AI-enabled Logistics Intelligent Decision Support (A-LIDS)

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ABSTRACT

The goal of AI-enabled Logistics Decision Support (A-LIDS) is to enable operational commanders with informed logistics decision making for command and control of crewed and autonomous resupply operations. A-LIDS leverages AI models, trained on simulation generated data lakes and future fleet wide data streams, to enhance the commander's ability to observe and orient to both the existing situation and future battlefield conditions. A-LIDS relies on statistical techniques and AI services for decision support that:

- *Provide overall readiness measures across all classes of supply*
- *Tracks and predicts key measures of effectiveness*
- *Provides LogScores: a comparative evaluation of logistics courses of action*

Training effective AI for A-LIDS relies on data from many warfighting situations and platforms. To capture the logistics posture, data must be both broad and deep, capturing not just individual unit actions, but the entire logistics chain. To model the future fight, we train the AI using synthetic data from a U.S. Army validated simulation. This simulation exceeds the limitations of data quality not currently available in the real world. The A-LIDS dashboards provide improved situational awareness through recommendations, predictions, and optimizations. The intent is to stimulate autonomy, reduce cognitive load of commanders, and improve mission success.
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1.0 MILITARY PROBLEM STATEMENT

Providing continuous and timely sustainment to the force will become more challenging on the modern battlefield. Secure and reliable networks will pass data to allow sustainment team to accurately monitor consumption of all classes of supply and conduct predictive analysis using AI, while robotic vehicles deliver diagnostic support to the point of need, enabling the Army, Joint, and Combined Force to continue combat operations with little or no delay. Additionally, medical providers must be able to anticipate the time and location that casualties will likely occur so critical treatment assets can be staged to facilitate the collection, triage, treatment, and evacuation of casualties.

Currently, during mission planning, operational commanders often do not have full awareness of platform readiness. As complexity of mission increases, so does the courses of actions (COA). Operational commanders are often tasked with assimilating multiple sources of information to decipher which COA is most viable. In addition, supply chains supporting joint operations do not always have full visibility of current and predicted mission needs. Thus, commanders often are not able to appropriately preposition assets where needed. In summary, there is a recognized need for next generation automated Sustainment Decision Support.

2.0 TECHNOLOGY DESCRIPTION

Our approach will focus on the development and refinement of an AI-driven Logistics Intelligent Decision Support (A-LIDS) system shown at the centre of Figure 1. Our approach integrates validated wargaming methods, advanced analytics, and AI/ML decision tools to enhance logistics and sustainment decisions and predict outcomes of various courses of action (COAs), based on the logistics posture of the force. The first series of learning experiments will focus on the future state for accelerated fires.

There are two primary user classes for the A-LIDS solution. First, A-LIDS enables operational commanders to make command and control decisions that are informed by real time and projected logistics/readiness postures and capabilities of the force by incorporating logistics constraints/capabilities into their battle management Command and Control systems. This inclusion of logistics intelligence and awareness will speed the commander's decision timelines by enhancing his/her ability to Observe and Orient to both the existing situation on the battlefield as well as future conditions based on the current state and decisions. Second, A-LIDS aims to provide advanced decision aids to logistics commanders to accelerate and improve their decision-making capabilities to proactively maximize logistics and sustainment capabilities to support combat operations.

