From Factory to Field: Modeling Production Capacity and Logistics Effectiveness for Defense Systems

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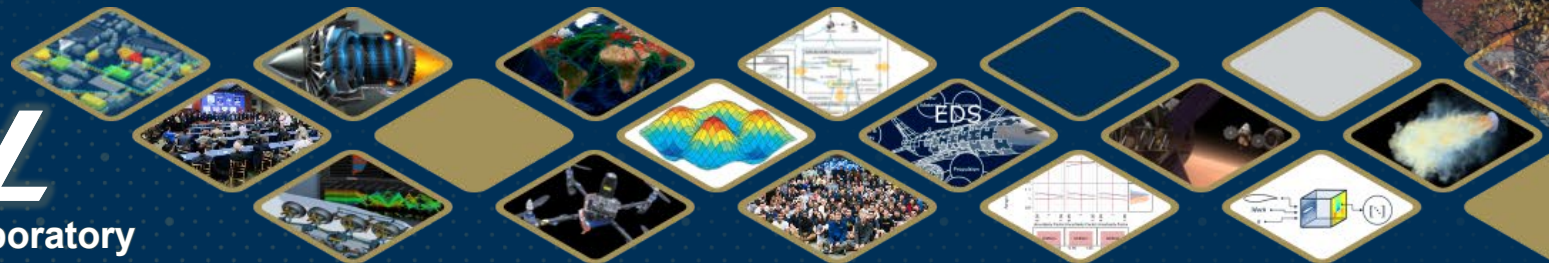
ASDL
Aerospace Systems Design Laboratory



Current & Future Challenges

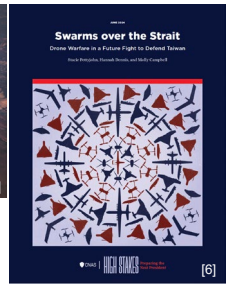
Military Operations

- Contested logistics in isolated and dispersed islands strain maintenance and readiness [1]
- Continuously evolving technological, political, socio-economical environments
- Conflicts beyond kinetic force [2]
- Growing gap in operational deployment timelines between U.S. and adversaries

Systems

- Systems fulfilling multiple roles
- Systems need to demonstrate resilience and adaptability
- Quick and efficient adaptation to new threats needs to be accelerated


[7]

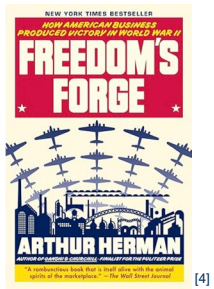


[6]

Supply Chain & DIB

- Lack of demand visibility for supply chain
- Defense Industrial Base (DIB) is shrinking
- Slow response to sudden demand changes

[5]



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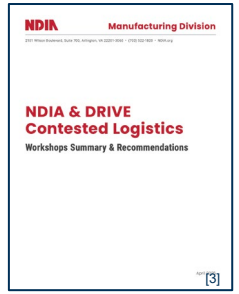


[3]

Digital continuity and traceability are needed to facilitate the integration of kill chains and supply chains, and enable data-driven decisions to increase speed of response

Objective and Methodology

I. Modeling and Simulation Environment for the Quantitative Assessment of Operational and Technological Improvements in Military Logistics [1]

Research Goal: Evaluate the predictive capabilities of digital twins (DTs) in **forecasting vehicle maintenance needs** and **equipment degradation** across a variety of scenarios

Research Objectives

1. Develop a M&S environment capable of: Simulating interactions between logistical assets (trucks, ships, ports, warehouses etc.) under different draw conditions
2. Assess the impact of having full situational awareness and a comprehensive view of the logistics landscape on key metrics of interest

II. Manufacturing & Production Modeling for Throughput Estimation and Demand Fulfillment

Research Goal: Better **quantify** the **impact that predictive digital twins have on logistic systems.** Gain a greater understanding of the impact that scenarios of interest will have on the supply of high-value systems, which in turn could **help inform an Industry-led Surge Buy-Plan**

Research Objectives

1. Develop a M&S environment capable of: Simulating different intensities and conflict duration levels, simulating missile launcher production
2. Conduct sensitivity analyses examining how variations in manufacturing parameters affect throughput
3. Quantify the effectiveness of different factory configurations

