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Intelligence Support and Mission Planning for Autonomous Precision-Guided Weapons

Implications for Intelligence Support Plan Development

Myron Hura, Gary McLeod

Prepared for the
United States Air Force

Project AIR FORCE

Preface

This report provides a framework for developing an Intelligence Support Plan (ISP) in support of the acquisition of autonomous precision-guided weapons (PGWs). It discusses intelligence data requirements and examines functions, organizations, systems, and operating protocols that may be integrated into alternative intelligence-support and mission-planning architectures to support this category of weapon. The report suggests an evolving architecture to support autonomous PGWs with target-imaging sensors and highlights the fact that any element of the evolving architecture can support autonomous PGWs that rely on their inertial navigation systems, aided only by the Global Positioning System, to guide to their targets. The work presented in this report builds on earlier research on intelligence-support and mission-planning requirements for advanced conventional cruise missiles.[1]

This research was sponsored by the Air Force Assistant Chief of Staff for Intelligence as part of the Aerospace Technology Program of Project AIR FORCE. The report should be of particular interest to members of intelligence support working groups, which support ISP development, and decisionmakers, who approve ISPs and are involved in developing a coherent approach to precision strike. It also should be of interest to members of the various communities involved in the analysis, development, support, or employment of autonomous PGWs, including weapon developers and contractors, acquisition personnel, operators, and intelligence and mission-planning personnel.

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[1]This work is discussed on pages 20–24 of the *Project AIR FORCE Annual Report, Fiscal Year 1991*, RAND, AR-3700-AF, 1992.

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Summary

The vast majority of Air Force precision-guided weapons (PGWs) are "man-in-the-loop": They require the assistance of an operator to reach their targets. The development of new autonomous PGWs, particularly ones with target-imaging sensors, would enable the Air Force to attack high-value ground targets with very high delivery accuracy without the aid of an operator. Earlier RAND research (Reference 1) showed, however, that these weapons require substantial data to achieve their very high delivery accuracy and that many intelligence functions, organizations, systems, and operating protocols are required to support their mission planning and responsive employment.

Operators of newly developed weapon systems have often complained that the intelligence support for their systems was *too little and too late*. Problems of this nature were highlighted during the recent air operations in support of Operations Desert Shield and Desert Storm. Because autonomous PGWs with target-imaging sensors have such demanding intelligence-support requirements, we believe that operators could again encounter significant problems if the required intelligence infrastructure is not in place prior to these weapons entering the inventory.

Recognizing the need to provide adequate intelligence support for new weapon systems, the Air Force initiated a requirement in 1992 for the development of intelligence support plans (ISPs) for designated weapon-acquisition programs. The purpose of this report is to assist Air Force development of an ISP for advanced PGWs. Specifically, we examine the support requirements for two categories of autonomous PGWs: those with target-imaging sensors and those that rely only on an inertial navigation system (INS), usually aided by the Global Positioning System (GPS).[1]

Our approach is to (1) define a framework for developing an ISP for advanced PGWs (focusing on autonomous PGWs with target-imaging sensors); (2) examine the data required by these weapons and explore unresolved issues; (3) examine the intelligence functions required to support these weapons, reviewing current organizations that can perform these functions and identifying systems that

[1] An *autonomous* PGW is defined as one that, following launch, acquires and then guides itself to its target without the assistance of an operator; this definition permits the use of external aids, such as the GPS.

might be procured to improve their capabilities; (4) structure four potential alternative architectures to support the use of these weapons and then describe an evolving architecture that changes from one alternative to another as required; and (5) examine training requirements.

Developing an ISP

Because of the complexity of providing effective support for autonomous PGWs, the development of an ISP for such weapons requires close working relationships between weapon developers (system program offices), operators (representatives of intended users: Air Combat Command, Pacific Air Forces, and U.S. Air Forces in Europe), intelligence personnel (both service and national agencies), and mission-planning personnel. The weapon developers must keep operators informed of key PGW technical characteristics and associated mission-planning systems. With this information, operators can formulate a concept of operations (CONOPS) that reflects the systems' true capabilities. Similarly, weapon developers must work with the intelligence and mission-planning communities in defining the intelligence data requirements. With an understanding of the data requirements and the CONOPS, operators, weapon developers, and intelligence and mission-planning personnel can develop an ISP that will support the effective (and responsive) use of these weapons.

Data Requirements

Autonomous PGWs with target-imaging sensors require substantial mapping, charting, geodesy, and imagery products; target data; threat data; and weather data. Unlike man-in-the-loop PGWs, this category of autonomous PGW cannot be employed effectively without such data.

As a result of our research in this area, we have **identified two major unresolved issues relevant to the effective employment of autonomous PGWs with target-imaging sensors:**

- **There are no definitive specifications for the intelligence data required to support effective terminal-area planning, against a wide range of targets.**
- **The methodology for validating terminal-area products (templates) has not been developed.**[2]

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[2]Templates are scenes or models of the target and nearby objects that are created by mission planners and then used by the PGW's target-imaging sensor and autonomous target-acquisition

Without definitive terminal-area data requirements, the intelligence community cannot develop an effective support plan for autonomous PGWs with target-imaging sensors. Without a methodology for validating templates, operators will be unable to estimate the probability of mission success and thus will be unable to effectively employ these weapons. Therefore, we recommend that the ISP discuss these issues and identify the organizations that are responsible for resolving them. As a point of departure, we define an interim solution to the target data specifications issue and suggest several approaches to resolving the template validation issue.

Autonomous PGWs with GPS-aided INS guidance require much less information on their targets; however, to achieve best possible delivery accuracy, these PGWs require more precise absolute coordinates for their targets. Using DMA's most accurate data products, trained intelligence personnel or aircrew members can obtain precise absolute coordinates to support this category of autonomous PGW.

Intelligence Functions, and Existing Organizations and Systems

To provide the data required by autonomous PGWs with target-imaging sensors, the intelligence community must perform a number of functions: data collection, data exploitation, target material production, threat database generation, and intelligence product dissemination. It will also support the functions of targeting and post-strike assessment. A number of centralized intelligence organizations within the continental United States (CONUS) and at developed theaters currently support many of these functions.[3] The capabilities at deployable air operations centers (AOCs) and wing operations centers (WOCs) are much more limited.

In a budget-constrained environment, maximum leveraging of existing capabilities is prudent. Thus, it is suggested that the capabilities of existing CONUS and developed theater central facilities (or centers) should be used

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algorithm to acquire the target. Validation is the process to determine, with some level of confidence, that the template (or sequence of templates) is unique and that it will correctly identify the target in the imaged scene.

[3]CONUS organizations include the 480th Air Intelligence Group at Air Combat Command and the Atlantic Intelligence Command (AIC) at U.S. Atlantic Command. *Developed theaters* such as the Pacific theater and the European theater, are theaters that have substantial intelligence-support and mission-planning infrastructure in place which could be used to support advanced PGWs. Organizations at developed theaters include the Joint Intelligence Center, Pacific (JICPAC) at U.S. Pacific Command and the Joint Analysis Center at U.S. European Command.

first before procuring additional systems and adding personnel at AOCs or WOCs solely to support these weapons.

Evolving Architecture

We define four alternative intelligence-support and mission-planning architectures. The first architecture relies on *central facilities* (CONUS and developed theater centers) to perform all the intelligence-support and mission-planning functions, except aircraft mission planning, integration of aircraft and PGW mission data, and loading of mission data into data-transfer devices. The next three architectures build on the centralized architecture by *distributing* the required capabilities to lower levels, ultimately to wings and squadrons.

In the absence of a CONOPS for advanced PGWs, we cannot recommend a particular architecture. However, **because of today's budget constraints and personnel reductions, we suggest that an evolving architecture, which initially relies on CONUS and developed theater centers, is appropriate to support autonomous PGWs with target-imaging sensors.** Such central facilities now support unified commands and the Air Combat Command.[4]

If required, this initial centralized architecture could, in the near future, include a deployable PGW intelligence-support and mission-planning center directly linked to an AOC, which would support the Joint Forces Air Component Commander (JFACC). The deployable PGW center would have the same capabilities as a CONUS or developed theater center. However, this center would provide the JFACC with increased flexibility for planning PGW missions because he would have direct control of all support assets.

Using the experience gained at the central facilities and assuming that resources are made available, the architecture could then evolve, if required, into a more distributed architecture, with WOCs also capable of performing all the necessary functions to employ autonomous PGWs with target-imaging sensors.

Because autonomous PGWs with GPS-aided INS guidance require less intelligence data and mission planning than those with target-imaging sensors, any element of the evolving architecture can support their employment. We

[4]Further savings may be realized if these centers are made available to support joint-service weapon systems. AIC and JICPAC now provide intelligence support, for the mission planning of the Navy Tomahawk autonomous cruise missile, to the two joint-service Cruise Missile Support Activities, one located at Camp Smith, HI, and the other at Norfolk Naval Base, VA. The capabilities of these activities to support other autonomous PGWs should be examined.

suggest that WOCs, equipped with appropriate mission-planning systems, be used to perform all required intelligence-support and mission-planning functions for this category of autonomous PGW.

Training

Training is sometimes overlooked during the early phases of the acquisition process. Mission planning for autonomous PGWs will require personnel who are well trained in the skills of PGW targeting (particularly geopositioning of critical aimpoints), threat analysis, and post-strike analysis. Personnel assigned to support mission planning for autonomous PGWs with target-imaging sensors will require substantial additional training in imagery analysis and mensuration, tailored mission-data development, and template building. There is no such training at present, and we recommend a formal training program to develop these skills.

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Acronyms and Abbreviations

ACC	Air Combat Command
ACFT	Aircraft
AF	Air Force
AFIC	Air Force Intelligence Command
AFISA	Air Force Intelligence Support Agency
AFMSS	Air Force Mission Support System
AFOTEC	Air Force Operational Test and Evaluation Center
AIC	Atlantic Intelligence Command
AIF	Automated Installation Intelligence File
AIG	Air intelligence group
AIS	Air intelligence squadron
AOB	Air order of battle
AOC	Air operations center
AOI	Area of interest
AOR	Area of responsibility
APPS	Analytical Photogrammetric Positioning System
APS	Automated Planning System
ASC	Aeronautical Systems Center
ATC	Air Training Command
ATO	Air tasking order
ATTG	Automated Tactical Target Graphic
BDA	Battle damage assessment
BTG	Basic Target Graphic
CALCM	Conventional Air-Launched Cruise Missile
CARS	Contingency Airborne Reconnaissance System
CATIS	Computer-Aided Tactical Information System
CDIP	Council of Defense Intelligence Producers
CINC	Commander-in-chief
CMPPS	Conventional Mission Planning and Preparation System
CONOPS	Concept of operations
CONUS	Continental United States
CS	Constant Source
CTAPS	Contingency TACS Automated Planning System
DB	Database
DIA	Defense Intelligence Agency
DIDB	Digital imagery database

DMA	Defense Mapping Agency
DMOB	Defensive missile order of battle
DoD	Department of Defense
DPF	Digital Production Facility
DPPDB	Digital Point Positioning Data Base
DSNET	Defense Secure Network
DTD	Data-transfer device
DTED	Digital Terrain Elevation Data
EISS	EUCOM Intelligence Support System
ELINT	Electronic intelligence
EOB	Electronic order of battle
EPS	ELINT Processing System
ESC	Electronic Systems Center
ETG	Enhanced Target Graphic
EUCOM	U.S. European Command
FOL	Forward operating location
GOB	Ground order of battle
GPS	Global Positioning System
HTG	Hard Target Graphic
ICM	Intelligence Correlation Module
IDB	Integrated Data Base
IDEX	Imagery Data Exploitation System
IES	Imagery exploitation system
IIR	Imaging infrared
IITS	Intratheater Imagery Transmission System
INS	Inertial navigation system
IOC	Initial operational capability
ISP	Intelligence Support Plan
ISWG	Intelligence Support Working Group
ITG	Infrared Target Graphic
JAC	Joint Analysis Center
JFACC	Joint Forces Air Component Commander
JIC	Joint Intelligence Center
JICPAC	JIC, U.S. Pacific Command
JSIPS	Joint Service Imagery Processing System
JSORD	Joint system operational requirements document
JSTARS	Joint Surveillance Target Attack Radar System
LAN	Local area network
LANTCOM	U.S. Atlantic Command
LANTIRN	Low-Altitude Navigation and Targeting Infrared System for Night

LCWS	Low-cost workstation
LTMS	Light Table Mensuration System
MCG&I	Mapping, charting, geodesy, and imagery
MIIDS	Military Intelligence Integrated Data System
MITL	Man-in-the-loop
MOE	Measure of effectiveness
MPS	Mission-planning system
MSS	Mission Support System
MTO	Mission type order
NOB	Naval order of battle
OB	Order of battle
ORD	Operational requirements document
P^3I	Preplanned product improvement
PACAF	Pacific Air Forces
PACOM	U.S. Pacific Command
PGW	Precision-guided weapon
PP	DMA Points Program
PPDB	Point Positioning Data Base
RAAP	Rapid Application of Air Power
RPC	Rapid Positioning Capability
RTG	Radar Target Graphic
SAF	Secretary of the Air Force
SAR	Synthetic aperture radar
SATCOM	Satellite communication
SB	Sentinel Byte
SCIF	Sensitive compartmented information facility
SIDS	Secondary imagery dissemination system
SPO	System program office
SPOT	Satellite Pour l'Observation de la Terre
STG	Seasonal Target Graphic
STRATJIC	U.S. Strategic Command JIC
TACS	Tactical Air Control System
TDF	Tactical Data Facsimile
TENCAP	Tactical Exploitation of National Capability
TEP	Tactical ELINT Processor
TIBS	Tactical Information Broadcast System
TMWS	Target Material Workstation
USAFE	U.S. Air Forces in Europe
VLDS	Very large data storage
WCCS	Wing Command and Control System

WGS84	World Geodetic System 1984
WOC	Wing operations center
XIDB	Extended Integrated Data Base

1. Introduction

The purpose of this report is to assist the Air Force in understanding the intelligence-support and mission-planning requirements for autonomous precision-guided weapons (PGWs) and in developing the infrastructure necessary to meet those requirements. Specifically, the research is directed to help Air Force intelligence support working groups (ISWGs), with representatives from other services, joint-service organizations, and national agencies, construct intelligence support plans (ISPs) to support the employment of advanced PGWs. Although the report is focused on autonomous PGWs of interest to the Air Force, much of the content should be useful to other services developing similar weapons.

Autonomous PGWs

The vast majority of the Air Force's conventionally armed PGWs are "man-in-the-loop" (MITL): They require the operator to acquire the target prior to weapon launch (e.g., Maverick), to illuminate the target using a laser designator (e.g., GBU-24), or to guide the weapon into the target using a video data link (e.g., GBU-15). Development of new autonomous PGWs would enable the Air Force to attack high-value ground targets with high delivery accuracy, but without operator assistance. Development of standoff versions would reduce the vulnerability of non–low observable delivery aircraft to threats in the target area. Currently, two categories of autonomous PGW are of interest to the Air Force.

One category relies on its inertial navigation system (INS), aided by the Global Positioning System (GPS), to achieve high delivery accuracy.[1] Two warhead options are usually considered: (1) a unitary warhead and (2) a submunition-dispensing payload. The modest number of Conventional Air-Launched Cruise Missiles (CALCMs) used during Operation Desert Storm were configured with GPS-aided INS guidance. Thus, the intelligence-data and mission-planning requirements for this weapon category are reasonably well known.[2] However,

[1] An *autonomous* PGW is defined as one that, following launch, acquires and then guides itself to its target without the assistance of an operator; this definition permits the use of external aids, such as the GPS.

