SYSTEM OF SYSTEMS DESIGN FOR WORLDWIDE COMMERICAL AIRCRAFT NETWORKS

Sudhakar Shetty Ph. D
The Boeing Company

Keywords: *System of Systems, NCO, Networks*

Abstract

This paper will present the vision, architectures and technologies for the next generation System of Systems design of commercial aircraft systems worldwide. The future success of commercial aircraft production, operations, and maintenance will depend on the network centric capabilities of its System of Systems both on-board and off-board the aircraft.

Aircrafts systems in the past typically have been designed and developed with a focus on domain dependant features in order to meet the stringent security and certification requirements of aviation industry. Also in the past most of these systems were based on analog technologies. However, with the digital and Information Technology (IT) revolution of the past decade airplanes systems are beginning to embrace more and more of the digital/IT technologies that are pervasive in the commercial world. Although some of these aircraft systems are adopting the digital technologies they are still designed and optimized on an individual systems basis by the specific user community, maintaining their own sphere of control. As a result of these disparate systems both on-board and off-board the aircraft, the end-user communities have not been able to take full benefit of their digital systems. One key factor leading to this limitation is the lack of an overall System of Systems design of end-user systems on-board and off-board the aircraft. Moreover these end-user systems are standardized by various independent standards bodies without a centralized forum to harmonize these systems. But, in the new digital environment the aircraft is nothing but a mobile node in a world wide network infrastructure of various communities where every one's needs can be streamlined to provide the right data to the right end-user community at the right time to make the right decision. To this end Boeing Commercial Airplanes has now developed a Network Centric Operations Vision for the commercial airplanes to benefit all the end-user communities around the world. This presentation will provide Boeing's vision, and approaches for Network Centric Operations of Commercial Aircrafts.

Network Centric Operations (NCO) is an integrated environment of systems, processes, and the communities of interest to create shared awareness and collaborative decision making. The NCO concept was initially driven mainly by the Department of Defense but, since then has been gaining acceptance world wide to reduce cost and improve operations. Boeing Commercial Airplanes (BCA) has been implementing some aspects of NCO in their e-Enabling solutions. However, the overall BCA NCO goal would be to include all phases of the life of an aircraft.

This presentation will provide an overview of the BCA NCO vision, its complexity and a structured approach to its implementation. It will address the design and constraints of various system of systems involved in the NCO vision such as the integrated aircraft systems, various off-board systems such as Satcom and Broadband satellite systems, Ground receiver systems, and the various end-user systems such as Factory/Productions Systems, Flight Test Systems, Flight Line Systems, aircraft Operations and Maintenance, Air Traffic Management (ATM), and the public at large. In

the past most of these systems have been developed mainly with domain dependent focus, optimized for their local use. The new scope is to develop system of systems architectures to ensure that all of these systems will have the necessary domain independent capabilities to support NCO along with their domain dependant capabilities.

The presentation will also address the complexities and the diverse subsystems that make up the on-board systems with an approach to integrate them to support the overall NCO goals. The on-board systems will include the integration of both wired systems as well as wireless systems. The presentation will also address the various NCO issues and the challenges for Boeing. Overall the presentation will discuss Boeing's approach, the System of Systems engineering (SoSe) methodologies, the architectures, the capabilities and the technologies needed. It will also discuss the roles of some of the industry bodies to support the overall NCO vision.

1 General Introduction

The worldwide commercial aircrafts eco system is a complex environment of systems, organizations and technologies that have evolved independently over many decades by the respective agencies. Each entity developed and maintained their systems and operations in a loosely coordinated fashion to maintain the integrity of their part. This has served the aviation industry well in the past by meeting the necessary safety and certifications. However, this industry is now undergoing a major paradigm shift due to the impact of Information Technology (IT) explosion in the commercial and consumer industry, and the increasing operating costs. In general the aircraft systems have become extremely safe and reliable over the years. Nevertheless, the aircraft industry is working on continually improving the reliability and availability of systems and components through better prognostics and diagnostics. One key capability towards this end that is still in its infancy is the net enabling of the Aircraft systems from-end-end-end globally. The aviation industry has no choice but to jump on to this bandwagon to leverage and co-exist with the commercial IT technologies. Another factor that is accelerating this need is the intention of airframers to provide airplanes on "Power-by-the-hour" contracts instead of selling them outright. This takes the complex maintenance tasks off of the hands of the airlines, particularly the small airlines that do not have a large maintenance organization. This can only be achieved through an advanced remote monitoring and operational capability that is enabled through world wide network centric operations. However, this industry has some unique safety and regulatory constraints that make this process much more complex and cumbersome than other industries.

