TRANSFORMING AVIONICS ARCHITECTURES TO SUPPORT NETWORK CENTRIC WARFARE

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Network Centric Operational Concepts

Network Centric Warfare (NCW) is an illusive concept with different meanings to many different people. It will be applied differently to the many different layers in the military force structure to enable commanders and direct combatants to monopolize information to increase lethality and survivability. The logistics and supply operations will be greatly changed. The primary premise in NCW is the capitalization of information dominance. The ability to share information between battlespace entities is predicated on an infrastructure (infostructure) that enables information flow. The flow of information, the amount, type, and other attributes to be discussed, heavily impact the aviation sector of military operations and acquisition. This paper concentrates on the impact of NCW on avionics architectures and, hopefully, provides insight to the changes required of aircraft systems to fully utilize the NCW tenets. First, definitions of these NCW concepts will be described along with properties of information necessary for Network Centric Operations (NCO). This will set the stage for an understanding of where the avionics architectures will need to go to achieve these NCW concepts and doctrine. One major lessons learned from commercial applications of NCO is that without changes in the way an organization does business, it is not possible to fully leverage the power of information [1]. Therefore, a review of the revolutions in military acquisition will be addressed to emphasize the complexity of organizational transformation required to achieve these NCW goals.

Domains

Three domains have been identified associated with a comprehensive understanding of the information superiority construct [2]. The physical domain is the battlespace where engaging forces maneuver. This can be the terrestrial, sea, air, and space environments. Offensive operations seize the initiative and dictate the time, place, and objectives of the battlespace. Information about the situation enhances the ability to dictate the battle operations and also facilitates effective reactive counter-operations. Information exists in the information domain. The information domain is where information is created, manipulated and shared. The sources of information come from sensed observations, usually from radar, electro-optic devices, and other aviation sensors. Information in and of itself is not enough to dominate adversaries in the battlespace. A comprehension of the meaning of the information is required to take appropriate actions. This is the cognitive domain, of sense making and decisions. The cognitive domain exists in the minds of the combatants, be it commanders, command and control personnel, pilots, or forward observers. The participants create an understanding of the situation from the various pieces of information received. Some of the information may contradict other information, may not be available for timely assessment, or be incomplete or inaccurate. This leads to a measure of the value of the interaction of information in the information domain.

Valued Information System Attributes

The intent of network centric operations is to provide information to the needed entities when and where it is needed. Information systems, the information domain infrastructure where the information lives and is shared, have desirable attributes of availability, privacy, integrity, authenticity, and non-repudiation. Availability is the amount of time the users have access to the needed information. Privacy means only authorized users have access to the information. Integrity is the degree that the information has not been tampered with by unauthorized access. Authenticity measures the degree that the data is in the original form as provided by an authorized user. Non-repudiation is the evidence of information transfer; neither sender nor receiver can deny the transfer.

These desirable attributes of information systems have applicability to advanced avionic systems due heavily to the need to take advantage of beyond visual range weaponry and multi-level secure requirements being imposed to reduce the cost of security operations on maintenance, repair, and physical security of access denial.

Valued Information Attributes

Information qualities can be divided into three primary attributes [3]. First, information richness is the quality of the information. Second, information reach is the vastness of the number of users and quality of information sharing. The third primary attribute, quality of interaction, is the degree to which the information is usable to provide a common understanding of all the participants in the cognitive domain. Forgoing a complete explanation of detailed traits to all three primary information attributes, the traits associated with information richness will be described since they are directly applicable to avionics architectures. Secondary measures of the quality of information richness are traits like completeness, correctness, currency, accuracy, consistency, relevance, timeliness, and assurance. Completeness is the degree to which all information is available to the networked entities. Correctness is the degree to which the systems represent the realities the information represents in the physical domain. Currency is the age of the information. Accuracy is the level of precision contained within the information item. Consistency is the degree to which the information is applicable across multiple processing elements. Relevance is the degree to which the information is usable in forming awareness or understanding in the cognitive domain. Timeliness is the degree to which the information is delivered to some processing element based upon the processing elements needs. Finally, information assurance is the degree to which the user has confidence in the information presented to them. These measures of the quality of information richness are relevant to the development and/or migration to advanced avionics architectures. The relevance in manifested in the information flow within the avionics suite. To be further discussed, avionics architectures will require certain properties, like deterministic behavior and minimal information loss due to protocol translations, to be able provide the desired traits of information richness. Just providing a lot of information to a pilot does not provide the needed cognitive situational awareness and understanding and may certainly affect synchronization of battle operations. NCW desirable operational capabilities like time sensitive targeting and machine-to-machine communication will drive the avionics architectures to facilitate, manipulate, share, and fuse large amounts of on-board and off-board information.

