Dissemination of ISR Data in the Coalition Aerial Surveillance and Reconnaissance (CAESAR): Results and the Way Ahead

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ABSTRACT

In 2001, seven nations developing future Aerospace Ground Surveillance and Reconnaissance (AGS&R) applications initiated the Coalition Aerial Surveillance and Reconnaissance (CAESAR) Project. This paper is focused on AGS&R, which provides a substantial subset of the overall Intelligence Surveillance and Reconnaissance (ISR) effort.

The findings presented in this paper are based on a set of exercises conducted from project inception up to June 2004. Several AGS&R architectures were tested with numerous sensor and exploitation capabilities providing support. The sensors applied included JSTARS, ASTOR, HORIZON, CRESO, GLOBAL HAWK and RADARSAT-2. These sensors were used to provide Ground Moving Target Indicator (GMTI) data, Synthetic Aperture Radar (SAR) images and Link 16 Ground Tracks to airborne and ground based exploitation stations. Within the AGS&R architecture, various data streams are stored and made accessible through a CAESAR Shared Database (CSD), which supports network centric operations. Some of the features of the CSD are explained.

The Multi-Sensor Aerospace-Ground Joint Interoperable Intelligence Surveillance and Reconnaissance Coalition (MAJIIC) project will expand on the findings of CAESAR in the years 2005 to 2009.

COALITION AERIAL SURVEILLANCE AND RECONNAISSANCE (CAESAR)

A short introduction to Aerospace Ground Surveillance and Reconnaissance

The work presented in this paper describes the achievements of a multi-national project team over four years of effort. In 2001, seven nations developing Aerospace Ground Surveillance and Reconnaissance (AGS&R) applications initiated the Coalition Aerial Surveillance and Reconnaissance (CAESAR) Project. The CAESAR Project is designed to develop the CONOPS (Concept of Operations), TTPs (Tactics, Techniques and Procedures) and Technology to allow the efficient and effective use of multiple GMTI (Ground Moving Target Indicator) and SAR (Synthetic Aperture Radar) sensor platforms in a Coalition environment. The project aims to maximize the military utility of scarce and expensive Ground Surveillance resources through the development of operational and technical means that enhance interoperability to support the Intelligence, Surveillance, and Reconnaissance (ISR) cycle.

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AGS&R assets are used as part of an overall ISR Architecture. ISR architectures can take advantage of a variety of platforms supporting sensors that make use of a wide range of the electromagnetic spectrum; from optical wavelengths to radar In addition, ISR architectures require associated exploitation capabilities and integration of the information gained through exploitation into intelligence networks and command and control systems. Figure 1 depicts some of the platforms, supporting a number of sensor classes with relative fields of regard, used in ISR operations.

It was clear from the very beginning of the CAESAR project that the scope of work for an overall solution of ISR integration was beyond feasibility. Therefore, CAESAR focused on GMTI and SAR, but elected not to consider electro-optical or infrared sensors.

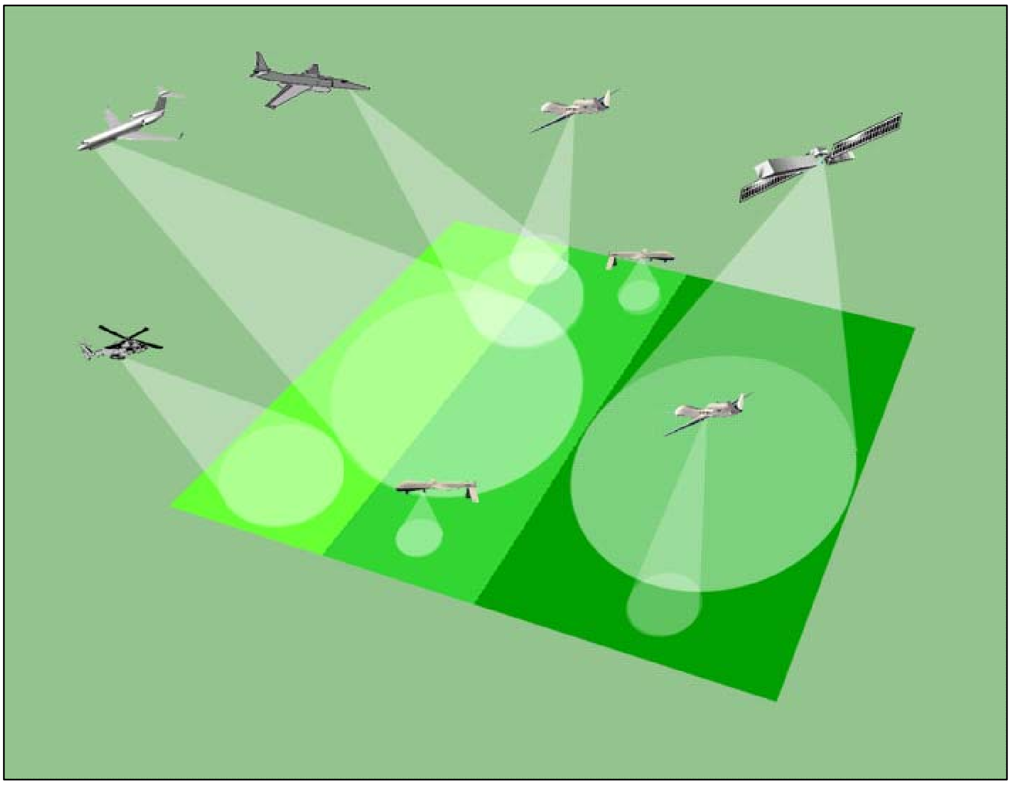

Figure 1 Various Aerospace Ground Surveillance and Reconnaissance Systems

A short history of CAESAR

In 1997, immediately after the Paris Air Show, the NATO C3 Agency and six Nations participated in the Paris Interoperability Experiment, which showed that various AGS&R sensor and exploitation systems could be made to operate with each other in a real world environment. The participating Nations were France, Germany, Italy, Norway, the United Kingdom and the United States of America. Two years later in 1999, both the US Joint STARS and the French HORIZON flew in Kosovo collecting GMTI data in a common area. Despite the efforts of many, these systems were never integrated into a true interoperable capability during that conflict.