1.1 Background

NCO is a concept whereby the efficiency and effectiveness of a user community can be enhanced significantly through a networked environment, to improve the speed of communications and the situational awareness. This concept has been widely adopted by the Department of Defense for over a decade, although the terminologies may have evolved in to different forms. For example in some circles NCO may now be referred to as Data Centric Operations, where the focus is mainly on the information centricity and its flow rather than the network itself. In some communities this may also be referred to as Net-Enabled systems or Capabilities. Irrespective of what it is called, the principles are still the same – *getting the right information, to the right place, at the right time, to make the right decision*. The principle is just as applicable to the commercial aviation industry as to the military side, although the commercial side brings in some of its unique challenges in terms of its diverse set of independent communities spread around the world with their own unique regulations. The concept of NCO has not been widely used in the past in the commercial aviation world but, it is being noticed more and more these days. In order to reduce cost and improve efficiencies in the commercial aviation world, it is imperative that these aviation communities adopt the basic tenets of NCO as fast as possible.

2 Vision

The vision for commercial aviation is that within the next decade or two every commercial airplane irrespective of its location will be a securely and seamlessly connected node in the world wide web with Net Centric Capabilities enabled for all of its user communities around the world. This will help improve their efficiency through better shared awareness, and decision making capabilities. The user communities includes the entire life cycle of an aircraft from its design to its disposal, such as Passengers/Crew/Sensors on-board the aircraft, and the Airframers, suppliers, airlines, Airport, Air Traffic Management, on the ground worldwide.

Figure 1 Commercial Aviation Communities

As shown in Figure 1 there are 6 key groups of communities involved in a commercial aviation industry. Each may belong to a different organization, in a different geographical location around the globe, require a different level of service and security, and operate under different financial needs and constraints. But it is one global community that depends on each other for their performance and success. Therefore the challenge is to interconnect them through an integrated infrastructure to help each other to improve their businesses, without impinging on their Safety, Security and independence.

3. Systems and Challenges

Over the past decade the 6 user communities have been busy developing their own e-business plans in piece meal trying to leverage the IT revolution, without a combined vision for the overall industry. This has led to fragmented implementations and applications that have only provided partial benefits to the industry. There has not been a concerted effort to establish an overall worldwide infrastructure with interoperability to support everyone's vision. The following is a brief summary of the current state of each of these users, the challenges facing them, and some of the current initiatives under way.

3.1 Net Enabling Passengers, Crew & Sensors

The industry has developed many applications and features for passengers and crew on-board, such as e-log, cell phone connectivity, laptop connectivity, telemedicine, Electronic Flight Bag, etc. However, an end-to-end high bandwidth, seamless, secure connectivity infrastructure for reliable worldwide communications is still not realized. Without such a facility the potential benefits of these features will only be realized partially.

The potential benefit of net-enabled on-board sensors for production, operations, and maintenance is huge. Airplane status and health monitoring sensors are the eyes and ears of the user community for this mobile platform as it flies around the world. However, this potential is not fully realized due to the cost, connectivity, security, and regulatory issues of sensors on-board the aircraft. Without the capability to add sensors at low cost to the production as well as retrofit airplanes, this will never have wide deployment. In order to implement cost effective sensors in aircrafts, it is imperative that the industry develop low energy, low cost, & energy harvesting wireless sensors that can be easily installed during production and also retrofitted in to the existing fleet. The key technical issues the industry is still grappling with in this area are the wireless sensors that are reliable, safe, secure, and spectrum compliant around the world over a long period of time.

