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Measurement and Signature Intelligence

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The term *Measurement and Signature Intelligence* (MASINT) to describe this intelligence discipline is of relatively recent origin. It dates from the late 1970s. "The discipline comprises different techniques that are much older."

Until shortly after World War II, the techniques that are now considered part of MASINT were almost exclusively applied to support military operations (SMO). Underwater sound collection to identify and locate submerged submarines dates from World War I, as does the use of acoustic sensors to locate enemy field artillery. The use of radar to detect, identify, and track aircraft and ships blossomed during World War II. Chemical detectors to identify chemical warfare agents were in wide use by the end of World War II. Even unattended acoustic and seismic sensors, under the Igloo White Program, were first introduced by the United States in the late 1960s during the Vietnamese conflict to monitor infiltrating enemy soldiers and supplies entering South Vietnam from the North along the Ho Chi Minh trail at night.

It was not until the USSR began nuclear weapons testing that MASINT was rapidly refocused to national-level strategic needs. This was particularly significant since the timelines for supporting military operations were shrinking at the same time, making it less useful for SMO. The strength of MASINT was in its scientific core, answering the really hard intelligence questions where the speed of reporting was secondary to the accuracy of reporting. Therefore, the discipline developed, grew, and evolved in response to the Cold War with the former Soviet Union. A strategic need to understand Soviet, and later Chinese, nuclear weapons capability drove the development of several MASINT subdisciplines. The stringent internal security measures that these two countries imposed made it difficult to get the needed intelligence from human intelligence (HUMINT), signals intelligence (SIGINT), and imagery intelligence (IMINT). Nuclear MASINT, in contrast, could provide accurate information on weapons types and yields from measurements taken during and after nuclear tests. Radar MASINT could provide intelligence on the range and accuracy of ballistic missiles as well as the number and design of their nuclear warheads. Acoustic MASINT could identify and track ballistic missile submarines on patrol. All these developments required the computing capability and the in-depth analysis expertise provided by engineers and scientists from research laboratories.

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New technologies and analytical methods, along with heavy influence from the new space race with the Soviet Union, drove what could be described as the third major wave of MASINT development (tactical applications and the strategic weaponry shift being the first two). The old joke about needing to be a rocket scientist to understand something was actually true about MASINT in that era. This has been an ongoing process over the past five decades. Science and technology (S & T) principles were applied to extracting new types of intelligence from IMINT and signals intelligence (SIGINT) collectors using their unexploited sensor capabilities. HUMINT collectors were tapped for sampling missions and to emplace new types of MASINT sensors. At the same time, existing MASINT collection capabilities were being steadily improved by the application of technological advances.

Finally, in the last two decades, carefully focused MASINT innovation along with strengthened national-level oversight and war fighter advocacy have driven a fourth major wave of development and application. MASINT has returned to its origins in the battlespace. Although this coincided with the standup and operation of the Central MASINT Office (CMO), enabling innovation was a necessary factor. New levels of analytic expertise combined with more powerful computers and extensive communications networks, new sensors, signature-based processing and exploitation technologies, and diverse collection platforms all came together to allow real-time delivery of a variety of MASINT products to combat units. As a result, MASINT has become an integral and important part of military operations. In applications as diverse as weather prediction, search and rescue operations, battlefield terrain mapping, targeting battle damage assessment, theater warning and operations planning, MASINT has served the war fighter well.

This chapter follows the same general format as that of the other major intelligence collection disciplines (INTs) already discussed. After this introduction, the reader will see a discussion of the definition of MASINT—which is far and away the most difficult of all INTs to define. We then provide a short history of MASINT under that name, followed by a description of its six distinct subdisciplines. Then comes a discussion of how MASINT is managed and an overview of MASINT efforts in countries other than the United States. The chapter concludes with a section on the types of intelligence targets where MASINT is a contributor. For purposes of comparison among the INTs, similar if not identical intelligence issues will be used.

MASINT Defined

One of the more descriptive definitions of MASINT that the authors prefer came from the then newly formed Central MASINT Office of the mid 1990s:

> Measurement and Signature Intelligence (MASINT) is technically-derived intelligence that enables detection, location, tracking, identification, and description of unique characteristics of fixed and

dynamic target sources. MASINT embodies a set of sub-disciplines that operate across the electromagnetic, acoustic and seismic spectrums, and material sciences. MASINT capabilities include radar, laser, optical, infrared, acoustic, nuclear radiation, radio frequency, spectro-radiometric, and seismic sensing systems as well as gas, liquid, and solid materials sampling and analysis. MASINT is an integral part of the all-source collection environment and contributes both unique and complementary information on a wide range of intelligence requirements. MASINT is highly reliable since it is derived from the performance data and characteristics of actual targets.[1]

This definition provides some insight into what MASINT is and what it is used for, rather than what it is not—as many of the word-of-mouth definitions from the 1980s and early 1990s did.

The other INTs discussed in this book tend to be easily understood and often relate to the literal human senses—seeing and hearing, those primary senses used by most people for gathering information on a day-to-day basis. SIGINT is thought of as the "ears" of the U.S. Intelligence Community (IC); IMINT as the "eyes"; the new geospatial intelligence (GEOINT) gives geographic context to IMINT, now its subdiscipline; and everyone knows that HUMINT is "James Bond." In contrast, MASINT has no such core collection method tied to the literal senses with which it can readily be identified. Therefore, one might consider MASINT methods to be tied to the "nonliteral" senses—smell, taste, and touch.

Whereas many of the other intelligence disciplines are considered collection INTs, MASINT has always been considered to be more of an in-depth exploitation and analysis discipline, often taking its data from a different collection discipline and applying MASINT techniques in order to gain more information than would otherwise have been reported by the original collector. On the other hand, MASINT does offer some unique collection capabilities, thus adding to the inability to clearly type it as collection or exploitation. Nonetheless, MASINT has long since proven itself as an INT, co-equal with the others discussed in this book.

With its longstanding emphasis on in-depth exploitation and analysis, MASINT has long defined itself in terms of the underlying sciences and technologies it uses. But this view only tends to further mystify MASINT for its nontechnical customers.

Some of this mystery might be stripped away by looking at MASINT from different perspectives beginning with the U.S. government definition. The U.S. Department of Defense (DoD) defines MASINT more by *what it does* than by what it is, as in the following:

Information produced by quantitative and qualitative analysis of physical attributes of targets and events to characterize, locate, and identify them. MASINT exploits a variety of phenomenologies to support signature development and analysis, to perform technical analysis, and to detect, characterize, locate, and identify targets

and events. MASINT is derived from specialized, technically-derived measurements of physical phenomenon intrinsic to an object or event and it includes the use of quantitative signatures to interpret the data.[2]

Beyond this general definition, MASINT is not easily defined. It evades a strict disciplinary definition. However, it might be instructive to explain "technically" how the name came about. This may provide more insight than any formal definition.

