Improving Coalition Interoperability Through Networking Military/Civil Air Traffic Control Systems

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Abstract

This conceptual paper identifies the availability of air surveillance data that has been unexploited for use in national and regional air sovereignty and air traffic control. The emergence of standardized data formats and communications standards could facilitate information sharing for benefits that include improved situation awareness and air sovereignty and corollary benefits for improved shared (civil and military) use of the available airspace. Currently there are commercial off the shelf solutions to make nearly any air surveillance data available in a standard format and there are data distribution networks available to nearly any location. The exact needs of varying countries for regional collection and distribution of radar data remain unknown, but could be identified through a targeted effort. The overall approach to create interoperability requires exploitation of available data sources, use or possible adaptation of available systems and application of standards to format data, and use of available communications networks. Residual issues for this implementation include: identification of information security needs when data are distributed, timeliness of data for intended purposes and time synchronization of data, and minimum essential elements (architecturally-based investments) to participate effectively in coalition and regional data sharing.

Overview

Collecting surveillance data from air objects remains expensive while the cost of distributing that data has been declining. Access to relevant surveillance data for situational awareness is a key requirement for air sovereignty and safety of flight operations. This conceptual paper describes the sources of available surveillance data, identifies alternatives for data distribution, and addresses the potential benefits of networking air traffic data to provide situational awareness. This data, obtained from existing or planned ground sensors (and potentially in the future from aircraft self-reports), can be used within a coalition partner country or regionally between coalition partners to help build and maintain a common air picture. This paper identifies message and data formats along with recommended standards for data and its distribution in an internet working environment. Potential means of disseminating data between airbases and air operations and/or air traffic control centers, such as land lines, fixed microwave relay, and mobile satellite communications, are also presented. The conceptual roadmap and high-level architectures provided support a set of recommended tasks to achieve a set of objective capabilities. These architectures rely entirely on existing or currently planned coalition air operations or air traffic control centers without the need to develop new centers. Most of the required capabilities are readily available in currently available commercial off the shelf (COTS) products.

Regional Security and Air Sovereignty

Security must be cultivated in the spirit of close regional cooperation. In recent years this has been evidenced in Central and Eastern Europe (CEE). Regional security in CEE is a necessary precondition to the overall security of Europe and NATO. CEE countries must ensure their own national sovereignty and regional stability as part of the larger goal of strengthening global security and to provide support for international operations to combat global terrorism. One important aspect of regional stability and security is having complete and up-to-date knowledge of all military and civil air traffic (a common air picture) within the region. If you can know with improved certainty where all the expected friendly aircraft are, the job of identifying potential threats is greatly simplified. In addition, the problem of knowing when to provide civil access to military airspace is reduced and additional capacity returned to the global airspace system has commercial value.

In the past, air sovereignty objectives were maintained by establishing close control over the airspace and limiting access to defined airspace corridors. More recently, the Regional Airspace Initiative (RAI) under the Partnership for Peace (PfP) program has promoted more open access to airspace and suggests improved capacity to detect, identify, track, assess and respond to air traffic. More open access has been granted to meet the overall demand for improved airspace capacity and efficient operation. In turn, increased traffic has helped fund investment in civil air traffic system improvements. Availability of civil airspace for overflight traffic has benefited the military traffic that uses the available routes. However, continued improvements in opening airspace will likely require some investment in military systems to provide assurance to those responsible for air sovereignty that they are capable of performing their mission in the face of increased traffic densities.

Investment in military air traffic and air defense systems lacks the type of funding source and incentives that have been available to the civil systems. However, keeping track of the air objects within the sovereign airspace remains a critical function. Sharing information among partners is critical to build the common air picture both within a country and within a region. It is difficult for any country to provide full air defense system surveillance throughout its sovereign space, but adjacent countries often have surveillance assets that can fill-in the gaps for air defense. Countries sharing borders and common interests are in the position to exploit this capability. In forward deployed situations with military air traffic surveillance assets owned by varying services or coalition partners, the ability to disseminate the available data can become the critical difference for full combat identification from ground to air and back.

The Air Picture Objective

An important part of air sovereignty operations is the ability to build and maintain an accurate air picture. This is seen most easily in the attempt to create a Coalition Common Air Picture (CCAP). Having an accurate and up-to-date CCAP provides coalition operations center staff with improved situational awareness and the capability to better manage friendly air assets. However, the actual assets deployed by the Coalition and their locations may not provide the full coverage desired. Additional assets potentially available to form the full air picture have often been used in a standalone mode. Among these are the mobile radars used to support air operations at expeditionary airfields.

These systems are essentially stand-alone air traffic control systems with a fairly long-range interrogator for cooperative aircraft in addition to the primary radar (and precision approach radar which is less useful for the context here). If these assets are exploited for dual purpose, that surveillance data becomes available at a low acquisition cost to the CCAP. In essence an expensive asset with expensive data can be used for merely the additional cost of transmission.