3.2 Net Enabling Airframers

Airframers have been net-enabling their design, production, test, and delivery processes over the past decade. But the progress has been slow and the benefits are only partially realized. The key technical needs are high-bandwidth, seamless, secure connectivity, low cost secure RFID technologies with location identifications, and open standards.

Recently airframes are venturing in to the services arena to support airlines with the management of such a complex environment. One example of this is Boeing's Commercial Aviation Services (CAS) that can take care of airline operations from A to Z, such as Boeing's Gold Care. The underlying technologies behind Gold Care are commonly known as e-Enabling, which is a facet of NCO. It is a powerful concept enabled by a number of key applications such as Electronic Flight Bag, e-Log and other features to help improve airline operations and maintenance. Additional bandwidth and worldwide interoperability will help the airlines immensely in the future.

3.3 Net Enabling Suppliers

Suppliers around the world have been implementing piece meal net enabling capabilities such as Net Centric Product Support (NCPS) in a limited way [1]. However, the focus has been mostly on the applications working with the existing infrastructure of limited capabilities. The key technical needs are mature RFID technologies for part tracking with location identification, ubiquitous network connectivity, security, high performance low cost computing, decision tools, and open standards.

3.4 Net Enabling Flight Operations

With all the modern digital and IT revolutions the Air Traffic Management (ATM) system is still antiquated with primarily using analog communications with only a very narrow bandwidth unsecured digital network that is based on 1980's technology. Currently this is an area of intense work within the ATM community, with a roadmap to convert to an all digital ATM within the next decade or two. Once again that community only looks at their communications as a separate subsystem. In reality an aircraft is an integrated system with many subsystems, and the airlines need to maximize their benefits by looking at them as an integrated network with the right priorities, safety, and security. The future ATM will be mainly based on digital communication, but how we get there will have serious implications to both airframers and airlines. The all digital ATM will help relieve the airport congestion, improve safety, and reduce cost.

3.5 Net Enabling Airports

The airport is a key entity crucial to the success of airlines. However, due to their varying technical and business interests, net enabling the airport systems has not been smooth. For example, the gate connectivity has been implemented only at a handful of airports around the world due to patent issues, performance issues, and operational and business issues between the airlines and airports. Connectivity at an airport is a key component that is crucial to the success of airlines. The key technical issues are High BW, Seamless, Secure Connectivity, Open standards, and business issues. For example there are 4 industry standards (ARINC 763, 821, 822, and 830) either developed already or are currently in development, to address the airplane to airport interface on the ground. In spite of these efforts and standards the world wide acceptance and implementation of this interface is still very slow.

3.6 Net Enabling Airlines

The airlines are the ultimate end customers for all of these products and services. Each airline around the world has their own systems and processes used for their operations and maintenance. Some of the major airlines have started net-enabling their systems but, by and large these are piece meal efforts not well coordinated at the international level to take full advantage. In light of increased competition and the recent raise in fuel costs it is more important now than ever to help stream line their operations to reduce cost and improve performance. It is also important that any approach developed should work equally well for a small airline in a remote country with few airplanes, as well as the large ones with hundreds of airplanes. Net enabling their operations and maintenance is the only way to help streamline their business. The key technical needs are high bandwidth, seamless, and secure worldwide connectivity, distributed high performance computing architecture for fast data processing, data management tools, and open standards

4.0 System of Systems Design, Technologies, and Challenges for the Global Aircraft Infrastructure

As discussed in section 3, all 6 of the user communities have their own systems that have evolved over time, and are optimized for their own applications. The classic system of systems design dictates that each of these systems should possess full capabilities to work in their local environment as well as in its new environment as it flies around the globe. Current aviation systems were designed mostly to meet their domain-dependant requirements, with little knowledge and consideration of the dynamic domain-independent capabilities required to support the global communities.