[1] N.S Birbasov, P. Wang, S. Cimtalay, O.J. Pinon Fischer, M.G Balchanos, and D.N. Mavris, A Modeling and Simulation Environment for the Quantitative Assessment of Operational and Technological Improvements in Military Logistics, AIAA SciTech 2025 Forum, Orlando, FL, January 6 10, 2024, AIAA-2025-2025-0708,

Objective and Methodology

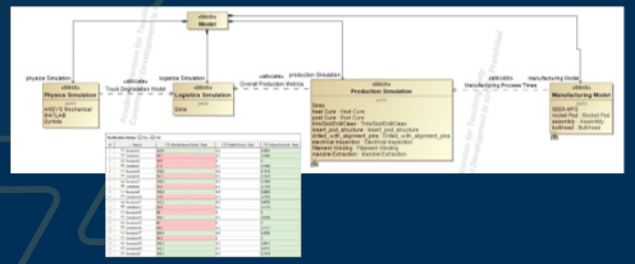
I. Modeling and Simulation Environment for the Quantitative Assessment of Operational and Technological Improvements in Military Logistics [1]

II. Manufacturing & Production Modeling for Throughput Estimation and Demand Fulfillment

Architect, model, simulate the resupply/logistics operations for missile launchers

I — MBSE

Model Based Systems Engineering
Used for conducting **requirements verification** (e.g.,. suspension fatigue life, number of missed launches)

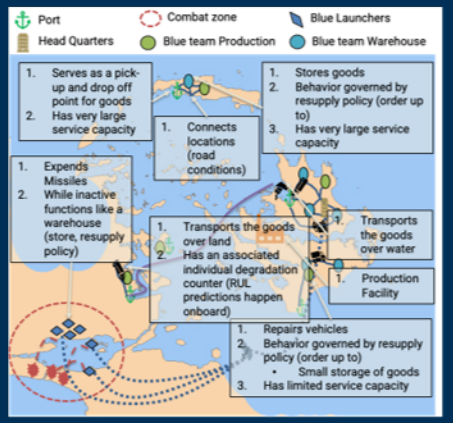


II — MFG/PS

Manufacturing and Production Simulation
Modeled and simulation the steps and processes involved in the **manufacturing** and **production of launchers**

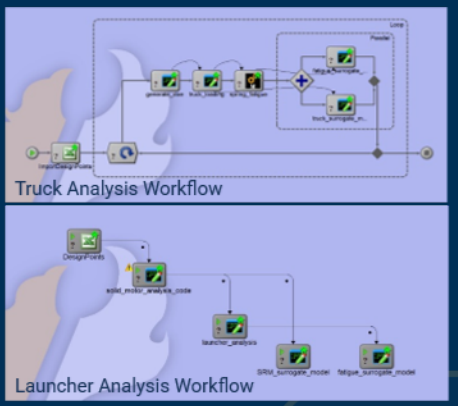
I — LS

Logistics Simulation
Represents a **notional logistical** system to study **technology infusion** on the **capacity of the logistical system**



I — PB

Physics-Based Simulation
Physics-based models for system components: **Trucks** and **launchers** (Digital twin representation)



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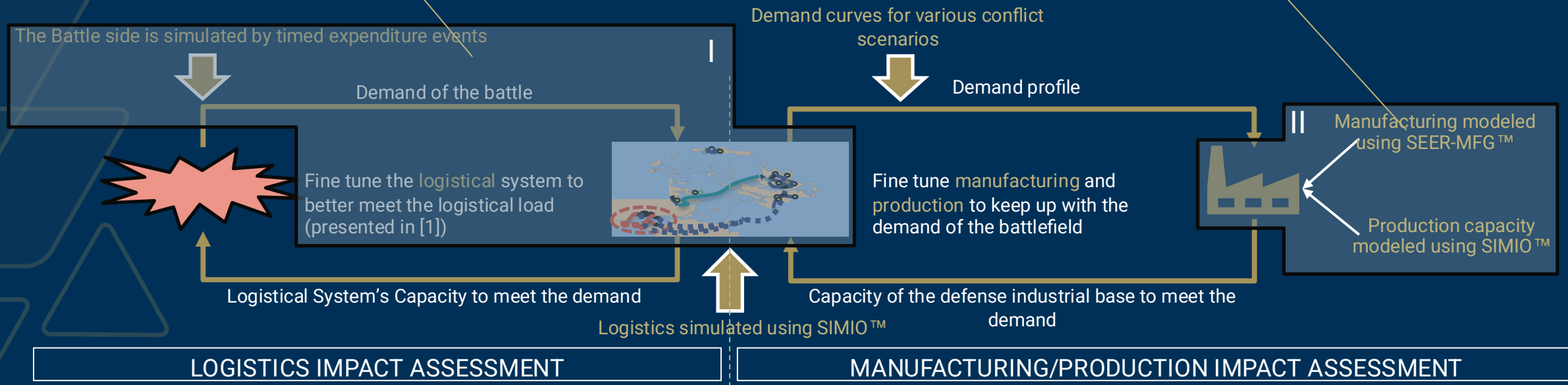