The CAESAR Nations and organizational structure

The CAESAR Project was initiated to overcome some of the problems observed in Kosovo and to achieve operational and technical interoperability among the GMTI and SAR platforms of many Nations. In 2001, the seven CAESAR Nations initiated the CAESAR Project. These are, in alphabetical order: Canada (CA), France (FR), Germany (GE), Italy (IT), Norway (NO), the United Kingdom (UK) and the United

States of America (US). Each nation funds and manages a national program that leverages national projects to support CAESAR. The overall project is coordinated via a Project Officers (PO) group and is supported by NC3A in The Hague, The Netherlands, which provides technical management and expertise to help achieve the goal of coalition interoperability.

The project is managed by a group of nationally appointed Project Officers, one from each nation, supported by the Technical Manager from NC3A and the Chairmen of three inter-related working groups: the Operations Working Group, the Architecture Development Working Group and the Technical Interoperability Working Group.

Each group addresses topics of specific interest to their group and supports the other groups' efforts. At each CAESAR conference, cross group meetings are an important fixture for problem solving. The international co-operation beyond the work group topics is a key element for the fast progress of CAESAR. NC3A and the CAESAR nations provide equipment and personnel to participate in working groups and exercises that are focused to identify and solve problems.

CAESAR main emphasis

The CAESAR main emphasis was to enhance the current system capabilities, to improve interoperability of the various AGS&R systems, to develop the operational procedures and to integrate the new capabilities into existing processes. Interoperable Coalition Ground Surveillance is not feasible without agreed CONOPS and TTP. This approach covers operational, procedural and technical interoperability. The plan was to achieve this by developing and evaluating technologies for the integration of diverse GMTI/SAR platforms, by maximising the military utility of surveillance and reconnaissance resources and by optimising data collection and exploitation of GMTI/SAR assets.

AGS as a new task for NATO

NATO is currently in the process of defining a NATO owned and operated Alliance Ground Surveillance (AGS) core capability that will be interoperable with supplemental national systems. NATO AGS will provide a new capability for NATO. Some nations are currently developing national AGS capabilities while other nations already have operational capabilities. In any future, NATO coalition operations with AGS capabilities, one of the critical areas will be to achieve interoperability between the various national and NATO AGS assets. The following sections describe how the CAESAR team has approached this challenge.

AGS&R data streams observed in exercises

Introduction

The CAESAR Project has taken part in many exercises, with both live and simulated assets, since it was started. The following table provides an overview of the exercises, experiments, and demonstrations that have provided and will provide the basis for demonstration and validation of the CAESAR concepts. Following the table, is a detailed description of the Simulation Exercise 2003 (SIMEX 2003) held in October 2003 at NC3A in The Hague [Kreitmair 2004]. Upcoming exercises with CAESAR participation planned for later in 2004 and 2005 are shown in italic.

Table 1: CAESAR Exercises, Experiments, and Demonstrations

Event Name	Asset Type	Location	Time
Clean Hunter 2001	Simulated	FR, GE, UK	June 2001
Strong Resolve 2002	Live	NO	February 2002
Dynamic Mix 2002	Simulated	SP	May 2002
Cannon Cloud 2002	Simulated	GE	June 2002
Technical Interoperability Experiment (TIE)	Simulated	NL	May 2003
SIMEX 2003	Simulated	NL	October 2003
Joint Warfighter Interoperability Demonstration (JWID)	Simulated	NO	May 2004
Joint Operator Tactical Meet (JOTM)	*Live / Simulated*	*GE, NL*	*September 2004*
Technical Interoperability Experiment (TIE)	*Live / Simulated*	*NL, US*	*October 2004*
Trial Hammer 2005	*Live*	*FR, GE*	*May 2005*
SIMEX 05	*Simulated*	*GE, NL*	*October 2005*

Simulations involved in SIMEX 2003

SIMEX 2003 is described in the following paragraphs in detail. It serves as a model for the other simulated and live exercises. Tables 2 and 3 identify the simulated sensor systems and the exploitation systems participating in SIMEX 2003, while Figure 2 provides a representation of how they are networked together.

Table 2: Simulated Sensor Systems Participating in SIMEX 2003

Nation	System Name	Function
CA	RADARSAT-2	GMTI Sim
FR	Hélicoptère d'Observation Radar et d'Investigation sur Zone (HORIZON)	GMTI Sim
FR	Systèmes Intérimaires de Drone Moyenne (SIDM)	GMTI Sim
IT	Complesso Radar Eliportato di Sorveglianza (CRESO)	GMTI Sim
NATO	NATO Airborne Early Warning and Control (NAEW&C)	Air Picture
UK	Airborne Stand-off Radar (ASTOR)	GMTI Sim SAR Sim
US	Global Hawk	GMTI Sim SAR Sim
US	Joint Surveillance and Target Attack Radar System (JSTARS)	GMTI Sim SAR Sim
US	U-2 Advanced Synthetic Aperture Radar System (ASARS) Improvement Programme (AIP)	GMTI Sim SAR Sim

Table 3: Exploitation and Support Systems Participating in SIMEX 2003

Nation	System Name	Function
FR	HORIZON Ground Station	Exploitation
FR	Système d'Aide à l'Interprétation Multicapteur (SAIM)	Exploitation
GE	Interoperable Imagery Exploitation System (IIES)	Exploitation
IT	CRESO Exploitation Station	Exploitation
NATO	CAESAR Shared Database (CSD)	Data Repository
NO	Mobile Tactical Operations Centre (MTOC)	Exploitation
NO	Norwegian Command and Control Information System (NORCCIS)	Situation Awareness
UK	ASTOR Ground Station (AGS)	Exploitation
US	Joint Services Work Station (JSWS)	Exploitation

US	Motion Analysis, Tracking and Exploitation (MATREX)	Exploitation
US	Moving Target Indicator Exploitation (MTIX)	Exploitation
US	Transportable Mission Support System (TMSS)	Exploitation

The capabilities of the various systems are described in Ref. [3] and will not be discussed further in this paper. The sensor systems listed above provide accurately simulated representations of operational capabilities. Some of the systems use operational software to support the sensor simulation. The ground stations and/or exploitation stations, in most cases, are represented by operational equipment.