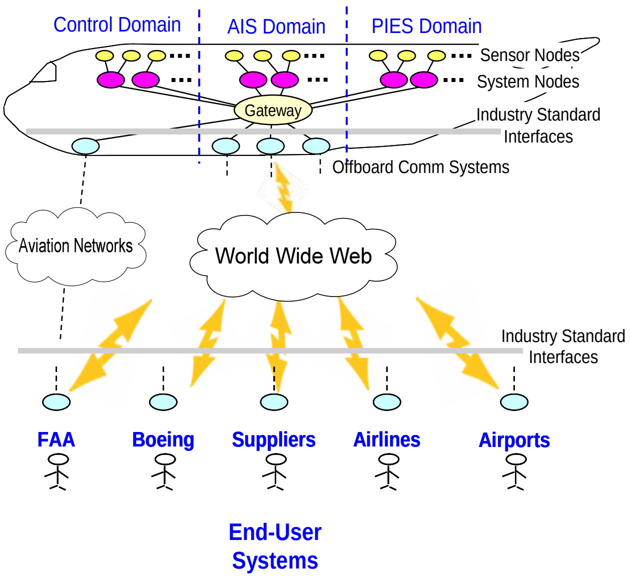

Figure 2 Connectivity Architecture

Figure 2 shows a high level architecture where the aircraft system is compartmentalized in to 3 broad domains called the Control domain (Critical), Crew Information Services domain (Essential), and Passenger Information and Entertainment (PIES) domain (non-essential). Each sensor or LRU (Line Replaceable Unit) node in an aircraft, irrespective of its domain, is net-enabled with all of the 6 end user communities. That means every aspect of airplane behavior, performance, and condition can be monitored remotely, in real time, and used as needed by each of the communities at all times, irrespective of whether the airplane in on the ground, taking off/landing, or cruising domestically or internationally, over land or water. In order to make this a reality there are some key technologies and standards that needs to be developed by the aviation community to support this over the next decade or two. These are:

1. Connectivity
2. Underlying network technologies
3. Information Architecture (Design)
4. Information Management (Post processing)
5. High Performance Distributed Computing
6. Business Processes and Social Networks

4.1 Connectivity

The Connectivity can be divided in to two key areas – On-Board connectivity, and Off-Board Connectivity.

4.1.1 On-Board Connectivity

On-board connectivity can be divided in to 3 sub categories – Flight crew connectivity, Passenger connectivity and Sensor connectivity.

The flight crew connectivity can be further divided in to 2 categories – flight critical crew communication for voice and data, and flight essential crew communication which involves communications for weather, maps etc. and includes both voice communications as well as data communications. The essential communication currently uses UHF and VHF data links and over time all of this will be converted in to digital. In either case the full benefits of these systems can not be realized due to limited connectivity. The key missing component is highly reliable, secure, high bandwidth, seamless global digital connectivity.

The passenger communications is another important aspect of the flight experience that is being demanded more and more by the flying public. This is by and large driven by the consumer industry where passengers expect to extend their connected experience from home and office, to the in-flight environment. The demand on the passenger connectivity will grow significantly in the future. In the future passengers are expected to be carrying a personal communicator integrating mobile telephony, mobile internet, mobile TV and radio, and e-commerce. Passengers will demand access to airline services on board such as changing the itinerary and the booking of hotels or tours at the passenger's destination. Onboard services could include specifying meal requirement, selecting onboard entertainment, and booking wake up calls [2], and accessing content on their own carried devices etc. Although there are systems providing data as well as voice connectivity this experience can not be fully realized due to the limited connectivity, cost, and performance. Going forward passengers will demand access to their home & office data as well as other amenities they are accustomed to in their home office environment. The main technological challenge preventing this is the lack of broadband, secure, seamless global connectivity.

There have been some advances in sensor technologies as it applies to airplane health management. However, this area is in its infancy and will require significant growth to make the overall airplane net-enabling a reality. For example current sensors impose extensive wiring and power requirements that prohibit their wide use not only in production, but they are also not practical for retrofit applications. In order to advance this industry and provide a wide benefit to airlines the solution should be applicable fleet wide. The industry has realized that in order to achieve this sensors need to meet the following 3 key criteria:

- Sensors should be wireless for data, and must be frequency spectrum compliant around the world.
- Should be extremely low energy or energy harvested so that no power wires are required
- Require high reliability, availability, and security.