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LS Logistics Simulation

- The SIMIO simulation consists of objects with internal logics
  - Port
  - Warehouse
  - Repair Facility
  - Production Facility
  - Launcher
  - Logistical Truck
  - Cargo Ship
  - Battle Demand
  - Road
- The demand is defined by timed events
  - Time between events are specified as a distribution
  - The number of missiles needed are specified as a distribution
- Logistical Trucks and Launchers are subject to degradation
  - Launcher is defined by number of launches until failure (fatigue life)
  - Truck utilizes miner's rule and a scheduler
    - Calendar-based maintenance
    - Condition-based maintenance (DT)

PB Physics Based Summary

"Digital twins" are created for:

1. A missile launcher
2. A supply truck

These are not true digital twins, since they are not calibrated, nor do they ingest data from a physical counterpart

Modeling

- A loading model predicts the applied load on the system during operation
- A degradation model predicts the fatigue life under the applied load
- These models are called by the logistics model when an event happens

Surrogate Modeling

- Surrogate models are trained on BOTH models
- Regression analysis is used to obtain closed-form equations

MFG/PS

Production Simulation in SIMIO

Model the **manufacturing steps and processes** involved for the design and materials considered and **estimate manufacturing processing times** and costs

Due to public availability the production line was modeled after that of LTV's Multiple Launch Rocket System (MLRS®)[1]

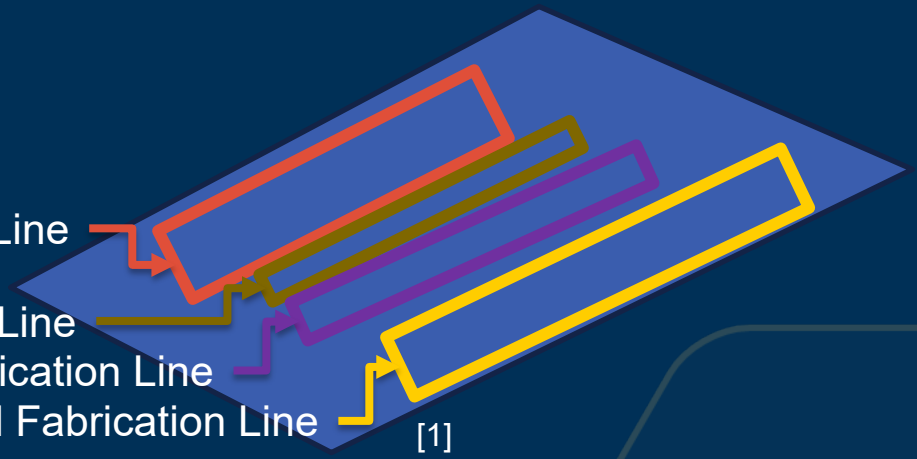
- Production of missile pods
- Assemble of missile boxes
- Armament Loading

The simulation consists of 65 inputs

- Number of machines
- Production times
- Part Quality
- Delivery Delays
- Stockpiles

Assumptions

- The queue for each manufacturing step can be very large (for most setups it hasn't gotten over 10)
- There are always enough workers for the shifts
- The machines don't break



[1]

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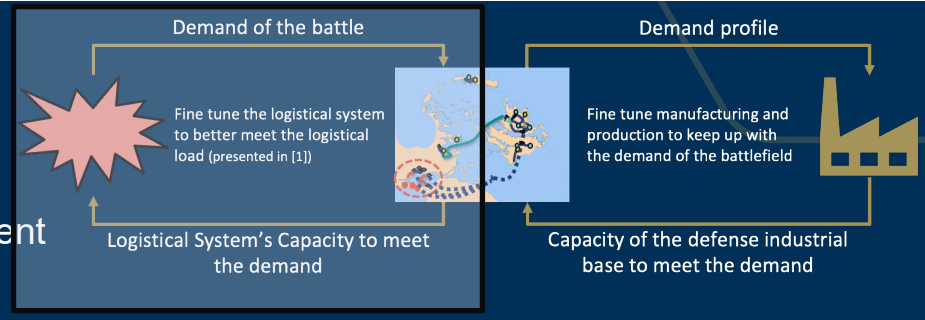
[1] Available online at https://www.youtube.com/watch?v=NYRNjghl61U. Accessed 6 May 2025.
[2] Available online at https://www.dvidshub.net/image/9118561/41st-fab-conducts-unloading-and-loading-procedures-during-saber-guardian-25. Accessed 27 Apr 2026.
The appearance of U.S. Department of Defense (DoW) visual information does not imply or constitute DoW endorsement.
MLRS is a trademark of Lockheed Martin Corporation.

