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# SENSOR TO ANALYST: IMPROVED DECISION-MAKING IN AERIAL ISR THROUGH TRAINING AND DECISION SUPPORT TOOLS

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From sensors to analysts, modern day intelligence, surveillance and reconnaissance (ISR) requires concerted efforts from players in the aviation, aerospace, and intelligence domains to complete the Planning and Direction, Collection, Processing and Exploitation, Analysis and Production, and Dissemination (PCPAD) cycle. While the pilots, analysts, and consumers of ISR products in the PCPAD cycle have very different tasks and duties, all of them must constantly adapt to new environments, new challenges, and new enemies. The uncertainty generated by the nature of these environments places considerable decision-making and workload demands on the various operators. Currently, government, industry, and the operational community are addressing cognitive challenges placed on operators at each stage of PCPAD through training, decision aiding, and automated tools. This paper will provide a macroscopic view of the PCPAD process and discuss the current challenges being addressed within each phase.

## Introduction

Good information is a critical enabler for good decisions. In its review of a series of intelligence failures leading up to the terrorist attacks of September 11, 2001, the 9/11 Commission concluded that despite readily available data indicating an attack might have been imminent, poor information analysis due to inadequate dissemination and integration of information across agencies prevented authorities from making the right decisions to prevent the attacks (National Commission on Terrorist Attacks upon the United States, 2004). Data alone is not sufficient; ". . . information is of greatest value when it contributes to or shapes the commander's decision-making by providing reasoned insight into future conditions or situations" (United States Joint Chiefs of Staff, 2011). While some efforts to improve intelligence have focused on structural changes among government agencies, far less effort has been devoted to understanding the human element in intelligence, surveillance, and reconnaissance (ISR). The Air Force's PCPAD model for ISR refers to the *planning* and direction, *collection*, *processing* and exploitation, *analysis* and production, and *dissemination* of information. In this paper, we outline the key operators and warfighters involved in PCPAD and discuss recent advances in training and decision support technologies to improve aerial ISR.

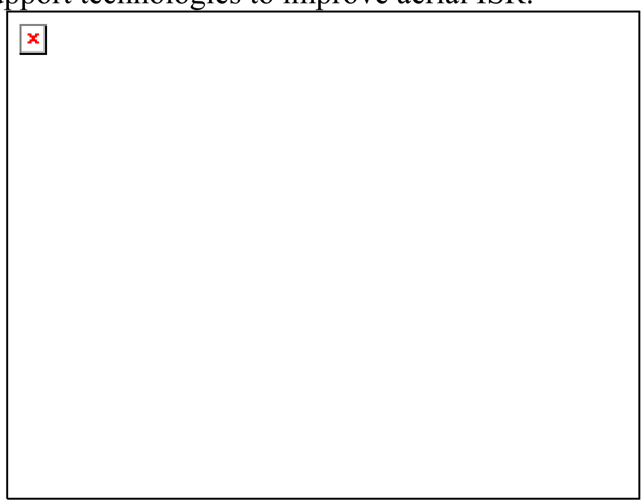

*Figure 1*. The PCPAD cycle involves the coordinated effort of commanding officers, dedicated field elements, and intelligence specialists to support critical decision makers at all echelons. *Photos within the image are courtesy of the U.S. Air Force.*

## Who is involved in PCPAD?

*Planning* for an aerial ISR mission might begin when a commander at the battalion or brigade echelon identifies an intelligence gap and issues a Commander's Critical Information Requirement (CCIR). Command and operational intelligence staff may then generate priority information requirements (PIRs) from the CCIRs, select a subset of PIRs for the upcoming operation, and decompose the PIRs into Essential Elements of Information (EEIs) that specify what data is necessary to fill each PIR. Operators then *collect* information using sensors based on manned or unmanned aerial vehicles (UAVs) to address as many of the prioritized EEIs in their stack as possible during the current operation. Analysts working the sensor feed *process* and exploit what was collected to reformat the raw data and extract the information relevant to each EEI. Other analysts either co-located with the exploitation element or distributed in reach-back organizations then *analyze* patterns across the filled EEIs in conjunction with previously acquired data to re-evaluate both the PIRs and the overall understanding of the area of operations and the human terrain. To *disseminate* these analyses, the analysts must develop intelligence products, identify necessary supporting documents, and use the appropriate protocol given what is contained within the analysis before sending the products on to the appropriate consumer.

## Challenges for Operators and Analysts Throughout the PCPAD Cycle

Research and development efforts in government, industry, and operational communities like the Air Force ISR Agency (AFISRA) are working to address specific challenges (cognitive, environmental, situational, etc.) placed on operators at each stage of PCPAD. The following sections will highlight how these challenges can be addressed through training, decision aiding, and automated tools and what progress has been made on these fronts.

### Planning

Pre-mission planning is an on-going and essential part of successful military operations. Commanders at all echelons continually work with intelligence staff to identify gaps in the current understanding of the area of operations and of the human terrain. ISR synchronization refers to the part of the planning process in which intelligence officers: analyze Information Requirements (IRs) and intelligence gaps, identify all assets that are available, identify gaps in how the assets are being used, and make recommendations regarding which assets should collect data against the IRs and intelligence gaps (Department of the Army, 2008). ISR synchronization must consider areas, structures, capabilities, organizations, people, and events (ASCOPE) to enable commanders to make decisions based on information embedded within an appropriate socio-cultural context. While ASCOPE provides the broadest and most detailed picture possible of the area of operations and of the human terrain, managing all of the information necessary within this framework simultaneously can prove cognitively challenging for commanders charged with making critical decisions. In addition, fusing this information with the sensor assets available to collect it temporally aligned with operations is a great challenge to joining the intelligence collection planning process with the operational planning process. To address this challenge, one potential solution is to develop a tool to more seamlessly share intelligence and operational planning information across their processes and systems using novel visualizations to support decision-making during the planning cycle (Jackson, Pfautz, & Bauer, 2011).