Recently the industry has realized that the only way to implement reliable wireless sensors is to dedicate some spectrum specifically for aviation sensor applications. However, it is also important that this spectrum supports and leverages the consumer industry solutions. The dedicated spectrum effort has already started at the international level through ITU. Boeing is currently leading an industry consortium to achieve this goal. In January 2008 Boeing, along with a key group of aviation industries initiated this effort at the ITU-R called "Installed Intra-Aircraft Wireless Communications" (IAWC). The purpose is to obtain a dedicated frequency allocation at the international level for on-board aircraft wireless applications. The team consists of Boeing, Airbus, Gulfstream, Goodrich, Honeywell, Sikorsky, and NASA. Of course this is a long term effort that may take a decade or more. Other related industries are urged to join this effort to make it more successful.

There are also numerous industry efforts developing energy harvesting sensors with secure communications. Only when all of these technologies are matured, the ubiquitous sensor vision for aviation industry will be realized where we can net enable every aspect of an aircraft and manage it remotely from any corner of the world through net capabilities.

4.1.2 Off-Board Connectivity

Off-Board connectivity can be further divided in to 3 categories – Connectivity on the Ground, Connectivity during Take-off & Landing, and Connectivity during Cruising. Each one of these connections has its own requirements, benefits, and challenges.

4.1.2.1 Connectivity on the Ground

The only reliable ground connectivity at the present time that is available around the world is the Cell Phone connectivity. However it's Bandwidth (BW) may vary from a few Kbps to 500 Kbps, depending on 2G, or 3G and 4G may provide a slightly higher performance. Due to its limited bandwidth this connectivity can support only some limited functionality. For full functionality at the gate the industry needs a low cost link with high BW connectivity in excess of 100 Mbps or more, so that operational and maintenance data as well as movie content can be reliably transferred at the gate within the allotted gate turn around time. One such technology currently being implemented around the world at few airports is the WiFi gate connectivity that can provide around 10 to 20Mbps. Even that is only partially implemented in a few airports around the world due to airport business issues, Spectrum crowding, and lack of open standards. It appears that this will not be a universal global solution any time in the near future. WiMax is another technology being currently implemented; however it is also mired in global spectrum issues and is a long way from becoming a universal solution. Physical connectivity using Gbit copper or fiber cables has been explored many times in the past, but has not been successful due to maintainability and logistical issues. There are some new technologies being explored, but the bottom line is this area is in need of some breakthrough technological solution that can provide broadband reliable connectivity on the ground that can be deployed around the world securely, at low cost.

4.1.2.2 Connectivity during Take-Off & Landing

This connectivity probably is limited to flight essential communications and may not be needed for other purposes. The flight essential communications currently are through VHF, UHF radios, and Satcom. Most of the communications are analog, although more and more digital communications are being explored, such as the "Automatic Dependent Surveillance Broadcast" (ADS-B). The main issues confronting the digital communications are the lack of high BW, seamless connectivity with high reliability, multi domain Security, and end-to-end information assurance.

4.1.2.3 Connectivity during Cruising

This is one of the key areas of connectivity where an aircraft spends most of its time cruising around the world. These communications can be broken in to 3 categories – Control Domain communications, Crew Information Services Domain communications, and Passenger Domain communications. Currently these communications are typically fire walled on board the aircraft so that they can be secure and reliable. However, going forward in the digital world, there may be other ways to provide appropriate security for the information onboard an airplane. Industry is working to develop standards and guidelines so that the digital communication links can be shared securely between multiple systems domains to reduce cost, weight and volume onboard the aircraft. While some changes may be coming, it is highly unlikely that flight critical information will ever exist in any way other than being separated from other kinds of information flowing through the airplane. There is also a critical need for high bandwidth, seamless, secure connectivity that can be reliably used around the world.