The desired effect of an NCW strategy is to remove targets of interest as quickly as possible. To accomplish this, the "kill chain" needs to be shortened. The kill-chain is "find-fix-track-target-engage-assess". This chain can take hours to find the appropriate target, fix the location, track its movement, target it with the appropriate weapon, attack the target, and assess the results. Sharing of information among combatants can decrease this kill-chain dramatically. Figure 1 shows desired effects the three basic levels of information sharing, voice, data-linked, and networked have to shorten the kill-chain. What are important in shortening the kill-chain are the amount, quality, and timeliness of the information being shared among the combatants. An airborne network infrastructure is being developed to provide this information and quality of service, however, each combatant's weapon system requires connectivity to this infrastructure if the objectives of NCW are to be achieved.

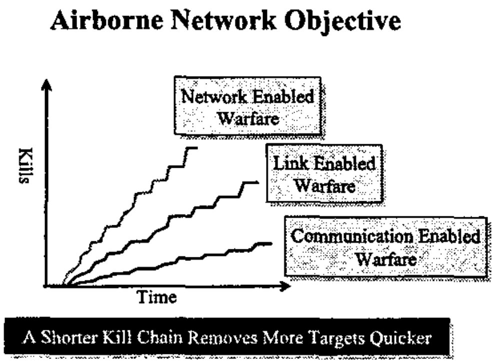


Figure 1. Exploiting Information Dominance

Platform Centric Avionics Architectures

Figure 2 describes the earliest, first generation, avionics systems were a single thread of information from a sensor to a display. The operator typically had to read the raw data displayed and make sense of what the system was providing. This system provides for a dedicated information flow between sensor and display. Early voice communication, radars, and electro-optical devices tended to operate in this fashion. High operator interaction with the system was necessary to make sense of what the raw sensor data was providing about the physical domain. Digital technologies provided the means to process the raw data and present a simpler picture to the operator. Verification of functional or capability changes tended to be localized and therefore, less costly.

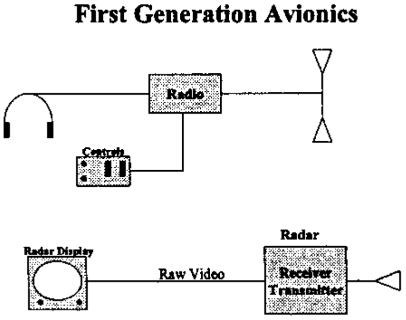


Figure 2. Dedicated Single Thread Subsystems

The second generation architectures employed digital technology to permit the sharing of the processed and refined information across some digital communication medium. Figure 3 illustrates this federated architecture, which loosely coupled the processing elements in discrete computers with serially distributed information flow between them. Thus, the refined information from one subsystem was shared with other on-board subsystems. The operator typically had flow of information from one system at a time to a display. This refined, processed, data was easier to interpret and comprehend, but the operator work load increased through the controls and display activity to get the required information from the various subsystems needed at a particular time. Verification of change was also becoming more expensive, partly due to larger software applications and system level testing.

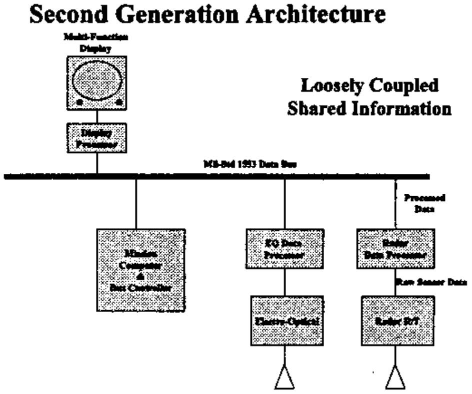


Figure 3. Federated Architecture

The third generation of avionics architectures shared physical resources and information flow between processing elements could use shared memory, parallel backplane interfaces or other techniques. Integrated architectures need to be functionally federated to minimize regression testing of unchanged functions due to changes in other functions. The physically integrated and functionally federated properties retard the growth of cost due to fewer required physical devices, power supplies, input/output drivers, etc. However, the architectural and functional complexity increase caused cost growth and these complexities were more than the situational awareness was enhanced in the cognitive domain. More sensor operating modes, tightly coupled functions, reliance on unsupportable military interface standards [ADA, Mil-Std 1750, etc.], and difficulty in completeness of laboratory verification, and thereby dependent upon flight testing with extreme difficulty in environmental repeatability, are the primary causes of cost growth. The logical architecture, implemented in software, has typically been tightly coupled to the physical architecture, implemented in highly volatile digital hardware. One more lesson learned with third generation avionics architectures was the interdependencies of the physical (hardware) and the logical (software) architectures. The employment of digital systems in avionics applications was predicated on the ease of software change versus the cost, time, and complexity of changing hardware to add capability.

However, the software functionality complexity increased exponentially, and the hardware costs have decreased exponentially while functionality of the hardware has increased exponentially. The hardware market has become extremely volatile, resulting in digital product lines quickly going obsolete. These phenomena invalidate the original premise that software was easy and cheap to change. Throwing hardware at the design problem is a very affordable option. Today, changing the tightly-coupled software functions has become very expensive. It is now more desirable to keep the software functionality and replace the hardware with newer technology, a reversal of the original premise. The third generation of integrated avionics architecture tended to couple hardware with software forcing constant change in both domains.