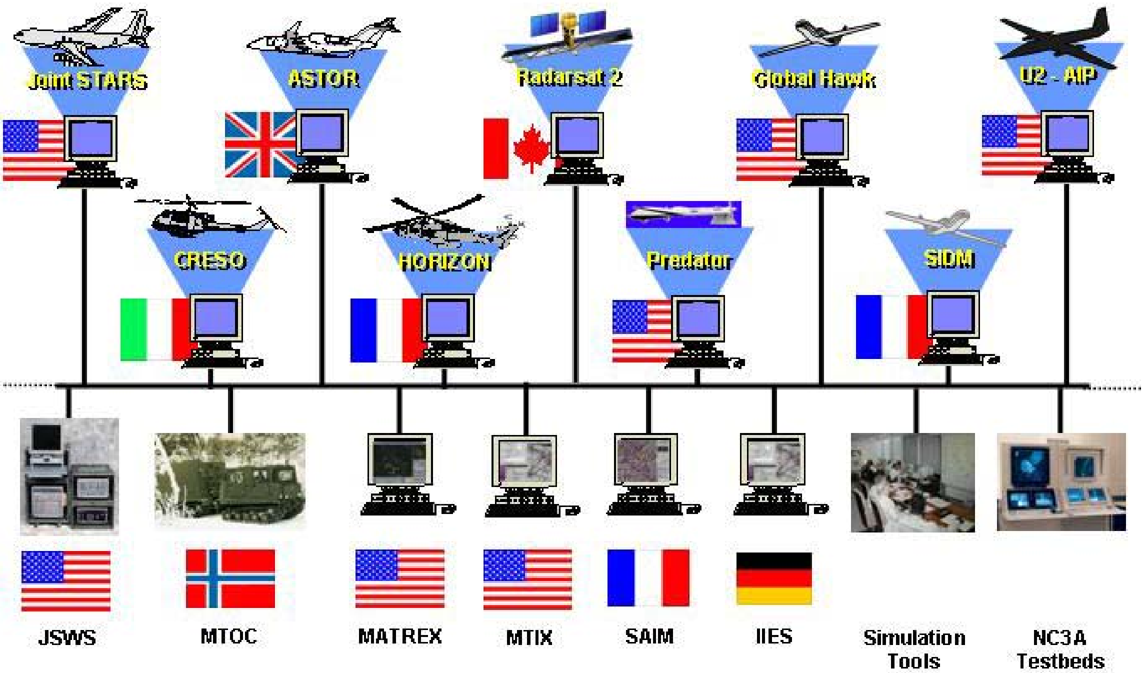

Figure 2 AGS&R sensor and exploitation stations in SIMEX 2003

A single common scenario was created by combining the outputs from three simulation drivers:

- Joint Combat and Training System (JCATS) for military ground movement,
- Integrated Training Capability (ITC) for air operations of aircraft and helicopters, and
- Ground Vehicle Simulator (GVS) for background, non-military ground movements.

All three simulations reported Distributed Interactive Simulation (DIS) Entity State Protocol Data Units (PDU) to a single socket, from which the sensor simulations received their input. The sensor simulations were used to determine which entities would be visible to their respective sensors, based on characteristics of the sensor, the terrain, and the movement of the vehicles. The sensor simulations then provided their resultant data and information to a local area network. This data was disseminated over a wide area network to all of the ground stations, exploitation stations, and to the CAESAR Shared Database (CSD), which were distributed throughout the simulated theatre. The dissemination of the ISR data streams is discussed in detail below. Most of the data streams, such as DIS traffic, Link 16 messages, SAR images, GMTI Data and formatted messages produced by operators were checked for format compliance against the appropriate Standardization Agreements (STANAG).

Based on disseminated data, military operators and commanders planned, monitored, and managed the operations. The exercise started with two weeks set-up and training and one week of full operations. In total, about 90 operators and military personnel participated. The network supporting the exercise was composed of seven subnets with a total of more than 120 computers and was in about 400 m^2 of laboratory space. In addition to the laboratory space, briefing rooms and offices were also provided. The entire exercise was run in a classified configuration. Figure 3 below shows operators of the sensor simulations Global Hawk, JSTARS, CRESO and RADARSAT-2, working next to each other.

Figure 3 AGS&R sensor simulations in laboratory during SIMEX 2003

An important aspect was the coalition planning, tasking and management for all of the AGS&R sensors available in the coalition. [Mahaffey 2004] provides more details and insight on this particular important aspect. The military operators provided by the various Nations were all experts in their area, whether they were specialized on sensors, exploitation, or command areas. They exercised roles in the NATO and multinational command centres. Depending on the command relations of the various AGS&R sensors and exploitation stations, the roles changed. Figure 4 below shows an AGS&R manager planning session.

Figure 4 Multi-national coalition AGS&R manager planning session

Simulation Architecture in SIMEX 2003

Figure 5 shows the Node Connectivity Description of the simulation architecture used in SIMEX 2003. Multiple scenario simulations (JCATS, ITC, and GVS) provided scenario data via a single socket to the various AGS sensor simulators (JSTARS, ASTOR, HORIZON, etc). Some of the AGS sensor platforms can produce track data (e.g. JSTARS), other AGS sensor platforms report the sensor detection data to the ground stations, which then produce tracks (e.g. ASTOR). All AGS sensors report their GMTI data and, if applicable, SAR imagery data to a network, where it is picked up and stored by exploitation workstations and the CSD. Not all exploitation workstations produce track data.