Origin of the Name

First, the word *measurement* refers to any data observed and recorded during a MASINT collection. It's that simple.

All of the sensors described in this chapter collect measurements of phenomenology unique to their particular sensor types. For example, radars transmit a radio frequency (RF) wave of a known strength and measure the return strength, or amplitude, from a target, along with the location and movement of the target. Normalizing this data set—removing the noise, sensor, motion, and atmospheric effects—and putting it into a signature-like format, such as a graph or spreadsheet, allows one to isolate the phenomenology being measured. We refer to this normalized, corrected data as *signature data*. Many erroneously think that this is a signature, but it is only normalized, corrected data at this point.

These normalized, corrected data do enable comparison with a known *reference signature*, which can yield information about the performance and/or characteristics of the target. If this data set yields more unique details about the characteristics of the target than the reference signature does, the new information can be used to update the reference signature as "the new validated signature" for that target. As this process continues, the "validated" or reference signature progresses in its utility—first being about to detect a particular target among other targets, noise, or clutter; next being able to classify the target; and ultimately being able to uniquely identify the target, just as a fingerprint uniquely identifies a specific individual.

Thus, a *signature* is a repeatable representation of data from a given collection phenomenology that is characteristic, sometimes uniquely so, of a specific target or class of targets. Not all collections will result in a new signature of that target; many collections will either be incomplete or even duplicative of previous signature data. But all will provide information on the characteristics of that particular target, to include performance, at the time of collection.

A second perspective is by analogy; think of it as a *methodology* perspective. MASINT involves obtaining signatures on targets of intelligence interest. These targets exhibit some phenomena or have some characteristics that can be measured by sensors, quantified, and compared to known

values in databases for identification. In that sense, MASINT analysis is often described as being like a forensic examination: A technical specialist takes measurements from the crime scene, such as blood splatter patterns, bullet holes in a victim and elsewhere at the crime scene, biological samples such as saliva on a cigarette butt, etc. He or she derives signatures from the blood collection (typing) and biological samples (DNA) to determine the identity of the victim and/or perpetrator as well as, from analysis of the victim's position and the trajectory of the bullet, determine certain attributes of the perpetrator—all helping to solve the "intelligence problem." This perspective leads one to think of MASINT as the CSI of the U.S. IC and is the most popular perspective for those without intelligence training.

A third perspective is that of the scientific phenomenology being measured—that is, the science perspective. Reduced to its essentials, MASINT involves finding a defining characteristic, or fingerprint, for target identification. It typically includes observing physical or chemical features, measuring phenomena, and plotting signatures. This information can be derived from collecting many different types of emissions from target-related phenomenologies—nuclear radiation; electro-optical (EO) energy such as ultraviolet (UV), infrared, and visible light; radar waves; unintentional RF waves; geophysical elements such as acoustic, seismic, magnetic, and gravitational data; and material samples.

By comparing the signatures gained from these emissions or samples, MASINT professionals can detect, locate, and track targets. MASINT generates precise measurements that reveal unique characteristics of targets. The variety of these characteristics and the precision with which they are measured further reinforces the fingerprint analogy. Looking at these different views separately as most people did in the early days, one can understand why MASINT is the least understood of the INTs by both users and IC members. It is often perceived as a strategic collection INT with limited tactical application. But increasingly, MASINT is providing real-time warning, situational awareness, and targeting within timelines that make it operationally relevant to the military customer and more useful to the other INTs for tip-off and cueing of their collection assets.

To summarize, MASINT diversity has provided it with an inherent resiliency to operate in an increasingly complex world. For example, MASINT is now called upon to provide traditional Cold War treaty monitoring and strategic analysis simultaneously with reliable military applications such as real-time tactical warning, targeting, search and rescue and accurate weather predictions in addition to rapid support to asymmetric operations of counterterrorism, homeland defense, and environmental crises. MASINT has finally taken its place as one of the recognized INTs. In fact, in the next section, you will note that major intelligence agencies are now competing to incorporate MASINT technologies and capabilities into their tradecrafts.

A History of MASINT

It was pointed out in the introduction that many of the techniques used to collect MASINT predate the creation of that term. Acoustic collection and materials collection, for example, date back centuries. The use of radar for intelligence dates back to World War II. Prior to the 1970s, military services and other intelligence organizations used various scientific and technical methodologies to gather data for intelligence purposes. However, this section will relate how the policy was developed to bring modern technologies together as a coherent system to better serve the intelligence needs of the United States.

Developing Policy in the Beginning

As the U.S. intelligence organizations were being formed after World War II and focusing on strategic intelligence, they needed scientific and technical intelligence (S&TI) that could be gathered by an organization with global reach. Thus, the U.S. Air Force took on the mission as a natural complement to its mission of air defense of the homeland. In the early days of U.S. intelligence collection of MASINT information before MASINT was named, three players dominated the scene within the United States—the U.S. Air Force, the Central Intelligence Agency (CIA), and the Defense Intelligence Agency (DIA).

The National Security Agency (NSA) also took more than a casual interest, but as an agency they were committed to getting their arms around a diverse and globally separated U.S. SIGINT System. Thus there was no real commitment for NSA to pursue MASINT as a separate INT, only as yet another subdiscipline of SIGINT. CIA, on the other hand, was "the national agency" that looked more broadly at applying S & T principles to its own collection, exploitation, and all-source assessments. They fully supported it standing up as a separate INT to ensure the survival and growth of a capability that could enhance their strategic analysis which supported U.S. policymakers every day.

DIA did not have its own collection assets but did have strong influence within DoD circles, including a close relationship with the program manager of the General Defense Intelligence Program (GDIP), who funded all service-related intelligence activities. DIA was a firm believer in the value of MASINT as an independent INT and formed a solid partnership with the U.S. Air Force as their executive agent.

Although the assistant chief of staff of intelligence (ACSI, now the A2) for the Air Force was only a major general at the time, he had assigned full colonels as the intelligence program element monitors (PEMs) and had given them experienced Pentagon-savvy lieutenant colonels as their action officers (AOs). They were able to obtain approval for programs not only by doing outstanding staffing but even by attending to small details, such as the naming convention for newly proposed collection programs.

In one instance, the PEM for the Air Force technical sensor program named a proposed new mobile radar system after his wife and then proceeded to confide to key people in the Pentagon whose coordination he might need that he named it after their wife, girlfriend, daughter, etc., who had the same first name. Cobra Judy was one example of this strategy. Nonetheless, several key decision makers nonconcurred on the proposed Presidential Decision Directive (PDD) that went forward; however, President Gerald Ford was the one who counted, and he approved Cobra Judy, the new mobile precision radar program, anyway.