Fourth generation avionics architectures have taken the best features of the federated architectures and the integrated architectures and created a hybrid system. The off-board communications are integrated into a suite of cards which are federated form the processing (data and signal) elements. The data processing fuses on-board with off-board information streams of widely different spectral sensor types. The logical architecture is information centric being designed with object oriented constructs. Another advance is the information protection schema supporting multiple levels of security classifications in a declassified physical environment. Classified information is encrypted during communication transfers through a trusted operating system. Another aspect of the avionics information system is that it provides advance real-time failure diagnostics which supports the information availability quality by being re-configurable in the presence of component failures. The increase in digital processing and growth in software size, two measures of system complexity, are compensated for by the powerful software development tools, the functional federation through object oriented design, decoupling of hardware and software domains, less regression testing of unchanged processes, and less cost associated with the maintenance of classified components. These fourth generation avionics architecture attributes provide for ease of integration, change, verification and support the evolutionary delivery concept.

One aspect of the architecture which must function to provide the cognitive awareness is the sensor and data fusion concepts. This is still a very complex issue undergoing much research. Fusion of sensors and data are not only a command and control function of battlespace management. Fusion is also required for each combat aircraft if comprehension of the large amounts of information provided is to occur. Fusing multi-spectral information sources, on-board sensors with off-board data, at different levels, pixel-to-pixel, track-to-track, etc., is very complex with great potential for information loss. The massive amount of information generated through NCW, be it on-board or off-board, MUST be fused to simplify presentation to the aircrew operators. However, these fusion algorithms MUST provide information quality measures, accuracy, completeness, assurance, etc., to be useful to the aircrew operators for engagement of network centric operations while not exacerbating and propagating information error to other network users. The combatants must trust the information provided by their on-board systems as well as off-board sources through all the filtering, fusing, correlating, and other data manipulation. Much of the commercial networking is focused on interoperability between information systems by sharing the "raw" data, text files, video, etc., without much data manipulation. User trust is not dependent upon complex correlation of real-time data and fusion with other sensor created data. Current avionics architectures provide the capability for the operators to disengage fusion and correlation algorithms and rely on trusted stand-alone on-board sensors. The operators need not just rely on their on-board algorithms, but also the algorithms from other aircraft. Building trust with the operators, to fully utilize the information available and achieve the effectiveness and efficiency that NCO can provide, will be the most difficult achievement for NCW.

Information Loss in Communication Systems

Forcing information flow through data links introduces information loss, through a transformation of objects observed in reality in physical domain to predefined messages in the information domain, and reduces the desired information quality of correctness. Message-based communications truncate, transform, compress, and lose information fidelity in the process. An example of information loss is the system-of-system communication via message-based Link-16 (J-series tactical digital information link, TADIL-J). If a strike aircraft senses hostile radar emissions, the platform attempts to identify the emitter via the characterization of emissions through its electronic order of battle database. If the emitter can be located but not identified, the platform enters an unknown emitter at the determined spatial coordinates into the TADL-J message and sends it to other networked entities. Thus, a stand-off jammer may not be able to provide effective counter-measures to this "unknown" threat. However, if the sensing platform sent the actual sensed characterization parameters, center frequency, pulse repetition frequency, etc., the stand-off jammer can determine appropriate counter-measure techniques. So, messaged-based communication schema inherently induces information loss. Even sending streaming video compresses the imagery to be decompressed by the receiving entity. Advanced signal and data processing compression algorithms still operate on discrete units of information for comparison of neighboring information elements. The levels of discrete quantization are dependent on semiconductor technology, number of bits in the analog-to-digital transformation, and the needed speed of the information transfer.

Another source of information loss is in the information transfer from one medium's protocol to another's protocol. The ever evolving communication technology industry proliferate this phenomenon with the introduction of new higher speed connectivity systems with different protocols. Translating between two languages, say English and Portuguese, inherently looses information by using similar words which may have different meanings in the other language. Ancient Greece had many different words, with different meanings, for the concept of love.

Finally, low observable (LO) aircraft tend to not want to emit radio frequency energy due to the desire not be detected nor tracked. If a LO platform observes or senses a physical domain event, the information may not enter the cognitive domain of network connected combatants minds due to the information never being entered into the information domain. Since most up and coming platforms have high degree of LO'ness, Low Probability of Intercept (LPI) and Low Probability of Detection (LPD) communication technology must be introduced for NCW to become applicable to the aerospace realm. Not until trust and confidence (information assurance) in the information provided is achieved can these capabilities be employed in the rules of engagement or battle doctrines on which the NCW concepts depend. The few cases of fratricide in recent military operations have gained higher scrutiny due to the comparison of low friendly casualty rate due to enemy fire, and may force multiple sources providing identical information for appropriate engagement.

Off-Board Communications

Off-board communication can be divided into five categories: voice; text; data; imagery; and video. Off-board communication is the major information domain enabler of NCW in terms of sharing information and providing a common coherent situational awareness in the cognitive domain of all the participants. This information domain provides the connectivity, the command and control of combatant entities, and the means to accomplish a Single Integrated Air Picture (SIAP). Off-board communications enables higher adversary target removal in a shorter amount of time and increases survivability. These are the primary goals of NCW. Current airborne networking prioritization planning incorporates data links for connectivity, but a new schema is required to: minimize information loss; provide accurate and timely (weapons quality tracks) information for targeting; incorporate LPI/LPD characteristics; and the rest of the quality measures of information richness. Also, to increase the cognitive awareness and understanding of aircrew operators, the massive amounts of information entering the aircraft needs to be filtered, correlated and fused to provide an intuitive comprehension without saturating the operator with extraneous work load. Current off-board communications provide a limited amount of situation awareness. The information is not correct, current, accurate, nor relevant enough to stand on its own. The aircrews currently take the off-board information to cue on-board sensors to achieve these desired information attributes.

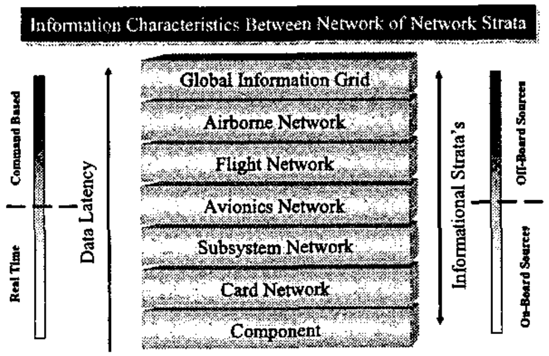
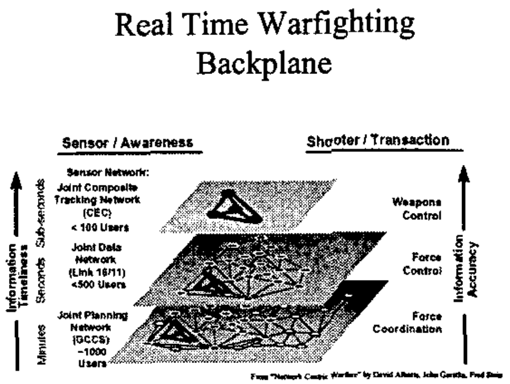


Figure 4. Network of Networks

Another phenomenon of off-board communication is that it tends to be command-based, as the information is provided on a "push" basis depending upon the command and control data provider or data link network. This introduces another complexity of coupling a real-time, deterministic, avionics suite with the command-based external environment and maintaining the desired information quality. The off-board information must be relatable to the on-board sensors information. Correlation between different off-board data sources as well as with on-board sources poses complex mathematical solutions. Figure 4 presents the stratification of information within a network-of-networks. Current data-linked information can only provide a situational awareness because the operator must still utilize on-board sensors to prosecute a target. Accuracy, latency, and relevancy mismatches of information sources degrade the intuitive cognitive awareness and understanding for the aircrew. Figure 5 demonstrates the level of accuracy and timeliness of the information different stratification required in the network of network concept. A low latency sensor network is needed to link combatants' sensors directly with correlated information flow. In such a network, a sensing platform's target track information may be transmitted to a shooter platform with enough accuracy and timeliness to prosecute the target without onboard sensor information. Currently a Tactical Targeting Network Technology (TTNT) low latent data link is being developed to achieve these ends.



From "Network Centric Warfare" by David Alberts, John Garstka, Fred Stein

Figure 5. Timeliness and Accuracy in Network of Networks

Joint Tactical Radio System

The Department of Defense is developing a software communication architecture compliant radio frequency management system, Joint Tactical Radio System (JTRS). This system employs software controllable waveforms used for voice and data exchange, see Figure 6. Currently the aerospace applications are being developed in three form factors. The first contains eight modules, each supporting one wave form. The second is identical to the ARC-210 form factor to facilitate aircraft integration with like radios. The third form factor is called the MIDS-JTRS (Multifunctional Information Distribution System), to facilitate aircraft integration with MIDS Low Volume Terminals (LVT) of Link-16.

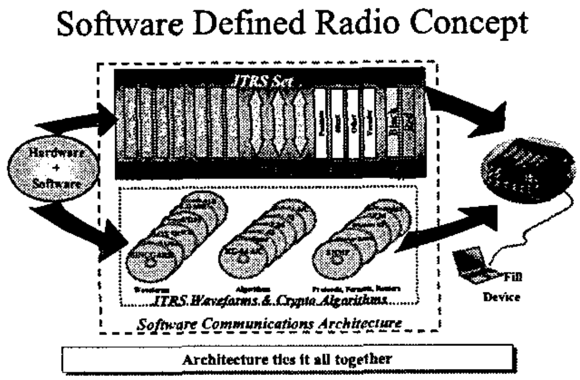


Figure 6. The Joint Tactical Radio System

This joint software communications architecture provides for ease of adding waveforms provided the aircraft wiring and antenna's are available as well as any digital on-board communication path. Currently, voice radios on aircraft typically do not have digital connectivity to the rest of the avionics suite. This would require extensive aircraft integration effort to utilize the JTRS waveforms for network enabled capabilities. The JTRS technology is a major step in achieving interoperability between service communication devices.

On-Board Communications

With the advent of federated architectures, on-board communications between processing elements has become a vital feature for functional interoperability. The sharing of processed sensor data saved weight and increased reliability but created dependence on functional interoperability. Serial digital communications has dominated the legacy systems information sharing needs. The command and response protocol of Mil-Std 1553 is a widely used data transport medium in military applications, but has extremely limited capabilities. This protocol has highly deterministic behavior; desirable in real-time avionics applications but is limited to 1 megabits per second and 31 receiver-transmitters on a single bus. Thus, as capability was added to weapon systems, serial buses were added. Much of the commercial communication technology is developed for client-server topologies. Fiber optical communications offer a much higher bandwidth for avionics applications, however most protocols are aimed at commercial applications being demand-based (information pull) and require major re-wiring of the avionics suite. This demand-based technology requires the network to be severely de-rated, in order to achieve timely message delivery, but this is no guarantee of deterministic system behavior.

A major revolution in avionics communication applications is the Mil-Std 1553 Xi-channel. Xi-channel Digital Subscriber Line (DSL) technology, transmitting and receiving pertinent information within the noise margins of the current Mil-Std 1553 to increase data flow to 200 to 500 megabits per second without the need to replace the current legacy wiring infrastructure. Only the communication cards in the desired federated subsystems need to be replaced. This technology has great potential for facilitating information flow between remote data processors and to transform legacy avionics suites to support the NCW concepts with a minimal cost. This physical medium of information transfer facilitates the physical architecture transformation, but the logical architecture also requires transformation as well.

Avionics Logical Architecture

Avionics logical architecture requires transformation to enable aviation engagement in NCW. The avionics logical architecture resides in the software design. The logical architecture defines the functional elements that require information exchange. The physical architecture facilitates the data exchange, while the logical architecture creates and depends on information exchange. The logical architecture is spatially independent related to processing elements. The logical architecture must not corrupt the qualities of information richness required to enable NCW. Early attempts at implementing logical architectures did so without sophisticated software design tools supporting the unified modeling language. The logical architecture was designed with functional decomposition techniques without the object-oriented design. Therefore, changes tended to cross functional boundaries thereby adding to the integration complexity and verification effort. Functional decomposition tended to separate process from data [4]. Object oriented design centers around the information flow between functional entities. UML is a graphical representation of the information flow between producers and consumers via class, case, interaction, activity, and state diagrams. This information centric design technique is now supported by many sophisticated software development tools. These tools provide for ease of adding functionality and verification of system level operability in support of evolutionary development. These tools also provide an intuitive graphic approach to facilitate communication between developers. As legacy weapon systems add functionality and system upgrades to engage in network centric operations, the legacy software architecture should be migrated to an information centric design.

Another very important feature of embedded digital applications is that they tend to control the behavior of a system in response to the stimuli produced by the external physical domain. They tend to operate under time constraints or deadlines, be it hard of soft constraints. Soft real-time operation tolerates information loss in that time constraints may be missed occasionally, by a little bit, or occasionally all together skipped. Most avionics functions tend to have hard deadlines. When a deadline arrives and a process is not complete, it has not generated the information required for proper system performance. When an external event is detected, a timely system response can be critical to proper system behavior. Therefore, the logical architecture must schedule the concurrent functional processes in a predictable manner to ensure incoming information is not lost. This describes a deterministic system, where the input stimuli get predictable and repeatable system response. The following table shown in Figure 7 describes fair scheduling schema. [5]

Scheduling Policy	Description	Pros	Cons
Cyclic Executive	The scheduler runs a set of tasks, each to completion, in a never ending cycle. Task set is fixed at start-up.	• Fair • Simple • Highly predictable	• Unresponsive • Unstable • Non-optimal • Non-robust • Requires tuning during design
Time-Triggered Cyclic Executive	Same as cyclic execution except the start of a cyclic is begun in response to a time event.	• Fair • Simple • Highly predictable • Resynchronizes cycle with reference clock	• Unresponsive • Unstable • Non-optimal • Non-robust • Requires tuning during design
Round Robin	A task runs until it voluntarily relinquishes control of the scheduler	• Fair • Simple • *More flexible*	• Unresponsive • Unstable • Non-optimal • Non-robust •Short Tasks
Time-Division Round Robin	A round robin schema but if a task does not relinquish control voluntarily, it is interrupted with in a specified time period, called a time slice	• Fair • Simple • Robust • More flexible than round robin	• Unresponsive • Unstable • Non-optimal

Figure 7. Fair Real-Time Scheduling Policies

A priority scheduling schema is "unfair" because some tasks are scheduled preferentially to others due to task importance or urgency. Scheduling determined by the importance of the process is required to achieve correct system performance (correctness), while urgency is based upon how close the process deadline is. The table in Figure 8 describes priority based scheduling schema.

Scheduling Policy	Description	Pros	Cons
Rate Monotonic Scheduling RMS	All tasks are assumed periodic with dead lines at the end of the period. Priorities are assigned at design time. Tasks with shortest periods have highest priority.	• Stable • Optimal • Robust	• Unfair • May not scale up to highly complex systems
Deadline Monotonic Scheduling DMS	Same as RMS except it is not assumed the deadline is at the period end. Priorities are assigned at design time, base on the shortness of the task's deadline	• Stable • Optimal • Robust	• Unfair • Handles tasks more flexibl
Maximum Urgency First MUF	Priorities are assigned at run-time when the task is ready to run, based on nearness to deadline.	• Optimal • Scales better than RMS or DMS • Robust	• Unstable • Unfair • Lack of Operating System Support
Least Laxity LL	*MUF is a hybrid of LL and RMS.* A Critical task set is run using the highest set of priorities under and RMS schedule, and the remaining tasks run at lower priorities of LL	• Optimal • Robust	• More complex • Unfair •Critical task set runs preferentially to other tasks to some stability, although not for the LL task set
Earliest Deadline Scheduling EDS	Laxity is defined as the time-to-deadline minus the remaining task-execution-time. LL scheduling assigns higher priorities to lower laxity values.	• Optimal • Robust	• Unstable • Unfair • Lack of Operating System Support • More complex

Figure 8. Priority Based Scheduling Policies

The avionics system architect needs to evaluate the scheduling schema which provides required system performance of timely information flow between processes and without information loss of hard real-time needs.

Another desirable aspect of the logical architecture is hardware independence. The logical and physical architectures are decoupled through layering of software with discrete communication calls, information requests, between the functional entities. The hardware can be changed, processing elements can be added (scalable) or upgraded with new digital technology, without the need to modify functional application entities. The higher software functions are hardware agnostic. This is very much akin to desktop computers. The word processing software can operate on many different hardware environments. Figure 9 illustrates a generic software layered approach. The extra layering of software must not interfere with timely information flow from one process on the same layer or to a process on another layer. The avionics system still requires real-time process deadline properties and deterministic system behavior.

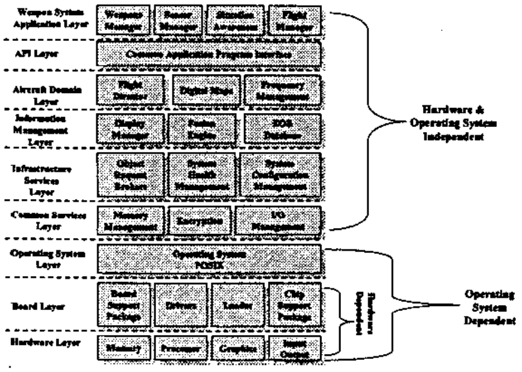


Figure 9. Generic Layered Software Architecture

Levels of Network Capability

It has been estimated that over 80%[1] of the cost for an airborne networking enabling capability for NCW is associated with aircraft avionics development and integration. These multiple tens-of-billions of dollars will not be available in one huge transformational effort. Rather, weapon systems will need to migrate over time and offer various levels of information sharing. A typical second generation federated avionics suite provides limited voice point-to-point communication and depends upon its internal sensors for lethality and survivability. This concept is displayed in Figure 10.

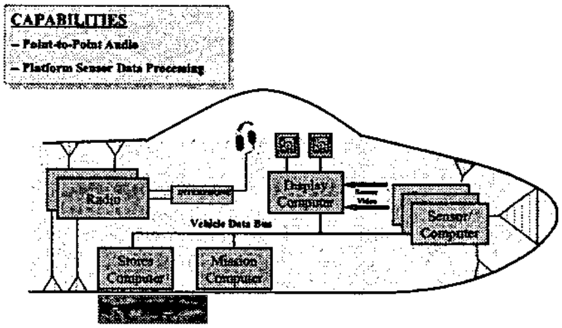


Figure 10. Platform Centric Architecture

Many of these platforms have or are integrating the Link-16 data link system. This addition of data exchange provides for situational awareness but still the weapon system relies on sensor processing for lethality and survivability. The data link information is used to cue platform sensors for the weapon system operations. This concept is displayed in Figure 11.

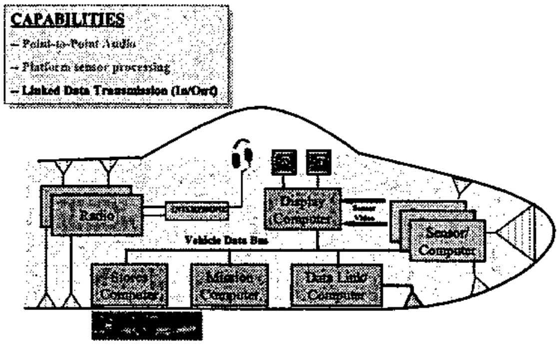


Figure 11. Data Link Enabled Weapon System

A network enabled weapon system, shown in Figure 12, provides for digital connectivity between the voice radios, data-link transceivers, and platform sensors. This avionics connectivity provides for the inter-networking of digital voice, sensor information (not just processed data) exchange, and the reception of streaming video from other weapon systems sensors. This network enabled system has major changes required to provide the digital connectivity. First is the physical layer of group-A wiring changes, the physical connectivity path. Second is the control of information flow within the avionics subsystems and external to airborne network. Third is the enormous amount of data manipulation through correlation and fusing the dissimilar sources into a comprehensible picture of the physical domain events. This network enabling architecture incorporates the JTRS with the advanced Wideband Networking Waveform (WNW) and TTNT for compatible information exchange between weapon systems and sensors. This architecture also incorporates the Mil-Std 1553 Xi-channel to facilitate information exchange between avionics components. This Xi-channel ebbs the transformational cost by not requiring a physical medium change to increase information flow, nor

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[1] From a briefing entitled Avionics Viability and Network Enabled Warfare, by Will Urschel, Chief Architect, Aeronautical Systems Center

does it require change of systems that do not require increased information flow.

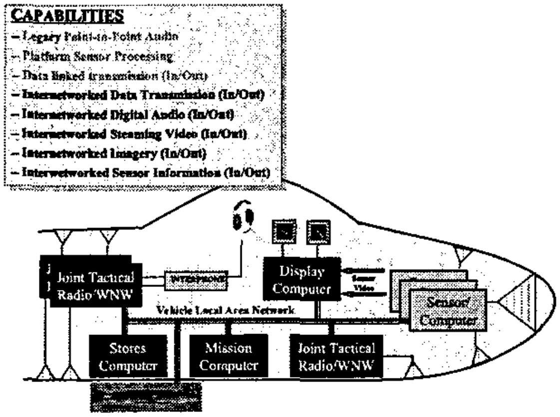

Figure 12. Networked Enabled Weapon System

Subsystem Transformation Levels

Legacy systems can not transform into network enabled systems in one discrete step. Rather, they will have to migrate over time. Development of primitive or elementary avionics architectural building blocks will be required. These building blocks must bestow the system and information qualities necessary for NCW and be shared across weapon systems, as well as Department of Defense services. Five levels of subsystem transformations have been identified to achieve the data link level of weapon system network capability. Figure 13 describes the baseline configuration for the first step for legacy systems toward a network enabled capability. Two primary changes have been identified in this first step toward data linked connectivity. First is the incorporation of the JTRS, the software communication architecture for Link-16 data link connectivity, and second, the Common Link Integrated Processor (CLIP) which decouples the external protocols with what ever weapon system's internal communication protocols are employed. The current installation of the MIDS into most federated systems is as shown in Figure 13.

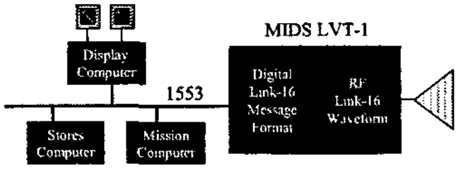

Figure 13. Current Link-16 Network Architecture

Level-0 requires three changes to the MIDS LVT terminal. First is the incorporation of the CLIP interface to convert Link-16 TADIL-J messages into aircraft messages, typically Mil-Std 1553. The second required change is to provide provisions within the MIDS LVT to permit Internet Protocol version 6 (IPv6) addressing. The IPv6 provisions are dormant (not utilized) in level-0, see Figure 14. The third change is the JTRS software communication architecture.

Link-16 Processing
IP Provisioned (not employed)

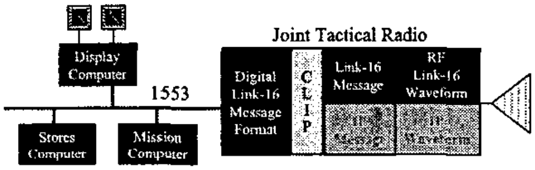

Figure 14. Level 0

Level-1 changes enable the IPv6 addressing for the aircraft, but the avionics suite is unchanged. The Link-16 data link connection remains active also. Figure 15 describes the front end changes to the JTRS.