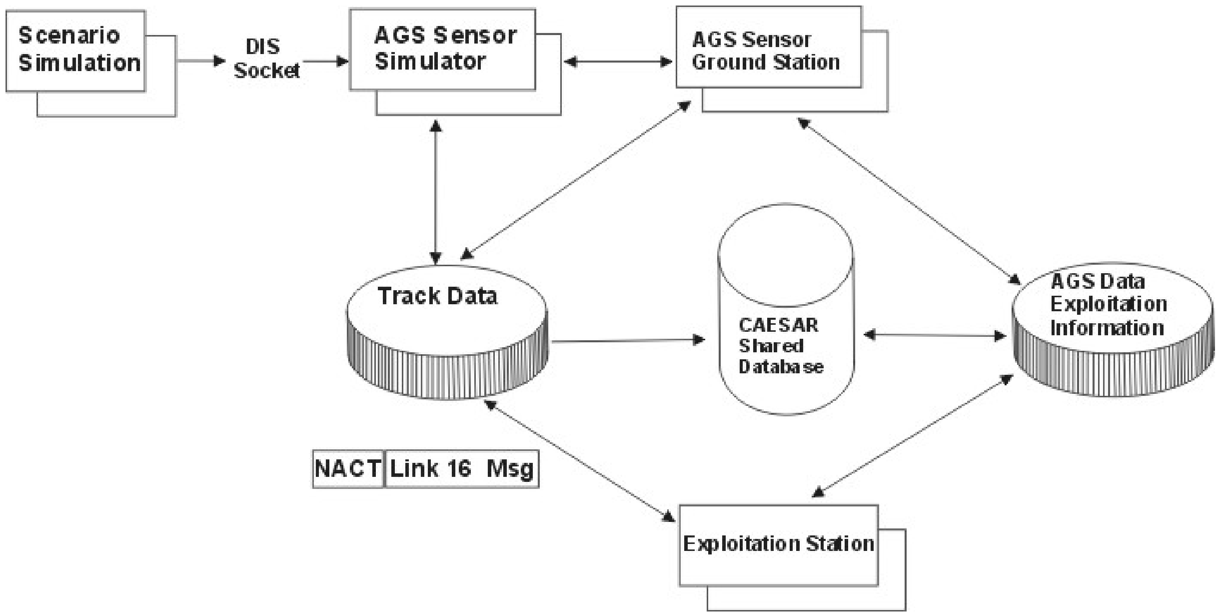

Figure 5 Node Connectivity Description of AGS&R Architecture during SIMEX 2003

Exploitation workstations can use near-real-time track data or retrieve "old" track data from the CSD. They use near-real-time AGS data or retrieve "old" AGS data from the CSD. They also receive exploitation results from the CSD. The CSD records all track data. The CSD also records all the AGS data (GMTI, SAR) and all the exploitation results that are broadcast on the network. In addition, the CSD contains the Coalition Collection Plan, from which the AGS sensor ground stations derive the tasking for the AGS Sensor Simulation.

Nature of AGS &R data flow in the SIMEX 2003 architecture

The following table shows the main AGS&R data flow within such an architecture. The table shows the transmitter of AGS&R data in the top row with the receivers in the first column. The AGS&R data flow consists mainly of GMTI data, SAR images, track data and exploitation results. Some data flow is required for planning, tasking and re-tasking. For simplification, some of the other minor data streams were excluded.

Table 4: Schematic Information Exchange Matrix during SIMEX 2003

Transmit ---------------- Receive	Scenario Generator	AGS Sensor Simulator	AGS Sensor Ground Station	Exploitation Station	CAESAR Shared Database
Scenario Generator	-	-	-	-	-
AGS Sensor Simulator	Scenario data	-	Tasking, Re-tasking	-	-
AGS Sensor Ground Station	-	GMTI, SAR	-	Re-tasking	Tasking, Re-tasking
Exploitation Station	-	GMTI, SAR Track data	GMTI, SAR, Track data	Exploitation Results	GMTI, SAR, Track data Exploitation Results
CAESAR Shared Database	-	-	GMTI, SAR, Track data	Exploitation Results	GMTI, SAR, Track data, Exploitation Results

Table 4 does not include specific details about the communication means and data formats used to transmit data. There are numerous formats, both Standardization Agreements (STANAG) and other standards. Track data, such as the J3.5 Ground (Land) Track Message, is based on STANAG 5516 (Link 16). GMTI data is shared using STANAG 4607. SAR and other imagery is shared using STANAG 4545. In addition, exploitation systems can send exploitation reports in a number of different text formats.

The distribution architecture was tested successfully in SIMEX 2003. Since then, some of the systems within the architecture have been upgraded and improved significantly. These improvements will be tested during a Technical Interoperability Experiment (TIE), planned for October 2004 at NC3A in The Hague. During TIE 2004, the same architecture as in SIMEX 2003 will be used.

Other exercise simulation architectures

CAESAR had successfully demonstrated producing tracks, GMTI, SAR and exploitation results. The next logical step was to make these achievements accessible to a wider range of user, e.g. existing command centers. NC3A selected a two step approach to make these achievements accessible to a wider range of user:

1. In a computer exercise during JWID 2004.
2. In a live exercise during the planned JOTM 2004.

The first step was to combine the scenario generator with a NC3A J3.5 Ground (Land) Track Message generator in order to produce a less complex experiment environment. A single powerful PC with the right software tools is enough to produce generic ground tracks, removing the need for a sensor simulator and a ground-track producing. While this does not provide an exact replication of the real systems or its simulation representation, it provides a simpler and more controllable environment for testing.