Logistics Impact Assessment

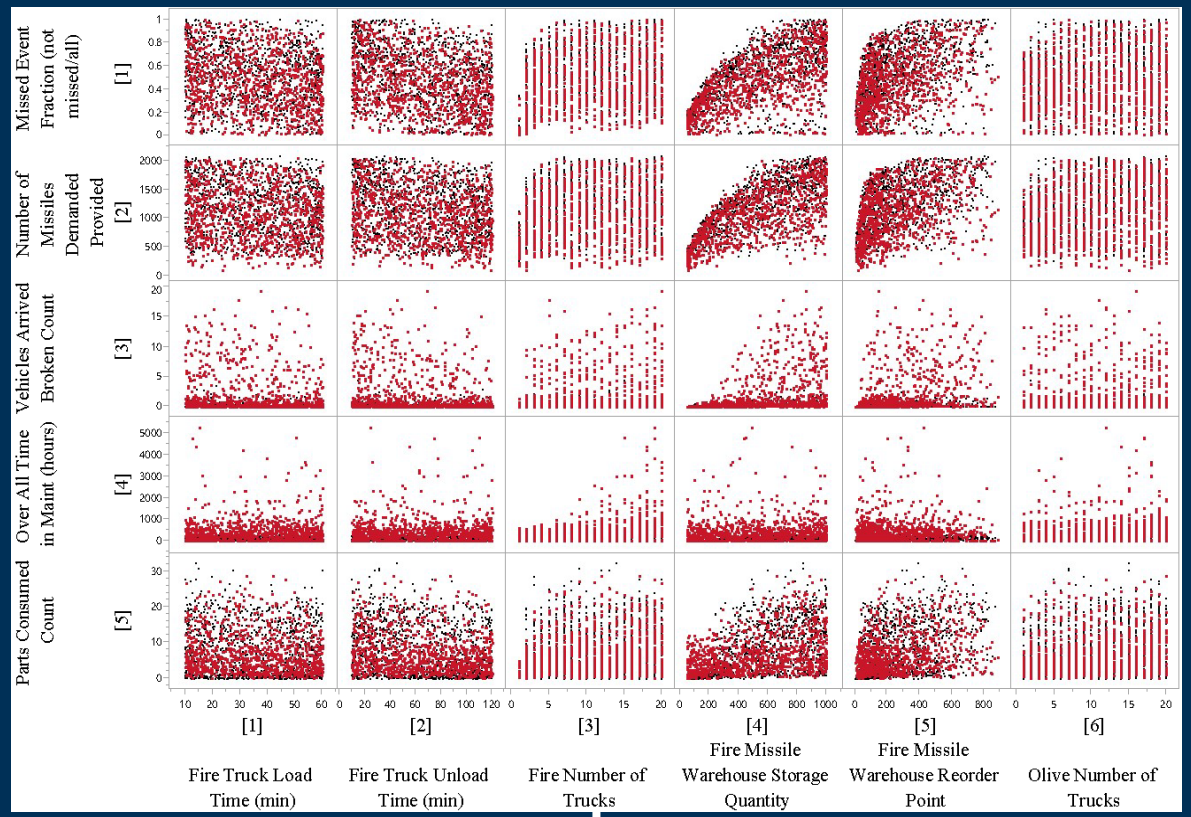


To investigate the impact on operational requirements, the M&S environment is run for different engagement conditions