Early MASINT Radars

Beginning in the late 1950s, the U.S. Air Force developed and fielded very powerful (for that day) fixed-beam radars, the most mature of the modern MASINT technologies at that time, along the periphery of the Soviet Union in order to monitor the progress and performance of the Soviet ballistic missile program. Turkey and Alaska provided the closest access from which testing of Soviet intermediate-range ballistic missiles (IRBM) and intercontinental ballistic missiles (ICBM), respectively, could be observed and monitored. Since technology only allowed fixed-beam radar operations at that time, the AN/FPS-16 and the AN/FPS-17 were the appropriate radars to install in the late 1950s at Diyarbakir, Turkey, and at Shemya, Alaska, respectively.

The Air Force's newly established Air Defense Command (ADC, later dubbed ADCOM, and today titled the Air Force Space Command) was assigned the responsibility for operating these radar sites, and the Foreign Technology Division (FTD), now the National Air and Space Intelligence Center (NASIC), of the Air Force Systems Command (AFSC), was assigned the executive agency responsibility for analyzing and reporting the results to the DIA and the CIA as well as other national and defense agencies as well as military services that were concerned about the growing Cold War threat environment. AFSC acquired and deployed the radars to ADC and FTD specifications. These radars, however, only gave the most rudimentary of performance information as the ballistic missiles flew through the radio frequency fences that were established by the FPS-16 and FPS-17 radars.

With the successful launch of the Soviet Sputnik satellite capping off the 1950s, the United States now needed more precise performance information about the USSR space systems and their dual track space booster-ICBM development program. Thus, high-precision, single-beam tracking radars were developed and established at Diyarbakir and Shemya, the AN/FPS-79 and AN/FPS-80, respectively, in the mid-to-late 1960s. These radars enabled the first precision tracking of the growing USSR strategic missile program.

At the same time, the Air Force began developing advanced mobile MASINT sensors—film-based ballistic framing cameras for determining reentry vehicle (RV) terminal trajectory performance, optical spectrometers

for warhead heat shield materials definition, and first generation phased array radars for determination of the size/shape/motion of the RVs as they approached reentry into the atmosphere and impacted on an instrumented ICBM range on the Kamchatka peninsula.

These sensor programs were developed by AFSC in the early 1960's and phased into airborne intelligence operation by the Strategic Air Command (SAC) later in the 1960's with such exotic program nicknames as Lisa Ann and Nancy Rae/Wanda Belle, which were later formalized to Rivet Amber and Rivet Ball, respectively.

According to the legendary former director of the BIG SAFARI Program Office, Colonel Bill Grimes (USAF, retired), the Lisa Ann development was initiated with Hughes Aircraft Co. in Aug 1963 and later renamed Rivet Amber (RC-135E) prior to delivery to SAC in Sep 1966—operations began immediately. On 5 Jun 1969, the aircraft was lost on a flight from Shemya AB to Eielson AFB, AK. No trace was ever found of the aircraft. "The 2 MW computer-controlled, phased array radar could track a target the size of a soccer ball at a distance of 300 NM," according to Colonel Grimes.

The first RC-135S, initially named Nancy Rae, then Wanda Belle, then Rivet Ball, was built in Oct 1960 and flown directly to Shemya AB, AK — where it crashed upon landing on 12 Jan 1969. A second fully capable Cobra Ball aircraft was delivered one year later to Shemya AB.

In addition, in the 1960s, AFSC began developing what was to become a patchwork global network of optical telescopes and space track radars to assist ADC in their evolving space object identification (SOI) and tracking mission. Although FTD had no responsibility in the space track mission, their all-source threat assessment analysts did have a directed charter from DIA to assess the capabilities of all foreign spacecraft as an integral part of their intelligence assessment mission.

Air Defense Command, now ADCOM, along with the global network of space track optics/radars, continued as the operator of the ground-based radars, whereas FTD continued as the intelligence processor and exploiter for all Air Force–collected radar intelligence (RADINT) and optical intelligence (OPTINT) data for the nation.

As the nuclear arms race heated up in the early 1970s, both the United States and the USSR escalated their testing of ICBM delivery systems. Growing alarmed, the leaders on both sides decided that diplomacy might be a wise course or the race might yield a winner—with dire consequences to the losing side. Therefore, two key treaties limiting these weapons of mass destruction (WMDs) were negotiated and signed within a matter of just two and one half years of intense negotiation. The first treaty (Anti-Ballistic Missile Treaty, or ABM Treaty) limited the number and placement of anti-ballistic missile (ABM) systems. The second treaty (Strategic Arms Limitations Talks, or SALT I) was an interim agreement on limiting strategic offensive arms. Both the ABM Treaty and the interim agreement stipulate

that compliance is to be assured by "national technical means (NTM) of verification," and were signed in May 1972 in Moscow.

The United States took this opportunity to replace the AN/FPS-17 and AN/FPS-80 radars with a modern L-band phased array radar at Shemya, Alaska—referred to as Cobra Dane and shown in Figure 6.1. This radar was declared a "national technical means of verification" for the SALT Treaty between the United States and the Soviet Union. The specifications were provided to the Soviet Union to emphasize the U.S. capability to monitor the SALT Treaty. The FTD had provided the specifications for the technical capabilities of the radar and provided onsite performance monitoring and support to contractors who operated the radar.

Earlier in the late 1960s, the FTD had developed a tasking plan for the Advanced Range Instrumentation Ships (ARIS) to support the U.S. IC, although the ships were primarily developed to support the U.S. manned space flight program at that time. The ships' mobile C-band radar gave the U.S. Air Force the capability to quickly move to broad ocean areas and dwell for long periods where the USSR announced closures to international maritime traffic due to impending ICBM testing.

Unfortunately, the ARIS radar ships were not capable of providing the precision radar data needed to support the more stringent protocol of monitoring the SALT Treaty. Therefore, the ARIS mobile radar capability was eventually upgraded in the late 1970s with a dedicated intelligence-gathering

Figure 6-1   Cobra Dane Radar

Source: U.S. Air Force Space Command. Source: Public domain, from Air Force Space Command website, accessed at http://www.afspc.af.mil/news/story.asp? id=123343230

platform that employed a state-of-the-art S-band phased array radar that could track multiple objects the size of a soccer ball at 1,000 km range. This new capability was named Cobra Judy. Cobra Judy's acquisition coincided with the signing of the final protocol of the Strategic Arms Limitation Treaty (SALT II) after several years of intense negotiation in 1979. Several years later, the Missile Defense Agency added a single beam X-band precision signature capability to the Cobra Judy platform.

Real-Time Missile Warning from MASINT

In the 1960s, the Air Force had fielded an operational ICBM launch detection system to give as much early warning against an attack to the nation as possible—an over-the-horizon forward scatter radar system (OTH-F) known as Project 440L. The AN/FRT-80 transmitters in Europe established a high-frequency curtain at low grazing angles across the top of the Sino-Soviet landmass from Europe to multiple AN/FSQ-76 receivers along the eastern periphery of the USSR to close the curtain. When ballistic missiles disrupted the electron density of the ionosphere within this curtain directly above the landmass, the receivers would detect the missile movement via a Doppler shift in the observed frequency. This "disturbance" to the ionosphere was designed to detect only a mass missile raid and "ring the alarm bell" but could not provide much definitively about individual missiles. There were numerous false alarms—both positive as well as negative. A new, more reliable phenomenology was desperately needed to handle individual missile warning and ultimately targeting information, since there was clearly a growing threat in the aftermath of a successful Soviet Sputnik I satellite launch in 1957.