The second step was to provide a gateway from the network environment to the Tactical Data Link environment. The first achievement was demonstrated during JWID 2004. For the live exercise JOTM 2004, it is planned to demonstrate passing the J3.5 Ground (Land) Track from the Message generator through a JTIDS terminal into the Link 16 network of a live exercise. Other planned JOTM participants are NATO NAEW&C aircraft as well as the British, French and US equivalents (E-3A, E-3D, E-3F and E-3B), Dutch F-16 aircraft, German PATRIOT SAM, British WESSEX helicopters, a German Frigate and more. The NATO AGS&R exercise capabilities will be significantly enhanced by the addition of the J3.5 Land (Ground) Track Message generator.

Magnitude of AGS &R data flow in the exercise architectures

In TIE 2003 and SIMEX 2003, NC3A performed almost continuous measurements of the data flows during the exercise. The results of the measurement validate that, as expected, the AGS&R data flows are determined by the scenario contents (size of forces, scenario area) and the collection plan (areas to observe, re-visit rates, requested data type). The largest driver for bandwidth requirements is generally the number of SAR producers available and the number of SAR collections required. SAR imagery causes large spikes in bandwidth requirements. Other data types and products provide a lower level, but more constant requirement. The addition of the CSD and the number of data services provided by the CSD has also increased the need for bandwidth.

There is no simple answer to the question of how much bandwidth is needed to support a networked AGS&R capability. Based on the experience collected, the CAESAR Project has published rules of thumb for guidance and checklists that help determine needs for different architectures in a System Architecture Design Principles (SADP) document.

Network-enabled capability for AGS&R data via CSD

CAESAR Shared Database (CSD)

One of the findings of the CAESAR project has been that there is a need for searchable, persistent storage of AGS&R data and data products. This need resulted in the design and implementation of the CAESAR Shared Database (CSD). The CSD was designed by the CAESAR team and a prototype has been produced by NC3A. NC3A has provided the CAESAR partners with software that assists the development of thin client and thick client interfaces with the CSD. In addition, a web browser based thin client has been developed to interface to the CSD. Within a coalition, the various coalition partners can put releasable data on a CSD. As part of the CAESAR Project, partners determined what data each system is able to share with the others. This is necessary since data placed in the CSD is made available to all partners.

The CSD provides users with a single interface through which they can search for tracks, GMTI, SAR and other imagery and exploited data products. Data produced by the CAESAR sensors and exploitation stations is gathered by the CSD, is automatically tagged using metadata inherent in the data standards, and then stored in the database. This data is then available for search by time, geographic region, platform type, data type and other parameters. In this way, data that may not have been received in real time due to local or network equipment failure can be retrieved. Figure 7 schematically illustrates how a user outside the AGS&R architecture can access AGS&R data through the CSD. This methodology was demonstrated during JWID 2004.

Once data is stored in the CSD, it is available for the rest of the exercise. For example, GMTI observations from day 1 can be combined with SAR from day 2. Similarly, collection plans, selected data from Air Tasking Orders (ATO) and other document based information can be stored and exchanged.

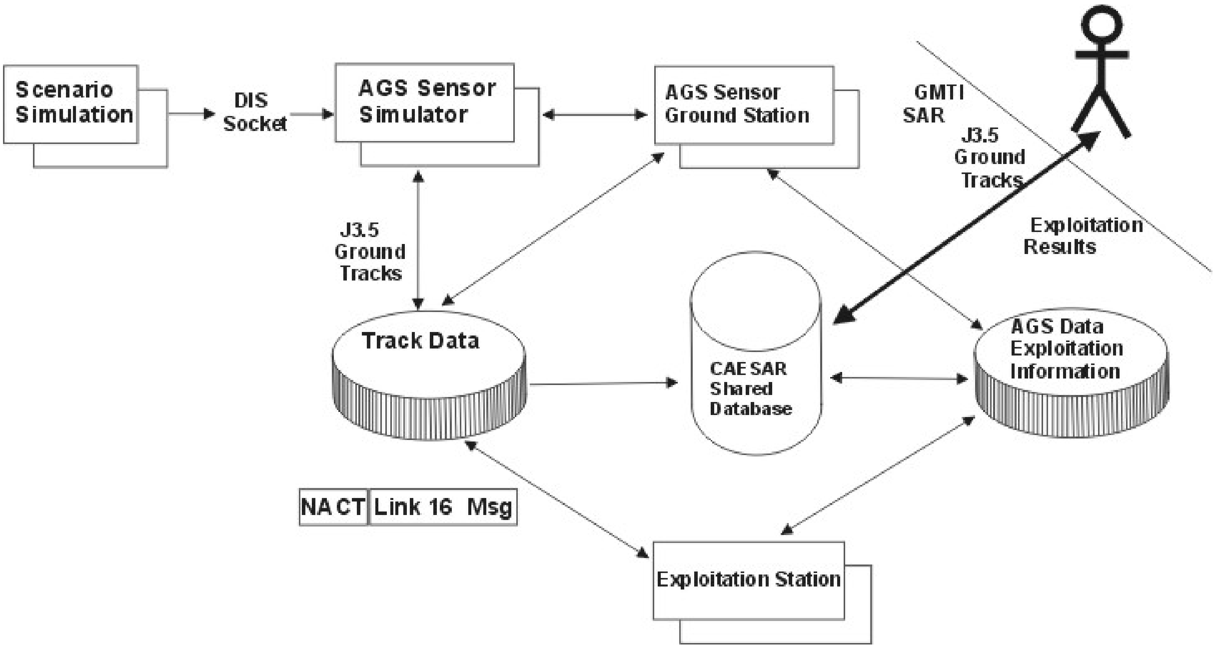

Figure 7 User outside the AGS&R architecture

Some CSD features

The following figures illustrate some of the CSD features. Figure 8 shows the CSD File search menu, which allows searching with a list of criteria.