### Collection

In the collection phase, managing widely varying levels of task load is a primary challenge for pilots of UAVs. Under current concepts of operations (CONOPs), navigation and sensor operations are performed by two different crewmembers. During prolonged transits or sustained monitoring periods, workload can be quite low and lead to task disengagement (Baldwin et al, 2010; Szalma & Hancock, 2006). However, a low-workload mission can become a high-workload mission quite quickly and with little warning, such as when a potential high-value target is spotted unexpectedly. Furthermore, the increasing autonomy of UAVs has enabled future CONOPs in which a single operator performing both navigation and sensor operation functions will control multiple UAVs (Reising, 2003). Under such future CONOPS, monitoring and workload demands on the operator are only likely to increase (Parasuraman & Riley, 1997). UAV pilots currently lack a system that can adapt to these rapid fluctuations in demand and provide them with the optimal levels of control or support they currently need. On-going efforts at the AFRL seek to address this gap using neurophysiologically-based adaptive automation. Using state-of-the-art models and algorithms to integrate physiological, system, and behavioral data, AFRL's HUMAN laboratory has developed a system capable of detecting changes in operator workload in near real time (Christensen, & Estepp, in press; Pappada, Geyer, Durkee, Freeman, & Cohn, 2013). These efforts hold great promise for the future of adaptive decision aid technologies triggered by rapid detection of changes in operator state.

**Processing**

Processing and extraction varies in scope and duration, depending on the type of information that is being processed. Some sensors have the capability to automatically process data into a consumer-ready form, while others require manual processing and user-guided feature extraction. In the latter case, accurate processing and classification of ambiguous data can require extensive training and experience to establish fluency. Furthermore, incoming data must be monitored for time-sensitive information that must be distributed to consumers prior to extensive processing and analysis. In both cases, AFRL's Warfighter Readiness Research Division is making enormous strides in developing innovative training regimens to speed skill acquisition and retention while improving overall analyst skill level (Tossell, Jackson, Tripp, & Nelson, in press; Carlin, Jackson, Pratt, Marc, Kramer, Champagne, Kriete, & Dunlop, 2012).

**Analysis**

All-source and other intelligence analysts synthesize and integrate data collected from numerous sensors into meaningful patterns and predictive analyses. Analysts produce intelligence preparation of the battlefield (IPB), intelligence preparation of the operational environment (IPOE), intelligence estimates, and other products that provide leaders at all echelons of command with the information and recommendations necessary to make mission-critical decisions, yet they are plagued by two inherent difficulties in dealing with the enormous corpus of data that is collected: 'big data' management (i.e., finding the proverbial needle in a haystack when seeking a particular piece of information), and data fusion (i.e., identifying related bits of data from different sensor modalities and merging these bits together to develop a more complete picture). These difficulties have been magnified by the shift in the nature of intelligence work from what Treverton has called the 'puzzles' of the Cold War (i.e., questions with finite, knowable answers such as 'How many intercontinental ballistic missiles does the Soviet Union possess?') to the 'shapeless mysteries' (i.e., questions of speculation with no discernible answer, such as 'Will Iran develop a nuclear weapon?') of modern ISR (Moore, 2011). To address these issues, researchers are developing innovative human-computer interfaces that allow geospatial intelligence analysts to manipulate, visualize, and fuse information through a natural, multimodal interaction experience (Jackson, Pfautz, & Bauer, 2011). In addition, researchers are developing a framework for judging the value of fusing intelligence data across different sensors to determine the utility of combining the information to reduce the load on commanders while simultaneously improving their decision quality (Scarff, Jackson, Burke, Jones, Pratt, Weil, Gilfillan, & Fiore, in press).

**Dissemination**

Analysts disseminate the products of their work to the customers that requested the intelligence or to other intelligence consumers that may conduct forensic analyses on the newly acquired intelligence. This dissemination must be timely and efficient for the consumers to benefit from the intelligence. Given limits on communication bandwidth, particularly within forward deployed units, analysts must carefully choose with whom they share intelligence products and how the products are routed to reach the desired consumer. Redundant forwarding of information among intermediary units in the dissemination chain can tie up communications lines with the passing back and forth of the same intelligence products (Global Integrated Intelligence, Surveillance, and Reconnaissance Operations, 2012). Furthermore, intelligence products can contain supporting documents that require different security classification levels. Analysts must be sure to keep the products that are shared at the appropriate classification level for each intended consumer. While some of these concerns could be addressed with future automated, data distribution tools, decision support tools and improved training regimens would also be beneficial both for the analysts disseminating products and the consumers receiving them.

## Future Directions

USAF General Norton Schwartz wrote, "We disseminate knowledge to better support decision-makers and shape operations. Still, we must never lose sight of the need for continuing to evaluate our methodologies for employing and integrating ISR capabilities vice simply increasing the density of ISR capabilities (United States Air Force, 2012)." While the operators, analysts, and consumers of ISR products in the PCPAD cycle have very different tasks and duties, all of them must constantly adapt to new environments, new challenges, and new enemies, placing considerable decision-making and workload demands on each player. The solutions outlined here are critical steps forward to mitigate these demands and will further benefit the ongoing introduction of UAVs to the civilian airspace.

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