[2] We assume that the mission planning for this category of weapon is done prior to takeoff. New employment concepts that include in-flight retargeting are not addressed.

the intelligence infrastructure necessary to support the responsive employment of a large number, assuming only limited warning, has not been defined.

The other category relies, for precision delivery, on its target-imaging sensor and its autonomous target-acquisition algorithm, a correlation algorithm that compares a sequence of preplanned templates (scenes or models of the target and nearby objects) to information gathered by the sensor. En route navigation errors and target location errors must be small enough so that the target appears in the sensor's field of view when the sensor is activated. To minimize en route navigation errors, the PGW usually relies on a GPS-aided INS. Once the target is acquired (i.e., its location is identified in the image) by the terminal guidance system (sensor and acquisition algorithm), the PGW then *homes* on the target.

This novel end-game guidance concept (target imaging, autonomous target acquisition, and homing) means that these PGWs can achieve a very high delivery accuracy. To take advantage of this delivery accuracy, the weapon is normally equipped with a unitary warhead, usually one with some penetration capability. A variety of target-imaging sensors have been proposed: synthetic aperture radar (SAR), laser radar, imaging infrared (IIR) sensor, and dual-mode concepts, such as an IIR sensor combined with a laser radar or a millimeter-wave radar. However, neither the intelligence-data and mission-planning requirements nor the intelligence infrastructure necessary to support autonomous PGWs with target-imaging sensors have been defined (Reference 1).

Intelligence Support Background

In the past, newly developed weapon systems often were not adequately supported as they emerged into the operational environment. Problems of this nature were again highlighted during the recent air operations in support of Operations Desert Shield and Desert Storm. For example, adequate intelligence products were not always available to support optimal F-117 employment and F-15E Low-Altitude Navigation and Targeting Infrared System for Night (LANTIRN) operations. The F-117 problem was in part due to data-access constraints. For special-access programs, such as the F-117 program, the intelligence community has very little visibility into the intelligence data being provided for development and testing. Consequently, it may be unprepared to provide adequate support when a weapon system developed in the special-access world becomes operational.

Similar problems may be encountered in the development of autonomous PGWs. In particular, autonomous PGWs with target-imaging sensors require substantial mapping, charting, geodesy, and imagery (MCG&I) products, target data, threat data, and weather data to achieve very high delivery accuracy. Also, many intelligence functions, organizations, systems, and operating protocols are involved in providing the intelligence support for the mission planning and responsive employment of these weapons. Thus, a plan is necessary to define and provide the intelligence infrastructure so that this complicated support process does not fall through a crack in the operational world and so that major programs are not developed with serious shortfalls.

Recognizing the need to develop and provide adequate intelligence support for new weapon-acquisition programs, the Air Force Assistant Chief of Staff for Intelligence (AF/IN), in coordination with the Air Force Deputy Chief of Staff for Plans and Operations (AF/XO) and the Assistant Secretary of the Air Force for Acquisition (SAF/AQ), initiated a requirement in 1992 for the development of ISPs for designated weapon-acquisition programs. ISWGs have been created to develop these ISPs.[3]

ISP development should be tied to milestones of the acquisition process for a designated weapon-system program. An initial version of the ISP would be produced at the end of the concept exploration and definition phase (Phase 0 of the acquisition process) and discussed at Milestone I.[4] ISPs are intended to be living documents to be modified as required during the life cycle (from acquisition, through operational capability, to retirement from inventory) of the weapon systems. The ISPs will become the authoritative documents defining the intelligence infrastructure for designated weapon systems.

Research Objective and Scope

Air Combat Command (ACC) has the primary responsibility for producing the ISP for advanced PGWs. In coordination with the various weapon-system program offices (SPOs), ACC will submit the PGW ISP for approval by AF/IN, AF/XO, and SAF/AQ. Although the initial focus of the PGW ISP is on Air Force programs, the intent is to evolve the ISP to include joint-service weapon-acquisition programs.

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[3]An ISWG usually comprises representatives from the following organizations: Air Force headquarters organizations (AF/IN, AF/XO, SAF/AQ); the weapon-system program offices (SPOs); the requirements community (ACC/DR); the operational community (ACC/DO, PACAF/DO, USAFE/DO); service, joint-service, and national intelligence-support agencies (ACC/IN, AFISA, AFIC, PACAF/IN, USAFE/IN, AFOTEC/IN, STRATJIC, DIA, DMA); the mission-planning community (ACC/DRX, ESC/YV); and the test community (AFOTEC).

[4]For more information about the DoD acquisition process, see Reference 2.

To assist the Air Force in the PGW ISP initiative, this report presents a suggested framework for developing an ISP, discusses intelligence-data requirements and issues, defines alternative intelligence-support and mission-planning architectures (organizations, systems, and operating protocols) that may be used to support advanced PGWs, and discusses training requirements.

In particular, the focus of this report is on autonomous PGWs with target-imaging sensors, because (1) the development of these advanced PGWs is of high priority to the Air Force; (2) our earlier analysis of intelligence-support and mission-planning requirements for advanced conventional cruise missiles provided a good point of departure; and (3) to be effective, this category of weapon has very demanding intelligence-support requirements.

Although the focus of this report is on autonomous PGWs with target-imaging sensors, we also discuss the intelligence-support requirements of autonomous PGWs with GPS-aided INS guidance. This category of PGW requires somewhat less intelligence support and mission planning. These autonomous PGWs are included in the report to show how their intelligence-support infrastructure may vary from, or may be subsumed under, the architecture for autonomous PGWs with target-imaging sensors.

Report Organization

Section 2 of the report describes the suggested framework for developing an ISP for autonomous PGWs. We believe that this framework is also applicable to the development of ISPs for other designated weapon systems. Section 3 presents the intelligence-data requirements for autonomous PGWs, highlighting two major issues that need to be resolved and presenting approaches to resolving those issues. Section 4 outlines the functions, organizations, and systems required to support autonomous PGWs. In discussing systems, we identify existing systems capable of performing the necessary functions, as well as near-term systems that are under development or that might be procured to improve the intelligence support. Section 5 defines alternative intelligence-support and mission-planning architectures and suggests an evolving architecture to support autonomous PGWs. It concludes with a general approach for assessing the benefits and cost of the alternatives. Section 6 discusses the training requirements to support the mission planning for these weapons. The final section presents the conclusions and some recommendations that emerged from our research.

2. Suggested Framework for Developing an ISP

The first step in developing an ISP is to ensure that effective dialogues are established and maintained between weapon developers (system program offices), operators (representatives of intended users: ACC, USAFE, PACAF), and representatives of the intelligence (AF/IN, ACC/IN, DMA, and DIA among others) and mission-planning communities responsible for providing the support necessary to effectively employ the weapon systems. Weapon developers and their contractors have the best understanding of the technical capabilities and limitations of the weapon systems and the data required to plan their missions. Operators are the customers for the weapons and, as such, establish how these weapons will be employed. Intelligence and mission-planning personnel have the best understanding of how the existing intelligence-support and mission-planning infrastructure can support these weapons. Figure 1 provides a framework for evolving the suggested dialogues between the major players into

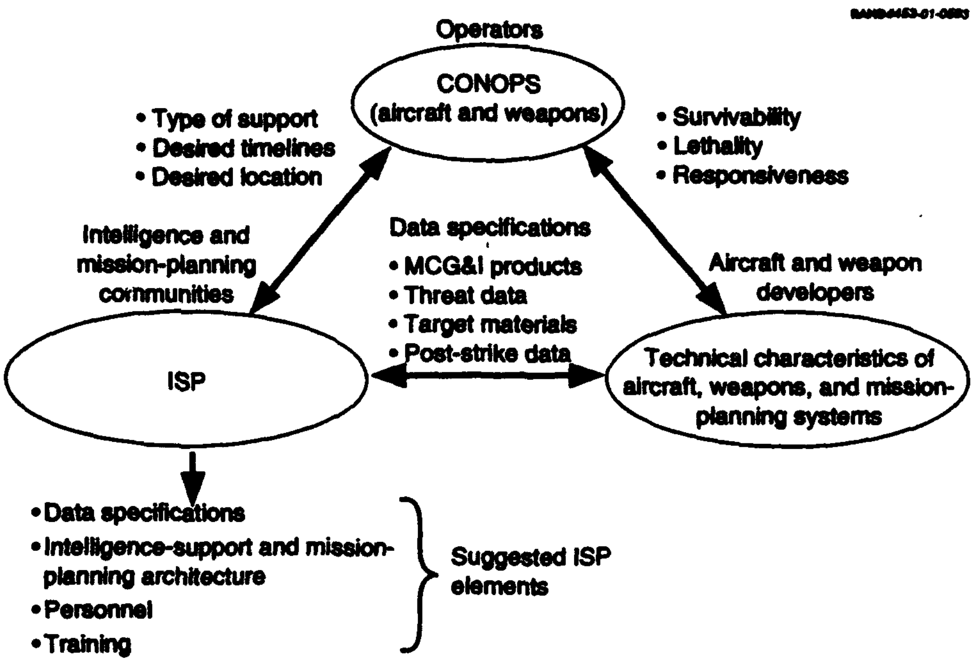

Figure 1—Suggested Framework for Developing an ISP

the working relationships that we believe are necessary for developing an ISP that will effectively support the employment of autonomous PGWs.

At the outset, it is important to emphasize that weapon developers are responsible only for ensuring that system specifications are met. In some cases, these specifications may be incomplete or vague from an operational perspective. Also, for some lengthy development programs, original system specifications, unless updated, may not call for capabilities that operators demand as a result of changing target sets and threat environments. Consequently, as they acquire increased understanding of the technical capabilities and limitations of the weapon system, the weapon developers must communicate this information to the operators. At a minimum, operators should be kept abreast of the weapon's (1) inherent survivability characteristics; (2) projected and demonstrated lethality against alternative target categories, as a function of the intelligence information available for mission planning; and (3) projected and demonstrated employment responsiveness, including the responsiveness of the mission-planning system. Operators need this information to formulate a concept of operations (CONOPS). In return, operators should inform weapon developers if they consider the current technical characteristics inadequate and then suggest potential improvements.

The CONOPS defines how the advanced PGW will be employed. It is based on mission needs to achieve defined measures of effectiveness against specific target sets in various threat environments. With visibility into the development program and with the information provided by the weapon developer, operators can develop a CONOPS that exploits fully the weapon's technical capabilities. Alternatively, if the technical capabilities of the weapon program cannot support the mission needs, operators may (1) ask for modifications to the development program; (2) accept the initial shortcomings, but require a preplanned product improvement (P^3I) program after the system reaches initial operational capability (IOC); or (3) ask for termination of the development program. If either or both of the first two options are deemed necessary, its effects on intelligence support and mission planning should be reflected in the ISP.

To develop an ISP, the intelligence and mission-planning communities need to derive from the CONOPS the following information: (1) the type of support they are required to provide, (2) where the support is required, and (3) the timelines that they have to meet. It would be very helpful if the type of support required were defined in terms of functions and data. By functions, we mean data collection and exploitation, target material and threat database production and dissemination, targeting, mission planning, and post-strike assessment. Information on where and how fast the support is desired is essential for evaluating the capabilities of the existing intelligence-support and mission-planning infrastructure to meet requirements and for identifying shortfalls that have to be corrected. If shortfalls cannot be corrected with available resources, the operators should be informed so that they can either adjust the CONOPS or endorse the allocation of additional funding to correct the shortfalls.

The intelligence and mission-planning communities need to understand what MCG&I products, target materials, threat data, and post-strike data are required. Target-material specifications, in particular, are an unresolved issue for autonomous PGWs with target-imaging sensors (this issue is discussed in some detail in Section 3). Consequently, an effective dialogue must be established and maintained between the weapon developer and the intelligence community as the weapon progresses in the acquisition cycle.

At a minimum, we believe the ISP should define (1) the intelligence data that will be provided to support mission planning and post-strike assessment, (2) the architecture (organizations and systems) that will develop and provide this data to mission planners, (3) the intelligence personnel that will support the architecture, and (4) the training that will be provided to support weapon employment. The ISP should also define the key tasks to be accomplished, the organizations responsible for completing them, and the timelines for their completion. Each of these elements is discussed in some detail in the subsequent sections of the report.

The suggested framework should also include a methodology for either (1) assessing the adequacy of the intelligence support to meet the objectives of the CONOPS, given the technical capabilities of the weapons, or (2) the adequacy of the weapon system to support the CONOPS, given a particular level of intelligence support. The unresolved issues discussed in the next section are major impediments to developing this methodology.

In developing an ISP, key budget, institutional, and security constraints have to be considered. The decreasing Department of Defense (DoD) budget suggests making maximum use of existing organizations and systems, with new initiatives addressing only critical shortfalls or revolutionary changes that render existing organizations and systems obsolete. A joint-service weapon system should rely as much as possible on joint-service intelligence support, with service intelligence support tailored to accommodate differences in weapon technical characteristics and CONOPS. An ISP for autonomous PGWs that requires other than collateral-level information should identify specific security requirements and provide recommended system and procedural solutions.

3. Intelligence Data Requirements and Issues

Typically, system specifications list the intelligence information that the government has agreed to provide to weapon developers and contractors in suppon of their advanced PGW development programs. Often, it is assumed that this information can be extracted from standard intelligence products. Contractors do not have sufficient visibility into the intelligence community to determine whether standard products are adequate or how difficult it is to develop additional information to support their development of advanced PGWs. They are reluctant to ask for additional information, because added requirements may eliminate them from competition. On the other hand, intelligence personnel do not have visibility into development programs to determine whether new weapon systems require information that standard products do not provide. Because of these factors, developers and the intelligence community have to work together to ensure that the intelligence data specifications in the ISP reflect the real requirements of advanced PGWs. However, developers have the primary responsibility for defining what intelligence support their systems require.

This section discusses six categories of data required to support autonomous PGWs with target-imaging sensors:

- Enemy threat data (including countermeasures)
- MCG&I data
- GPS data
- Target materials and tailored mission data
- Post-strike data
- Weather data.

The intelligence community and the Defense Mapping Agency (DMA) are responsible for producing the first five categories of data.

Threat Data

Threat database requirements for autonomous PGWs are not unique; most air-to-ground weapon systems and delivery aircraft require comparable data for planning routes that reduce the risk of attrition to enemy defenses. However, the ISWG for autonomous PGWs should review the format, content, and accuracy of the threat data provided to developers and ensure that operational threat databases will provide comparable information. As a point of departure, the ISWG should examine the threat data that will be generated by operations intelligence personnel using Sentinel Byte, a unit-level intelligence workstation designed to support the employment of conventional aircraft and weapons. **In addition to conventional air-defense threats, accurate information about any ground- or aircraft-based GPS jammers is also required.**

According to current plans, unit intelligence personnel will develop threat data from four threat data sources:

- A reference database provided by the Defense Intelligence Agency (DIA) or a Joint Intelligence Center (JIC), associated with a unified command
- A theater database developed by the intelligence component of the air operations center (AOC), which supports the Joint Forces Air Component Commander (JFACC) and which provides the intelligence data to generate and execute the air tasking order (ATO) or mission type order (MTO)[1]
- Constant Source, which provides near-real-time threat emitter data
- A local database consisting of pilot and ground liaison officer reports and other unit mission reports.