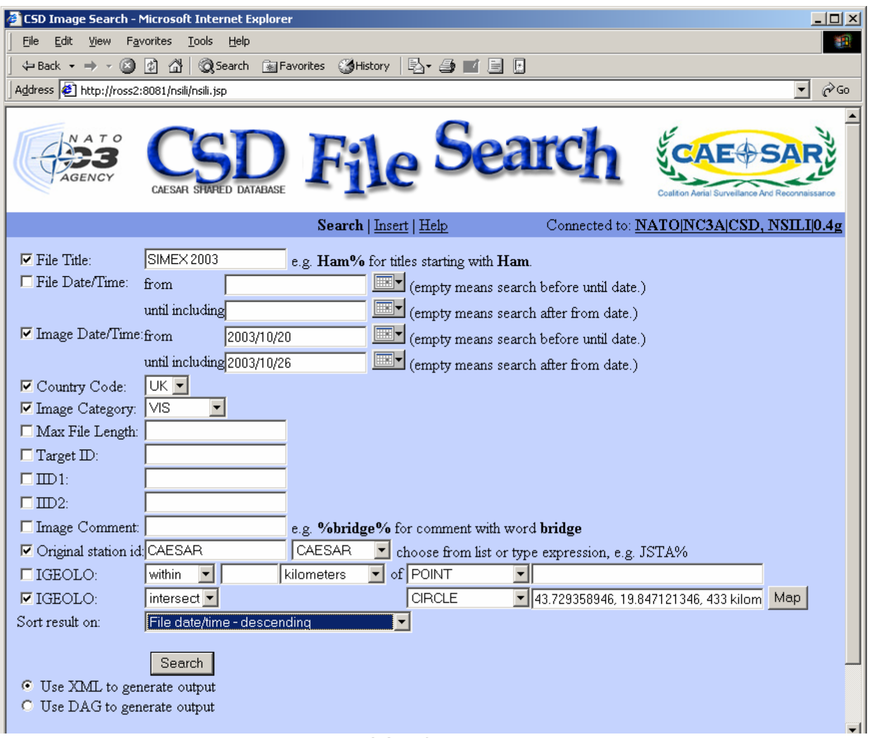

Figure 8 CSD file search menu

Figure 9 shows an example a set of thumbnail images and metadata information that were returned as a result of a search.

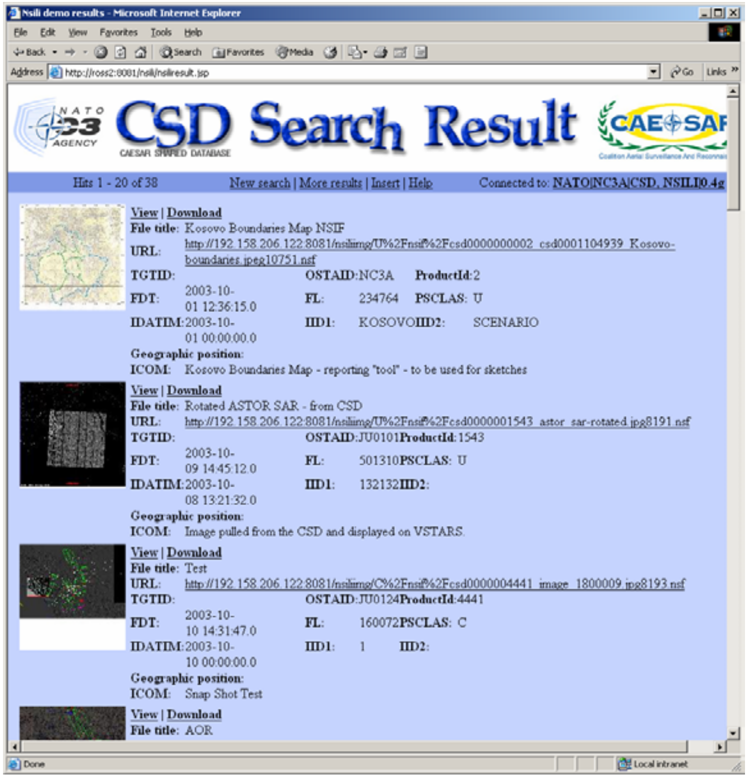

Figure 9 CSD file search results

Figure 10 provides an example of a more detailed image and additional information that can be obtained from the search results. The example shows a search result that provides a thumbnail, an associated overview picture, and a set of metadata that describes the image: e.g. file title, URL address, the date when the image was acquired, geographic position information and a short annotation. The overview picture (1024*1024 pixels JPEG within an NSIF file) is only 270 kB in size, while the complete picture is about 56 MB.

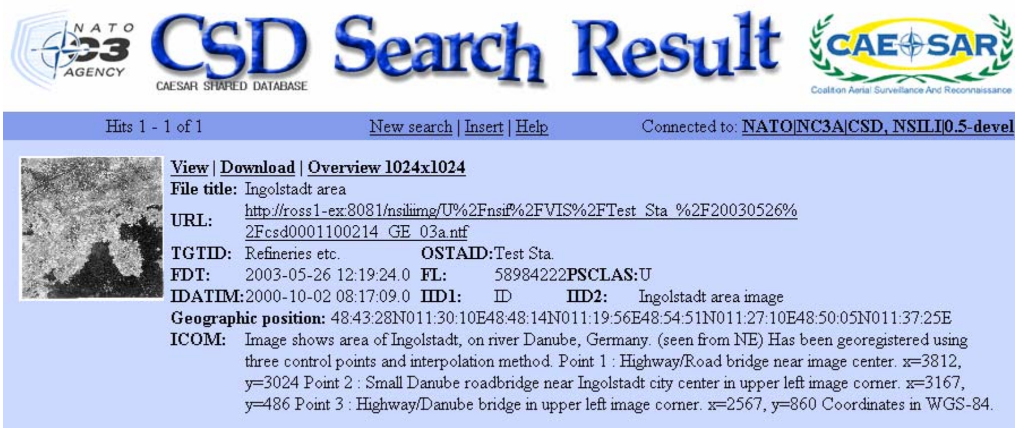

Figure 10 CSD file search results

Based on the search results, the user can either view or download a selected file, or request a smaller "chip" of the image to be generated and provided by the CSD server, as shown in Figures 11 and 12. The chipping function reduces bandwidth requirements and increases access to desired information. Images are provided in STANAG 4545 (NSIF) format and GMTI data is provided as STANAG 4607 data.