Therefore, the newly created Advanced Research Projects Agency (ARPA) assumed responsibility for experiments begun by the Air Force in the late 1950s on a new missile detection phenomenology—infrared detection—dubbed Project 461 or Project MIDAS. Project 461 was a special access program that developed and launched a small infrared sensor, shown in Figure 6.2, in conjunction with a series of Discoverer satellites over a period of several years. Responsibility for the program was transitioned back to the Air Force by 1960 after successful tests. The most striking detection successes of two Polaris missiles, one Minuteman, and one Titan II were reported immediately to the White House via a supplement to the president's weekly report in May 1963. As a result of this series of successful experiments, the decision was made to develop and deploy an operational infrared missile detection network, starting in 1970; that network is still fully operational today as the Defense Support Program (DSP). DSP satellites—shown in Figure 6.3—are slowly being phased out by their replacement capabilities, called the Space-Based Infrared System (SBIRS). More will be discussed in the EO MASINT section of this chapter.

Figure 6-2 MIDAS Satellite

Source: Wikipedia/Flickr/Cliff. Source: Public domain image, accessed at http://en.wikipedia.org/wiki/Missile_Defense_Alarm_System

Intelligence application of this new technology initially was referred to as infrared intelligence (IRINT) but today is known as overhead persistent infrared (OPIR). At the time that this initial IRINT feasibility success was being reported to the president in 1963, it was considered critical to demonstrate that ICBMs could be reliably and repeatedly detected and tracked in order to provide accurate and timely early warning of nuclear-tipped strategic missile attacks. As a result, the 440L OTH network was deactivated as soon as the DSP system became fully operational.

MASINT Analysis and Tradecraft

This explosion in precision RADINT and OPTINT collection in the 1960s and early 1970s gave rise to closer coordination and collaboration among the key data providers and producers of "national intelligence"—the Air Force as data provider, and the CIA and DIA as national and defense, respectively, intelligence producers. As a result, seniors at the air staff, the DIA, and the CIA signed several bilateral and trilateral agreements of cooperation and data sharing, including (1) an analyst exchange program between CIA and FTD and (2) chartering a peer-level analytic group for sharing exploitation techniques and debating data analysis results in the

Figure 6-3   Defense Support Program Satellite

early 1970s to the late 1980s—the RADINT and OPTINT Working Group (ROWG). Both programs were highly successful in sharing data, exploitation technology, and common tradecraft but especially in creating a collaborative relationship. The ROWG experience was most likely the first identifiable starting point for developing a "MASINT culture."

Analytic representatives from every U.S. intelligence organization participated in the ROWG. This Air Force-, CIA-, and DIA-chartered and FTD-chaired technical working group was the forerunner to the DCI-chartered MASINT Committee (MASCOM) technical working groups more than a decade later. Quarterly meetings were normally held at FTD, Wright-Patterson Air Force Base in Ohio, since the CIA headquarters at Langley, Virginia, was still considered a covert location.

Under a separate agreement in the early 1970s, FTD's Engineering Directorate, CIA's Directorate of Science and Technology, and NSA's Directorate of Advanced Weapons and Space Systems merged their analytic tools for performing ballistic missile flight reconstruction into a common program. All three organizations funded the development of the Modularized Vehicle Simulation (MVS) program, which was originally designed as a diagnostic tool for the Titan missile program that accepted external sensor observations as well as telemetry. The missile profile-driven MVS program was updated, observables from all relevant U.S. intelligence sensors (especially MASINT) were included as individual optional modules, and all three organizations validated the results against known standards. FTD maintained the missile profile database for all to access, in coordination with the DIA all-source S&TI assessment centers. This arrangement allowed trajectory analysis comparisons to be made based upon analytic differences and not tool differences and thus enabled development of a common tradecraft for ballistic missile analysis that has stood the test of time. An abbreviated version of this trajectory analysis program, dubbed the Trajectory Reconstruction Program (TRP), was developed in the late 1970s in order to host on smaller general-purpose computers, such as the Hewlett-Packard VAX. Some versions of these common tools are still used today, especially by NASIC, NSA, CIA, and the National Geospatial-Intelligence Agency (NGA).

Finalizing MASINT Policy

Over the course of the 1970s, a number of different (but somewhat related by scientific principles) disciplines that were unaligned within the IC began to coordinate and collaborate with more urgency: RADINT, OPTINT, IRINT, electro-optical intelligence (EOINT), acoustic intelligence (ACINT/ACOUSTINT), nuclear intelligence (NUCINT), laser intelligence (LASINT), and unintentional radiation intelligence (RINT).

In the early 1980s, there was significant discussion over both IRINT (renamed as overhead non-imaging infrared, or ONIR), and directed energy weapons intelligence within the U.S. intelligence Community. NSA made the case for including them as a SIGINT subdiscipline. However, the Air Force suggested a simple test to determine whether a given subdiscipline was SIGINT or MASINT: If the observable carried information content, it was SIGINT. If it did not and was unintentional or observed from a weapon system, it was to be MASINT. The observables from directed energy weapons (DEW)—RF

or high-powered microwave (HPMW) weapons, particle beams, electromagnetic pulse (EMP), and high-energy lasers—were deemed by the director of Central Intelligence (DCI) to be MASINT. However, certain low-energy lasers that carried information, such as laser communications, were clearly SIGINT. Deciding which intelligence discipline that IRINT (later renamed ONIR), fit into became a much more highly debated political decision, but it remained with the Air Force as MASINT.

In the mid 1970s during a series of policy meetings among Air Force, CIA, and DIA seniors, consensus was finally reached on naming this bundle of overlapping yet separate capabilities under a single unifying nomenclature—MASINT. And the recommendation was approved by the DCI in about 1977, although DIA had already begun to use the name informally.

DIA had already leaned forward and developed a defense requirements process in order to provide specific guidance to collectors with respect to analytic needs. Shortly after the official "naming" of MASINT, this process was formalized around the name of the new collection requirements—Measurement and Signature Data Requirements (MASDRs). Among the first to actively use the new process were the DIA-chartered U.S. Air Force, U.S. Army, and U.S. Navy S&TI centers and the Defense Special Missile and Astronautics Center (DEFSMAC), jointly chartered and manned by DIA and NSA.

Formalizing MASINT Management

In 1983, the DCI formed the MASINT Subcommittee from key DIA and Air Force individuals and assigned it under the SIGINT Committee solely for its administrative support until the community could evaluate the MASINT management experiment. The MASINT Subcommittee recommended policy directly to the DCI, established national collection priorities, advocated for MASINT programs, and collaborated with the ROWG to assure a forum for technical exchange.