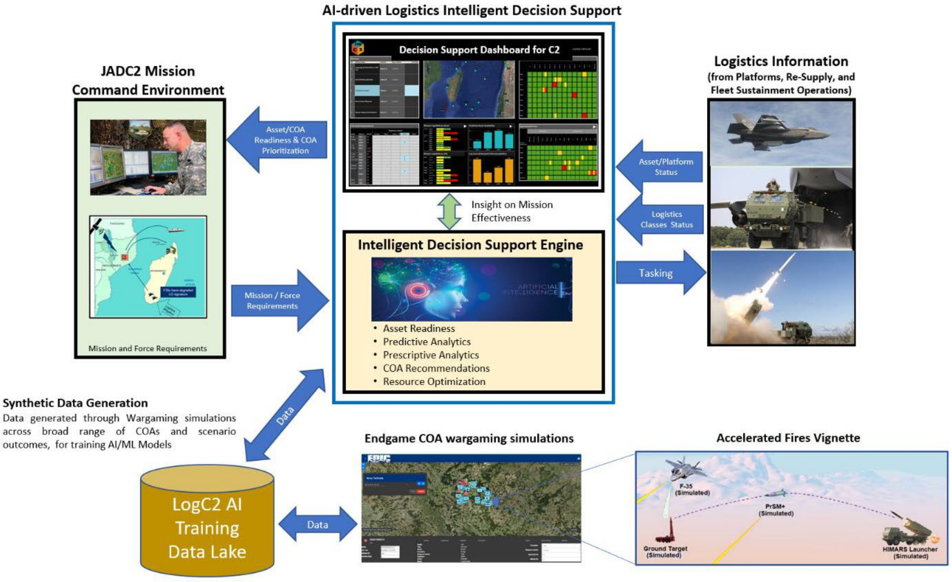

Figure 1 – AI-driven Logistics Intelligent Decision Support (A-LIDS) System Architecture

To build training models accurately and effectively, there is a definite need for data encompassing potentials scenarios and outcomes. In the absence of real-world operational data for the future fight, we plan to leverage synthetic data generated using a suite of simulation tools Lockheed Martin is investigating for a Future Constructive simulation capability.

This evolving collection of simulation tools are identified by Lockheed Martin as Endgame, which consists of;

1) Army validated Warfighter Simulation (WARSIM) to represent the ground maneuver and combat, and combat support of future Army force structures,
2) web-based interface for the Battle Staff Trainer (EPIC) to plan, prepare, execute and assess scenarios and Order of Battle (ORBAT)
3) high fidelity engineering models for key enabling platforms for future accelerated fires scenarios (such as the F-35, PrSM, and HIMARS), as add-ons to WARSIM or the simulation environment

Leveraging Endgame for synthetic data generation will allow training of AI models in A-LIDS to provide intelligent decision support services such as predictive and prescriptive logistics recommendations, projected asset readiness, and course of action confidence ratings. Endgame will be used for modeling mission scenario execution as well as generating the logistic information reports and combat unit assessments such as attrition, casualty assessment, asset failures and repair delays for a range of specific simulation runs based on identified Courses Of Action.

The Training Data Lake will be generated over multiple (hundreds or thousands of) simulation runs in order to provide a meaningful dataset upon which to train AI models. Specific measures and rule sets will be utilized to train the initial models through supervised and unsupervised learning techniques, benchmarked against minimum confidence levels. Once trained, the models will be converted to a number of LogC2 decision support services within an Intelligent Decision Support Engine, to be tested in a simulated decision environment. Lockheed Martin will request the participation of Army Logistics subject matter experts to participate in the desktop analysis of both measures and verification testing.

Once the rule sets and confidence levels are verified, the A-LIDS Decision Support Dashboard will be used to validate the effectiveness of A-LIDS against sample scenarios. Ultimately (and if successful), we envisage A-LIDS ingesting real time situational awareness and joint logistics posture to continuously provide accurate sustainment decision support and recommend the best course of action that is most logistically sound.

3.0 CONCEPT OF EMPLOYMENT

This project will focus on the ability to access and intelligently fuse data from multiple sources (supply chain, personnel, maintenance, equipment status, etc.) real or synthetic to provide situational awareness, decision making, and predictive intelligence based on logistics and sustainment postures. The demonstration focuses on the ability to link the data sources and decision tools to provide Logistics Command and Control "speed of relevance" insights to aid commanders and staff to take better decisions in a contested environment.

Our goal for the A-LIDS System to provide actionable situational awareness for the Joint all-domain operation commanders. A few examples are as follows:

- Theater-wide knowledge of current and projected Asset readiness and logistics posture
- Integration with the Commander's C2 to inform/enlighten combat operations
- Operational/strategic level maintenance decisions to maintain or restore combat readiness
- Forecast sustainment needs to maintain/anticipate operational pace
- Dynamically position inventories to minimize response times and minimize/reduce risk
- Plan intra-theater transportation and distribution

Consolidating these and related capabilities in support of JADC2 is a challenging endeavor. For purpose of the Project Convergence 22, we will focus on testing, integrating, and demonstrating novel AI-based capabilities of Logistics Intelligence Decision Support that fuses and matches predictive asset readiness & availability to evolving mission needs. The next few paragraphs briefly introduce the visualization concepts to be tested and then explains the underlying asset to mission matching.

A-LIDS Dashboard: As previously mentioned, A-LIDS strives to provide insight about the current and future readiness of key military equipment relative to evolving mission intent. Figure 2 illustrates an aspect of the insight visualization concept we want to provide in contested logistics scenarios. The Dashboard would allow commanders to see current and predicted readiness of forces at multiple echelons – COA readiness, Asset readiness, Logistics class readiness and Parts availability. It would also provide commanders with various types of COA analysis such as (a) Current status and locations of assets needed by the COAs (b) Predicted time when all assets needed by a COA will be ready to engage (c) Logistic impact of running a COA on logistics classes including supply, fuel, manning (d) Provide a time sensitive Logistics score for each COA that reflects its viability of a logistics point of view, taking into account the status of logistics classes and predicted readiness of assets.

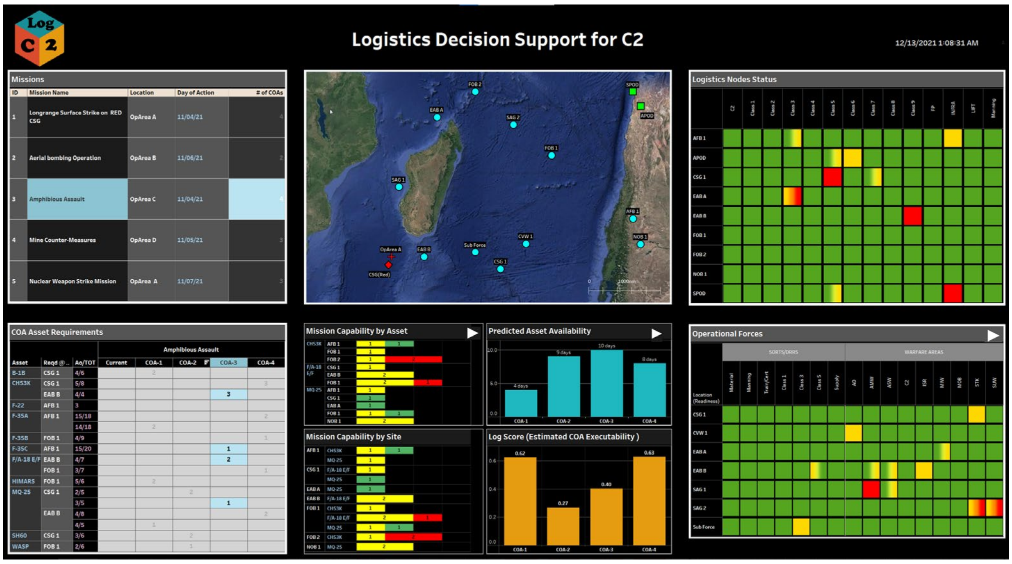

Figure 2 - Prototype A-LIDS Dashboard that provides decision support

Asset Readiness Prediction: Obtaining an accurate estimate of current equipment readiness is a technical challenge alone because mission readiness can be driven by supply or maintenance issues and future readiness requires predictive modeling of both equipment and logistics/supply chain health. A contested logistics environment additionally challenges the efficacy and resiliency in the predictions to evolving mission matching. Figure 3 shows a prototype instance of the Readiness Prediction within A-LIDS for a Sikorsky rotorcraft that is predicting unscheduled maintenance drivers within a time horizon based on estimated future usage (e.g. mission type) so the aircraft with the highest readiness for the mission can be selected or targeted mitigating action can be prioritized. This prediction is accomplished with a fusion of dynamic Neural Network-based classifiers and survival models at the key component level. If near real-time equipment health data (e.g. fault codes) or future mission types change, the estimates change accordingly.

Aircraft

Aircraft Id	Position All
162497	87.013%
162503	93.702%
162504	89.184%
162507	92.431%
162508	91.429%
162510	90.406%
162513	72.657%
162516	73.413%
163052	89.663%
163054	88.284%
163055	90.798%
163056	86.471%
163057	73.413%
163065	92.596%
163066	92.992%
163067	90.352%
163069	93.323%
164764	91.211%
164765	91.092%
164766	91.701%
164767	90.354%

Chance of Unscheduled Mx in Next 150 Hours

Aircraft Id	Nomenclature	1	2	3
162497	Damper	18.085%	14.582%	12.079%
	Main Gearbox	28.443%		
	Main Rotor Blade	4.753%	4.753%	4.753%
	Tail Gearbox	19.410%		
	Tail Rotor Blade	3.659%	3.659%	3.659%
162503	Damper	21.596%	21.596%	18.202%
	Main Gearbox	28.393%		
	Main Rotor Blade	5.531%	5.531%	5.531%
	Tail Gearbox	22.287%		
	Tail Rotor Blade	3.198%	3.940%	3.940%
162504	Damper	15.306%	21.596%	10.125%
	Main Gearbox	27.703%		
	Main Rotor Blade	5.427%	4.886%	5.427%
	Tail Gearbox	13.261%		
	Tail Rotor Blade	3.683%	3.683%	3.683%
162507	Damper	18.118%	18.267%	18.267%
	Main Gearbox	28.335%		
	Main Rotor Blade	5.597%	5.597%	5.597%
	Tail Gearbox	16.917%		
	Tail Rotor Blade	4.111%	4.111%	4.111%
162508	Damper	21.596%	20.549%	12.514%
	Main Gearbox	28.186%		
	Main Rotor Blade	5.479%	5.072%	5.072%
	Tail Gearbox	15.985%		
	Tail Rotor Blade	2.647%	2.647%	2.647%
162510	Damper	21.197%	14.850%	19.381%
	Main Gearbox	28.114%		
	Main Rotor Blade	5.493%	5.493%	5.493%

Figure 3. Asset Readiness Prediction

Parts Survivability Analysis: We will also leverage one of our recent IRAD on Predictive AI for Supply and Sustainment to accurately predict parts demand, so that Operational commanders can preposition the right parts in the right place at the right time. This IRAD focused on using Machine Learning models and Statistical algorithms for predicting parts survivability while taking into account several operational and weather factors that may have had an impact on the part's life. We were able to demonstrate the variability of survival curves under the influence of varying operational and weather conditions. We plan to leverage this work and extend it to predicting part demands in a contested environment.

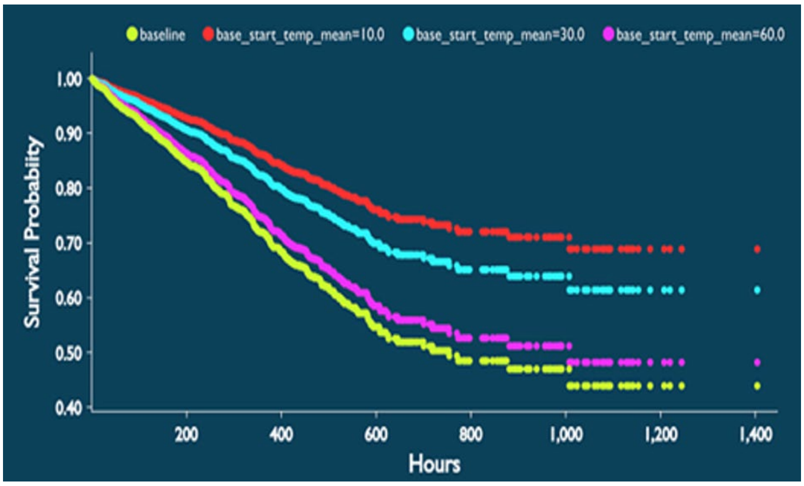

Figure 4. Effect of varying temperature on Survival Curves

Synthetic Data Generation using Endgame: These capabilities will require a significant amount of data to demonstrate their full potential. Endgame includes WARSIM which will be used to augment real platform and logistics data to help introduce additional scenarios and constraints that could result in alternate logistic courses of action. WARSIM's unique aggregate-entity design provides the detailed modelling down to the individual vehicle level necessary to train the Commander and staff while providing the aggregate-level modelling for larger Brigade and Division scenarios (Figure 5).

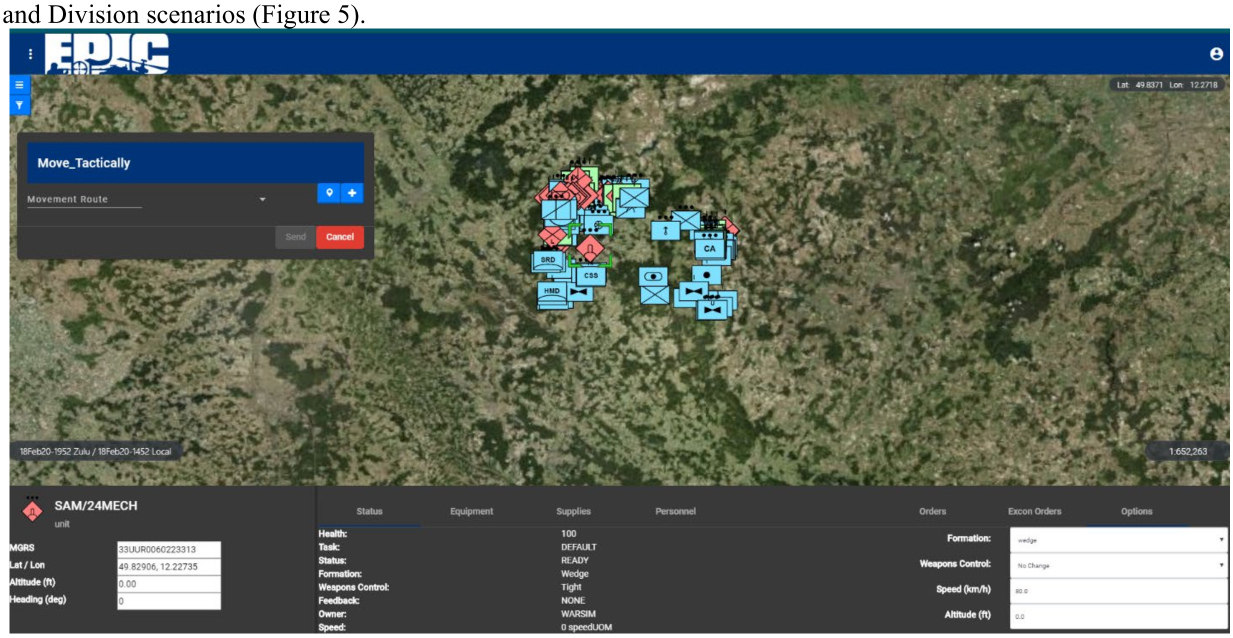

Figure 5. ENDGAME will be based on Army validated models of WARSIM and the EPIC User Interface

WARSIM also models supply of food, water, fuel, engineering supplies, ammunition, major end items (platforms), medical treatment supplies, and maintenance repair parts. Supplies are explicitly tracked and can be loaded on transports, moved on transports, unloaded, established in caches, and consumed. Supplies are subject to attrition based on their actual location (what platform they were loaded on). Damage can be increased with the attrition of fuel or ammunition. Personnel are loaded, transported, and unloaded on specific platforms for the purposes of transportation. All these capabilities allow detailed tracking of who and what are on all the transports in the battlespace, allowing detailed logistics tracking. In addition, this level of detail allows the WARSIM model to be easily linked to detailed entity level models representing future fighting capabilities. Lockheed Martin has more specific engineering models and simulations which represent air and surface assets.

4.0 TECHNOLOGY MATURITY

The current decision tool framework and tools that will be used for A-LIDS are TRL 4 and have been developed under Lockheed Martin IRAD projects such as JADO BMC2 (Battle Management Command and Control) to support Log C2 capability integration with JADO modelling. We will also be leveraging a recent IRAD on Predictive AI for Supply and Sustainment. This IRAD attained TRL 6. Endgame includes WARSIM and EPIC which are currently fielded for battle staff training globally (TRL 10). WARSIM which has been the backbone of single service and Joint constructive simulation exercises and experiments for more than 15 years.

5.0 MUTI-DOMAIN OPERATIONAL ENVIRONMENT

Mission Thread: Conduct Joint Sustainment Operations
The mission thread will include US Army, US Air Force, US Marine Corps, and Coalition partner (Australian Army) components participating in simulated Joint Sustainment Operations, providing combat support including resupply.
Use Case: Sustain Dispersed Forces Along LOCs in Contested Environment
The use case will incorporate a strategic fires battalion employing advanced warfighting capabilities such as PrSM employed against a near peer threat.

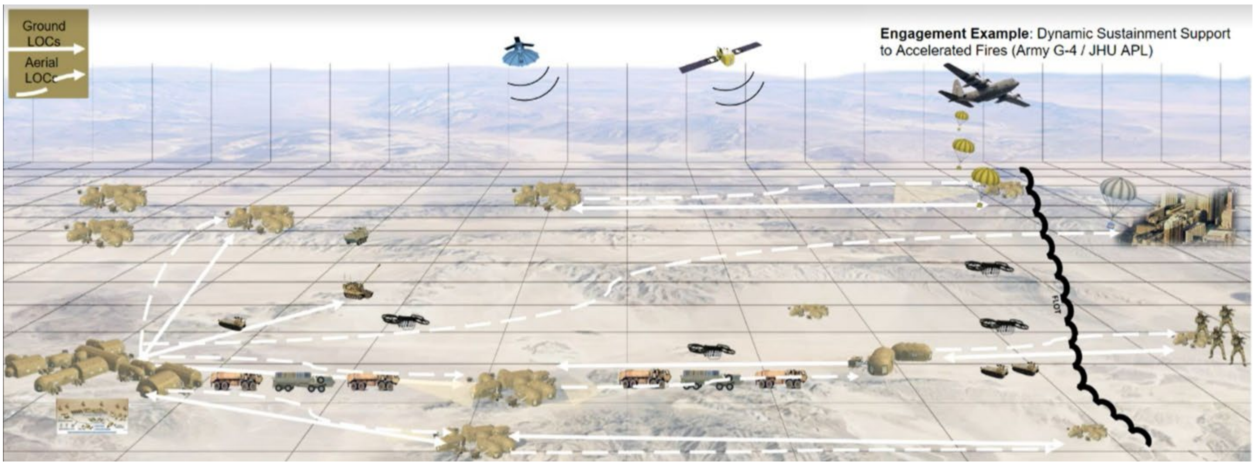

Figure 5. Engagement Scenario: Dynamic Sustainment Support to Accelerated Fires (Army G-4 / JHU APL)

The engagement scenario will consist of supporting fires to Coalition ground forces, utilizing Joint assets to perform both targeting and resupply tasks. The scenario will include the option to conduct manned and/or unmanned resupply operations.
+ Area of Influence:

The A-LIDS experiment will focus on elements of combat support across all three areas;

- Strategic Support Area
- Operational Support Area
- Tactical Support Area

+ MDO phase supported:
The mission thread is relevant to all MDO phases of operation;

- Compete
- Penetrate
- Disintegrate
- Exploit

+ MDO Tasks addressed:
While the accelerated fires scenarios will incorporate many or all of the MDO tasks;

- Stimulate
- See
- Strike
- Move
- Communicate
- Decide
- Sustain

the objective of the A-LIDS experiment is to investigate the suitability of this technology to enhancing Decide and Sustain tasks.