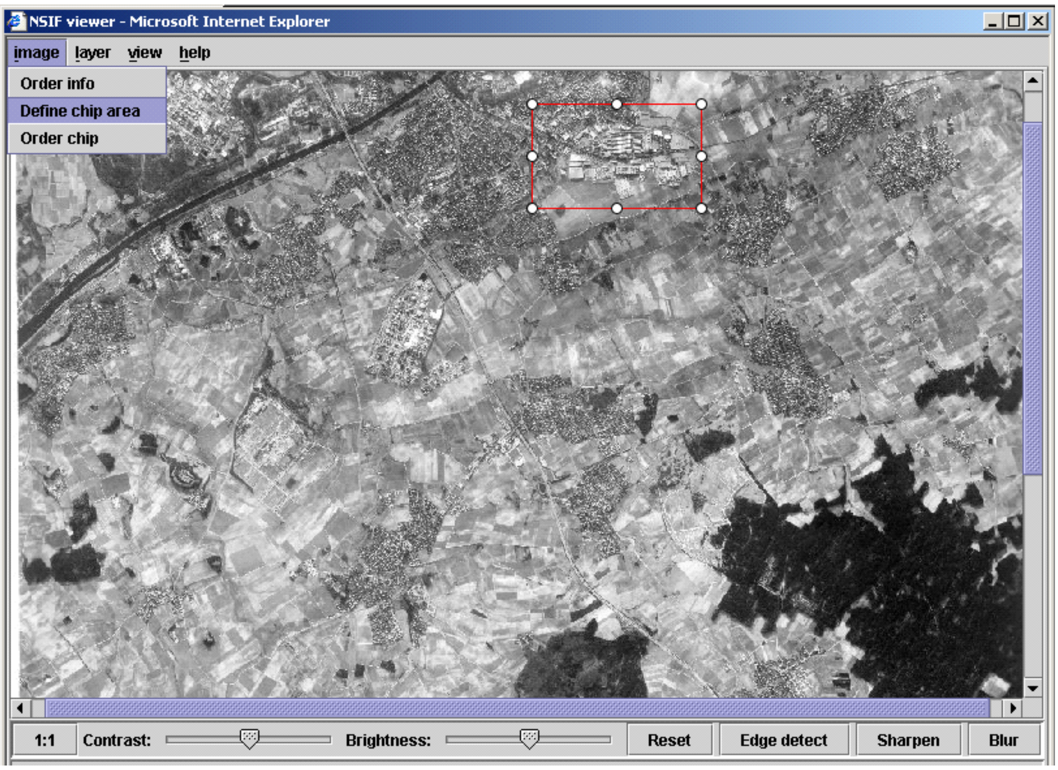

Figure 11 Definition of chip area

Figure 12 Chipped area

The chipped area is selected from the overview image and the CSD server will then generate a new NSIF image which will be delivered to the client. While the total image has a size of 56 MB, the selected area is only 0.95 MB.

Ground track data in near-real-time without JTIDS

The CSD allows multiple users to access data through a subscription mechanism. The time delay between receipt of data from the network and availability through subscription is very small. Consequently, it is possible for users to receive J3.5 Ground Tracks in near-real-time, with a few seconds delay caused by the CSD storing and retrieval mechanisms without the need to be connected to a JTIDS terminal.

Combination of various AGS&R data types

With the CSD, various AGS&R data types can be retrieved, and with an appropriate exploitation capability, combined. For example, historical track data can be combined with georeferenced SAR images, and overlaid with the collection and exploitation plan. Figure 13 below shows an example of 3-dimensinal terrain display, a SAR image and GMTI data.

CSD security

The CAESAR network mechanism is designed to operate within a single security domain. This means that in most operations, for a user to have access to CAESAR AGS&R data, that user must be operating at the same security level as the CAESAR AGS&R network; in most applications at a NATO classified level. The CAESAR Project is working with several NATO and National projects that are attempting to solve the cross domain information transfer problem. During JWID 2004, cross domain information sharing was successfully demonstrated using NATO Information Exchange Gateway (IEG) devices.

CSD concept and functionality

The use of the CSD has proven to be important and useful. The CSD has demonstrated an ease for achieving interoperability for C2 systems that need data and information to support decision makers. The delivery of data using established STANAG formats and XML schemas can provide global availability. The CSD, coupled with the use of a web browser based thin client interface allows users from any location to retrieve AGS&R data in near real time through user friendly query interfaces.

It is important to note that the CSD provides information and services, but does not provide a Geographical Information Systems (GIS) display capability. Within the CAESAR community, the nations have integrated the CAESAR and CSD capabilities into existing or development workstations that provide the GIS capability and the applications required to exploit this data. These applications download the information and display the CSD data on their respective GIS systems. In essence, the CSD combined with STANAGs and the CAESAR dissemination techniques provide a network enabled data storage, retrieval and dissemination capability to all users on a network.

Operational findings and assessment by the CAESAR Project

Following the SIMEX 2003, the CAESAR Project convened an assessment and evaluation conference in order to capture lessons learned from the exercise and to ensure that the lessons were captured in the CAESAR Tactics, Techniques and Procedures document. This conference was supported by representatives from the ISR management offices from Allied Forces North (AFNORTH), Air Forces North (AIRNORTH), Air Forces South (AIRSOUTH), Supreme Headquarters Allied Powers Europe (SHAPE), and the Allied Rapid Reaction Corps (ARRC). The review by these offices and a separate, independent Military Utility Assessment (MUA) performed by the US Defense Information Systems Agency, (DISA) determined that the CAESAR concept provides military utility to the warfighter and enhances surveillance, situational awareness and battle management [DISA 2003].