4.2 Underlying Network Technologies for Global Interoperability

Since each of the end user systems were developed and optimized over time to meet the local organizational needs, they have not addressed the key underlying information technology factors that are essential for an integrated System of Systems to operate in a most efficient way. The following sections will explore some of the key issues and their challenges.

4.2.1 Internet Routing Standard for Mobile Aircrafts

Current internet is not designed to support a large volume of mobile platforms moving around at 600 miles/ per hour due to the routing disruption it causes on the internet. Boeing is currently leading an effort through the IETF to rectify this problem by developing a new standard based IPV6 and mobile IP technologies.

4.2.2 Aircraft DNS Naming Standard

Currently the aircraft systems have pre-assigned fixed IP addresses for their devices. This may not be a good way to go forward and perhaps should be like a corporate environment with a DNS and DHCP server that can dynamically assign IP addresses. This will help airlines with a consistent operational scenario across their fleet with domain names instead of fixed IP addresses. The current standards under way at the ARINC Network Infrastructure and Security sub committee may help address this.

4.2.3 Standard Aircraft Identity

Today airframers and airlines identify their airplanes many different ways. Going forward the airlines should have a common ID format, process, & other key A/C identity related parameters so that the systems and tools don't have to be customized in each case. These IDs should be electronically embedded in the aircraft so that it can be identified at all times reliably and securely; they should also link directly to the unique ICAO provided aircraft transponder code critical in ATM. However, if it is embedded in hardware then there is a risk that it may not be properly restored when the part is replaced without a robust process in place. This task is expected to be taken up by the Digital Signature Working Group (DSWG).

4.2.4 IPV4 & IPV6 Support Worldwide

Although some countries are aggressively pursuing the conversion from IPV4 to IPV6, it is a given that around the world some countries may still be in IPV4 for the next 10 to 20 years. Therefore, it is imperative that existing and new aircrafts will have to seamlessly connect and operate in countries with IPV4 as well as IPV6 infrastructure. It will be essential to develop some global standards to maintain this compatibility around the world

4.2.5 Cognitive Connectivity

Technologies need to be developed so that aircrafts at any location around the globe can connect to any specific link dynamically based on its security level, reliability, bandwidth and other characteristics and transmit the right type of data appropriate to that location. The industry has not really addressed this issue and some standards may have to be developed to ensure worldwide compatibility.

4.2.6 Multi Domain Level Security

Security is a critical component of aviation industry that determines if a system can be certified to fly safely and securely around the world. In general all systems in the aircraft eco system can be categorized based on their certification level into 3 broad areas – Flight Critical, Flight Essential and Non-Essential. In the past these were physically separated in most cases so that there are no security issues. However, going forward in the integrated systems environment physical separation will defeat the entire purpose of net enabling and will not provide the necessary benefits to the user. Therefore it is imperative that the industry figures out a way to integrate these multi domains in to an integrated networked environment without compromising their integrity. This is being pursued aggressively on the DoD side, and the commercial side needs to solve this fundamental issue so that the entire industry can be benefited.

4.3 Information Architecture (Design)

As part of the System of Systems design, one key factor is to consider proper information architecture across the various systems and entities. This will ensure optimum use of the resources both on-board and off-board the aircraft, better performance, and interoperability. Two key components of this information architecture are given below.

4.3.1 Standard Data and Directory Structures

Standards need to be developed for standard data and directory structures for all interoperable systems for network centric operations. The Air Transport Association of America (ATA) has done some work in the data structures area but, this issue hasn't been addressed more comprehensively from an NCO perspective.

4.3.2 End-to-End Information Assurance

Most of the current information assurance is based on key management and authentication processes based on policies. If the aviation industry wants to use digital wireless communications for critical functions the policy based authentication process may not work since in many parts of the world the policy based key management just may not be that dependable. Boeing is working this issue through ATA digital Security Working Group, Specification 42.