In 1986, the experiment in national MASINT management was deemed a success; therefore, the DCI approved the establishment of a full MASCOM. The committee provided policy and guidance for developing future MASINT capabilities; validated and prioritized current collection and exploitation requirements; evaluated MASINT programs; defended MASINT programs as appropriate in the budget cycle; advocated for new MASINT programs as appropriate; and provided structured technical working groups to foster information exchange and collaboration and to advise the MASCOM chairman as required. The committee continued as the sole IC body for overseeing MASINT until the Central MASINT Office (CMO) was established in 1992.

In 1992, the CMO was formed under DIA as a joint DoD and IC organization overseeing all MASINT activities, including both national and theater budgets. The DCI signed a DCI Directive 2/11 (DCID 2/11) naming the director of CMO as the MASINT functional manager; this DCID was a carbon copy of that for the new Central Imagery Office (CIO), except that

the CMO was also given authority to plan and execute research, development, test, and evaluation (RDT&E) projects and the funding to support the function. The deputy secretary of Defense signed a DoD Instruction (DODI) paralleling the DCID authorities. The DCI and the secretary of Defense funded CMO with both national and Defense line items, to include RDT&E. This allowed CMO legitimacy in operating with both the strategic and the tactical communities as the functional manager for MASINT in both the National Foreign Intelligence Program (NFIP) and the Tactical Intelligence and Related Activities (TIARA) programs. MASCOM was physically co-located with CMO as an advisory forum for both the IC and the DoD; the MASCOM chairman was dual-hatted as the deputy director of CMO, reporting to the director of CMO. However, CMO stood up as a very lean organization, with only thirty-eight funded manpower slots, and received a multiagency, multiservice budget and execution oversight responsibility of several billions across the entire Defense and national ICs that rivaled that of many larger agencies.

Initially the director of CMO reported directly to the director of DIA; however, within the first year, the CMO was placed within the DIA National Military Intelligence Collection Center (NMICC) and under the DIA director of Operations, who became dual-hatted as the director of CMO. In 1993, an agreement between CMO and the Air Force created the Central MASINT Technology Coordination Office (CMTCO) to help plan and to execute the CMO RDT&E budget. The purpose of this RDT&E budget was (1) to give CMO leverage with other research and development (R & D) agencies, and (2) to allow CMO to initiate new technologies and processes quickly in a new "INT" that was known for fast-moving innovation.

In 1997, after some maturing of its processes, CMO regained a director unencumbered with other responsibilities when the principal deputy director was redesignated as the director. This organizational placement remained until later in the year when a DCI Principals' Committee review of MASINT management recommended more community transparency, greater authority for the director of CMO with a standing expectation to 'sit at the table' with the other three INT functional managers for IC planning and decision making, and a larger management structure for MASINT functional management and customer outreach.

At the same time, in late 1997 the CMO Director suggested to industry that they organize and form a MASINT trade association so that he could deal with industry in a more organized and efficient manner. Industrial leaders agreed and formed the Measurement and Signature Technology (MAST) Association, a non-profit 501(c)6 trade association that was incorporated in January 1999. MAST soon was renamed as the MASINT Association and in 2008 reorganized as the Advanced Technical Intelligence Association. Its mission is to provide education and training, in addition to awareness of MASINT and other advanced technologies that support the U.S. defense community.

In early 1998, the director of DIA elevated CMO to become a key component of DIA, on the same level as the Directorate for Intelligence (J2)

of the Joint Staff, the director of Operations, and the director of Intelligence Production. The director of CMO was invited to all community-level decision meetings, communicated directly with the DCI and the Congress, and the DCI made additional manpower and funding investments to expand the CMO functional manager's effectiveness and community outreach functions. CMO expanded the CMTCO authority to bypass execution year inefficiencies in the DIA comptroller process and created several new outreach functions.

The CMO Director, with the support of the DIA Director and the DCI, initiated several organizational changes that significantly expanded CMO's capability to operate as the MASINT functional manager. Several new oversight and outreach functions were extended or created:

- The CMTCO execution authority was expanded to bypass execution year inefficiencies in the DIA comptroller process.
- The Central MASINT Processing and Exploitation Coordination Office was established and collocated with NASIC at Wright Patterson AFB OH.
- The Central MASINT Training and Education Coordination Office was established and collocated with the Joint Military Intelligence Training Center at Bolling AFB MD.
- The MASINT Operations Center was collocated with the Defense Collection Coordination Center in the Pentagon.
- Recognizing that the military customers needed a jump start on tasking for relevant MASINT support, CMO placed the MASINT liaison officers in all combatant commands (COCOMs), the Joint Staff, and key national agencies to include the State Department.
- The CMO Director established "MASINT chairs" at the two service graduate schools, the Air Force Institute of Technology (AFIT), Wright-Patterson Air Force Base in Ohio, and the Naval Postgraduate School in Monterey, California.

By 1999, this organizational structure was fully in place and operating effectively. CMO was recognized as a co-equal by the other INT functional managers, agency directors, military services, and the COCOM customers, to include signing agreements independent of DIA. After almost five years of leading MASINT, the outgoing director of CMO was assigned to the Office of the DCI in mid-2000 to help transition MASINT more comprehensively into the intelligence analytic processes and products.

In 2003, the CMO organization was completely integrated into DIA to become the Directorate for MASINT and Technical Collection, thus considered by the IC as solely a DIA organization. The director of DIA assumed the authority of the MASINT functional manager. Once again, MASINT national priorities had difficulty competing with those of DIA mainstream programs, since DIA was primarily an all-source agency with heavy manpower bills to pay. MASINT technical sensors that were in most

need of modernization had difficulty competing with the priorities of critical manpower salaries within DIA and its S&TI centers, many of which were associated with ongoing conflicts in the Middle East. While most other agencies were on a steady resource curve upward after 9/11, CMO was struggling to maintain the modernization program that was initiated prior to 9/11.

Late in 2002, the Deputy DCI for Community Management and the Assistant Secretary of Defense for Command, Control, Communications and Intelligence jointly reassigned responsibility for tasking, processing, exploitation, and dissemination (TPED) of certain types of imagery-derived MASINT from DIA to NGA. After no consensus on responsibility for ONIR (now OPIR) was achieved, that decision was deferred pending the outcome of an in-depth evaluation by the assistant DCI for collection. The in-depth evaluation was tasked late in 2003; however, it was slowed by the stand-up of the newly formed DNI organization and the complexity of the issues involved. Successfully completed in 2005, the results of the ONIR Management Evaluation Study were documented in the July 22, 2005, decision memorandum referenced next. As a result, ONIR responsibilities were transferred to NGA, as originally proposed.