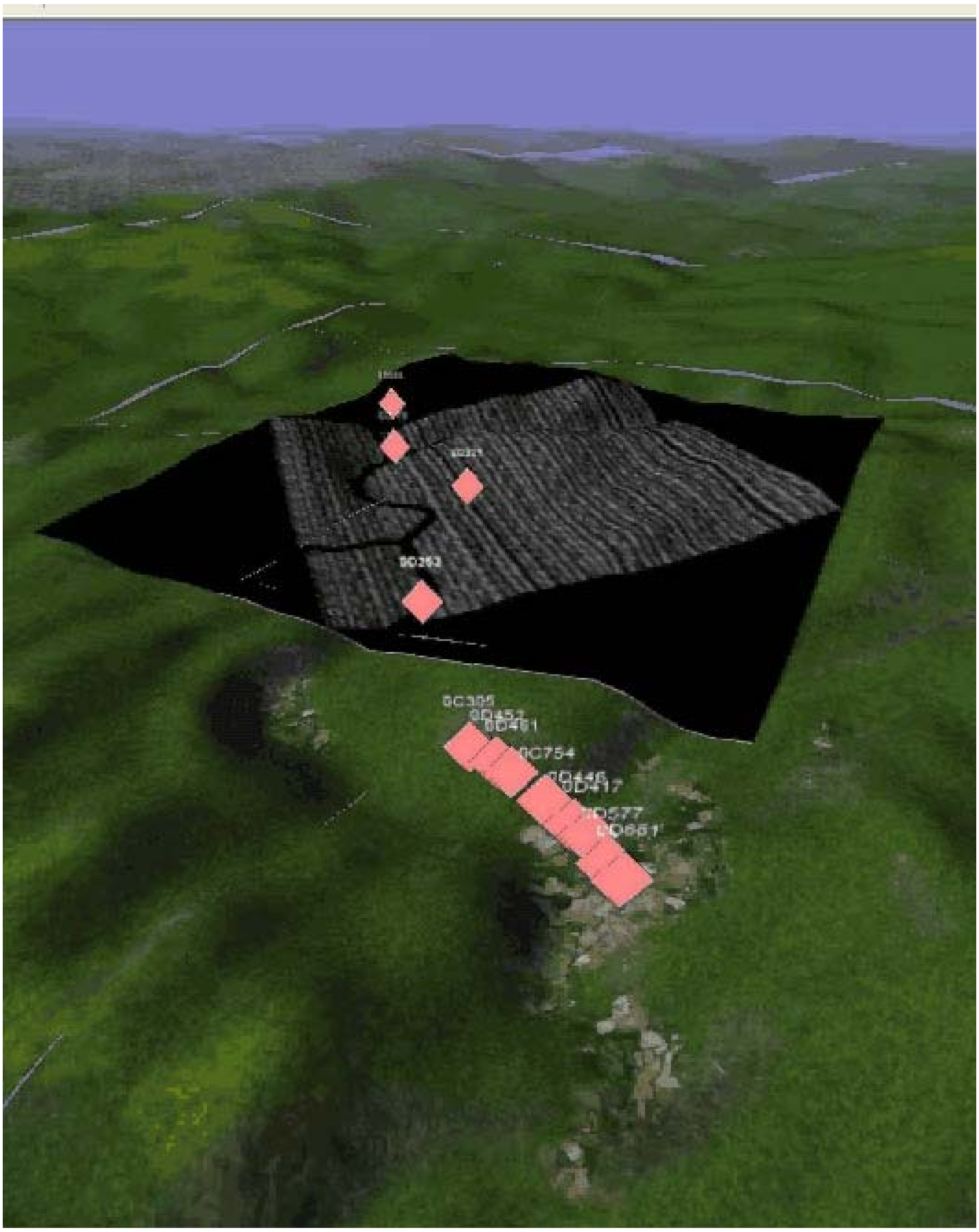

Figure 13 Terrain display with overlapping SAR image and GMTI

THE WAY AHEAD

Multi-Sensor Aerospace-Ground Joint Interoperable Intelligence Surveillance and Reconnaissance Coalition (MAJIIC)

The CAESAR project and its extension are on schedule to be completed in March 2005. Based on the success of the project, the CAESAR nations and two new nations, The Netherlands and Spain have created a new project: the Multi-Sensor Aerospace-Ground Joint Interoperable Intelligence Surveillance and Reconnaissance Coalition (MAJIIC). MAJIIC will begin in April 2005 and continue until March 2009. The goal of the project will be to make the information from more sensor types available to more users; using and expanding on the network enabled methodologies developed in CAESAR. The additional data will include

- Electro-Optic and Infrared (EO/IR) imagery,
- Motion video sensors, and
- Processed Electronic Support Measure (ESM) data.

In addition, enhancements to planning, tasking, monitoring, and management capabilities will be investigated along with enhanced tracking and sensor fusion capabilities. MAJIIC will continue to interact strongly with the user community and will continue to enhance and support the development of NATO and national doctrine.

Figure 14 MAJIIC logo and participating Nations

The MAJIIC project organization described above for CAESAR, with Project Officers and three working groups, will be maintained. As in CAESAR, national programs developing capabilities to support coalition operations will benefit from the new coalition project. The focus on live fly and simulation exercises will again be used to as the methodology for demonstrating the operational, system and technical interoperability proof of concept for coalition ISR assets. These exercises will also provide a robust training capability and will be used to demonstrate distributed coalition and network enabled capability operations. The planning for the first MAJIIC exercise has already started. The first exercise will be a simulation exercise, SIMEX 2005. This exercise will be conducted in October 2005, at NC3A in The Hague, and will be used to evaluate the integration of new nations and sensors into the MAJIIC environment. The Project plans to participate in a live exercise in 2006.

The CAESAR coalition has consistently demonstrated and validated that the dissemination and sharing of ISR data and information among multiple national organization and systems is feasible and beneficial. With new partners, the MAJIIC team is ready to face new challenges

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