Similarly, being able to provide the relevant surveillance data to the civil system for air traffic uses provides improved situation awareness and affords the opportunity for better real-time airspace management for shared use. Real-time availability of operations plans and comparison of planned flights with actual surveillance can help identify the availability of military air space for civil use and can be used to enhance the identification of unknown and enemy aircraft.

In the future the sources of surveillance data relevant to the CCAP will encompass the systems we know today (airport and long range primary surveillance radar, secondary surveillance radar, and the emerging availability of automatic dependent surveillance) and future capability including military aircraft position messages relayed from tactical data links and other self-report position data. In addition to position information, identification information is a fundamental requirement for both air traffic control and air defense. These data are largely available for civil traffic in both civil and military command centers and military data are generally available to the local civil system and regional entities (e.g., the Central Flow Management Unit at EUROCONTROL) for in the form a filed flight plan. Additional security concerns about military flights and the nature of their missions makes full disclosure to the civil system unlikely in many cases. This is not a major issue for air defense since the military system has the required knowledge. Effective segregation of civil and military traffic has limited safety concerns. Nevertheless, more widespread availability of data where appropriate can enable more effective identification and maintain identity across system boundaries, and support effective air traffic management.

Advantages

Knowledge of exact aircraft departure time and ability to access trajectory data can support real-time dynamic allocation of airspace. This could allow more precise windows for use of ingress and egress space (reducing vulnerability to offensive attacks, but more importantly allows more paths or coalition aircraft reducing their exposure to anti-aircraft fire).

Access to military surveillance system data can also reduce the need for additional civil SSR interrogators, and can reduce the potential for interference between civil and military interrogators. If there are fewer interrogators there is a reduced risk of over interrogation and misinterpreted transponder replies. This could enhance safety and service provision to civil and military aircraft.

Sharing radar sensor information within a region could reduce the need for additional national ATC systems. Overlaps in radar and Navaids coverage could be eliminated in the cross-border areas through more efficient regional ATC architectures.

Air Picture Capabilities Needed

The figure below illustrates generally the flight phases (launch, departure terminal, enroute, arrival terminal, and recovery) for US military or civilian aircraft. U.S. Terminal Radar Approach Control (TRACON) and Air Route Traffic Control Center (ARTCC) ground stations are US Federal Aviation Agency (FAA) designated facilities whose functionality would be duplicated in any global region. In order to transit this airspace effectively and be controlled efficiently certain basic capabilities are required.

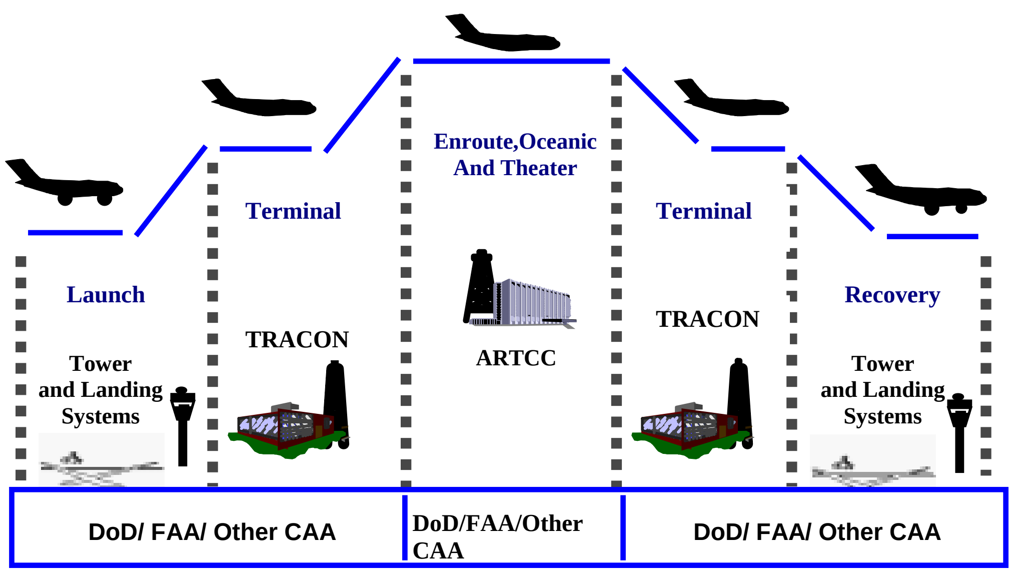

Figure 1. Phases of Flight

These capabilities are listed below, but not necessarily in a prioritized order.

- <u>Positive aircraft identification.</u> Within the region of interest from initial departure to final arrival, the specific identity of an aircraft is critical to establish and maintain effective communication. The volume of traffic in some airspace dictates that the controller has available the aircraft call sign. In civil systems this has been maintained by the matching of assigned transponder codes with a data base of flights. This function is largely automated today in modern systems. Such a capability enhances safety of flight for ATC and will facilitate combat identification. Combat identification is made much more effective if the aircraft that are known friendly have a continuous track with positive identification.
- <u>System-to-system data communication.</u> In order to minimize verbal over-the-air voice traffic, improve information efficiency, accuracy, and security, and free up frequency channels for other military and/or ATC uses, system to system communication should be maximized. If each aircraft departure from a military

airfield were to be coordinated verbally with adjacent air traffic or air defense unit, the volume of voice traffic could prove excessive. Additionally, the verbal information does not support the direct formation of a common air picture ithout additional effort to "translate" the verbal message. System data can be used directly to form the common air picture and provide that to the user.

- Shared use of interrogators. By using a regional approach rather than having each nation provide overlapping and redundant interrogators, it is possible for complete coverage to be gained with a much lower system-wide investment. This would reduce overall acquisition and ownership costs. An added benefit is the reduced interrogation of aircraft which can improve the identification of aircraft and reduce problems associated with over interrogation (e.g., replies being misinterpreted when intended for another interrogator, i.e., FRUIT and garble).
- Build and maintain a CCAP. By utilizing national and regional air traffic control (ATC) sensors and data and available military assets, all partners within a region can have a common air picture which would necessarily be tailored to each user's region of interest. This will facilitate joint use of airspace and serve to enhance the ability to maintain air sovereignty. In coalition operations while deployed, positive identification should improve targeting of enemy aircraft while reducing the potential for fratricide.

Challenges

Although it is theoretically feasible to provide the capabilities described above, in practice there are numerous impediments to implementation.

- Significant variance in coalition partner national military capabilities, in the area of ATC resources, makes it difficult to obtain common ATC sensor and operations data that can be displayed and updated rapidly.
- Many current military ATC systems in Eastern Europe and Western Asia are operated in stand-alone or highly limited data distribution modes due to obsolete analog designs, proprietary data formats, or doctrine/concept of operations.
- National approaches to ATC improvements may not enhance regional development of a CCAP and may not include generation of a national air picture.
- National ATC implementations may not be common to or interoperable with those implemented in adjacent or regional countries or with North Atlantic Treaty Organization (NATO) standards.
- Proprietary designs for processing and distribution of radar data complicate interoperability between national systems.
- Many of the developing countries do not have adequate funding for the implementation of a national radar data network or cross border sharing of information. External funding sources will have to be identified.
- Traditional operations concepts and long-standing suspicions between former enemies limit the speed of transition toward improved information sharing. In some cases, even the services within a country find coordination difficult.

Trends

Multinational coalitions are gaining in importance, dynamic by nature, and formed for a specific purpose – then disbanded. Coalitions must be adaptable, be established quickly, be agile enough to handle the addition and subtraction of member nations, must employ interoperable communications standards in order to share data effectively, and must minimize hardware and personnel required to establish and maintain coalition networks. Moreover, these coalitions must assume that assets could be widely distributed including command and control functions that are out of the theater of operations.

Many former Soviet block countries, such as Poland, Bulgaria and Romania are planning to acquire or have already installed modern radar systems for their designated coalition airbases. These systems commonly use Ethernet LANs and fiber optics as a medium to distribute digital radar sensor target data to operator and supervisor positions in operations subsystems and control towers within the confines of the airbase. Connecting these limited intra-airbase networks to external national and/or regional air operations centers could contribute useful information to a CCAP.

Technology for surveillance systems has evolved rapidly over the last ten years. In addition to solid state amplifiers, phased array antennas, software functionality, and increasing use of digital technologies for sensor hardware, Internet Protocol (IP) standards and associated routing technologies have been adopted for processing and distribution of digital sensor data within the system boundaries. Use of IP standards facilitates distribution of data beyond system boundaries.

The US DoD offered RAI and country Navigational Aids (Navaids) studies to most of the PfP countries in Central and Eastern Europe, and is extending the offer to western Asian countries, too. The Navaids studies resulted in national efforts to enhance national ATC capabilities through acquisition of Navaids and approach/landing systems by way of direct purchases and US Foreign Military Sales (FMS) programs. RAI studies resulted in one regional system known as Baltic Network (BALTNET).

A BALTNET Summary

BALTNET is a regional airspace initiative system for the acquisition, co-ordination, distribution and display of peacetime air surveillance data within the Baltic states of Lithuania, Latvia and Estonia. In times of crisis, BALTNET can be connected to a NATO CRC or Coalition Air Operations Center (CAOC) and an Air Sovereignty Operations Center (ASOC). System objectives encompass international co-operation between civilian and military authorities and the development of air traffic control functions in all of the participating states. The architecture of BALTNET includes radar sensors in each of the participating countries, a Regional Airspace Surveillance Co-ordination Center (RASCC), national air surveillance centers (National Nodes) in each of the participating countries, and a regional data and communications network. See Figure 2. for the current BALTNET architecture.

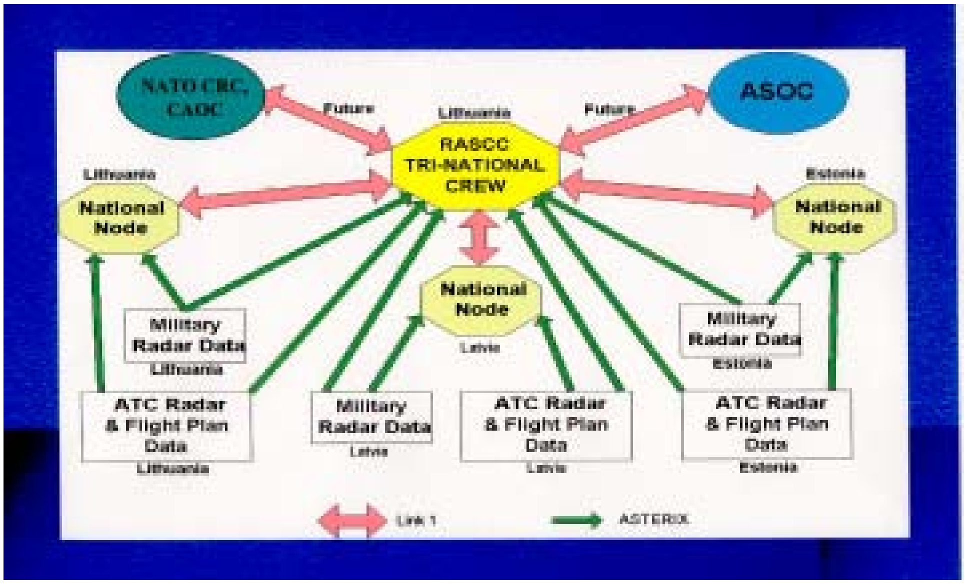

Figure 2. BALTNET Architecture

The RASCC receives, processes and displays primary and secondary radar data provided by national sensors. It also initiates tracking and identification of all aircraft within the radar coverage area and co-ordinates the exchange of regional airspace information with third parties.

Each of the participating countries has established a National Node which receives and displays a general integrated airspace picture and provides backup to the RASCC. National Nodes also display surveillance data provided by national radars that are not connected to the BALTNET infrastructure.

The RASCC and the National Nodes both use ASOC hardware and software, designed to process digitized radar data received from national civil air traffic control centers, from selected in-country command centers, and from flight plan information to provide an integrated air situation display. Capabilities exist within the BALTNET architecture for all national and regional radar information to be shared among all National Nodes and the RASCC, although national restrictions may be observed in some cases. A Future capability is also provided to interface other ASOCs and western Link 1 capable ground facilities.

BALTNET assets can also be used for an exchange of air pictures with NATO and/or individual NATO countries by use of NATO compatible data standards. NATO standards and procedures have been incorporated which provides the Baltic states with compatibility and interoperability. The BALTNET network has been recently integrated into the NATO CRC and COAOC infrastructures.

Why not propagate the BALTNET architecture?

BALTNET is a highly capable regional system with many desirable features. There are however limitations to its reuse in other regions and for *ad hoc* coalitions.

- BALTNET was not designed to be set up and torn down in a dynamic environment, such as a coalition operations center.
  - Fixed network structure
- BALTNET is too expensive
  - $100M cost to support a relatively small 3-country region -$10.3M for the ASOC equipment in the four centers
  - Cost cannot be justified by developing countries based on their priorities
  - NATO or NATO member sponsorship/funding not identified
- BALTNET is too complex, requiring
  - Complex RASCC and National Node centers
  - Complex communications infrastructure
  - Extensive training for operation and maintenance

A simpler and less expensive architecture, such as the one proposed in the following pages could provide useful air picture information while addressing COAC dynamic setup and break down requirements.

The Way Ahead

The evolution of technology in modern air surveillance and landing systems provides at least the technical ability to deliver digital target information using standard data and message formats over local area networks (LAN). Data and messages on these LANs could be further distributed to national and regional air operations centers. LAN interfaces to older analog systems have been achieved through use of target data extractor (TDE) equipment and analog to digital converters.

By providing surveillance data for situational awareness, we can implement the equivalent of civil aviation's "launch-to-recovery" aircraft coverage. In addition, this supports better prediction, planning, and execution of both ATC and command and control (C2) functions for not only these aircraft, but for other aircraft with which they interact. In the cases where military surveillance can be passed to the civil system, these same benefits could also accrue to it.

Data and Data Transport Formats

When radar systems were standalone or formed into small, isolated internal networks serving a single country or area, it was common for systems to have proprietary data formats that were largely incompatible with those of other suppliers or used in different regions. There was little apparent incentive to standardize on formats and systems were seen to be dependent on the selected format. Suppliers relied on "their" format exclusively and infrastructures were built around the format of choice. Over the last 20 years, there has been a dramatic move toward standardized formats in a variety of application areas including air traffic surveillance data. A few common surveillance data formats are described briefly below.

- **CD2** Common Digitizer Protocol A common use for CD2 is for processing air traffic control radar data (13 bit serial data comm) enabling the transmission and reception of synchronous radar data. When used for this purpose it is often known as FAACD2 (Federal Aviation Administration Common Digitizer). CD-2 format radars include ASR-9 and ASR-11 (short range) and ARSR-1, -2, -3, -4 (long range).
- **Proprietary Formats** have included Thomson's EUROCAT and AIRCAT500, Ericsson 200, Alenia, and a host of others.
- **ASTERIX** (All-purpose Structured Radar Information Exchange) is the radar data format that is emerging as the first world-wide standard in the field of surveillance. Development and application of a common format was central to the success of the program to harmonize and integrate Europe's air traffic control system. It has facilitated the sharing of surveillance data between states for civil air traffic purposes. ASTERIX has continued to be adapted for a wide variety of surveillance systems.
- **LINK-1** Tactical Data Link performs message formatting and error checking for NATO radar tracking and other systems. It is used to distribute surveillance from a sensor to a command center.
- **LINK-16** is the current Joint Tactical Information Distribution System (JTIDS) protocol. The concept of using LINK-16 for Air Traffic Control (ATC) is not new, however MITRE recently demonstrated a novel use to up link ADS-B messages received at an ARTCC as JTIDS tracks to a military aircraft, thereby enhancing situation awareness.

Vendors now supply off-the-shelf modular data format, protocol converters, and network security products that support a variety of protocols, electrical standards and message formats. At least one product supports directly data transfer using standard TCP/IP and UDP/IP communication protocols. Some of these systems are in use to interface legacy sensors to new automation systems for the Federal Aviation Administration's and Department of Defense's Standard Terminal Automation Replacement System (STARS) and Digital Airport Surveillance Radar (DASR) Programs. Recently, a communications server and radar receiver software application were demonstrated in the United States Joint Forces Command's Joint Combat Identification Exercise (JCIDEX), a large-scale strategic exercise to evaluate and assess field systems with intentions to improve tactics, techniques and procedures across all combat mission areas. This system also employed a commercially available system and an Ethernet distribution. The system was capable of handling a variety of formats such as CD-2, TPS-43, RAMP and others.

CCAP Architectures

The following architectures are notional and are presented at a high level consistent with the conceptual nature of this paper. These notional architectures do not address national, regional and CAOC CCAP requirements which could have a significant impact on the actual final architectures and roadmaps.

Figure 3. shows an overall notional architecture for a hypothetical 3-country region. In this architecture, national airfields which could be military or civil or combined military/civil are connected to National Centers via landlines, microwave communications networks, or mobile satellite links (See Figure 5. for a notional architecture of a National Center). National Centers could range from facilities as complex as an ASOC to a simple equipment layout within a room in Ministry of Defense (MoD) or national air force headquarters facilities. National civil ATC centers could also be used.

For a regional configuration, National Centers could be interconnected via high data rate landlines, microwave links, or mobile satellite links and National Centers could be directly connected to a Coalition Air Operations Center (CAOC). The figure shows a CAOC within one of the countries, but it could be in an adjacent or distant country provided adequate communications circuits were available between the National Centers and the CAOC.

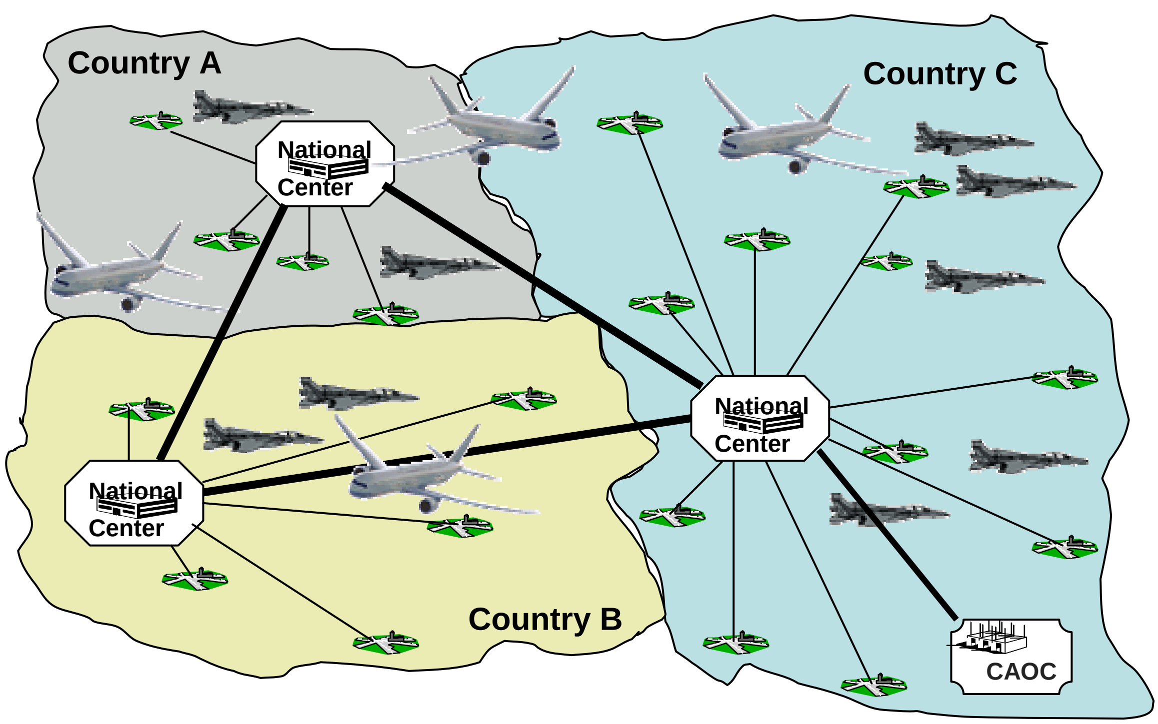

Figure 3. Notional Regional CCAP Architecture

Figure 4 shows a notional architecture for a national airfield. This hypothetical airfield has both a Airport Surveillance Radar (ASR) and a Ground Control Approach (GCA) radar. The ASR is normally a fixed facility located within a few kilometers of the airfield control tower. The GCA would be located near the primary runway so that it could provide 360-degree Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) coverage along with Precision Approach Radar (PAR) functionality. ASR, PSR and SSR processed target data would be useful to creation of a CCAP; PAR data probably would not.

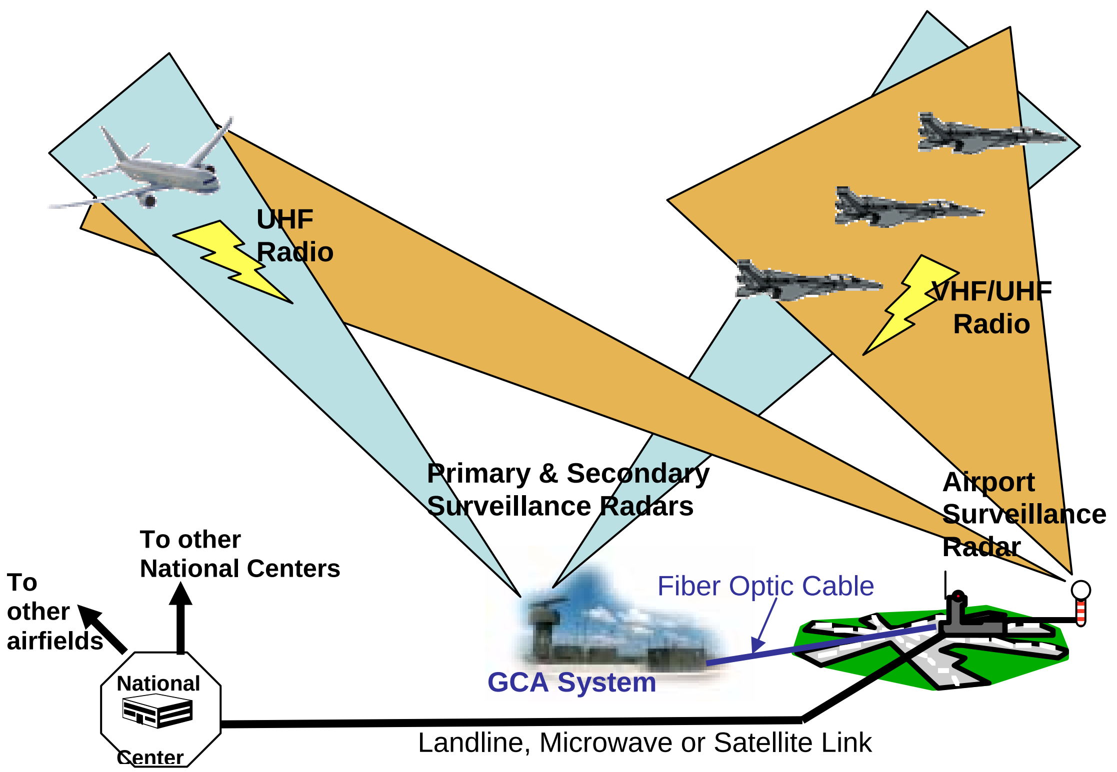

Figure 4. National Airfield Architecture

Aircraft within line-of-sight (LOS) of the control tower and the GCA communicate with ATC operators via Ultra High Frequency (UHF) or Very High Frequency (VHF) radios. Normally this communication is voice, but some countries use data links or networks.

ASR processed target information is sent to the control tower and displayed for the ATC operators. This display shows ASR targets, tracks and SSR information. The GCA operators could be located in the control tower or in a shelter/building adjacent to the GCA radars. The GCA displays show PSR, SSR and PAR target information. GCA target information is usually sent to the control tower over a fiber optic cable.

Since the air traffic control tower usually gets all the ATC information generated on an airfield, the tower would be a logical location for a hub to distribute this information to National Centers. Landlines, microwave communications networks, or mobile satellite links could be used if available at the airfield.

Figure 5. shows a notional National Center architecture. The components shown could be installed as part of an existing ASOC, if available, or in any location where access to national air traffic information could be made available.

A local area network (LAN) connects all National Center components. The national air picture (NAP) workstations would be used to display national air traffic information received from national airfields and could also be used to display CCAP information received from other National Centers, an ASOC, or the CAOC. The workstation operator(s) would have the capability to review and annotate airfield information before sending it to other potential recipients.

Information received and sent out would be routed through a communications interface. Routers and servers would be provided to support message protocols and to store and maintain processing software for the workstations.

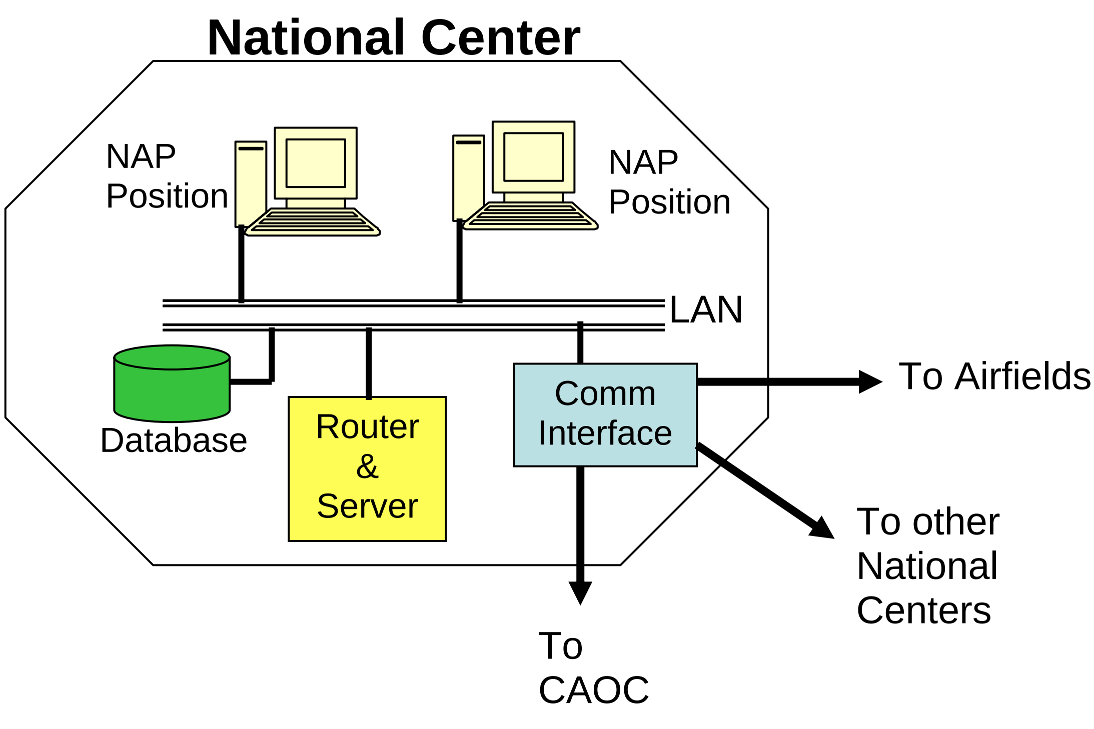

Figure 5. National Center Architecture

Figure 6. shows a highly notional architecture that could involve a portion of the CAOC. National Centers could send air traffic information to the CAOC that could become part of the Common Air Picture (CAP) currently maintained within the CAOC. National workstations could be set up for each country contributing information to a regional CCAP. As was proposed for the National Centers, a communications interface should be provided to support receipt of regional information and dissemination of CCAP information to the contributing countries.

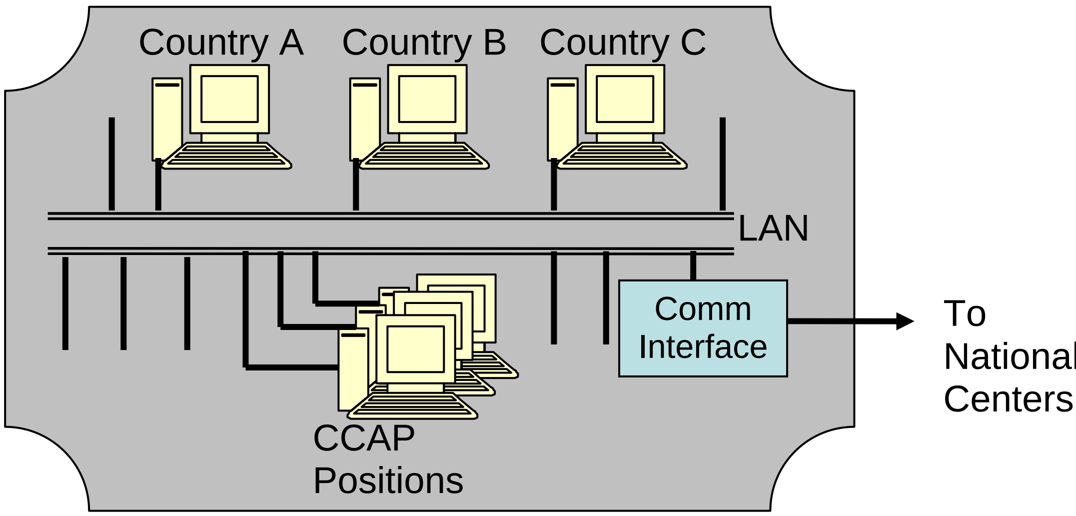

Figure 6. CAOC Architecture

Roadmap

In order to achieve the proposed regional CCAP conceptual architecture, a set of capabilities must be established for each of the countries within the region. A preliminary roadmap has been provided which indicates requirements definition and acquisition steps necessary to provide these essential capabilities.

Figure 7. provides a preliminary roadmap of the basic phases needed to initiate the requirements definition process and to implement the architectures discussed above. Three architectural elements are shown in the figure, national airfields, national centers, and a portion of a CAOC. The roadmap phases include the following:

- An evaluation of current capabilities (ATC systems, interconnects, and operations) at national airfields
- An evaluation of current capabilities, if any, at national civil and military ATC or command centers
- A definition of regional technical and security requirements for sharing airfield ATC information

- A determination of residual needs at national airfields
- A determination of residual needs at national centers
- An identification of funding sources for designing the integration of regional ATC information into current CAOC systems and operations
- Once architectures are finalized; acquisition of hardware (H/W) and software (S/W), installation, and testing at national airfields, national centers, and at an CAOC
- An identification of communications media, data formats, and security requirements at national airfields and national centers
- Installation and testing of data format processing and communications systems

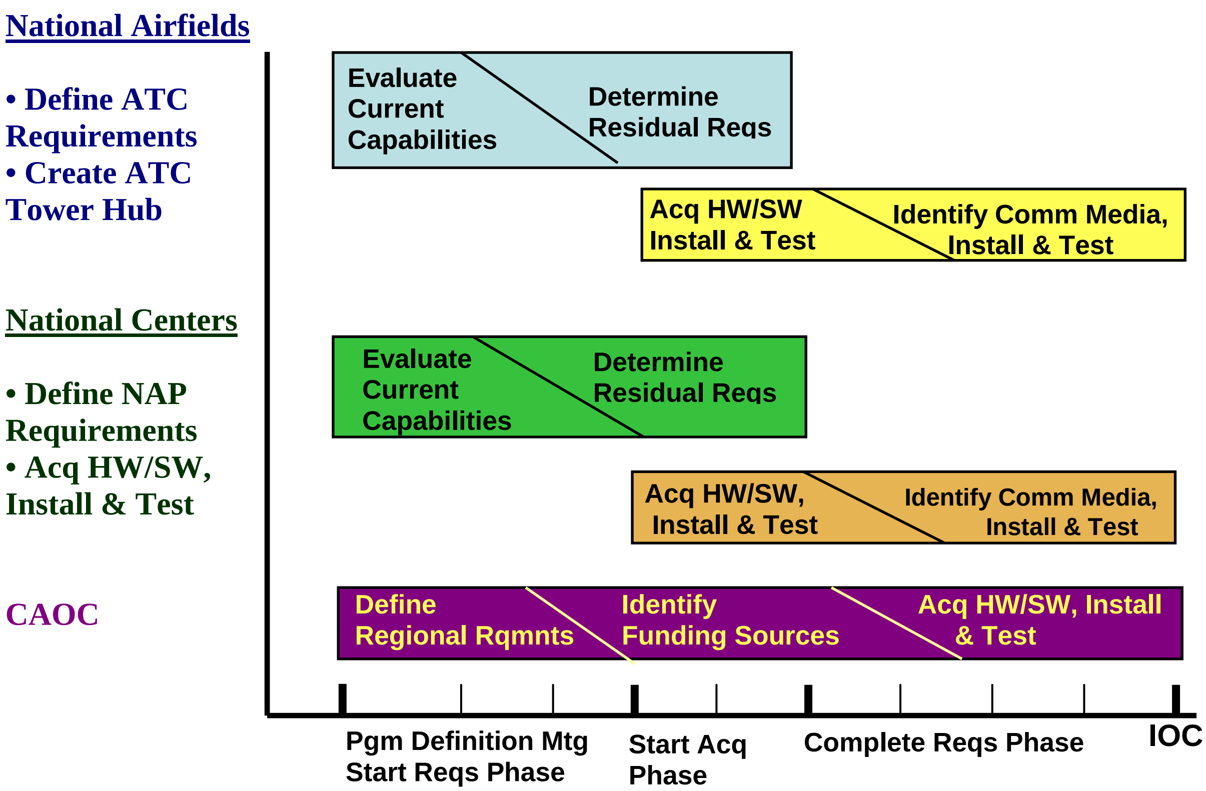

Figure 7. Proposed CCAP Roadmap

Recommendations

We recommend that the following steps be undertaken to ensure that CCAP systems and capabilities can meet the need for establishment of coalition operations within a region.

- Establish a multi-national working group to initially determine key coalition air picture requirements and the essential capabilities needed to meet these requirements.

- Obtain funding for a research and design tradeoff effort to transform the conceptual architecture to a mature architecture that can be rapidly and economically achieved.
- Once a mature architecture is developed and agreed by the working group, finalize an acquisition roadmap to identify those architectural components to be acquired by countries providing air operations centers and by countries that are primarily providing air picture sensor data.
- Work with potential coalition partners to develop Letter of Request (LOR) documents to acquire systems and components as required.

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