In 2005, the director of National Intelligence (DNI) and the director of NGA agreed to an expanded definition of GEOINT that incorporated what had previously been considered MASINT—the subdisciplines of overhead non-imaging infrared (now OPIR) and EO, infrared, and Synthetic Aperture Radar (SAR) MASINT. That agreement redefined GEOINT so as to do the following:

> To incorporate all Overhead Non-Imaging Infrared (ONIR) and space-borne Imagery Derived MASINT. This definition is in keeping with the DNI memo of 22 July 2005 transferring responsibility for tasking, processing, exploitation [and] dissemination of all overhead electro-optical and radar MASINT phenomenologies, including overhead non-imaging infrared.[3]

Notice that this action removed only "space-borne Imagery Derived MASINT" from the MASINT definition, thus leaving airborne imagery-derived MASINT where it remains today with the MASINT discipline.

As with all sudden organizational changes in direction, there was good news and there were challenges.

Here was the good news:

- NGA had a faster growing budget, with a smaller percentage of civilians on the payroll and thus more flexibility to address MASINT funding issues.
- NGA was inherently a collection and exploitation agency rather than an all-source agency.
- NGA had ready access and the delivery means to a much larger set of customers.

- NGA had acquisition authority and thus understood how to execute more effectively.
- NGA had an RDT&E organization, the InnoVision Directorate.
- NGA was happy to now claim some collection capability of their own.

The challenges were mostly cultural:

- NGA was accustomed to scientific personnel being support people, not mainstream data producers and intelligence producers.
- NGA middle managers had little time, patience, or motivation to support insertion of low spatial resolution product lines into their processes.
- NGA products did not usually require the higher level of characterization and calibration of their sensors that MASINT requires.
- The ONIR National Imagery Interpretability Rating Scale (NIIRS) rating was less than 1.0 in an agency that valued imagery with very high NIIRS ratings over everything else.

To overcome some of these challenges, the director of NGA did the following:

- Required specialized familiarization training for all deputy directors and for all senior personnel seeking promotions
- Established a flag-rank civilian manager co-located at NASIC to stand up an NGA Geospatial Intelligence Advancement Testbed to leverage the NASIC MASINT experience as now an integral part of the National System for Geospatial Intelligence (NSG), as well as to lead the integrated NGA Support Team already in place at NASIC
- Renamed ONIR to OPIR, which emphasized 'persistence', the trait that was considered a strength within NGA, even by those imagery analysts who favored high resolution over all else
- Normalized Advanced Geospatial Intelligence (AGI), a transition term which included OPIR, into all NGA processes and functions as quickly as possible to emphasize that middle managers were now accountable for treating it just like all other forms of GEOINT, including using it in all products and reports.

Unfortunately, it is not clear that enough visibility remained to allow for an unbiased evaluation of organizational performance, other than anecdotal.

MASINT Primary Subdisciplines

MASINT has six distinct components, or subdisciplines, as shown in Figure 6.4. Though shown as separate, they often overlap with each other and with other INTs, especially with GEOINT and SIGINT. Some of them are

Figure 6-4   The MASINT Subdisciplines
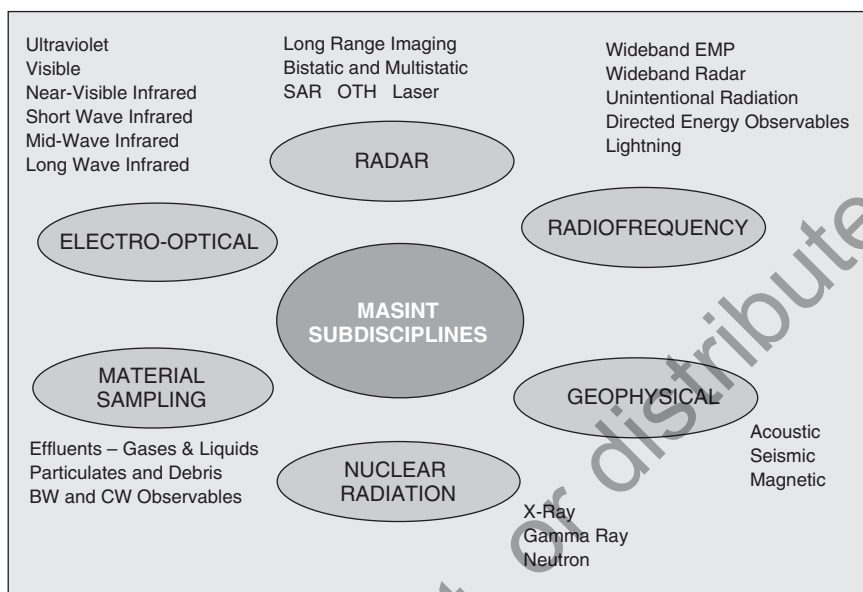
associated with measurements made in the electromagnetic spectrum, others with specific collection devices, and yet others with scientific measurements of phenomenology.

The goal of this section is to familiarize the reader with the different subdisciplines that make up MASINT, what might give rise to their observables, and some representative signatures to demonstrate how MASINT information might be used. In general, most intelligence agencies treat MASINT as one of their most closely guarded sources of information. Without violating those confidences, this section will also provide some insight into the utility of each of these subdisciplines, either separately or in combination with other subdisciplines.

Most of the signatures derived from MASINT are the result of collection in some part of the electromagnetic spectrum. The signatures are representative of electromagnetic energy being either emitted by an object or reflected from it. Three of the MASINT subdisciplines depend on these phenomena:

- EO MASINT relies on natural emissions, solar reflections, or emissions from artificially heated objects or events, such as explosives or rocket engine exhausts (often observable in the infrared region of the EM spectrum) that produce a characteristic signature.

- Radar MASINT depends on obtaining a signature from the energy reflected or retransmitted by a target toward the radar receiver.
- RF MASINT obtains its signature from unintentional RF emissions from man-made objects, from natural events such as lightning, or in some cases from very broadband emissions of highly energetic explosive events.

Once signatures have been validated, they can be used to either analyze a newly collected data set to determine its deviation from the norm or can often be automated to classify or even uniquely identify the specific target or event. Let's examine these three first and then discuss the MASINT signatures that are not electromagnetic in nature.
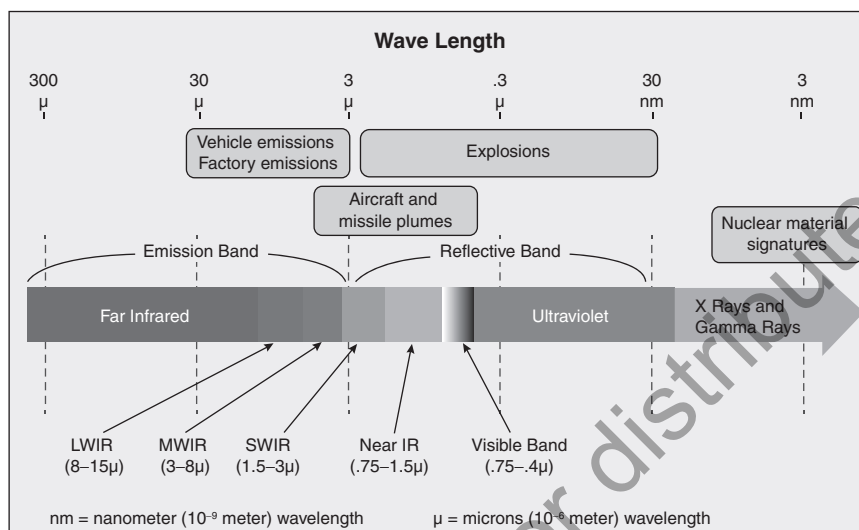
Electro-optical MASINT

EO MASINT involves measuring all physical phenomena associated with a target or scene – spatial, spectral, radiometric, polarimetric, phase (for active sources), temporal - and then analyzing those optical or infrared emissions to determine operating characteristics, material composition, temperature, and other unique signatures that are used to characterize an object, facility, or event. It is closely tied to GEOINT, because the same sensors often provide both imagery and signatures.

All objects emit electromagnetic energy both naturally and as a result of human actions. All matter (solids, liquids, and gases) at temperatures above absolute zero emits energy, mostly in the thermal (infrared) regions of the spectrum, as shown in Figure 6.5. Of primary intelligence importance are the emissive signatures created by explosions (especially nuclear explosions), facilities, and vehicles, as the figure shows. This emitted energy may be used to obtain a signature that is unique to a particular material object, or class of objects.

To illustrate the use of signatures, let's start with various classes of battlefield explosions. An easily understood example of a *temporal signature* (radiometric intensity vs. time) might be that collected by an EO radiometer of intensity (or brightness) of the *radiant emittance* from a series of battlefield weapons being employed—detonations, rocket exhaust plumes, and gun muzzle flashes. Figure 6.6 shows an example of this. If a MASINT analyst obtained a new data set from an unidentified target and compared it to these "known" signatures, he could readily classify the data set as an explosion and type or classify the *signature data* to a known temporal signature of certain classes of explosive devices.
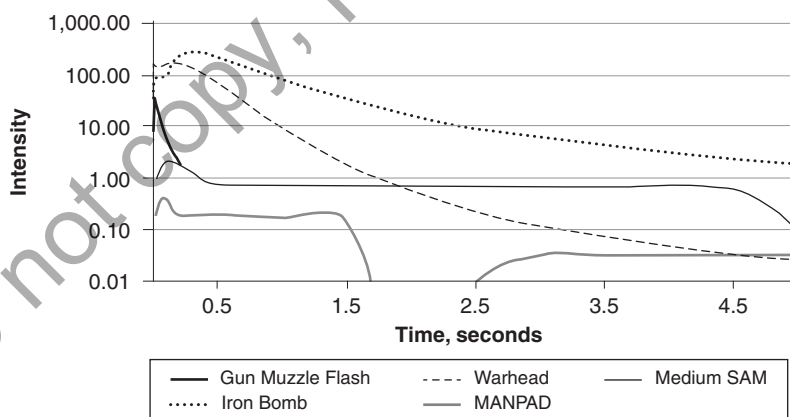
If one desires to know what size weapon generated the signature data, Figure 6.7, which shows the temporal signatures of flashes from differing guns, would allow an even finer grain characterization of the EO sensor observation. Therefore, careful inspection of the magnitude, duration, and shape of the gun flash signature in, Figure 6.6 given knowledge of the finer grain signatures in, Figure 6.7 would lead a MASINT analyst to conclude that the gun muzzle flash is indeed from medium caliber gun.

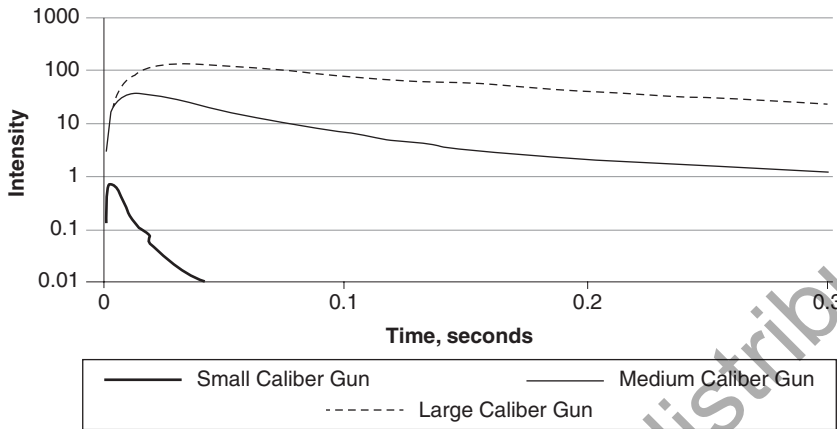**Figure 6-5**   MASINT Use of the Electro-optical Spectrum

Wave Length

| 300 μ | 30 μ | 3 μ | .3 μ | 30 nm | 3 nm |

Vehicle emissions
Factory emissions

Explosions

Aircraft and
missile plumes

Nuclear material
signatures

Emission Band

Reflective Band

Far Infrared

Ultraviolet

X Rays and
Gamma Rays

LWIR
(8–15μ)

MWIR
(3–8μ)

SWIR
(1.5–3μ)

Near IR
(.75–1.5μ)

Visible Band
(.75–.4μ)

nm = nanometer (10^{-9} meter) wavelength   μ = microns (10^{-6} meter) wavelength

Source: Created by authors from an original figure (Figure 1-5) in Clark's *The Technical Collection of Intelligence.*

Figure 6-6   Temporal Signatures of Battlefield Events

Intensity (y-axis): 1,000.00 / 100.00 / 10.00 / 1.00 / 0.10 / 0.01

Time, seconds (x-axis): 0.5   1.5   2.5   3.5   4.5

Legend:
— Gun Muzzle Flash   - - - Warhead   — Medium SAM
⋯⋯ Iron Bomb   — MANPAD

Source: Dr. James Lisowski, "Signatures," Memorandum for John Morris, April 5, 2014.

Note that the rapid rise time, the total intensity, the duration of the intensity, and more gradual decay time when taken together can literally "fingerprint" the explosive device as well as provide specific information about the explosive performance of this particular device.

Figure 6-7   Temporal Signatures of Differing Guns

Many other signatures of intelligence importance in the optical band are *spectral signatures*. The interaction of EO energy or heat with matter can cause the emission of energy in specific parts of the spectrum. This can be observed during daylight hours due to sunlight stimulation or as the release of emissions at night after heating during the day. The resulting signature will be unique to the matter that emits the energy. A rule of thumb as to where in the spectrum to look for these signatures is as follows: solids –visible/near-visible infrared/short wave infrared; liquids – short wave/midwave infrared; gases – midwave/longwave infrared. Spectral signatures, therefore, can be used to identify individual solids, liquids, or gases, —alone or in mixtures.