A/C Processing Unchanged
IP Selectable Communication

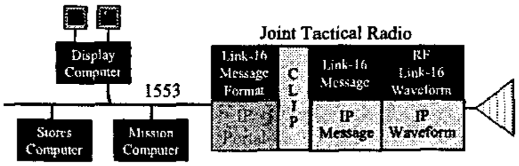

Figure 15. Level 1

Level-2, Figure 16, enables IPv6 communication through parts of the avionics suite while still providing the TADIL-J protocol. TTNT is also incorporated as a sensor-to-sensor network connection.

A/C Processing Enhanced
TADIL-J via IP selectable Communication

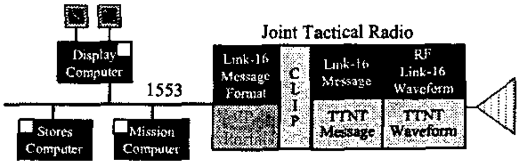

Figure 16. Level 2

Level-3 provides for complete IPv6 enabled information networking through a dedicated laptop computer. Obviously, this is a valid configuration for multiple operator aircraft. Figure 17 shows this architecture.

Stand-Alone IP Message Processing

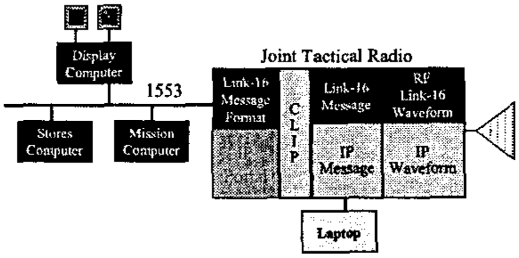

Figure 17. Level 3

Level-4 provides for complete avionics IPv6 internetworking capable. The internal communication is upgraded to a high speed network (Mil-Std 1553 Xi-channel) and all the avionics subsystems communicate with the IPv6 protocol. The IP based WNW waveform is the primary connectivity between weapon systems. This architecture is shown in Figure 18.

Integrated IP Message Processing

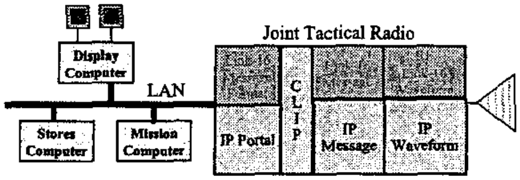

Figure 18. Level 4

Orchestrating the migration of each platform requires programmatic synchronization to unprecedented levels. Soon, platforms that are not network capable will be left out of the battlespace. Synchronizing these unconnected platforms will require too much effort and their contributions to target removal will be minimal. To coordinate the programmatic efforts, organizational changes are required. The current changes being implemented will be briefly discussed.

Capability Based Development

A major shift in the Department of Defense planning, acquisition, and employment methods is moving from a platform-centric threat-based process to an integrated capability planning and development. The developed capabilities are refined from the effects the battlespace commander requires to effectively and efficiently dominate the arena. This shift requires major changes in the organizational structures of the Air Staff, using, research and development, acquisition, and sustainment communities. This shift affects the way requirements are defined and money flows to the development communities. Air Staff is taking a major lead in this move to capability-based development by establishing a Capability Review and Risk Assessment process where capabilities are defined from the desired battlefield effects.

Capabilities are distilled with requirements allocated to platforms needed to provide the effects. Platform roadmaps are developed with identified funding needs to enable timely modifications.

Air Force Materiel Command (AFMC); the research, development and sustainment community, is being restructured in an attempt to capitalize on cross-cutting activities required to transform legacy weapon systems into networked enabled platforms. Weapon systems that support the Air Staff Conops; Global Strike, Persistent Attack, Mobility, etc., have been clustered into wings whereby the wing commander has execution authority for all the systems within their wing. This structure supports sharing of technology development and sustainment efforts, and human resources for program execution. AFMC is also standing up a capability management construct to orchestrate systems-of-systems capability development. The capability management construct must integrate efforts across multiple product development and logistics centers as well as across same product center wings. Close coordination is required between the network infrastructure, command and control, weapon system, armament, and space development communities. Also, many of the network infrastructure elements are being developed for use in all the services.

Summary

NCW offers great combat effectiveness and efficiency, but requires very complex changes in tactics, system development, and organization construct. NCW will be an evolutionary transformation for these complex changes. NCW is predicated on the concept of exploiting information dominance, of having information access while denying an adversary the same luxuries. The information domain serves to connect the combatants into a single comprehensible cognitive domain. The aviation information domain resides internal as well as external to the aircraft platforms. The network enabled aircraft will require many technologies like fusion, high speed real-time deterministic information transfer, and covert external communication capabilities. These technologies must not compromise the qualities of information richness through information loss associated with information processing and transfer. NCW requires the information domain to provide complete, correct, accurate, and assured information to the place when it is needed. Confidence and trust in the networked information needs to be established and maintained in all the battlespace participants to fully capitalize on the abilities the information can offer.

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