4.4 Information Management (Post Processing)

The pressure on airlines to improve their efficiency and reduce their cost will continue to grow in light of increased competition (due to open skies agreements etc.), and increased operational costs due to fuel costs etc. One key focus of their efficiency improvement will be by reducing delays and down times through increased prognostics. This will require extensive on-board fault detection and reporting system that is complemented by a reliable remote monitoring system from the ground side. For example the newer engines are being instrumented with monitoring features that can provide significant capabilities to monitor and analyze data remotely from the ground given a reliable off-board link.

For example, each engine on a civil airliner is capable of generating at least 1 Gbyte of data per flight [4]. For an overall aircraft including all the systems this data could be as much as 10 times that much per flight. Considering an airline or a power-by-the hour air-framer with 100s of aircrafts flying daily around the world, the transmitted data per day could be 100s of Gbytes. Without the proper advanced decision tools and processing power this will be an information overload without the capability to predict an event accurately and recommend an appropriate course of action in time. In commercial airlines these decisions are done at 2 levels – the first is at the flight crew level on board the aircraft and the second one is on the ground at the airline level or their designated agency.

In order to prevent information overload at the crew level it is crucial that the necessary decision tools are implemented on-board the aircraft systems. These will take into account 3 key types of toolsets as follows: – 1. Data Fusion tools, 2. Case Based Knowledge tools (Based on historical knowledge of similar events), and 3. Model based tools.

For ground systems the analysis is much more comprehensive and will be based on data from not only one airplane, but the data will be analyzed based on the current and past event data from a fleet of airplanes. The analysis will involve a much bigger data set and will be more comprehensive. These will also be based on similar type of toolsets discussed for on-board applications, but on a much larger data set from multiple aircrafts.

The future success of airlines and their improvements in efficiencies will be dependant on the decision tools and the speed at which it can be processed.

4.5 Distributed High Performance Computing

As indicated earlier the scope of shared awareness whether it is on-board the airplane or on the ground will depend on the speed at which the 100s of Gbytes of data can be analyzed on a daily basis and events can be predicted in time to reduce delays and down times. In particular the model based analysis is notorious for its intensive computing needs to provide timely predictions. During these days of low cost operation it is not practical to implement complex large scale computing systems both due to cost and complexities. Moreover, for on-board computing this is not even practical due to the limitations of volume, weight and power constraints. Therefore there needs to be a cost effective, high performance distributed computing capability that can be used by all the users at reasonable cost.

For example one revolutionary idea may be based on IBM's Cell processor technology [3]. Another radical approach may be to take advantage of unused computing power within an aircraft or on the ground within the airline enterprise.

4.6 Business Processes and Social Networks

Once reliable, inter-operable, high bandwidth connectivity is established, there is always a challenge of how the local organizations with their existing processes and tools will be integrated in to the new net enabled environment. There is a significant process and people based challenge that is often overlooked by enterprises in implementing the Net Capabilities. Without this key step the success of the entire approach and its benefits will be in jeopardy.

5.0 Next Steps

I have laid out a vision for the next decade or two, to net enable the entire commercial aviation eco system. However, there are many challenges before this can become a reality. Without a collective acknowledgement and willingness to work together, and develop the necessary technologies and standards this will remain only a vision with only partial benefits realized.

Acknowledgements:

I am thankful to Terry L Davis and Scott E. Marston for their contributions in reviewing and providing suggestions on improving this paper.

References:

[1] Dr. Sanguthevar Rajasekaran, UCONN, Dr. George Vachtsevanos, Georgia Tech, David Loda, Director NCPS Avetec Inc. *Using a Cell Distributing Computing Archtiecture to Create a Global Aircraft Support System*, IMAPP Conference, San Diego, California, 11 September, 2007

[2] Chris Davis, Steve Methley, *Transport Project – Air Transport Scenario Descriptions*, 18 February 2008

[3] Abhinav Saxena, Georgia Tech, George Vachtsevanos, *The use and future Direction of High Performance Computing in Commercial and Military Aircraft*, IMAPP Conference, 11 September, 2007

[4] M. Ong, X. Ren, G. Allan, HA Thompson and PJ Fleming, Rolls-Royce supported University technology Center, University of Scheffield, UK, *Future Trends in Aircraft Engine Monitoring*.

Copyrights: