NBS Enterprises
IT Services, Predictive Analytics, Optimization & Decision Support

DYNAMIC COMMAND AND CONTROL AND MULT-VARIABLE ANALYSIS OF AUTONOMOUS SYSTEMS

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DYNAMIC COMMAND AND CONTROL AND MULTIVARIABLE ANALYSIS OF AUTONOMOUS SYSTEMS

1.0 Operational Concept

Dynamic command and control of multiple battlefield systems requires automation and optimization. Decision support during pre-mission planning and execution expedites battlefield readiness and efficiencies. The intents are to:

a) Integrate representations of robotic and autonomous systems (RAS) with those of tactical units in order to compute a comprehensive mission plan.

b) Implement automation and optimization algorithms to assist with dynamic command and control.

c) Estimate future events and requirements of evolving missions.

The payoff and impact of automation and optimization is the reduction of mission planning time: It allows commanders to task/re-task resources within their mission command systems, and to reduce cognitive burden. They support force reduction by providing useful tools to mission command teams of manned and unmanned systems.

Further, optimization tools applied to the graphical representations of a mission produce greater battlefield and intelligence gathering efficiencies.

NBS Enterprises (NBS) is active with the US military in the research and development of common operating environments and the modeling and optimization of autonomous system deployments.

2.0 Objectives and Impact

a) **Objective 1:** Implement a hierarchical system that assists with pre-mission planning, execution, and prediction during mission evolution.

Objective 2: A spectrum of predictive analytics and deep learning algorithms are to be integrated with the NBS physical network tool suite, prototyped and tested. The composite software will encapsulate big data, impact upon planning, predict enemy activity and enhance intelligence gathering with self-organizing systems. An eventual integration with a common operating environment is envisioned.

b) **Issue:** Current processes and technology hinder a commander and staff's ability to manage large-scale autonomous system deployments and to rapidly develop and execute courses of action in response to threat conditions.

c) **Enhancement:** An automated approach minimizes the times to plan and configure/ reconfigure assets before and during mission execution.

d) **Impact:** The payoffs and impact of automation and optimization support are the reduction of mission planning time and the increased accuracy of decisions.

e) **Users:** The U.S. Military and commercial enterprises are searching for automated techniques to support dynamic command and control.

f) **Measures:** Measures of success are accuracy of results, ease of use and rapid computations of optimal resource assignments prior to and during the course of battle.

g) **Risk:** Because proofs of concept have been provided for many automation algorithms, risk for decision support is minimal.

3.0 Location Concepts

NBS has conducted studies and analysis of location optimization for a relay locator, a routing planner, a robotic mine, a ground based GPS system, and other use cases.

a) **Dynamically Optimized Net-Centric Connectivity**: A mobile relay operates within the midst of 20-50 radios and provides a way station for communications between mobile radios. Previous military analysis has shown that rather than transmitting messages point-to-point between radios, transmissions to a robotic relay improves communications performance. After applying NBS algorithms, the relay is positioned optimally such that successful communications probabilities are maximized. New solutions are computed in near real-time as tactical units change positions.

   After positioning a relay, the optimal paths of tactical units as they move to new locations are also computed. Selected paths are impacted upon by communications, terrain and threat.

b) **Dynamically Optimized Munitions Support:** A Mine System exists that is a man-portable, remotely controlled and command-able, man-in-the-loop, force protection and area denial munition. The mines change their locations as a deterrent mission progresses and require continuous optimality computations for effective communications and enemy destruction.

c) **Dynamically Optimized Navigation Support:** Mobile radios provide a GPS-like signal that can be used by military GPS receivers.

As many as 35 GPS fixed, ground and aerial vehicular transmitters may be available and active during a mission. They are used in order to maximize the GPS Position, Navigation and Timing (PNT) availability and location accuracy provided to tactical users given a potential jamming of GPS signals in a given area of operation. Since the users are constantly on the move, as are potential jammers, the ground and aerial vehicular transmitters require tasking to move and transmit in a manner that optimizes their potential utility to the tactical users.

d) **Dynamically Optimized Robotics Autonomy:** Research is ongoing to coordinate humans and autonomous systems in the battlefield.

e) **Cut-Set Algorithms:** Cut-set algorithms position detection devices in a complex road network so that, given that the detectors are capable of sensing a target such as fissionable material, no enemy can pass through the network without being identified. Compared to manual placements, the algorithms reduce the number of required detectors by more than a magnitude.

f) **Dynamic Communications:** The dynamic communications scheduler routes messages through a network so that response times are minimized. As message traffic is modified during operations, the algorithms produce new routing solutions almost immediately.

4.0 Assignment Concepts

Assignment algorithms optimally direct aircraft/ ground vehicles to areas of interest. Missions comprise logistics, persistent surveillance and weapon-target pairing. All aircraft/ ground vehicle routes, both manned and unmanned, are optimized in the planning stage. If during mission execution; asynchronous events occur such as aircraft destruction, detection of SAM sites or siting of oncoming enemy aircraft; friendly route assignments are reconfigured in near real-time.

a) **Persistent Surveillance:** Assign unattended vehicles to areas of interest while considering time of flight and endurance, time on station, sensor performance, environment and desired results.

b) **Weapon-Target Pairing:** Using the information collected from persistent surveillance, assign weapons and platforms to targets of interest.

c) **Battle Damage Assessment:** Report the results of targeting.

d) **Logistics:** In response to rapid requests, distribute supplies to units of operation in the battlefield.

e) **Communications:** Manage communications in the battlefield while considering information requirements, optimal routing, destructions and failures.

f) **Maintenance:** Coordinate scheduled and asynchronous maintenance so that overall mission effectiveness is maximized.

g) **Sensor Selections:** Select the best of available sensors for use during a mission of interest.

h) **Weapon Selections:** Select the best weapons for a mission objective.

i) **Additional Mission Support:** Address other missions such as rescue, medevac and troop deployment.

j) **Mission planning:** Synchronize logistics support and tactical assets to justify that a mission is possible.

k) **Battlefield Command and Control:** Provide decision support for commanders in the battlefield.

l) **Response to Detection:** Transition the resources from an objective of detection to an interdiction requirement.

5.0 Current Military Applications

A set of automation and optimization models and algorithms has been integrated with a common operating environment (COE).

a) Currently, optimization algorithms for a ground-based GPS system are integrated with simulators, and electronic jamming and terrain representations.
b) COE data, which represents a battlefield qualitatively, are mapped automatically to context models of a tactical mission. The models, when exercised, produce quantitative results for GPS radio selections from all those available to compute information.
c) The performances of multiple entities and their interactions with each other are computed simultaneously. The value and tradeoffs of every entity are displayed.
d) The optimization results are computed in near real-time. As the users in the battlefield change positions, new locations of the GPS radios are made available almost immediately. The computational speed, accuracy and the capability to scale up to hundreds of entity locations differentiates NBS algorithms from other approaches.
e) A comprehensive paradigm for applications has been developed and tested.

6.0 Hierarchical Decision Support

A major portion of military research is directed to the study of dynamic command and control for autonomous systems.

The provision of optimization and automation requires novel techniques not currently ingrained in decision support for tactical systems. Predictive analytics and deep learning are those techniques that transition dashboards to models conducive to multi-variable analysis.

Machine learning's task is to find patterns that appear not only in the data at hand, but in general, so that what is learned will hold true in new situations never yet encountered. The capability to generalize is the silver bullet of predictive analytics and deep learning.

Once data are available, the NBS Enterprises (NBS) decision support system (DSS) associates dashboards and provides answers within minutes and second for autonomous systems. Further, NBS has developed a set of optimization algorithms and value analysis techniques, premised upon deep learning, that assist with planning, forecasting and prioritization. Integration of the NBS algorithms with a common operating environment provides a great value addition and a quantitative means for decision support and forecasting. Further, multiple variables for singular technologies are placed in the context of tactical missions so that performance of all entities and their interactions are quantified.

Applications will produce great savings in costs and assessment times necessary for planning without the necessity of basic research.

Three components of decision support assist with mission planning, execution and predictions:

a) Pre-Mission Planning: Once data are available, algorithms compute optimal assignments and locations of autonomous entities in near real-time. Predictions of future events are also computed.
b) Execution: During the course of a mission, optimization algorithms provide reconfigurations of entities which might be required due to failures, jamming, terrain obstacles, destruction or evolving objectives.
c) Prediction: Automation is made available so that a tactical operations center and electronic warfare personnel are able to keep pace with the dynamics of command and control. Multiple autonomous systems, fires, jamming, terrain and deconfliction changing in split seconds might overwhelm analysts using manual techniques. What can be automated should be automated. Predictions are made of future events and the applications of self-organizing systems.

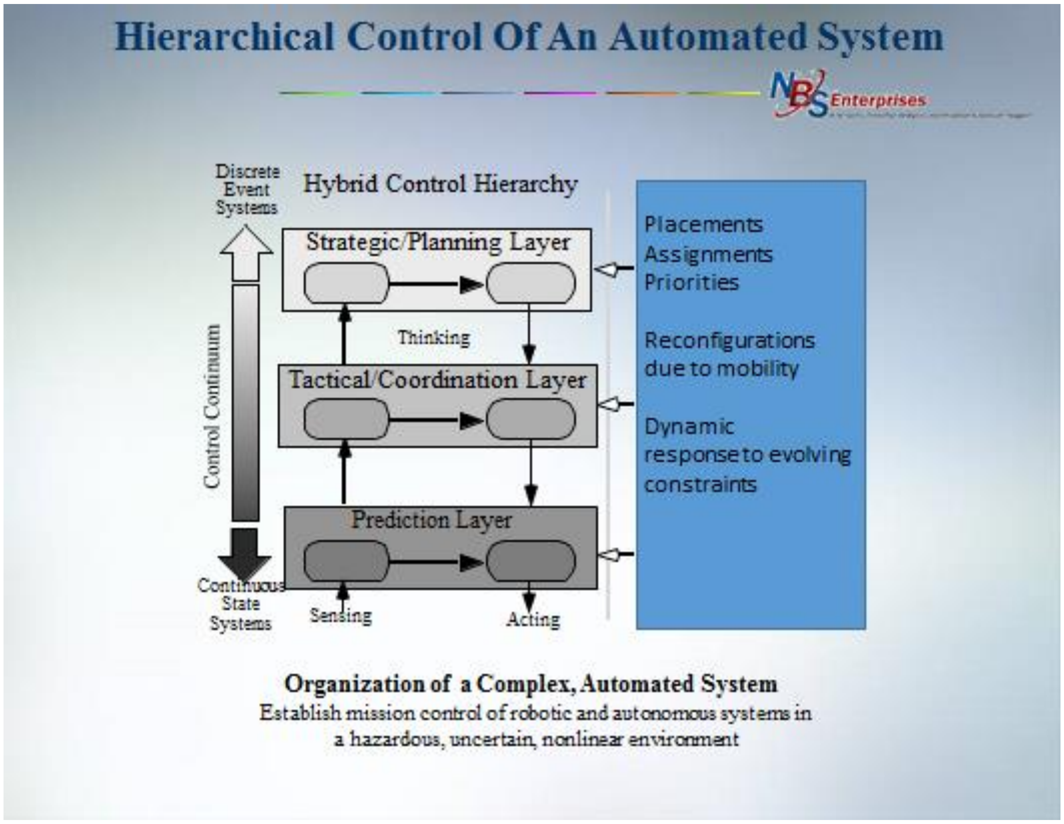

Exhibit 1

Assessments of every domain require a complete analysis of the implantation of automation algorithms that address the three hierarchies of mission applications.

For pre-mission planning, a process complete with assessments and displays provides an understanding of applications throughout the expected progression of a mission. Trade-offs and what-if analysis supplement the process. In response to mission objectives, optimization of placements and assignments are obtained.   .

Predictive analytics and deep learning algorithms are used to estimate the probabilities of future events. Based upon past events and experience, autonomous system requirements are forecast. Rather than simply responding to asynchronous events, planning occurs for likely mission outcomes as well. As the types of autonomous systems expand, the need for forecasting becomes a necessity.

7.0 Context Models

To initiate planning, data are transitioned to performance and optimization models. Each object represented in the data is operated on by metadata. The metadata structure the objects into a format compatible with the development of a semantic net. A set of associations is developed for

all disparate data structures. By inserting quantitative values at each node such as timing of events and distribution functions, the semantic net is transitioned to a performance model. In addition, optimization algorithms are attached. For tactical systems, integration occurs between the context model and automation algorithms with a common operating environment.
The NBS tool suite provides a representation scheme and a means to quantify context models. The backbone of system representation is a general purpose problem solver (GPPS) that employs one network representation for semantic nets, performance computations, learning and value analysis. The forecasting component begins with a general representation, but also accesses a spectrum of predictive analytics and deep learning algorithms. The predictive features have numerous applications. A flow diagram of the NBS methodology to transition from data to models is shown in Exhibit 2.

Flow Diagram for Data Transformations and Optimization and Analyses by the NBS Tool Suite

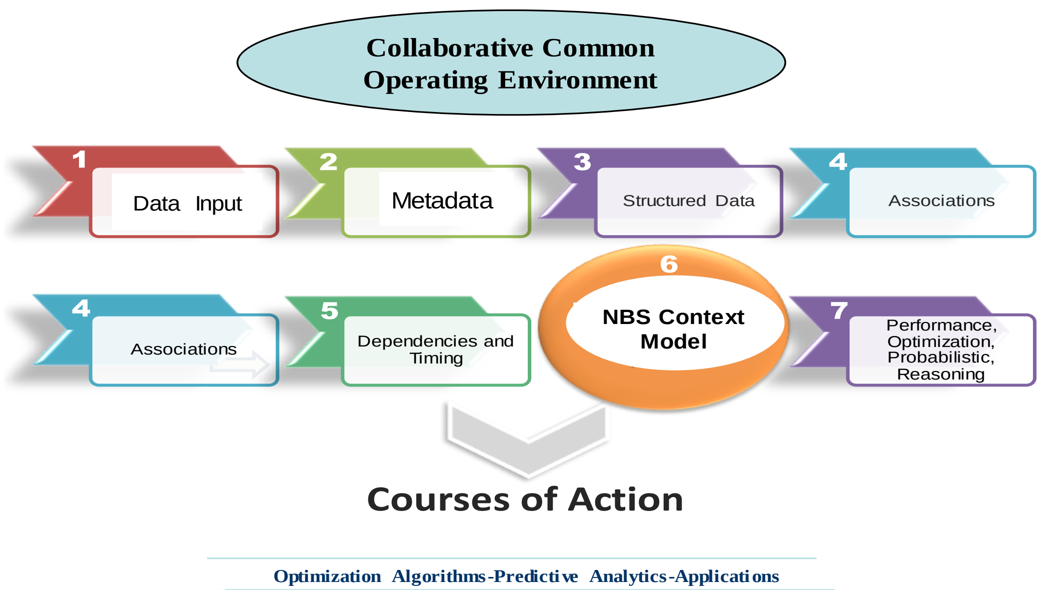

Exhibit 2

Graphics technology, now employed by the intelligence community, represents support that enhances the capability of commanders and staffs to predict resource requirements by integrating joint effects-based operations. Research of automated tools is in progress to assist a commander and staff in areas such as understanding and visualizing the current situation and to forecast battle space.

The intent is to provide a transformational capability to predict resource requirements as a battle progresses. A graphic of the action/ effect approach is shown in Exhibit 3.

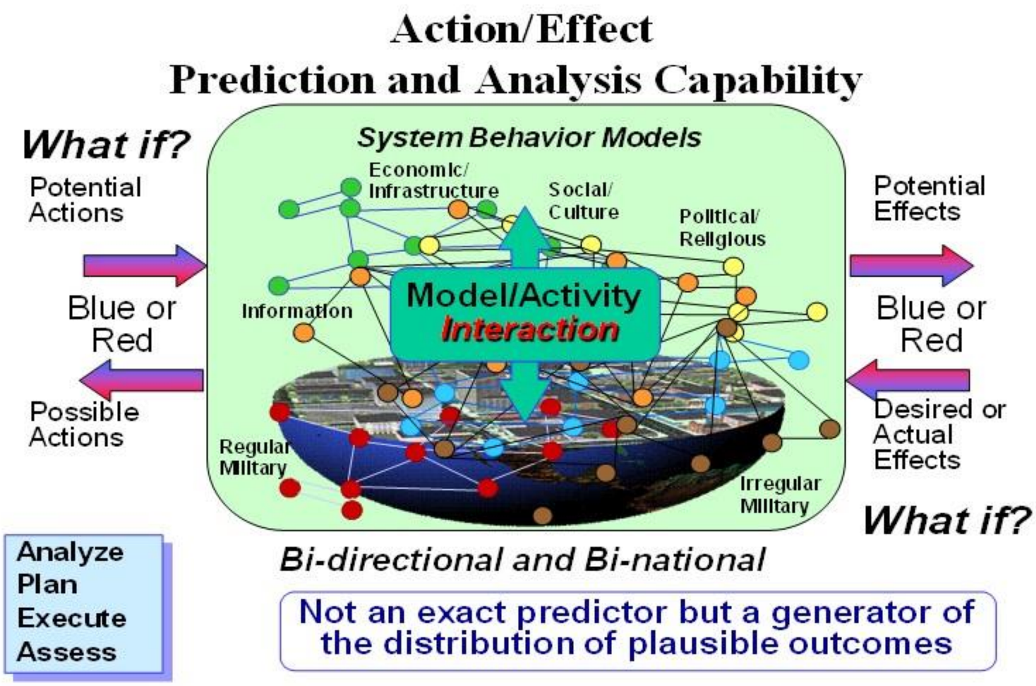

Exhibit 3

For a single or a set of actions, algorithms generate the distribution of plausible outcomes over a spectrum of changing variables. By visualizing these outcomes and collaborating with other users, a commander selects a course of action that achieves his objective without causing undue collateral damage.

The paradigm shift is outlined in Exhibit 4.

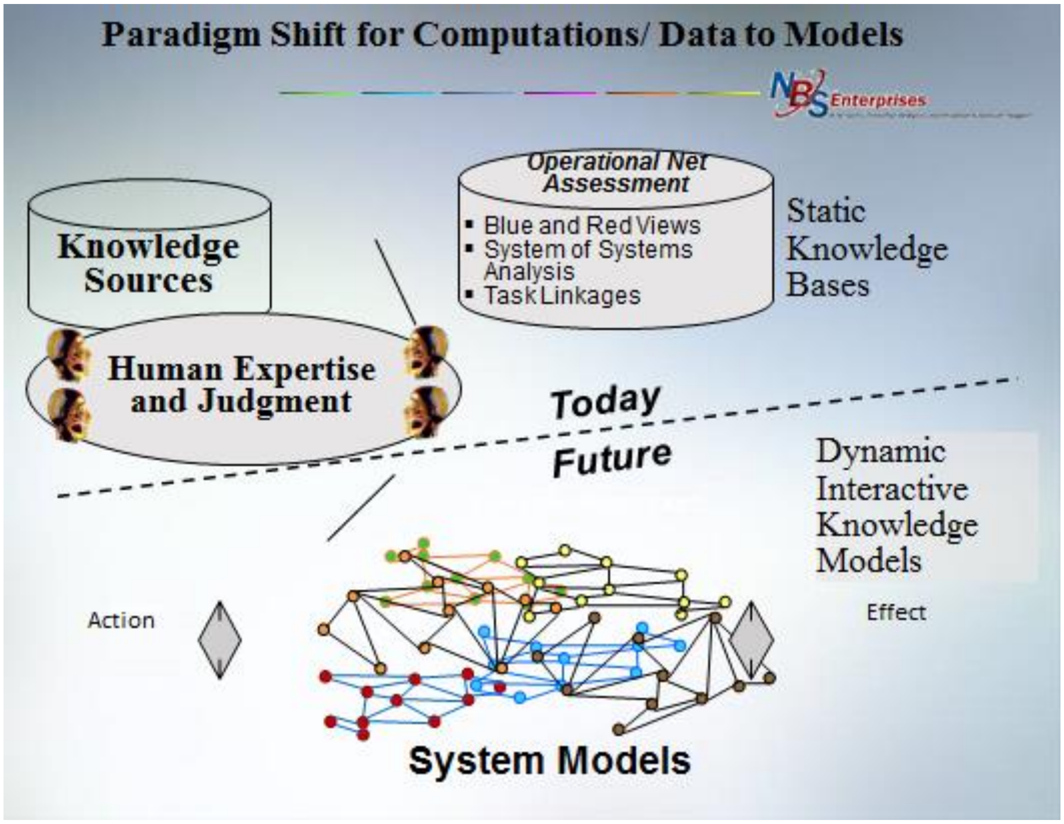

Exhibit 4

8.0 Multi-Variable Analysis

Multi-variable analysis is facilitated by the transition of dashboards to a context model and a further transition of the context model to a neural net.

8.1 Predictive Analytics

In addition to the basic physical network engine/ context modeling, a selection of optimization and predictive analytics algorithms are accessible. Predictive analytics (PA) permit an analyst to forecast future events based upon existing scenario information. It supplements the worth of dashboards. Projections in a dynamic, time-related environment become possible with the PA extensions.

8.2 Deep Learning

In machine learning, when high-level data abstractions are integrated with non-linear processes, deep learning is engaged. Artificial intelligence (AI) has for several years been in the winter of research. With deep learning and the solutions of complex associations, revitalization has occurred. In the world's top research laboratories and universities, the race is on to invent the ultimate learning machines that find books, movies, jobs, and dates for users, manages investments, and discover new drugs. More and more, learnings are obtained from the trails of data people leave in a newly digital world. Like curious children, they observe users, imitate, and experiment by discovering any knowledge from data, and doing anything one wants, before being asked. Deep learning has been applied to the defeat of Jeopardy, chess and Go champions. Similarly, an integration of multi-level neural nets and big data assists with a prediction of enemy behavior or the self-organization of autonomous systems.

5.3 Network Integration

A context model is derived from dashboards and represents lower level tasks of the dashboards and their interrelationships. The context/ network model is further transitioned to a neural net. The transition from a graphical representation to a neural net is shown in Exhibit 5. Input nodes of a neural net represent the variables of a system. Internal nodes are the learning mechanisms of the net. They are connected to the input nodes and the output nodes. Deep learning with neural nets is instigated when more than one layer of internal nodes is inserted in the network. The output nodes converge to the relative worth of each input variable. Through the novel transformation process, every variable represented in a system is ranked quantitatively with respect to every other variable.

Neural nets show great promise for the assessment and predictions of scores of research and development topics. Universities and enterprises such as Google are spending billions of dollars on research and development. The fruits of those labors now can be applied to tactical systems.

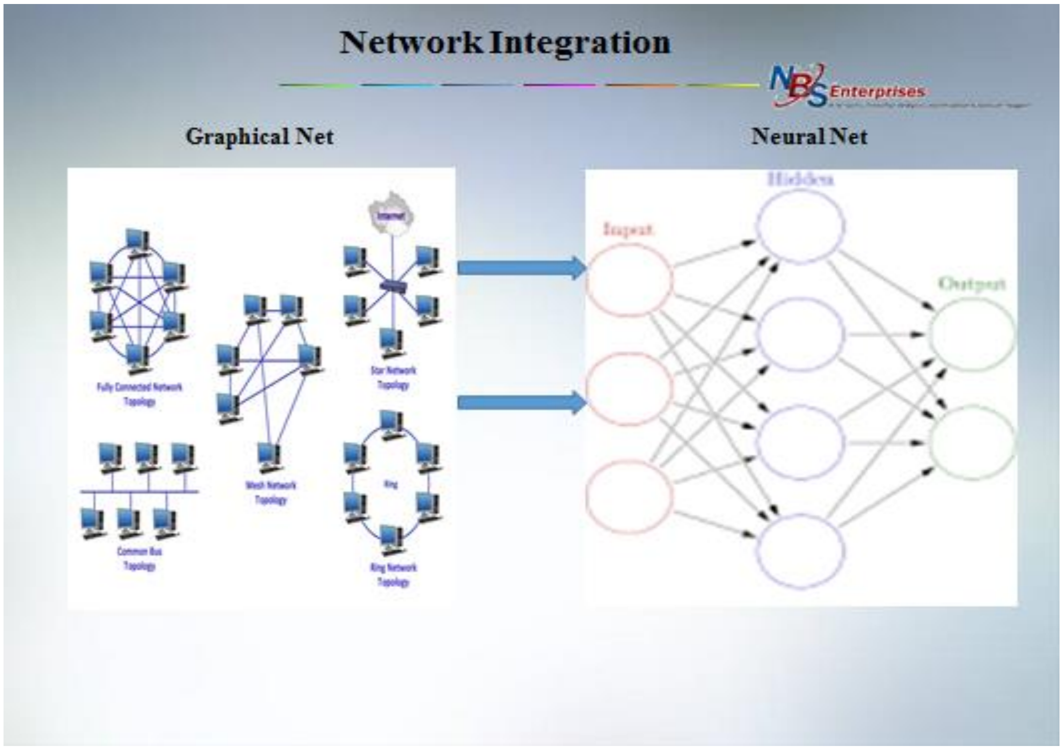
Network Integration
Graphical Net
Neural Net
Hidden
Input
Output

Exhibit 5