Sentinel Byte will provide these data to the Mission Support System (MSS II), or the follow-on Air Force Mission Support System (AFMSS) (see Reference 3). The data will be provided in two separate files: (1) a strategic file and (2) a tactical threat file. Currently, the transfer of threat data to the mission-planning systems is via floppy disk. In the future, the transfer of these files should be direct, over an electronic wire connection. Because the files and both systems are classified at the collateral level, there should be no security problems. (For programs of

[1]As we understand the concept of MTO, a JFACC would use an MTO to task a wing to achieve a particular objective (e.g., destroy the electrical power generation capability in a designated region), but the MTO does not designate specific targets, strike times, and weapons to be used (i.e., the information typically provided in an ATO). This increases the wing commander's flexibility in planning missions, but at the same time requires wing personnel to do more targeting (target development, target selection, aimpoint selection, and weaponeering).

higher classification than collateral, a floppy disk transfer or a secure guard will be required to get threat data to the mission-planning system.)

The strategic file will serve as the baseline threat for route planning on MSS II and AFMSS. This threat file is a combination of the DIA/JIC database and the theater database and it contains the locations of fixed and mobile surface-to-air defenses, positioned to protect strategic targets. It probably will contain the most complete and accurate data on known emitters. The tactical file, generated from Constant Source and the local database, does not always provide highly accurate threat position for weapon mission planning but does provide more nearly real-time data. It will likely have data on most pop-up (usually mobile) threats. This will pose a challenge to operations intelligence officers. They will have to combine data of different accuracy and completeness. Standard procedures should be developed to assist them in this effort.

Two other important issues related to threat data should be reflected in the ISP: (1) threat modeling and (2) development of a threat space (threat locations and capabilities, usually overlayed on a terrain database to model terrain masking). The weapon developer may select his own threat models and develop specific algorithms for building a threat space over which an autorouter or an aircrew member manually selects a weapon route with a low probability of attrition. These threat models and threat spaces may be inaccurate. If these issues are applicable to specific autonomous PGWs, they should be addressed in the ISP. A more detailed discussion of these issues is provided in Reference 4.

MCG&I Data

The primary MCG&I data being considered for mission planning of autonomous PGWs are charts (e.g., 1:250,000-scale Joint Operations Graphics), geographic imagery (e.g., 10-meter resolution SPOT imagery), Digital Terrain Elevation Data (DTED Level 1), and accurate locations of targets and other objects of interest. Charts (in both hard-copy and digital format) and DTED are standard DMA products. After DMA provides ground control, geographic imagery (SPOT) is formatted and distributed by the Digital Production Facility (DPF) at the 480th Air Intelligence Group (AIG) at Langley AFB, VA; in the future, DMA will probably provide this service. The geopositioning of targets and other objects of interest can be extracted by intelligence personnel from standard DMA products, such as the Point Positioning Data Base (PPDB) or can be provided by DMA through its Points Program (PP). In the future, this information will be available from Digital PPDBs (DPPDBs), assuming that a workstation that supports digital stereo imagery is also available. Because the specific accuracy and timeliness of various DMA geopositioning products and services vary, the ISP should define which of these products will be used to support autonomous PGWs.

It should be noted that PPDBs do not contain current imagery and have limited worldwide coverage (nevertheless, they are concentrated in target areas of past, high national interest). If funded, Rapid Positioning Capability (RPC), a DIA/DMA initiative, will provide an additional geopositioning capability during contingency, crisis, and wartime operations and a limited capability for regions without PPDB, DPPDB, or archival coverage. For additional information on current and future DMA MCG&I products, see References 5 and 6.

GPS Data

GPS enables autonomous PGWs with GPS-aided INS to update their positions and velocities while en route to the target. If the autonomous PGW relies only on its GPS-aided INS, the delivery accuracy is based on target location error, as well as navigation accuracy. Autonomous PGWs with target-imaging sensors can achieve a higher delivery accuracy by (1) using GPS updates to arrive at a preplanned basket for sensor turn-on (target location error should be small enough so that the target is in the sensor's field of view), (2) relying on a correlation algorithm to acquire the imaged target autonomously, and (3) then homing on the target. In most cases, the weapon-delivery platform will use its GPS-aided INS to provide initial conditions to the PGW at the time of release.

The amount of initialization required by the autonomous PGW depends strongly on the duration of the mission (PGW flight time). The most demanding are short-range missions, in which time to acquire and track GPS signals is very short. At the other extreme are long-range, standoff missions, typically flown by air-launched cruise missiles.

The time to acquire and track the GPS satellites depends on the quality of the initialization data transferred from the launch aircraft to the weapon. At the time of PGW release, GPS acquisition time can be minimized if the release conditions are accurately known. This requires the transfer of precise position, velocity, and GPS time. The most critical data is GPS time. If GPS time is known to a few microseconds, then a *hot start* (direct P-code acquisition) can be obtained, with acquisition in a few seconds. If the quality of the release conditions is degraded, the acquisition time can be much longer.

PGWs require the following data while in flight to update their positions using GPS: (1) cryptographic data to operate on the P(Y) secure code, (2) satellite ephemerides, and (3) almanac and satellite health status. Weapon developers, the intelligence and mission-planning communities, and operators need to establish the procedures for providing this information to PGWs. For additional information on operational issues associated with using GPS-aided INSs for autonomous PGWs, see Reference 7.

Target Materials and Tailored Mission Data

Target materials are sets of medium- or high-resolution imagery that have been annotated with intelligence data to assist force-level and unit-level intelligence personnel and mission planners in the identification of targets and critical aimpoints. The current standard target materials are the Automated Tactical Target Graphic (ATTG) and its follow-on, the Basic Target Graphic (BTG). ATTGs consist of annotated imagery with text describing structures that are likely targets. The description includes the general functions and dimensions (length, width, height) of the structures. ATTGs do not include any mensurated points, which are geodetic locations of objects (such as the corner of a building or the center of a runway and which are clearly indicated on the imagery). BTGs also consist of annotated imagery, with less description of structures than ATTGs. However, BTGs do have a small number of mensurated points. At this time, we believe that these particular products are not adequate to support the template building required by autonomous PGWs with target-imaging sensors to acquire successfully all targets of interest. In addition, it is not yet clear what the target material specifications should be to support these weapons.

Meanwhile, initiatives are under way in the intelligence community to develop BTG supplements that could potentially provide additional information to support targeting for advanced PGWs. The Enhanced Target Graphic (ETG) and the Hard Target Graphic (HTG) provide additional annotation and mensuration of structures beyond that in the BTG. For example, the HTG of an ammunition complex may include storage-bunker construction materials and thicknesses and archival imagery taken during construction, in addition to mensurated lengths, widths, and geodetic locations. The Seasonal Target Graphic (STG), the Radar Target Graphic (RTG), and the Infrared Target Graphic (ITG) are usually single images of the target area taken during different times of the year or taken with radar or infrared sensors. These BTG supplements could provide useful information to support PGWs with synthetic aperture radar (SAR) or imaging infrared (IIR) target-imaging sensors.

Even with these supplements, standard target materials may be insufficient because they cannot be tailored to a specific mission; additional analysis and research may always be required at the time the specific PGW mission is being planned. For example, since it may not be possible to mensurate every object depicted in a target material image, alternative methods must be found if additional mensuration is required. This additional data could then be used to produce a *tailored* target material supplement for this mission. Since the data will promptly be used to plan the mission, a formal product may not be necessary. However, at least a worksheet should be prepared and included with the target folder, and perhaps the information could be entered into a database. The data would then be readily available in case of possible target restrike or as an aid in developing offset aimpoints.

We refer to the data obtained during this research process to support a specific mission as *tailored mission data*. It should be recognized that this additional real-time support to terminal-area planning can be time consuming and could impact the responsiveness of weapon employment. If standard target materials do not exist for the particular target, the development of tailored mission data may be more time consuming. If appropriate target materials do exist, it may be possible to reduce the amount of real-time research.

This subsection addresses five areas related to target materials and tailored mission data. First, it discusses the target-material specification issue in a little more detail. Second, it addresses potential approaches to resolving this issue. Third, it discusses how the lack of a methodology for assessing weapon effectiveness (in particular, the lack of a procedure for template validation[2]) during mission planning can affect the establishment of requirements for target materials and tailored mission data. Fourth, it discusses possible approaches to resolving the template validation issue. Finally, it presents an interim solution to the target materials and tailored mission-data issues.

An Unresolved Issue: Specifications

Typically, system specifications list the target intelligence information that the government has agreed to provide to weapon developers and contractors in support of their PGW development programs. Often, it is assumed that this information can be extracted from standard target materials. Prior to contract award, contractors are reluctant to ask for additional information, because added requirements may eliminate them from competition. This position is reflected in the typical statement of some contractors: "My system will work with an ATTG

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[2]Validation is the process of determining, with some level of confidence, that the template (or sequence of templates) is unique and that it will correctly identify the target in the scene imaged by the sensor.

or a BTG." Under these conditions, the intelligence community could take the position that it will provide only standard target materials to support autonomous PGWs. That is not the position advocated in this report; it is also not the position of the intelligence community, as evidenced by the creation of ISPs.

In addition to our own research (Reference 1), another recent study on target material evaluation from the Air Force's Air-to-Surface Weapons Program Office (Reference 8) has concluded that existing standard target materials (ATTGs and BTGs) cannot reliably support autonomous PGWs with target-imaging sensors. Initiatives to develop "Pseudo ATTGs" to support these PGWs also reflect the concern that existing products are inadequate to support PGWs. Pseudo ATTGs have several mensurated points, precisely defined in latitude, longitude, and elevation, and an accurately placed image-orientation arrow (north arrow); standard ATTGs do not. Pseudo ATTGs describe the construction of many objects of interest and define their dimensions (length, width, and height). On the newer BTGs, this type of information is limited to critical elements according to function, to reduce BTG production times and thus enable more BTGs to be built and more frequent updates.

Recognizing that target-material specifications for autonomous PGWs with target-imaging sensors remain an unresolved issue, the intelligence community has undertaken several initiatives to determine what BTG supplements it may be able to provide in support of these weapons. The efforts of the 480th AIG and the DIA are examples of such initiatives. If it is determined that autonomous PGWs require such supplements, the intelligence community has to assess the feasibility and cost of providing the additional information. It should be remembered that BTG supplements may not be the complete solution; PGW mission planners may still require tailored mission data.

Weapon developers and the intelligence and mission-planning communities must work together to resolve the issues of target-material specifications and tailored mission-data specifications for autonomous PGWs with target-imaging sensors.

Suggested Approach for Defining Requirements

A suggested approach to defining target-material and tailored mission-data requirements is presented in this subsection. The first step is to define key intelligence-product characteristics, for example, type of imagery and resolution, number and absolute accuracy of mensurated points, relative accuracy between points, number of mensurated objects (objects annotated with length, width, height, and orientation with respect to north), and orientation of the imagery. The operational requirements document (ORD) (for joint systems, the JSORD) and the system specifications provide the starting point in this process (see Figure 2). Next, data from captive-carry or free-flight tests of PGWs in development should be carefully reviewed. The Air-to-Surface Weapons Program Office at Eglin AFB conducted numerous captive-carry tests with various target-imaging sensors and a limited number of PGW free-flight tests. The potential target-material specifications that this program office derived from its recent study (Reference 8) should also be considered. Operational experience with existing autonomous and MITL PGWs may also help to define key intelligence-product characteristics. The suggested output from this step would be a menu of alternative target materials and tailored mission data with defined characteristics.

The second step is to assess the producibility, cost, and time required to produce each of the previously defined alternative target materials and tailored mission data. For existing products, these parameters are known. They need to be defined for the proposed new supplements and new product initiatives. The suggested output from this step would be a menu of alternative products and

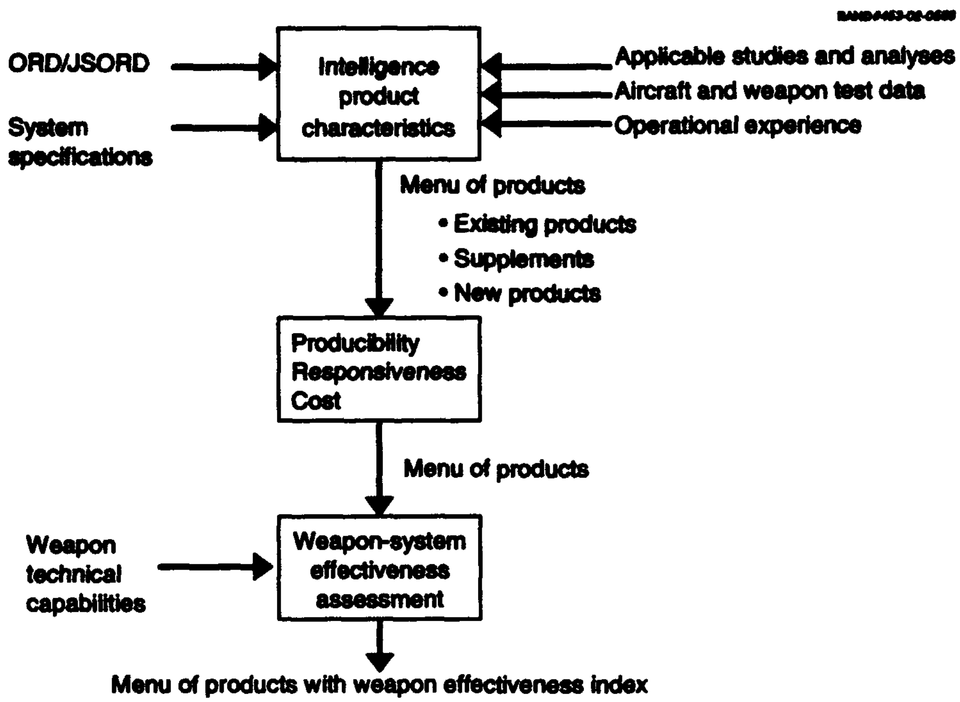

Figure 2—Approach for Defining Intelligence Product Requirements

tailored mission data, each now also characterized in terms of producibility, cost, and production timelines.

The third step is to determine weapon-system effectiveness against representative target sets as a function of alternative target materials and tailored mission data. The output of this process would be a menu of alternative target materials and tailored mission data, in which each product or data set would now also be assigned a qualitative weapon effectiveness index against the representative target sets. For example, the existing BTG may be evaluated as adequate to support an autonomous PGW mission against a large building in the open, provided that accurately mensurated coordinates of the building are available. On the other hand, existing BTGs may be assessed as inadequate for planning an autonomous PGW mission against a building located in an urban area, with several similar buildings in its vicinity; in this case, tailored mission data with the requisite mensuration may be needed to supplement the BTG.

The first two steps of the process may be time consuming, but are straightforward to accomplish. The third step requires the development of a methodology for assessing the expected effectiveness of autonomous PGWs with target-imaging sensors; this issue is discussed next.

An Unresolved Issue: Template Validation

The methodology for calculating the probability of mission success for autonomous PGWs with target-imaging sensors has not been fully developed. The probability of mission success is the product of the probabilities of (1) launch; (2) transition to flight; (3) PGW arrival at the sensor turn-on basket, as a function of clobber and survivability against enemy threats; (4) target acquisition by the sensor; and (5) target damage (a function of the weapon circular error probable, fuze reliability, and the target size and construct), given that the target is acquired by the sensor.[3] The principal problem with computing the probability of mission success is that neither PGW developers nor mission planning system developers have developed a methodology for calculating item 4, the probability of target acquisition. When a template is built using available data, there is no method for verifying prior to mission execution that the sensor and acquisition algorithm will actually acquire the target.