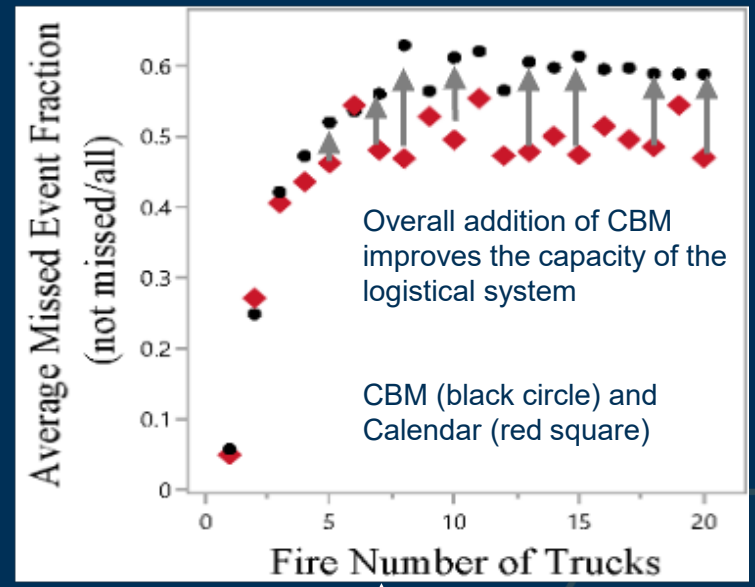
- Continuous Battle – prolonged low intensity ← The Results that are shown
- Intermittent Peak Demand – overwhelming in short bursts
- Continuous Battle+Intermittent Peak – combination of the above two

The battle is not simulated, but the expenditure is simulated with timed-events

- Time Interval(hours): N(7,1)
- Number of Missiles per Event: N(10,3)
- A DOE that varied vehicle design factors (load/unload times etc.) and resource distribution was generated



- **Saturation points exist** for number of trucks and storage levels
- In general, **Calendar-based maintenance causes vehicle to spend more time in maintenance** and more truck arrive broken



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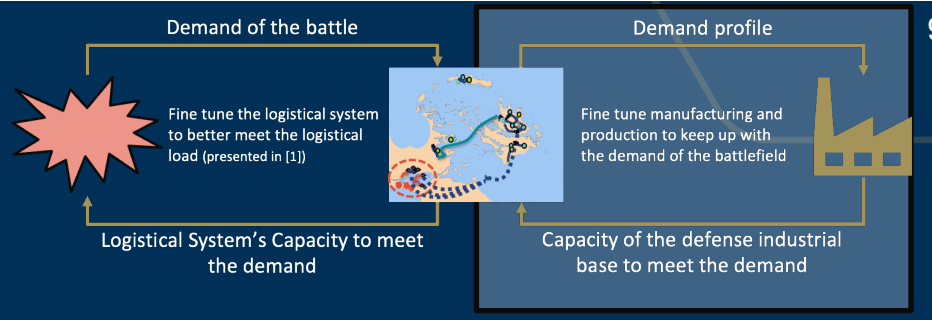
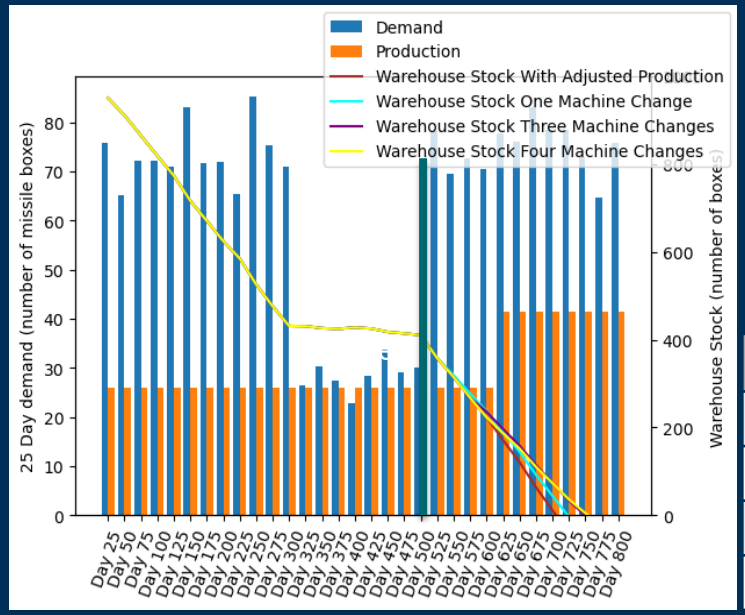
Detailed results discussed in: Birbasov, N. S., Wang, P., Cimtalay, S., Pinon-Fischer, O. J., Balchanos, M. G., & Mavris, D. (2025). A Modeling and Simulation Environment for the Quantitative Assessment of Operational and Technological Improvements in Military Logistics. In *AIAA SCITECH 2025 Forum* (p. 0708).

Manufacturing/Production Impact Assessment



- Evaluate ability of production facility to **meet demand profile for any specific scenarios of interest**
- Identify changes (e.g., change in number of manufacturing assets) to be made on the factory floor to **align production capacity with demand**
- Assess the impact of lead time on our ability to **meet an anticipated production rate**



Expenditure is simulated with timed-events in 3 stages
Time Interval (hours): **N(7,1); N(8,1); N(7,1)**
Missiles per Event: **N(10,3); N(4,1); N(10,3)**

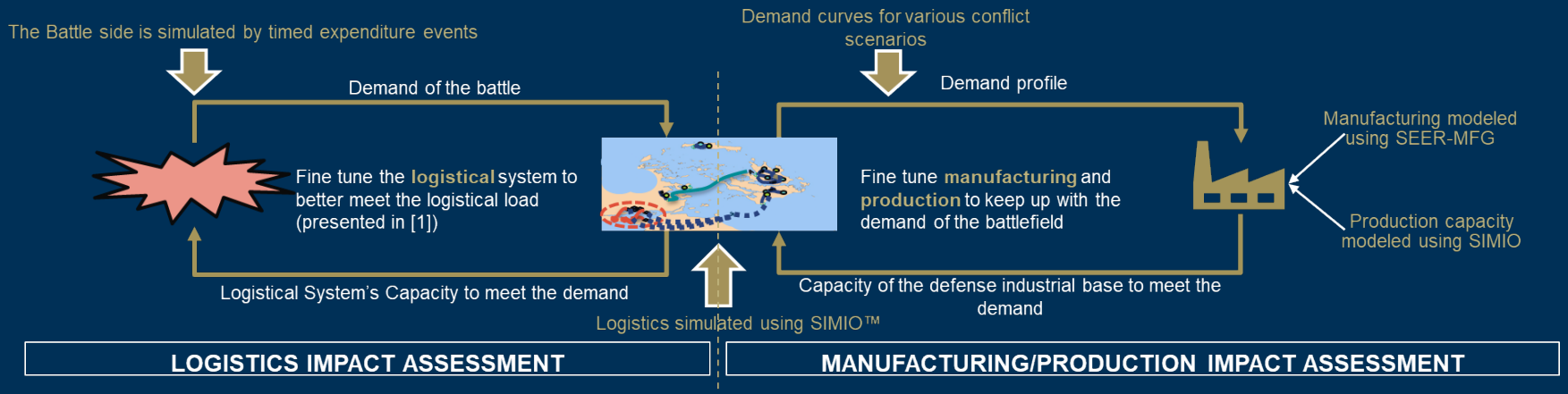
Assume that a change to manufacturing floor takes 25 days
With the given mission constraint and time to implement the changes, it would be impossible to fully meet the demand of the mission → **The time until stock runs out** can **be extended by implementing 4 changes**

Number of Changes to Factory Floor	Throughput Deficit (%)
1	27 %
3	15.6 %
4	13.76 %
6	15.27%

	Missile box made Response			Missile pods made Response		
Predictor	Contribution	Portion	Rank	Contribution	Portion	Rank
Filament Winding Number of Machines	915999	0.2612	1	48767684	0.2553	1
Drill machines Number of Machines	761031	0.2170	2	41384490	0.2166	2
Trimming Machines Number of Machines	748562	0.2135	3	40306383	0.2110	3
Mandrel Extraction Number of Machines	681230	0.1943	4	39552679	0.2070	4
Heat cure capacity	194383	0.0554	5	10002908	0.0524	5
Post Heat cure capacity	164301	0.0469	6	9438305.9	0.0494	6

Summary

- Developed an approach to **defense manufacturing planning** by combining process simulation, surrogate modeling, and MBSE-driven verification.
- The environment enables **rapid prototyping of factory configurations**, **identification of critical bottlenecks**, and **evaluation of response strategies** under **uncertain demand conditions**



Avenues for Future Work

- Relax some of the current simplifying assumptions
- Introduce greater granularity in the production model (e.g., include work shifts, material types, and part geometries)
- Explore the capacity of existing manufacturing facilities and supply chains to accommodate new or increased demand without adversely affecting ongoing high-priority operations.

Acknowledgement

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