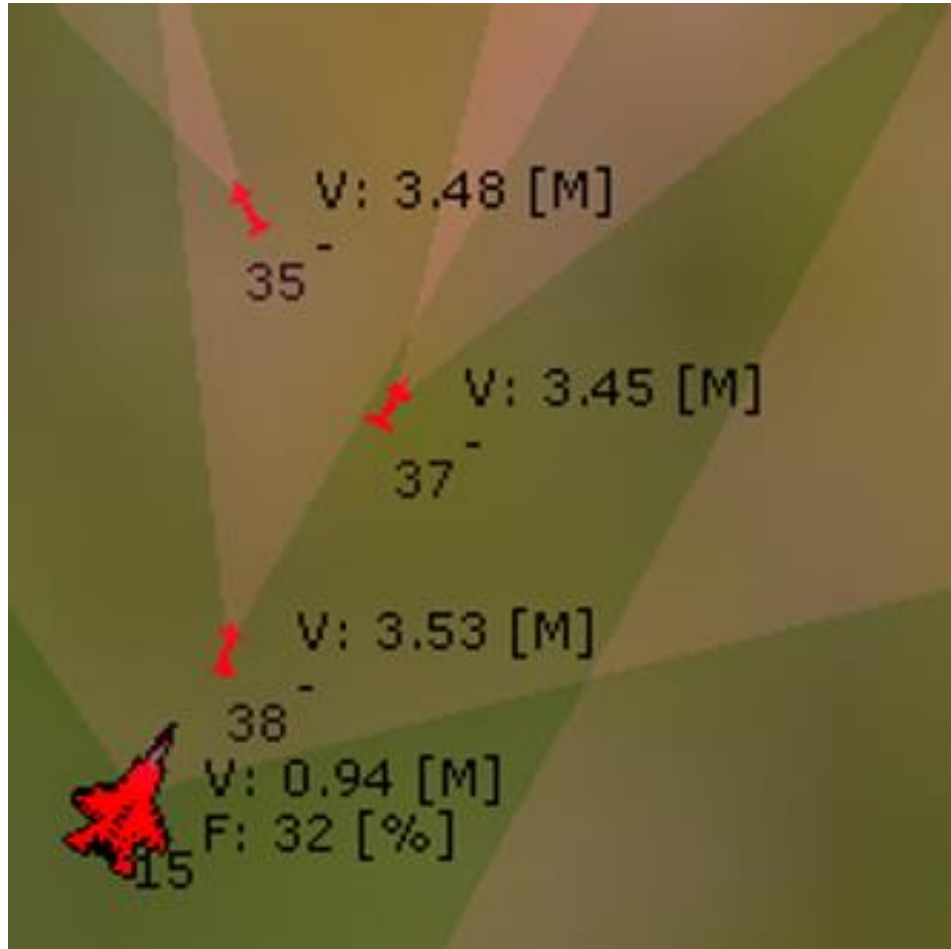


[De Lima Filho et al, 2022] Optimization of Unmanned Air Vehicle Tactical Formation in War Games

IEEE Access

The authors integrated the ASA infrastructure into an external optimization framework to apply **six different metaheuristics to optimize Unmanned Aircraft Vehicles' tactical formations**, considering enemy variables such as firing distance and initial position in a BVR air combat scenario

APPLICATIONS



[Dantas et al, 2022] Supervised Machine Learning for Effective Missile Launch Based on Beyond Visual Range Air Combat Simulations

Winter Simulation Conference [Accepted!]

This work compares **supervised machine learning** methods using reliable data from constructive simulations to estimate **the most effective moment for launching missiles during air combat, using resampling techniques** to improve the predictive model



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SUMMARY

- High-level overview of the ASA simulation framework
- ASA: Primary goal of evaluating military operational scenarios
 - Distributed Architecture
 - Some works using ASA in the air combat context
- For future work
 - AFSIM idea: release part of the source code with the general architecture to encourage the development of different applications in the same simulation platform
 - ASA will operate as a simulation-as-a-service tool to attend to diverse simulation demands in the defense and aerospace context



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