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[3]Without accurate data on target vulnerability, targeteers are unable to accurately *weaponeer* a target, that is, identify the critical aimpoints and determine with confidence the number of PGWs that have to strike the target to achieve a particular level of damage. This type of data is not readily available for MITL PGWs, much less autonomous PGWs with target-imaging sensors. The PGW ISWG should review this issue.

Since the probability of mission success cannot be calculated, targeteers cannot estimate the number of weapons required to achieve a specified level of damage against targets. This could be a major shortcoming in deploying autonomous PGWs with target-imaging sensors. Operators are likely to want (or even demand) such a capability before employing these weapons. This issue is also important to the intelligence community. Without a methodology for assessing expected weapon effectiveness as a function of the target material and tailored mission data provided, the intelligence community will not have a scorecard to evaluate the effectiveness of its support.

Depending on the mission, operators could also be very concerned with minimizing collateral damage. Without template validation, the likelihood of collateral damage is much greater. For example, if the the template is not unique, the terminal guidance system could easily acquire another object (false target) in the imaged scene. Then, this *precision* (and probably expensive) weapon would precisely hit the wrong object.

Even if template validation is performed during mission planning (and especially if it is not), it may be necessary to develop an additional decisionmaking capability for the PGW's onboard algorithm (if it is not already there) to determine whether target acquisition has occurred with high confidence. If confidence is not high, operators may want the autonomous PGW, presumably also configured with a GPS-aided INS, to default to that system in attacking the target.[4] The probability of mission success is lower because of the decrease in delivery accuracy, but the area of potential collateral damage is also lower. This default-mode capability (default to GPS-aided INS guidance) should also apply if the sensor has a hardware failure.

Approaches for Resolving the Validation Issue

This subsection discusses four possible approaches to resolving the template-validation issue. One approach is to create a statistical database, containing information on all captive-carry and free-flight tests of autonomous PGWs with target-imaging sensors, and then to use this database to determine the probability of acquisition for new missions against comparable targets, under

[4]Developing the capability to determine whether the confidence of target acquisition is sufficiently high, or if the decision to default to GPS-aided INS guidance should be invoked, is not trivial. Possible rules that could be implemented include the following: (1) the peak correlation is compared to a predetermined threshold setting (determined during mission planning); if this correlation value is below the threshold, the acquisition confidence is low, and the default to GPS-aided INS guidance rule is invoked, or (2) if the peak correlation is only slightly greater than other correlation values (with all values above the threshold), confidence is again low, and the default to GPS rule is again invoked.

comparable background clutter, day or night, and under varying weather (e.g., humidity level or amount of water accumulation from rain) and seasonal (e.g., extent of snow cover or amount of foliage on trees) conditions. Weapon developers, with modest funding, should be able to support this effort.

The second approach is to develop the capability to collect imagery of the target area at the same wavelength as the PGW target-imaging sensor and then to provide that imagery to mission planners. The ITG and the RTG are attempts to provide this information; however, these supplements are unlikely to exist for all targets. In that event, a database of infrared and radar imagery of some target categories may prove useful. In particular, this would be very useful for such target categories as armored vehicles with identical features, but probably not very useful for many high-value, fixed targets with disparate features.

In this approach, mission planners would use the collected imagery to validate the PGW templates prepared using visible imagery; alternatively, the planners could use the collected imagery to build the templates in the first place. This approach requires the use of specific collection assets (for example, imaging infrared sensors or synthetic aperture radars), which may or may not be available, and the distribution of this type of information to PGW intelligence-support and mission-planning personnel. This approach would not be applicable to PGWs with laser radars as their target-imaging sensor, because their template-building process, which consists of constructing three-dimensional shells of the target from high-resolution visible imagery, does not involve scene prediction.

The third approach is to develop a theoretical model of the acquisition process, possibly using matched-filter analysis, that could be partially validated by limited test data; this model could then be used to extrapolate to other situations. Because contractors understand their sensors and algorithms, they certainly should be involved in the model development.

The fourth approach is to develop a modeling capability that would simulate the image created by the target-imaging sensor. In this approach, many more details about the target (for example, the type of construction materials used) would be needed than are usually annotated on standard target materials. Imagery analysts would be needed to provide these additional data. Once the model is developed, it could potentially be used to generate additional templates, for example, for different weather and seasonal conditions. The development of this approach would be the most technically challenging of all the approaches discussed in this section.

While these (and any other) approaches are being debated, data from captive-carry and free-flight tests to date should be properly cataloged by weapon developers and the Air Force Operational Test and Evaluation Center (AFOTEC) and used to derive a preliminary weapon effectiveness index against flown target sets as a function of target materials. For example, if the majority of captive-carry tests proved successful against isolated buildings and were mission planned using only BTGs, then the BTG may be considered adequate against comparable targets.

Weapon developers should work with operators and the intelligence and mission-planning communities to resolve this issue of template validation because of its impact on calculating the probability of mission success.

An Interim Solution to Data Specifications

This subsection describes the target data that the intelligence community should provide to mission planners for developing templates until all these issues—the target-material specification, tailored mission-data specification, and template-validation issues—are resolved. It should be noted that the methods used to obtain these data may involve timelines that are not consistent with rapid weapon employment. A brief review of the terminal-guidance process will illustrate why particular data are necessary.

To attack a target, the PGW first uses its target-imaging sensor to create an image of the target area and then uses its autonomous target-acquisition algorithm to precisely locate the aimpoint within the imaged scene. The algorithm uses a reference template (or sequence of templates), developed during the mission planning process, to identify the aimpoint. The form of the template depends on the type of target-imaging sensor the PGW uses.

For most, if not all, target-imaging sensors, the template builder needs accurate three-dimensional data (length, width, height, and orientation with respect to north) for the target and usually for a number of *contextual objects*. Contextual objects are structures or terrain features in the vicinity of the target that are used to ensure that unique templates are built; this should also reduce the chances of false acquisition. When contextual objects are used, their three-dimensional location *relative* to the target must also be known accurately.

To ensure that the target appears within the scene imaged by the sensor, the mission planner needs sufficiently accurate absolute coordinates of the target. The accuracy is a function of the PGW's en route navigation error and the size of the sensor's field of view. By using a GPS-aided INS, the size of the en route navigation errors can be reduced. For typical sensor fields of view, it is envisioned that target coordinates obtained from DMA's more accurate MCG&I products and services will be adequate.

Therefore, at a minimum, the intelligence community should provide the template builder with

- High-resolution visible imagery of the target area
- Target location in World Geodetic System 1984 (WGS84) coordinates
- Three-dimensional data, including orientation, for the target and other contextual objects that make the scene unique
- The location of the contextual objects relative to the target
- Radar or infrared imagery of the target area, if available, to support SAR and IIR target-imaging sensors.

It should be noted that the first four items are required, but are not necessarily sufficient to support template building. The inclusion of item 5 is also not necessarily sufficient, but it is recognized that it does provide useful information to the template builder. Reference 8 provides information regarding the required accuracy of this data.

For simple targets, imagery analysts or combat target officers can extract the above information from BTGs or their supplements. For example, if the target is an isolated structure such that contextual objects are not needed, and if the annotation includes mensurated data and mensurated coordinates, the BTG may be sufficient. However, for targets in complex scenes or for targets for which no BTGs exist, imagery analysts and combat target officers must use alternative methods for acquiring the requisite information. The data obtained using these alternative methods is an example of tailored mission data.

Post-Strike Data

Because of their precision and relatively small warhead, autonomous PGWs do not typically destroy large targets, but rather cause functional kill of critical components. The PGW may leave only a small hole in the roof or the wall of a building. This may be the only damage visible on post-strike imagery. Therefore, other intelligence data, such as human intelligence, may be required to effectively determine battle damage.

Post-strike data, particularly imagery, are essential for planning restrikes with autonomous PGWs with target-imaging sensors. Changes to the target or to objects or features in the vicinity, as a result of damage caused by the initial strike, must be taken into account by mission planners in determining whether existing templates can be used, or new templates must be constructed. Without these data, these weapons are not likely to be employed in restrikes of the target, because the probability of successful target acquisition might be further reduced. These post-strike data issues should be addressed in the ISP.

Weather Data

The performance of autonomous PGWs with target-imaging sensors can be affected by adverse weather conditions. In particular, PGWs with laser radars or imaging infrared sensors are more susceptible to weather effects than those with synthetic aperture radars. Therefore, weather data over the target area are necessary for mission planning and scheduling of PGWs that are susceptible to weather effects. Useful weather and seasonal data include cloud cover and ceiling, visibility, humidity, precipitation, snow cover, and water accumulation from recent rainfall. Using this information, mission planners would build templates that take into consideration current weather conditions and, if necessary, could recommend delaying PGW mission execution.

The planning of autonomous PGWs with GPS-aided INS guidance does not require the preceding data, but mission planners of submunition-dispensing variants would benefit from wind data (speed and direction) in planning the PGW route, as well as the dispense point, speed, and heading.

4. Intelligence Functions, Organizations, and Systems

Many intelligence functions have to be performed to develop the data discussed in Section 3. Moreover, many organizations, systems, and operations protocols will be involved in providing these data to mission planners and operators. Therefore, a good understanding of these intelligence functions, organizations, systems, and operating protocols is essential in developing an effective intelligence infrastructure to support autonomous PGWs.

This section first discusses the functions required to support these weapons. Next, it identifies organizations and systems currently available to support these functions. Then, it identifies near-term systems that might be procured to improve the capabilities of existing organizations to support autonomous PGWs. Because of the many potential systems involved, we do not describe all the systems in detail, but limit our discussion to those that we consider most important.

Intelligence Functions

To support the employment of autonomous PGWs, the intelligence community must provide the following: target materials and most currently available imagery, target databases, threat databases, information on countermeasures, and post-strike assessment products. To provide this support, the intelligence community must perform the following functions: data collection (this includes requests for sensor tasking by user commands, sensor tasking by the controlling authority, and actual collection), exploitation, target-material production, threat-database generation, and intelligence-product dissemination. In addition, it will support the functions of targeting and post-strike assessment. Moreover, the intelligence community will share the responsibility, along with communications and operations personnel, for getting the required data to the end user.

To take full advantage of the capabilities of PGWs (autonomous or MITL), targeting can be a particularly time-consuming function, requiring skills of well-trained targeteers. The targeteers select targets, identify critical nodes, select aimpoints, and weaponeer to meet the damage criteria specified by warfighters.

Because of the complexity of producing terminal-area products (templates) for autonomous PGWs with target-imaging sensors, intelligence personnel will most likely be involved in the mission planning for these PGWs.

Existing Organizations and System Capabilities

Existing organizations and system capabilities are summarized in Table 1. This subsection discusses the system capabilities of central facilities (centralized organizations with systems and operating protocols) first and then those of the deployable organizations.

Central Facilities

Several existing centralized intelligence organizations—the 480th AIG at Headquarters, Air Combat Command (ACC), Langley AFB, Virginia; the Atlantic Intelligence Command (AIC) at U.S. Atlantic Command (LANTCOM), Norfolk Naval Base, Virginia; the Joint Intelligence Center, Pacific (JICPAC) at U.S. Pacific Command (PACOM), Hickam AFB and Makalapa, Hawaii; and the Joint Analysis Center (JAC) at U.S. European Command (EUCOM), Molesworth, United Kingdom—have the capability to perform all intelligence functions necessary to support autonomous PGWs, except sensor tasking. Although not discussed further, the U.S. Strategic Command Joint Intelligence Center (STRATJIC), Offutt AFB, Nebraska, has similar capabilities but provides support primarily to U.S. nuclear forces. We note, however, that it did support the mission planning of CALCMs launched by B-52s in Operation Desert Storm.

These central facilities receive imagery collected by national sensors and maintain data repositories of national imagery in both hard-copy and soft-copy (very large data storage [VLDS] tape) formats. They use the Computer-Aided Tactical Information System (CATIS) to manage imagery exploitation, to create and disseminate imagery reports, and to manage the imagery database. CATIS interfaces with the Imagery Data Exploitation (IDEX II) System for soft-copy imagery exploitation tasking and it supports an interface to Defense Secure Network (DSNET III) for file transfer and remote user access.

As shown in Table 1, only these central facilities have the IDEX II to exploit soft-copy imagery. Using IDEX II, targeteers and imagery analysts can work together to select the particular portions of images for target material production. IDEX II can also be used to mensurate very accurately the lengths, widths, heights, and orientations of structures, information that is required in target material

Table 1

Existing Intelligence-Support and Mission-Planning Capabilities

Functions	ACC 480 AIG	LANTCOM AIC	PACOM JICPAC	EUCOM JAC	JFACC 9/12 AIS	Wing	Squadron
Data collection							
Request	National	National	National	National	National		
Task/collect			Theater	Theater	Theater/ tactical		
Exploitation							
National imagery access	Courier	Electronic/ courier	Electronic/ courier	Electronic/ courier	Courier	Courier (B52, B1, F111, F117)	
Imagery management	CATIS	CATIS	CATIS	CATIS			
Imagery analysis	IDEX/LTMS	IDEX/LTMS	IDEX/LTMS	IDEX/LTMS			
Target material production							
Mensuration	IDEX/LTMS	IDEX/LTMS	IDEX/LTMS	IDEX/LTMS			
Geopositioning	APPS/PPDB PP	APPS/PPDB PP	APPS/PPDB PP	APPS/PPDB PP	APPS/PPDB PP	APPS/PPDB (PGW wings)	
Production	TMWS	TMWS	TMWS	Photo Lab		Film (F117)	
Threat database generation	AIF, OBs	MIIDS/IDB	EPS/IDB	EISS/IDB	TEP/ICM	CS/SB (TEP F117)	CS/SB
Intelligence product dissemination	Courier SIDS	Courier SIDS	Courier SIDS	Courier SIDS	Courier SIDS	Courier SIDS	Courier SIDS
Targeting and BDA	IDEX/LTMS TMWS	IDEX/LTMS TMWS	IDEX/LTMS TMWS	IDEX/LTMS	LTMS TMWS	LTMS (PGW wings)	
Mission planning							
Aircraft planning						MSS/CMPPS	MSS/CMPPS
Adv PGW planning							

production. Although IDEX II can be used to view stereo imagery, all mensuration is done on monoscopic imagery;[1] therefore, the determination of *relative* elevation, for example, between an offset aimpoint and a target is inaccurate (relative accuracy in the horizontal plane is good). For mensuration of hard-copy imagery, the Light Table Mensuration System (LTMS) can be used. Using just the control data provided with the imagery, IDEX II or LTMS cannot perform accurate *absolute* geopositioning of targets or other objects of interest.

To produce target materials, the 480th AIG, AIC, and JICPAC use the Target Material Workstation (TMWS), and the JAC uses the LTMS and a photo lab. The JAC is scheduled to get TMWS during the middle of 1993. Currently, a scanner is used to input hard-copy imagery into the TMWS for soft-copy manipulation. The hard-copy data from IDEX II, the host image database, or other sources can be used as inputs. Prospective soft-copy input options include direct connectivity to the IDEX II or to VLDS tape readers. TMWS can be used to sharpen, rotate, and merge images, draw lines and symbols, and annotate images. CATIS is used to determine the availability of imagery or, if not available, to request imagery.

To tie particular points or objects in the image to very precise geodetic locations, TMWS operators rely on geopositioning data derived locally by reading hard-copy PPDB using the Analytical Photogrammetric Positioning System (APPS) or they rely on information DMA provides via its Points Program (PP). The turnaround time for DMA to provide this data can vary depending on the priority assigned to the request and the availability of imagery; with an APPS, the user controls the timeline, assuming that PPDBs that cover the target area are available.

The major intelligence organizations are equipped with two or more secondary imagery dissemination systems (SIDSs) tied to standard DoD or commercial lines of communications. Therefore, they can electronically transmit images to deployed units. Alternatively, they can use courier services to deliver data.

Tasked by the national community, these central facilities also have the capability to produce all-source threat databases for their areas of responsibility (AORs). Databases are maintained in accordance with the Council of Defense Intelligence Producers (CDIP) guidance and include orders-of-battle (OBs) for air (AOB), defensive missiles (DMOB), and electronics (EOB). For joint-service centers, OBs include ground (GOB) and naval (NOB) as well.

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[1]IDEX II lacks the application software for extracting data, in particular elevation data, from stereo imagery.

Using the Automated Installation Intelligence File (AIF) and OBs, the 480th AIG produces threat data for its AOR. AIC uses the Military Intelligence Integrated Data System (MIIDS)/Integrated Data Base (IDB) to produce tailored threat databases for specific areas of interest (AOIs) within its AOR. JICPAC uses the electronic intelligence (ELINT) Processing System (EPS) and the IDB to develop and maintain a theater threat database. The JAC uses the EUCOM Intelligence Support System (EISS) and IDB to produce and update its theater database.

These central facilities do not have systems or personnel to plan aircraft and PGW missions. If required, their imagery analysts could provide target imagery support to a targeteer.

AISs, Wings, and Squadrons

The JFACC can, through the theater CINC, task theater and tactical assets for intelligence-data collection. During wartime, the JFACC has, through the theater CINC, priority on national sensor coverage for his AOR. National sensor organizations then task sensors to satisfy JFACC needs.

Unlike the central facilities, the air intelligence squadrons (AISs), wings, and squadrons do not have imagery exploitation systems or all of the equipment and trained personnel for target material production (the F-117 wing has limited wet film processing and exploitation capabilities). However, the AISs and PGW-capable wings have APPS and hard-copy PPDBs or may be able to request accurately geopositioned points (via theater-level support) from the DMA PP. For activities with APPS (but no IDEX II or LTMS), well-trained operators could provide very accurate lengths, widths, heights, and orientation of objects in addition to mensurated points; however, using the APPS is very tedious and time consuming.

AISs and most wings and squadrons receive imagery and target materials primarily by courier and a small fraction by Intratheater Imagery Transmission System/Tactical Data Facsimile (IITS/TDF). Recent experience during Operations Desert Shield and Desert Storm highlighted major inadequacies of existing SIDSs, including lack of interoperability between the various service (and joint-service) systems, poor image quality, long transmission times, lack of multiple addressee capability, and lack of on-line storage manipulation capabilities.

Most wings and squadrons do not have sensitive compartmented information facilities (SCIFs) or access to national imagery; F-111, F-117, B-52, and B-1 wings are the exception. In addition, PGW-capable wings have intelligence targeteers. The B-2 wings will have similar capabilities.

AISs develop and maintain theater-level threat databases. They currently rely on their Tactical ELINT Processor (TEP) vans and the Intelligence Correlation Module (ICM), a multisource correlator, as primary input. ICM will initially be fielded at the collateral level.

Wings and squadrons are being equipped with Sentinel Byte (SB) and Constant Source (CS) workstations to produce and maintain threat data for their AOIs. SB will provide threat data and OBs to wings and squadrons. SB II is currently planned to have the capability of displaying imagery and of being the repository for an electronic footlocker (digital target graphics, Common Mapping System database and application tools, target images, reference manuals). Constant Source will provide a near-real-time threat picture.

AISs supporting a deployed JFACC, which is equipped with an LTMS and a TMWS, can perform targeting and post-strike assessment functions, provided that they have access to those systems. AISs do not perform any mission-planning functions for weapon systems. PGW-capable wings are equipped with LTMS and personnel to perform limited targeting and post-strike assessment functions. Wings and squadrons are equipped with mission-planning systems to perform aircraft mission planning: Mission Support System (MSS II) for fighters and Conventional Mission Planning and Preparation System (CMPPS) for bombers; currently, these systems do not support autonomous PGW mission planning.

With current MITL PGWs, aircrews see and describe weapon effects on the target, and they return with cockpit video. With fully autonomous PGWs, there are no visual reports or gun-camera video to support post-strike assessment.

In a budget-constrained environment, maximum leveraging of existing capabilities for intelligence support and mission planning of autonomous PGWs with target-imaging sensors is prudent. Thus, it is suggested that the capabilities of central facilities be used first, before procuring additional systems and adding personnel at an AOC or at wings and squadrons solely to support these weapons. Central facilities, using existing systems and provided with PGW mission-planning systems and personnel trained to build target templates, can support *deliberate* (i.e., not responsive) mission planning of PGWs with target-imaging sensors now.

Potential Future System Capabilities

The ongoing communication and computer technology revolutions are likely to result in the development of new systems that may substantially alter the way the intelligence community does business. Table 2 highlights some systems or capabilities that are of particular interest.

The central facilities can be configured to receive national imagery electronically and store that data in a very large digital-imagery database (DIDB), using CATIS as a database manager. Assuming that IDEX II is modified so that it can directly access the DIDB, these capabilities would substantially expedite the exploitation of imagery. If the existing TMWS is modified to have electronic connectivity with IDEX II and the DIDB, and if DPPDBs become available, the timelines for producing target materials are likely to be on the order of a few hours. RPC will provide an additional geopositioning capability during contingency, crisis, and wartime operations and a limited capability for regions without PPDB, DPPDB, or archival coverage. This assumes that DPPDB and RPC application software is hosted on IDEX II or an upgraded TMWS (TMWS+).

The addition of PGW-specific targeting application software on a TMWS+ (or possibly on a low-cost digital imagery workstation [LCWS]) and an AFMSS to the central facilities would allow them to perform targeting, post-strike assessment, and mission planning for advanced PGWs. Air Force Tactical Exploitation of National Capability (TENCAP), under the TALON SCENE initiative, is currently examining LCWSs for limited deployment as prototyping baselines to various Air Force user commands. The Air Force Mission Support System (AFMSS) is currently under development at the Air Force Electronic Systems Center, Hanscom AFB.

A draft JSORD for the development of a rapid, high-quality SIDS was published in 1991. Development of such a system will improve substantially the dissemination of imagery from central producers to wings and squadrons.

Assuming the 9th and 12th AISs are provided with the intelligence systems and personnel required to support autonomous PGW mission planning, they would substantially enhance the capability of the JFACC to employ these advanced weapons. First, the addition of the Joint Service Imagery Processing System (JSIPS) and the Contingency Airborne Reconnaissance System (CARS) will provide the JFACC with an imagery processing and exploitation capability for both national and tactical imagery (CARS will also provide signals intelligence processing and exploitation). Next, the addition of an upgraded SB (SB+) (or a new LCWS) with application software for DPPDBs, RPC, and imagery

Table 2

Future Intelligence-Support and Mission-Planning Capabilities

Functions	ACC 480 AIG	LANTCOM AIC	PACOM JICPAC	EUCOM JAC	JFACC 9/12 AIS	Wing	Squadron
Data collection							
Request	National	National	National	National	National		
Task/collect			Theater	Theater	Theater/ tactical		
Exploitation							
National imagery access	Electronic/ courier	Electronic/ courier	Electronic/ courier	Electronic/ courier	Electronic/ courier	Electronic/ courier	
Imagery management	CATIS/DIDB	CATIS/DIDB	CATIS/DIDB	CATIS/DIDB	DIDB	DIDB	
Imagery analysis	IDEX	IDEX	IDEX	IDEX	JSIPS/CARS	SB+/LCWS	
Target material production							
Mensuration	IDEX	IDEX	IDEX	IDEX	TMWS+/SB+	SB+/LCWS	
Geopositioning	DPPDB PP/RPC	DPPDB PP/RPC	DPPDB PP/RPC	DPPDB PP/RPC	DPPDB PP/RPC	RPC	
Production	TMWS+	TMWS+	TMWS+	TMWS+	TMWS+/SB+	SB+/LCWS	
Threat database generation	XIDB	MIIDS/IDB	MIIDS/IDB	MIIDS/IDB	TEP/ICM XIDB	CS/SB+	CS/SB+
Intelligence product dissemination	Courier SIDS+	Courier SIDS+	Courier SIDS+	Courier SIDS+	Courier SIDS+	Courier SIDS+	Courier SIDS+
Targeting and BDA	IDEX/TMWS+	IDEX/TMWS+	IDEX/TMWS+	IDEX/TMWS+	TMWS+/SB+ RAAP+	SB+/LCWS	SB+/LCWS
Mission planning							
Aircraft planning					AFMSS	AFMSS	AFMSS
Adv PGW planning	AFMSS	AFMSS	AFMSS	AFMSS	AFMSS	AFMSS	AFMSS

NOTE: Plus indicates an upgraded system.

mensuration would provide the AIS with the capability to produce target materials and tailored mission data with mensurated coordinates. This assumes that additional trained personnel are available to perform these functions. The 9th and 12th AISs could also rely on ICM for all-source data correlation (currently, ICM is limited to threat correlation); they could also rely on an enhanced Rapid Application of Air Power (RAAP) for targeting (currently, RAAP is only envisioned for target nomination and force-level targeting). As in the case of the central organizations, the addition of an SB+ (or a LCWS) and AFMSS would permit soft-copy targeting and the mission planning of autonomous PGWs.

If the CONOPS requires that the mission planning of autonomous PGWs be performed at a wing operations center (WOC), an SB+ (or a LCWS) and AFMSS must be made available there.

The recent creation of composite wings, particularly the 366th intervention wing at Mountain Home AFB, may yield another organization that in the near future could be capable of performing all intelligence-support and mission-planning functions for autonomous PGWs. This organization could be equipped with existing systems or new systems suggested for the 9th and 12th AISs or for PGW-capable wings. The specific configuration of the intelligence-support and mission-planning infrastructure for composite wings is not yet finalized.

Assuming that trained personnel (see Section 6) are made available, the addition of new systems would truly revolutionize the intelligence-support and mission-planning capabilities at the wings and squadrons. They would have the capability to perform all functions except sensor tasking and data collection.

5. Alternative Architectures

To be most effective, intelligence and mission-planning functions, organizations, and systems should be integrated into an end-to-end architecture, from target data collection to post-strike assessment, with robust connectivity and clearly defined operating protocols. Before constructing alternative architectures, it is useful to consider where the requisite intelligence and mission-planning functions for autonomous PGWs could be performed. By this we mean, what functions are performed at central facilities (CONUS and developed theater centers) and/or force-level deployed centers, and what functions are performed at WOCs and/or forward operating locations (FOLs)?

From a functional perspective, we considered four intelligence-support and mission-planning architectures, summarized in Table 3. The first option is having the central facility (or facilities) perform all the intelligence and mission-planning functions required to support autonomous PGWs, except aircraft mission planning, integration of aircraft and PGW mission data, and loading of mission data into data-transfer devices (DTDs). For autonomous PGWs with target-imaging sensors, which typically require substantial intelligence support and mission planning, this option is always necessary if a large number of PGWs are to be used in the first days of a no-warning conflict. The second option is to slightly expand the capabilities of WOCs and/or FOLs and allow them to do PGW en route mission planning in addition to aircraft mission planning. The third option further expands the capabilities of WOCs and/or FOLs by providing them with the capability of building terminal-area products (templates), with current imagery and target materials or tailored mission data provided by the central facility. The fourth option is to enable WOCs and/or FOLs to do all the intelligence and mission-planning functions required for autonomous PGWs by providing them with a direct feed of imagery collected by national sensors.

The last three options in Table 3 list the minimal required support to the WOC or FOL by the central facility. These options do not preclude the possibility that the central facility maintains additional capability as listed in preceding options, including the first option.

In this section, we first describe in more detail the four alternative intelligence-support and mission-planning architectures: one *centralized* architecture and

Table 3

Intelligence-Support and Mission-Planning Architecture Options

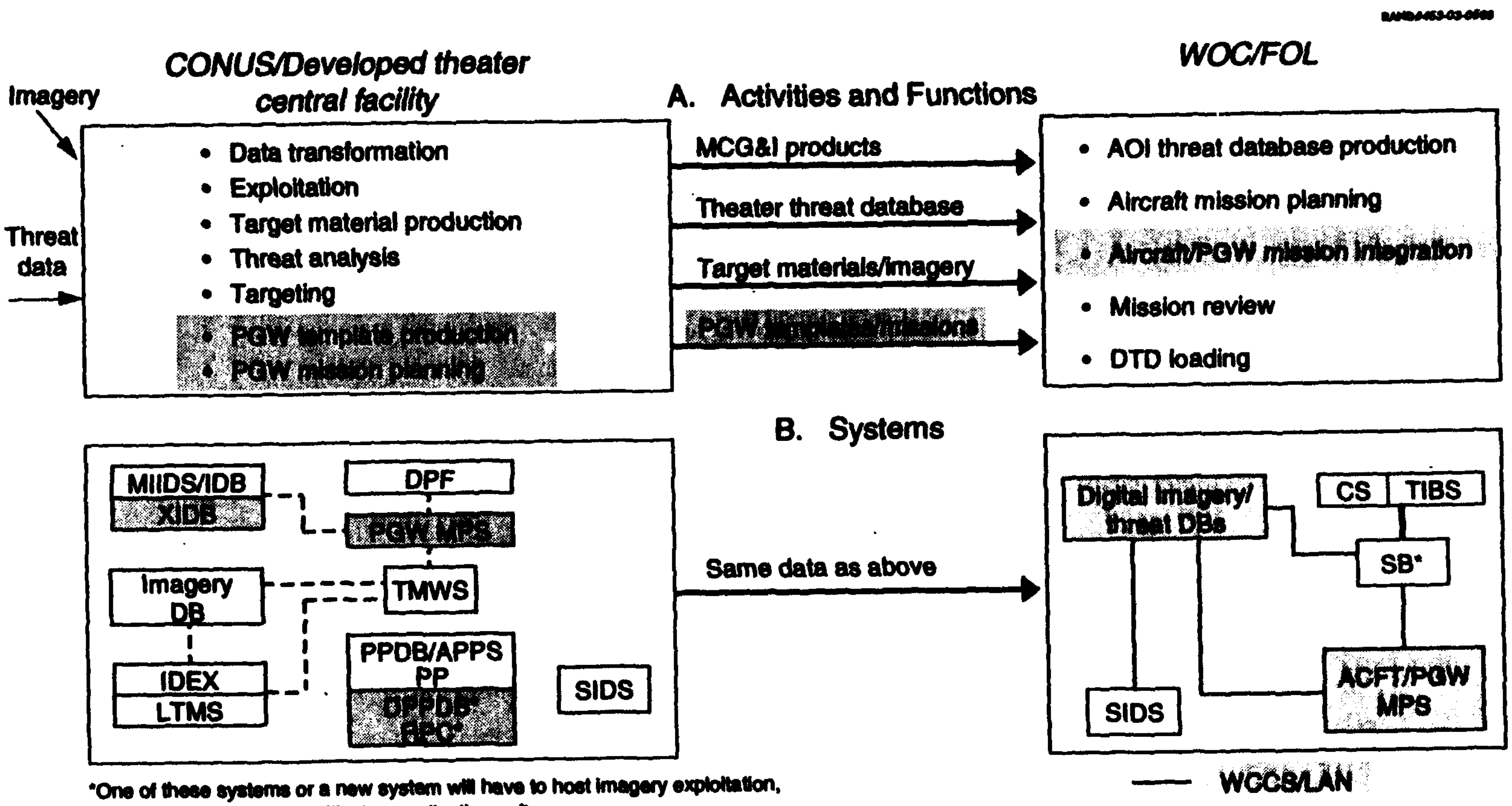
Option	Central Facility	WOC/FOL
Centralized	PGW en route and terminal area mission planning	ACFT mission planning, ACFT/PGW integration, DTD loading
Centralized intelligence support and partly distributed mission planning	PGW terminal area mission planning	Above plus PGW en route mission planning
Centralized intelligence support and distributed mission planning	Provide wings with target materials and current imagery	Above plus PGW terminal area mission planning
Distributed	Not Applicable	All intelligence support and mission planning

three *distributed* variants. Next, we suggest an evolving architecture, which begins with the centralized architecture and then, as required, evolves to a more distributed architecture, to support autonomous PGWs with target-imaging sensors. Then, we discuss an architecture specifically tailored for autonomous PGWs with GPS-aided INS guidance only. Finally, we discuss an approach for a preliminary assessment of alternative architectures. In the absence of a CONOPS, we chose not to conduct an analysis to select one of the four options as the preferred architecture based on postulated measures of effectiveness (MOEs).

Alternative Architectures for PGWs with Target-Imaging Sensors

Centralized Intelligence-Support and Mission-Planning Architecture

The upper section of Figure 3 depicts the activities and functions of the basic centralized architecture. In this configuration, the personnel of the CONUS (ACC/480th AIG, LANTCOM/AIC), PACOM (JICPAC), and EUCOM (JAC) intelligence-support and mission-planning centers perform all functions required to support autonomous PGWs, except route planning of delivery aircraft, integration of PGW missions with aircraft missions, PGW mission review, and loading the mission data on DTDs.



*One of these systems or a new system will have to host imagery exploitation, mensuration, and geopositioning application software.

NOTE: Shading indicates new activities and functions, and new systems or those under development.

Figure 3—Centralized Intelligence-Support and Mission-Planning Architecture

This architecture assumes that PGW terminal-area products (templates) and missions that are built in central facilities can be exported to aircraft mission-planning systems at WOCs and/or FOLs. The functions and systems highlighted in the figure either do not exist or are in development. The highlighted products (PGW templates and preplanned missions) from the central facility correspond to the PGW support options listed in Table 3.

The central facilities transform MCG&I products (including geographic imagery, for example, SPOT) into media and formats required by aircraft mission-planning systems (DMA may undertake this task). Following exploitation of target imagery, intelligence personnel supported by operators produce target materials and tailored mission data and conduct targeting analyses. To assist mission planners, intelligence personnel also provide the threat data used to perform penetration analysis. With this information, the mission planners determine PGW minimum risk routes, build the terminal-area products required by PGWs, and plan PGW missions. The information generated by the centers is distributed to the WOC or FOL using couriers and SIDSs. Obviously, effective dissemination systems are essential for this architecture.

With these data, personnel at the WOC or FOL plan the aircraft route to the preplanned launch basket for the PGW. Then, using their mission-planning system (MPS), they integrate the aircraft route data with the PGW mission data and review the mission. If they are satisfied with the mission, they transfer the information to a DTD for subsequent loading into the aircraft and PGWs.

In peacetime, these central facilities prepare all preplanned PGW missions according to priorities identified by CINCs in their AORs. For autonomous PGWs that require substantial mission-planning time or for which there is extended mission-planning start-up time, wings assigned PGW missions will have to rely on these centers, if they intend to use a large number of autonomous PGWs during the first days of a no-warning conflict. In contingencies, assuming that protocols have been developed, these centers can shift from scheduled PGW mission-planning operations to support mission planning for emergent targets in their AORs or in austere theaters, again as requested by the CINCs.

Most of the systems required to support autonomous PGWs are available at the existing central facilities (see lower section of Figure 3). For example, at the 480th AIG, a Digital Production Facility (DPF), which transforms national and commercial data (maps, charts, and SPOT imagery), is operational; to support advanced PGWs, the DPF systems may require some software modifications. LTMS and IDEX II and their associated database provide the imagery and mensurated target data required by the TMWS for the production of target materials. Because these systems are used to support DIA, a memorandum of agreement between the Air Force and DIA would be needed. Otherwise, the Air Force would have to buy and maintain their own systems and provide additional personnel.

Several options are available for obtaining precisely mensurated coordinates. Personnel at the central facilities can use the APPS to read points from hard-copy PPDBs. Through the PP, they can request mensurated points for objects of interest directly from DMA. Also, two new initiatives, DPPDBs and the RPC, will be available in the near future. Both initiatives will provide soft-copy (digital) imagery. DPPDBs will provide stereo imagery, but RPC may not. DPPDB and RPC applications software and the hardware that will host these applications would be needed.

The PGW and aircraft mission-planning system(s) and rapid, high-quality imagery dissemination systems are the major components of this architecture that are not in place at CONUS and developed theater centers. Also, a robust electronic connectivity for this architecture should be developed, and the personnel required to support the added functions should be provided. As indicated by the dashed lines in Figure 3, the existing connectivity within the central facility is manual, requiring an operator to either key-punch the information or to use an electronic medium, such as a floppy disk or magnetic tape, to transfer the information from one component of the architecture to another.

The WOC and/or FOL would be equipped with (1) a database repository (includes storage, file server, and security gateway) for MCG&I products, target materials, and PGW terminal-area products (templates) and missions; (2) an effective SIDS to request and receive updated imagery; and (3) a system to support aircraft mission planning, integration of aircraft and PGW mission data, and the loading of DTDs. CS, Tactical Information Broadcast System (TIBS), and SB workstations are available at WOCs and FOLs to provide updated threat data to support aircraft mission planning. The Wing Command and Control System/Local Area Network (WCCS/LAN) is being developed to provide electronic connectivity.

Deployable PGW Center

The obvious addition to the above centralized architecture is to build a deployable PGW intelligence-support and mission-planning center directly linked into the AOC, currently under development.[1] The deployable PGW center would use several systems currently programmed for the AOC, thus reducing investment costs (see Figure 4).

The deployable PGW center would rely on the AOC's JSIPS/CARS for access to national and theater imagery and on these systems' associated imagery exploitation system (IES) for imagery exploitation. The AOC's MIIDS/IDB would be the primary source of threat and target data, and ICM would provide fused threat data. The PGW center would use the AOC's geopositioning capabilities (PPDB/APPS, PP, DPPDB, or RPC).

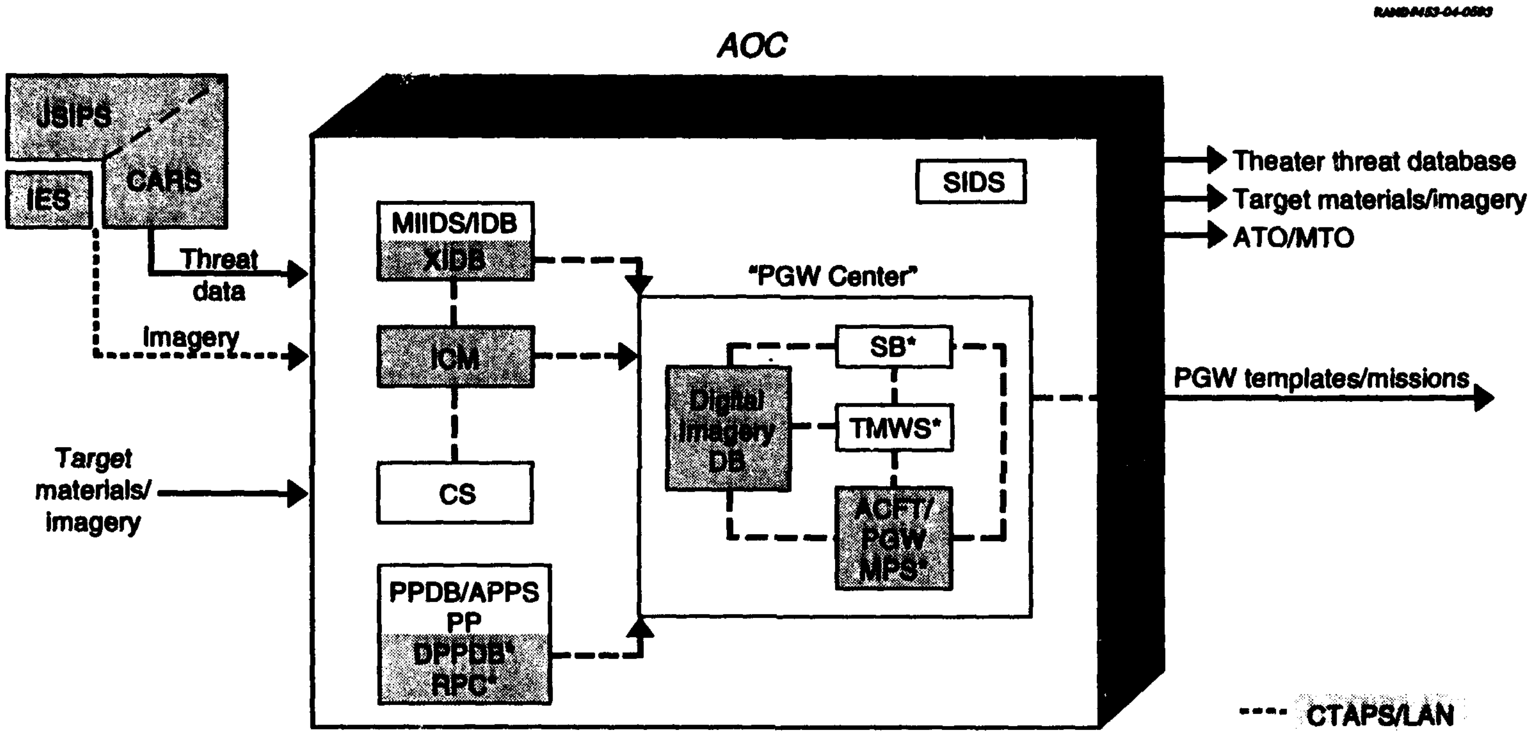
The center would consist of an SB workstation, a TMWS or a low-cost workstation with functions similar to TMWS, an aircraft (ACFT)/PGW MPS, a digital imagery database, and application software for mensurating and geopositioning imagery. To support these functions, the center would be manned with imagery analysts, targeteers, and mission planners. The AOC's Contingency Tactical Air Control System (TACS) Automated Planning System (CTAPS) would be used to provide electronic connectivity.

Adding the deployable center to the centralized architecture would improve the responsiveness of PGW employment in austere theaters by providing the capability of producing tailored mission data from national, theater, and tactical imagery and by increasing the number of systems and personnel available in theater to build target materials and plan missions. Moreover, it would increase the deployed JFACC's flexibility to employ autonomous PGWs by giving the JFACC direct control of all intelligence support and mission-planning functions. However, a substantial investment would be required to develop this added PGW intelligence-support and mission-planning center.

Centralized Intelligence-Support and Partly Distributed Mission-Planning Architecture

In this alternative architecture (see Figure 5), the central facilities and/or deployable center would perform all the functions as in the Centralized Intelligence-Support and Mission-Planning Architecture, except they would not do PGW mission planning. This function would now be done at the wings. This alternative would provide operators with more flexibility to select aircraft launch

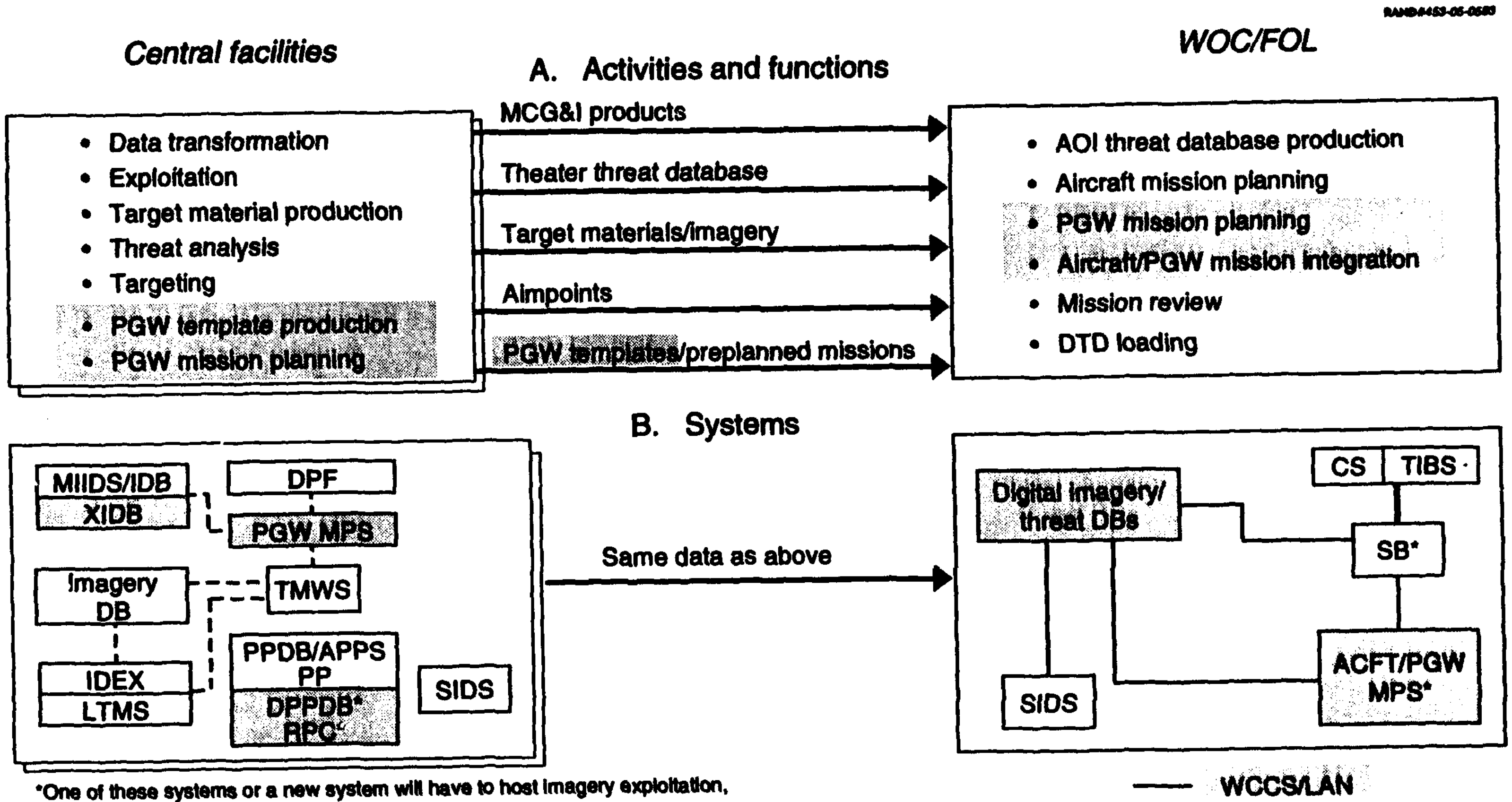
[1]The PGW center could be either an integral part of the AOC or a separate entity that has direct access to the AOC systems necessary to perform its functions. This report does not differentiate between these two alternatives.



*One of these systems or a new system will have to host imagery exploitation, mensuration, and geopositioning application software.

NOTE: Shading indicates new systems or those under development.

Figure 4—Deployable PGW Intelligence-Support and Mission-Planning Center Within an AOC



*One of these systems or a new system will have to host imagery exploitation, mensuration, and geopositioning application software.

NOTE: Shading indicates new activities and functions, and new systems or those under development.

Figure 5—Centralized Intelligence-Support and Partly Distributed Mission-Planning Architecture

points; however, it would also require that the operators spend more time in PGW mission planning. The system hardware and intelligence personnel needs would be the same for this alternative as for the centralized alternatives described above.

Centralized Intelligence-Support and Distributed Mission-Planning Architecture

In this alternative architecture (see Figure 6), the central facilities continue to perform the same functions for preplanned targets; however, wings have the added capability of producing tailored mission data and templates, from collateral target materials, recent imagery of the target area, and aimpoints provided by central facilities to cover emergent targets. To perform these functions, wings will require application software for mensurating and geopositioning imagery, hosted on upgrades to existing systems (SB, ACFT MPS), or on a low-cost workstation. Wings would have to be manned with imagery analysts to produce tailored mission data and templates.

Distributed Intelligence-Support and Mission-Planning Architecture

In this alternative architecture (see Figure 7), the wings would have direct access to national imagery and would not require terminal-area imagery or target materials from central facilities to develop tailored mission data or build PGW templates and missions for emergent targets. With aimpoints provided by the JFACC, they would simply perform all functions necessary to support autonomous PGW employment, which would now include limited exploitation of target imagery, the production of tailored mission data and templates, and targeting. To perform these functions, they would require a satellite communication (SATCOM) receive capability, a SCIF, a DIDB, targeteers, well-trained imagery analysts, and additional communication personnel. This would give wings a more responsive capability against emergent targets by eliminating the imagery distribution delays from central facilities and allow wing intelligence personnel to select aimpoints. The on-going intelligence personnel drawdown may limit the development of this alternative to a very small number of WOCs, perhaps only to those of composite intervention wings.

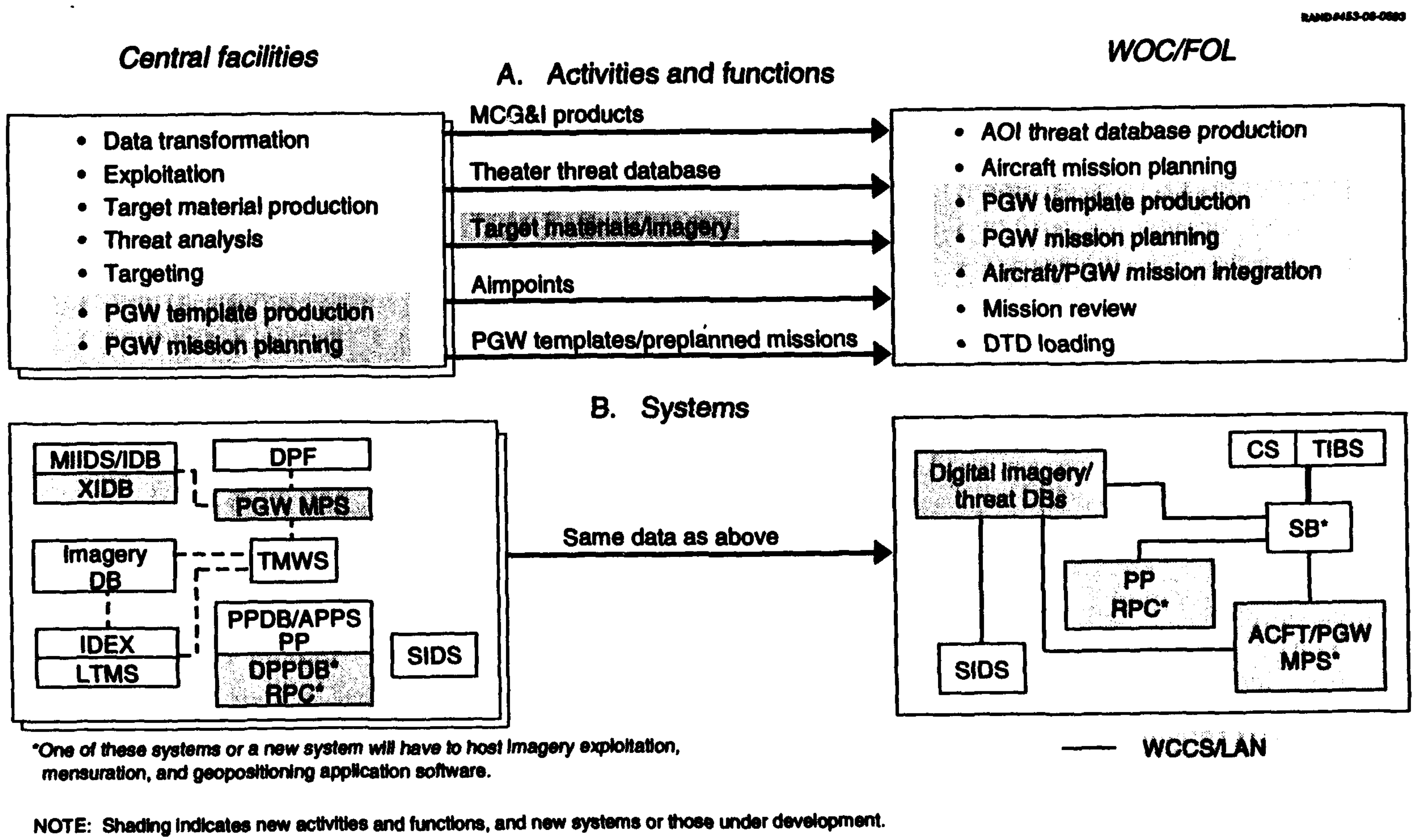
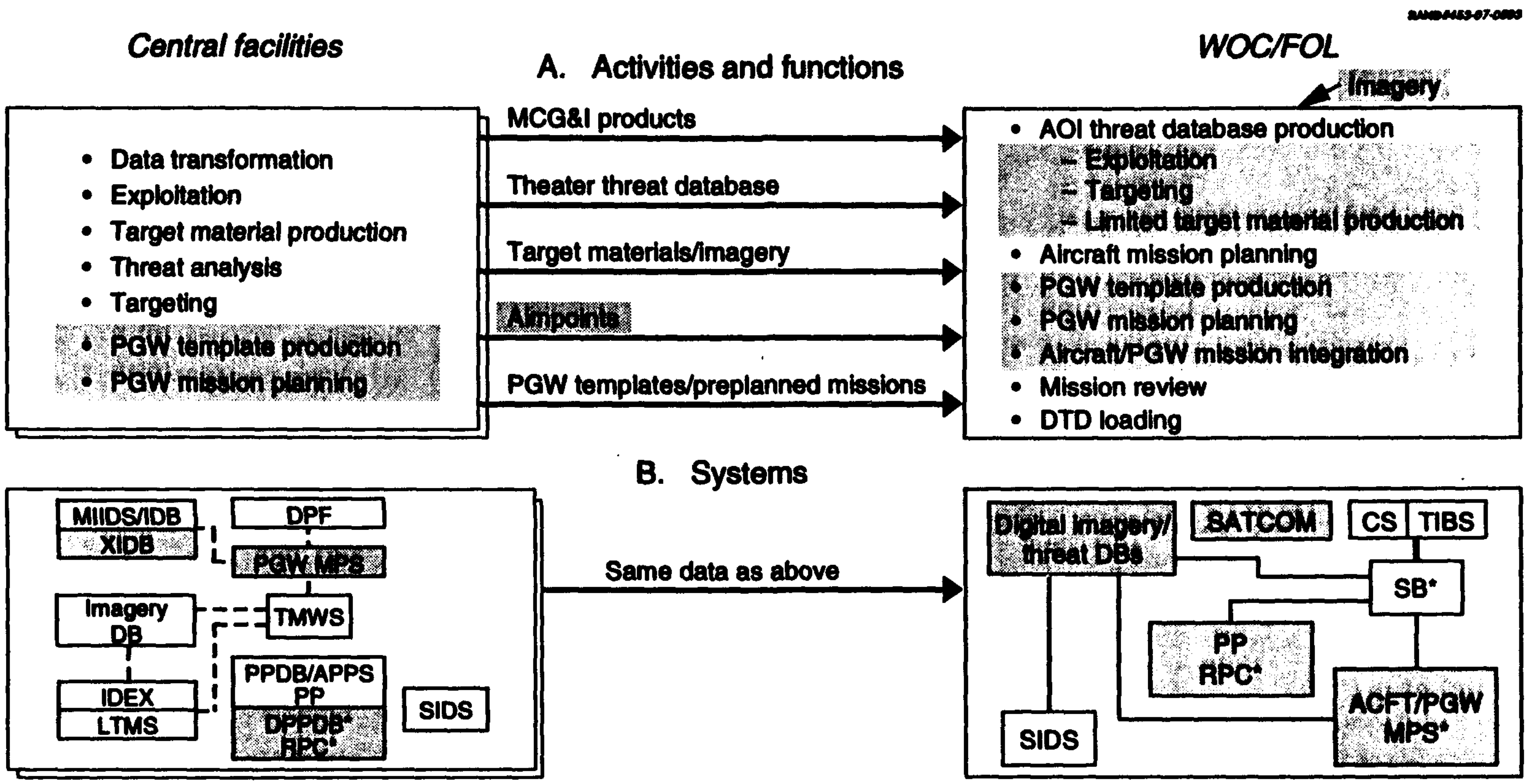


Figure 6—Centralized Intelligence-Support and Distributed Mission-Planning Architecture



*One of these systems or a new system will have to host imagery exploitation, mensuration, and geopositioning application software.

NOTE: Shading indicates new activities and functions, and new systems or those under development.

Figure 7—Distributed Intelligence-Support and Mission-Planning Architecture

Evolving Architecture

In the absence of a CONOPS and taking into consideration autonomous PGW characteristics, intelligence-support and mission-planning requirements, existing intelligence capabilities, budget constraints, and the intelligence personnel drawdown, we suggest an evolving architecture to support combat aircraft operations using autonomous PGWs with target-imaging sensors. This architecture begins with the centralized architecture option presented in Table 3, with possible evolution to a more distributed architecture. Lessons learned from the development and operations of the two Cruise Missile Support Activities that support the Navy Tomahawk autonomous cruise missile could be used in the design of the evolving architecture.

Initially, under this concept, CONUS and developed theater centers (ACC/480th AIG, LANTCOM/AIC, PACOM/JIC, and EUCOM/JAC) perform all intelligence and mission-planning functions required to support autonomous PGWs with target-imaging sensors, except aircraft mission planning, integration of aircraft and PGW mission data, and loading mission data onto DTDs. Aircrews at the WOCs perform aircraft mission planning, integrate aircraft and PGW mission data, and load the data into aircraft.

In the future, if required, a deployable PGW intelligence-support and mission-planning center, directly linked to the AOC, would be added to this initial centralized architecture. The deployable PGW center would perform the same functions as the CONUS and developed theater centers in supporting the WOCs and/or FOLs.

If a compelling operational rationale shows the need to increase the involvement of wings (and possibly squadrons), then the distributed intelligence-support and mission-planning architecture can be developed. Under this configuration, both the centers and the WOCs would be capable of performing all intelligence and mission-planning functions for autonomous PGWs.

In the past, bomber missions were typically planned in central facilities. Thus, for the bomber community, the continued reliance on central facilities for the mission planning for autonomous PGWs would be business as usual. On the other hand, fighter missions were planned predominantly at WOCs and FOLs. Therefore, for the fighter community, the reliance on central facilities for the mission planning for autonomous PGWs would be a major change. With the combining of bomber and fighter forces under one command and the creation of composite wings, the Air Combat Command will determine how mission planning should be done in the future.

Architecture for PGWSs with GPS-Aided INS Guidance

Two warhead options can be considered for autonomous PGWs with GPS-aided INS guidance: (1) a unitary warhead and (2) a submunition-dispensing payload. Assuming comparable range and survivability characteristics, both variants have MCG&I and threat data requirements for en route mission planning similar to those of autonomous PGWs with target-imaging sensors. In general, because there is no target-imaging sensor to support, this category of autonomous PGW requires much less information for terminal-area mission planning. However, to achieve their high delivery accuracy, they do require more precise absolute coordinates of the target.[2]

The miss distance of the unitary variant is, to a good approximation, the root sum of the squares of the PGW inertial navigation error to the target and the target location error. Therefore, this variant requires only the GPS coordinates of the target aimpoint, which can be provided from the force level to units in ATOs or may be obtained by unit-level operations intelligence personnel or by aircrews from standard target materials that provide mensurated coordinates of the target. Alternatively, if standard target materials do not include mensurated coordinates of the aimpoint, operations intelligence personnel could read these coordinates from hard-copy PPDBs with the APPS.

The miss distance of the submunition dispenser variant is a function of the PGW inertial navigation error at the dispense point, the submunition dispersal pattern error (including wind effects), and the target location error. Therefore, this variant requires location of the dispense point (latitude, longitude, elevation), weapon heading and speed at the dispense point, and wind direction and speed in the vicinity of the dispense point. Like the unitary variant, the GPS coordinates of the target aimpoint can be provided from the force level in ATOs or obtained by unit-level operations intelligence personnel and aircrews. To center the submunition pattern on the aimpoint, a mission-planning system module is needed at the unit level to compute the appropriate dispense point, heading, and speed. Wind data over the target area would be input parameters to the module.

The intelligence support and mission planning for autonomous PGWs with GPS-aided INS guidance could be performed at any of the elements of the evolving architecture suggested for autonomous PGWs with target-imaging sensors.

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[2]As discussed earlier, PGWs with target-imaging sensors can tolerate larger errors in target location as long as the target appears in the field of view when the sensor is activated.

However, only development of a WOC element is considered necessary to support their employment.

In-Flight Mission Planning. The planning of autonomous PGW missions onboard aircraft while en route to their targets, using information collected by onboard sensors or by a third party, such as the Joint Surveillance Target Attack Radar System (JSTARS), may be another viable option for PGWs with GPS-aided INS guidance. This would probably require (1) the development of application software to modify preplanned missions or construct new missions onboard the aircraft; (2) the use of existing reserve or, if necessary, additional data processing; and (3) the training of aircrews in identifying aimpoints (or choosing dispense points) from onboard sensor data and in building PGW mission data. Also, adequate communication equipment would probably be required if a third party were to provide the necessary data.[3]

An Approach for a Preliminary Assessment of Alternative Architectures

This subsection outlines an approach for assessing alternative intelligence-support and mission-planning architectures. The approach postulates two notional measures of effectiveness of possible interest to operators, estimates the equipment procurement cost, and estimates the personnel cost of each alternative. The two notional measures of effectiveness are (1) quick-reaction support—the number of autonomous PGW missions built and delivered to operators in the first few days of a conflict—and (2) support to sustained operations—the number of missions that are provided to operators over some specified time period.

Because this report discusses generic autonomous PGWs for which there are no CONOPS, the approach postulates the aforementioned measures of effectiveness. Additional measures of effectiveness are likely to be required by the CONOPS for a particular weapon-acquisition program. However, we believe that the steps suggested here will still be of value.

The approach consists of four general steps: (1) estimation of the various timelines for producing PGW missions, (2) calculation of the number of PGW missions built by alternative elements of an architecture, (3) estimation of the

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[3]We are in the process of assessing the feasibility, benefits, and costs of developing this option onboard heavy bombers.

investment costs for equipment and the support costs for both equipment and personnel, and (4) comparison of benefits and costs of alternative architectures.

Production Timelines. The first step is to estimate the timelines for (1) producing tailored mission data and PGW missions in central facilities, and then providing them to WOCs or FOLs, and (2) performing the same functions, except dissemination, at WOCs or FOLS. The timelines are the sum of the times required to perform PGW-specific intelligence and mission-planning functions: targeting, mensuration, geopositioning, template production, route planning, and mission dissemination. To perform these functions, data collected primarily by national sensors must be made available. The time required to complete this process can vary substantially, depending on the priority of the sensor tasking.

Mission Production. The next step is determining the number of missions that each facility can build over specific periods. This is a function of the number and type of systems available, the number and expertise of personnel assigned, and the number of working hours available to perform PGW intelligence and mission-planning tasks. It is also a function of whether the tasks necessary in building missions are done in parallel or in series.

An important consideration in determining the number of missions that can be built in the first days of a no-warning contingency is start-up time. In no-warning contingencies, CONUS and developed theater centers can begin building PGW missions almost immediately. This assumes that target imagery is available and that protocols exist to quickly shift from scheduled production to contingency support. The deployable center and WOC and/or FOL cells have to deploy into the theater of operations and set up the necessary equipment and facilities before they can begin producing autonomous PGW missions. Thus, they cannot produce any missions in the first few days of a contingency.

Cost Estimates. The investment and support costs of equipment of each alternative architecture are a function of the number and type of systems that are procured. Similarly, personnel costs are a function of the number and relative expertise of individuals assigned to autonomous PGW mission production. Initial cost estimates for alternative architectures should be developed by the PGW ISWG and included in the ISP. The PGW ISWG should develop the cost estimates for the alternative architectures in coordination with ISWGs for other weapon systems and, as appropriate, amortize the costs over all new weapon systems requiring similar support. This approach would provide decisionmakers with an integrated view of the investments necessary to provide adequate intelligence support for designated weapon systems.

Distinguishing Attributes. The approach described in this subsection provides decisionmakers with three attributes to assist them in selecting a preferred architecture: (1) rapid response capability, (2) sustained mission production capability, and (3) equipment and personnel cost. In addition to these attributes, decisionmakers should consider whether the increased flexibility of producing tailored products and planning missions at a wing for autonomous PGWs with target-imaging sensors justifies the cost.

6. Training Requirements

Training is sometimes overlooked during the early phases of the acquisition process of a new weapon system. Because well-trained personnel will be required to provide intelligence and mission-planning support for autonomous PGWs, this section discusses possible training requirements. For the most part, these requirements are applicable to both autonomous PGWs with target-imaging sensors and those with GPS-aided INS guidance only. Training requirements applicable only to autonomous PGWs with target-imaging sensors are noted.

Most likely, a team of intelligence personnel and selected aircrew personnel will be employed to plan the missions for these weapons and to conduct post-strike assessment. In the absence of a CONOPS, it is difficult to determine which of the required tasks should be allocated to intelligence personnel and which tasks to operators. First, we postulate a notional split of tasks and describe the skills and training required to accomplish those tasks. Next, we discuss a potential training regimen to develop those skills and maintain the necessary proficiency. Then, we summarize training data requirements.

Tasks

Based on experience and our current understanding of autonomous PGW mission planning, we postulate that intelligence personnel will (1) assist operators in obtaining the data required to support mission planning (e.g., threat databases, target materials, MCG&I products), (2) perform targeting, (3) develop tailored mission data for PGWs with target-imaging sensors and, if necessary, assist operators in building terminal-area products (templates), and (4) conduct post-strike assessment.

We also postulate that aircrews will oversee PGW mission planning and will perform the following specific tasks: (1) select and build aircraft routes, (2) interact with intelligence personnel in the building of templates for PGWs with target-imaging sensors, (3) integrate the aircraft and PGW data into an end-to-end mission, (4) review the entire mission, and (5) execute the mission. Central facilities are key elements of the evolving intelligence-support and mission-planning architecture described in Section 5, but it is not certain whether operators will be assigned to these facilities and, if they are, what tasks they will perform.

Skills

To assist operators in obtaining the required data to support autonomous PGW mission planning, intelligence personnel must know how to obtain, manage, and manipulate high-resolution imagery, target materials, and MCG&I products and how to perform target analysis. After obtaining the data, intelligence personnel (or a database manager) will have to catalog, store, retrieve, and provide the data in a useful format to mission planners.

These skills were traditionally taught in the Combat Targeting Officer Course (POI X30CR8081-003) at Air Training Command (ATC) and are applicable not only to mission planning of autonomous PGWs but also to other weapons and aircraft. This course is no longer being offered. The curriculum has been condensed and incorporated into the new Intelligence Applications Officer Course (POI X30BR8071-002) (Reference 9). Because of the importance of the skills taught in the Combat Targeting Officer Course, this restructuring should be closely monitored to ensure that the training provided will be adequate to support autonomous PGW mission planning.

Threat laydowns are required to build low-risk routes, from launch points to targets, for autonomous PGWs. Typically, for other weapons and aircraft, intelligence personnel build the threat database and mission planners use the data to build the threat space and assess mission survivability. This split in responsibilities will probably also apply to autonomous PGWs. For autonomous PGWs with low observable characteristics, additional instruction may be required.

Targeting

Using the available database and understanding warfighters' objectives, intelligence personnel will assist aircrews in targeting functions: (1) target analysis and target development, (2) critical node identification, (3) precise mensuration of aimpoint coordinates, (4) weaponeering, and (5) post-strike assessment. Air Force targeteers (Air Force specialty code 8085) are trained to perform these functions. In the restructuring of the Air Force intelligence community, this expertise may be lost, unless the new Intelligence Applications Officers (Air Force specialty code 8075) learn those skills in a formal training course and/or by extensive on-the-job training.

To support targeting of autonomous PGWs, Intelligence Applications Officers will have to understand the existing target database. For those targets not in the target database, they will have to identify target complexes, critical nodes, and aimpoints from imagery and other data sources. Moreover, they will have to understand the effects of alternative levels of damage on the functional capabilities of these complexes.

Enlisted Targeting Specialists will continue to require training on how to obtain precise coordinates for pertinent structures from (1) the DMA Points Program, (2) PPDBs using an APPS, and (3) archival geocoded imagery. This information will be required by Intelligence Application Officers to determine aimpoints and recommend impact angles.

Mensuration

As discussed in Section 3, autonomous PGWs with target-imaging sensors require precisely mensurated data not only on the target but also on nearby contextual objects (structures and terrain features). These data will be extracted from high-resolution imagery, probably by intelligence personnel trained in imagery exploitation techniques. The personnel should be capable of using the *IDEX II soft-copy exploitation system* and the *LTMS hard-copy exploitation* system to extract length, width, height, and orientation for objects of interest in the vicinity of the target. No formal IDEX II or LTMS training is currently provided by ATC; national agencies provide this type of training. Therefore, the Air Force should either ensure that an adequate number of seats for this training are available to Air Force personnel tasked to support these PGWs or should establish a tailored course at ATC.

In the absence of IDEX II and LTMS, intelligence personnel should be able to manually (e.g., by ruler, protractor, and compass) derive the requisite information from available target materials and hard-copy imagery to the best accuracy possible under these conditions. Enlisted Targeting Specialists currently are trained in manual mensuration procedures using hard-copy imagery.

An LCWS was postulated in some of the architectures defined in Section 5. If a decision is made to deploy this system, an LCWS user course should be developed.

Template Building

Template building is the novel requirement of autonomous PGWs with target-imaging sensors. It requires an understanding of how the PGW sensor and algorithm work to acquire the target. Obviously, complex targets in a cluttered environment will require a more knowledgeable template builder. To build templates, personnel will have to successfully identify and extract the *right* structures and data from imagery. Therefore, an individual with imagery exploitation skills and an understanding of the PGW sensor and algorithm is necessary. The curriculum for the course providing the training for new weapons is typically developed by the weapon contractor.

Air Training Command personnel should work with weapon contractors early in the acquisition process to develop a standard course for all Air Force users. At a minimum, one ATC representative should participate in the contractor-provided training module before it is delivered to the Air Force.

Suggested Training Regimen

To develop the skills identified in the previous sections, a training regimen should be established. The training regimen should consist of general and advanced classroom training (at the Air Training Command or at major commands) and on-the-job training. The general training for intelligence personnel should begin with the Intelligence Applications Officer Course. This course should teach the basic targeting skills and post-strike analysis necessary to support the mission planning of PGWs with GPS-aided INS guidance only and to provide the basis for the advanced training discussed in the next paragraph.

Graduates of the general course who are designated to support autonomous PGWs with target-imaging sensors would attend the advanced course. This course would teach intelligence personnel and operators the principles of PGW target acquisition and alternative methods for mission data production. Initial hands-on equipment training would also be provided. The curriculum for this course is usually developed by the contractor. After hand-off to the service, the course length and content should be modified as appropriate for intelligence personnel (and possibly for operators as well), and then the course should be formalized.

After completing the formal classroom training, graduates should be given on-the-job training by qualified personnel at central facilities or at wings and squadrons by a mobile training team, depending on the CONOPS. This team would certify personnel who have successfully completed on-the-job training as advanced PGW mission planners. This would ensure a standard level of expertise throughout the Air Force.

Training Data Requirements

To support the training for autonomous PGW mission planning, the intelligence community should provide representative (1) threat databases, (2) MCG&I products, (3) target materials, (4) imagery for tailored mission-data production, and (5) post-strike data.

Imagery for tailored mission-data production is a unique requirement for autonomous PGWs with target-imaging sensors. In particular, the advanced course discussed above will require high-resolution imagery of targets and their surrounding areas. This imagery database should include all target categories that are suitable for autonomous PGW employment. The imagery should include not only visible imagery, but also imagery of the wavelength of the PGW target-imaging sensor (for example, infrared or radar imagery). This would allow trainees to use visible images to build templates and then validate them against images at the sensor's wavelength.

7. Conclusions and Recommendations

An ISP is essential to support the employment of autonomous PGWs. At a minimum, we believe that the ISP should define

- The intelligence data that will be provided to support mission planning and post-strike assessment
- The architecture (organizations and systems) that will develop and provide this data to mission planners
- The intelligence personnel who will support the architecture
- The training that will be provided to support weapon employment.

There are usually a number of unresolved key issues regarding weapon support. The ISP should fully describe these key issues, define tasks to resolve them, assign organizations the responsibility for completing the tasks, and define timelines for their completion.

Intelligence and mission planning personnel, responsible for providing the support necessary to effectively employ the weapon systems, alone cannot develop an effective PGW ISP. They require the assistance of both weapon developers and operators.

The ISP should be a living document that is modified as required during the life cycle of the weapons. To ensure effective use of intelligence resources, the PGW ISP should be closely coordinated with the ISPs of their various delivery platforms.

Major Unresolved Issues

Weapon developers and the intelligence and mission-planning communities must work together to resolve two key issues for autonomous PGWs with target-imaging sensors: (1) the lack of definitive specifications for target data to support terminal-area planning and (2) the lack of a methodology for validating terminal-area products (templates). **Without resolution of the first issue, the intelligence community cannot determine what support it has to provide and what resources it should allocate to provide this support. If the second issue is not resolved, operators will be reluctant to use the weapons on missions for which**

collateral damage cannot be tolerated. Moreover, operators will be unable to estimate the probability of mission success. The PGW ISP should specifically address these two issues; the following paragraphs summarize suggested approaches.

Data Specifications

Existing standard target materials (ATTGs and BTGs) cannot support autonomous PGWs with target-imaging sensors. ATTGs lack mensurated points (precisely defining the absolute location of objects in latitude, longitude, and elevation) and an accurately placed image orientation arrow (north arrow). However, ATTGs do provide length, width, and height information for a number of objects in the imagery. The newer products (BTGs) do contain mensurated points, but the BTGs provide annotation for fewer objects than ATTGs. Because both products contain monoscopic (and often oblique) hard-copy imagery, subsequent mensuration and geopositioning of additional objects are much less accurate, even when done by trained imagery analysts.

Until firm data requirements are defined, we believe that the intelligence community, at a minimum, should provide the template builder with (1) high-resolution visible imagery of the target area; (2) target location in WGS84 coordinates; (3) three-dimensional data, including orientation, of the target and other contextual objects that make the scene unique; (4) the location of the contextual objects relative to the target; and (5) radar or infrared imagery of the target area, if available, to support SAR and IIR target-imaging sensors.

Template Validation

Currently, there is no method for verifying that the templates, built during the mission-planning process, are sufficient for the terminal guidance system (sensor and acquisition algorithm) to actually acquire the target. Without a method for determining the adequacy of the templates, targeteers cannot provide operators with a probability of mission success and, therefore, cannot estimate the number of PGWs required to achieve a specified level of damage against targets or the likelihood of collateral damage. This information is essential to operators.

We offer four alternative approaches to assist in the resolution of the template validation issue:

- Create a statistical database, containing information on all captive-carry and free-flight tests of autonomous PGWs with target-imaging sensors, and then use this database to determine the probability of acquisition for new missions against comparable targets, under comparable background clutter, day or night, and under varying weather and seasonal conditions.
- Collect imagery of the target area at the same wavelength as the target-imaging sensor and provide that imagery to mission planners. The mission planner would use the collected imagery to validate the templates they prepared using visible imagery or, alternatively, they could use the collected imagery to build the templates in the first place.
- Develop a theoretical model of the acquisition process, possibly using matched-filter analysis, that could be partially validated by limited test data; this model could then be used to extrapolate to other situations.
- Develop a modeling capability that simulates the image created by the target-imaging sensor. Once the model is developed, it could be used to generate additional templates, for example, for different weather and seasonal conditions.

Evolving Architecture

Our review of existing intelligence-support and mission-planning organizations, systems, and operating protocols indicates that, with very few modifications, autonomous PGWs with target-imaging sensors could be supported by existing central facilities: 480th AIG, AIC, JICPAC, and JAC. In the absence of a CONOPS for advanced PGWs and taking into consideration current budget constraints and the downsizing of the intelligence community, we suggest an evolving architecture that builds on the capabilities of these existing central facilities.

The evolving architecture first relies on existing central facilities to perform all intelligence and mission-planning functions except aircraft mission planning, integration of aircraft and PGW mission data, and loading of mission data into data-transfer devices. These remaining functions are done at the WOCs or FOLs. If required, this initial centralized architecture could, in the near future, include a deployable intelligence-support and mission-planning center. Then, the centralized architecture would evolve, if required, into a distributed architecture, with WOCs or FOLs capable of performing all the necessary functions.

Any major component of the suggested evolving architecture (CONUS or developed theater center, deployable center, WOC or FOL cell) is capable of providing the intelligence support and mission planning for autonomous PGWs with GPS-aided INS guidance. This assumes that appropriate mission planning modules are developed and fielded. Thus, operators do not have to rely on central facilities to employ this category of autonomous PGW.

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