Once one has addressed radiometric intensity and spectral content of signatures, another key component of an EO signature of an object is its polarization of the electromagnetic wave. All electromagnetic waves, RF or optical, are polarized, meaning that the electric field vibrates in a specific direction. *Polarimetry* is the measurement of the polarization of electro-magnetic energy, and a polarimeter is used to make these measurements. Optical polarimetry is often called *ellipsometry*. EO energy emitted by the sun is randomly polarized, meaning that the polarization changes constantly in random fashion. But when sunlight is reflected from a man-made object, the reflection will likely be polarized linearly in a preferential direction creating a specular or glint. One might think of polarization as a measure of roughness or smoothness of the observed object. For example, although EO energy emitted by the sun is randomly polarized, when it shines upon a polished surface it might reflect in a preferential direction thus exhibiting linear polarization and giving rise to a specular or glint. On the other hand, a

bead-blasted or uniformly rough surface would diffuse even polarized light, such as from a laser source, and scatter it from the bead-blasted surface in a lambertian manner, uniformly in all directions, with no evidence of a specular or glint.

The EO spectrum in Figure 6-5 also indicates that radioactive substances emit signatures in the form of gamma rays. These are discussed in the section on nuclear MASINT.

One of the early operational applications of EO MASINT was in the DSP, which collected what are now described as OPIR signatures. For many years, the DSP satellite was the primary sensor for OPIR collection. It has been replaced by the Space Based Infrared System (SBIRS). These satellites were designed to provide early warning of missile launches based on detecting and tracking the intense heat of the missile exhaust. These satellites measure energy wavelengths and strength in the infrared band and determine target locations and movements.

The U.S. Vela satellites dating from the 1960s carried a device called the bhangmeter designed to detect the dual flash from an atmospheric nuclear explosion. The bhangmeter technique was operationally tested in 1961 aboard a modified U.S. KC-135B aircraft monitoring the Soviet test of a hydrogen bomb nicknamed Tsar Bomba, the most powerful nuclear weapon ever detonated.

One of the rapidly expanding areas of EO MASINT is spectral sensing, which was introduced in the GEOINT chapter. Spectral sensing provides a graphic of energy versus frequency or wavelength. This graphic represents radiant intensity versus wavelength at an instant in time. The number of spectral bands in a sensor system determines the amount of detail that can be obtained about the source of the object being viewed. Sensor systems, both radiometers and spectrometers, derive their names from the following simplified definitions:

- multispectral (2 to 99 bands)
- hyperspectral (100 to 1,000 bands)
- ultraspectral (1,000+ bands)

The characteristic emission and absorption spectra in each wavelength of the spectral band serve to fingerprint or define the makeup of the feature that was observed. The intensity of emissions from an object is a function of several conditions including its temperature, surface properties or material, and how fast it is moving.

More bands provide more discrete information, or greater resolution, but not necessarily more intelligence. For many intelligence applications, only the signature from a few bands is enough, and a multispectral scanner is adequate. In the case of most lasers, for example, ultraspectral wavelength detection is required; however, that can be done by monitoring one specific spectral line that is characteristic of the laser.
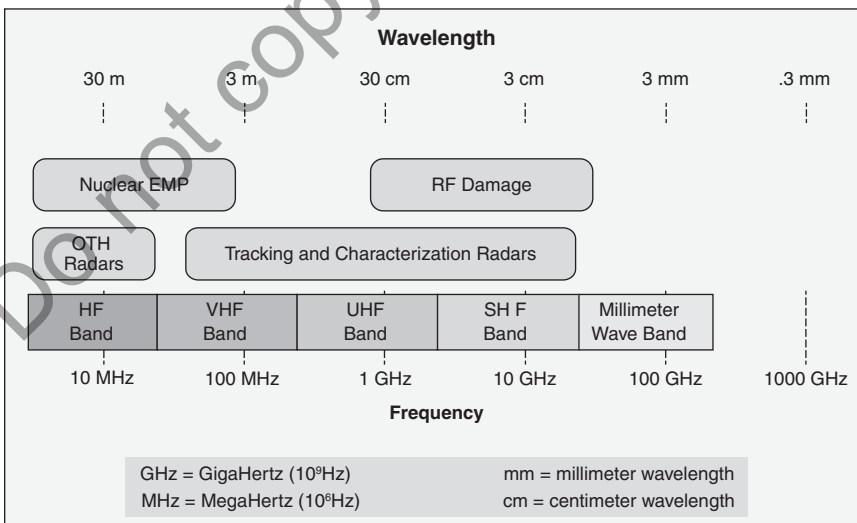
Radar MASINT

Often called RADINT, radar MASINT requires that we illuminate targets with electromagnetic energy and analyze the reflected energy. Radar can produce several types of signatures that have MASINT value. At the macro level, radar can provide location, velocity, and acceleration signatures that allow assessments of the performance of missiles and aircraft. At the micro level, radars can obtain signatures that indicate the configuration and composition of targets and even can produce images of targets such as aircraft, missile warheads, and satellites. Figure 6.8 shows the parts of the RF spectrum in which some important MASINT radars operate.

RADINT collection provides information on radar cross sections and radar reflectance and absorption characteristics. It also is used for tracking targets of intelligence interest, obtaining precise spatial measurements of components, and observing motion of dynamic targets. In these roles, radars are an important contributor to air and space situational awareness.

Several different types of radars collect specialized types of RADINT, as indicated in Figure 6-8.

OTH radars have for decades been used to monitor air traffic and ballistic missile launches in denied areas for intelligence. OTH radar operates in or near the high frequency band, where radio waves are reflected from the ionosphere—the phenomenon that allows international radio broadcasts to be received from stations thousands of miles away.

**Figure 6-8**   MASINT Use of the Radio Frequency Spectrum

Source: Created by authors from an original figure (Figure 1-4) in Clark's *The Technical Collection of Intelligence.*

A historical example of OTH radar for U.S. MASINT collection was the 440L. The Air Force developed an OTH forward scatter radar called 440L during the 1960s to detect missile launches from Chinese or Soviet territory. A series of high-frequency radio transmitters and receivers on either side of the Sino-Soviet landmass produced continuous signals that bounced between the ionosphere and the surface of the earth until reaching the receiving stations. Any disturbances in the pattern indicated missiles penetrating the ionosphere. Atmospheric nuclear tests also disrupted the signals produced by 440L transmitters, so the radars also were used to monitor nuclear weapons testing.[4]

Most radars can be used for target detection and tracking. Some, though, are built explicitly to conduct MASINT, due to either their placement or their design and calibration. The AN/FPS-17 was deployed to satisfy S&TI collection requirements during the Cold War. It allowed the derivation of missile trajectories on launches from the USSR test range at Kapustin Yar. It also allowed the identification of Earth satellite launches from Kapustin Yar, the calculation of a satellite's ephemeris (position and orbit), and the synthesis of booster rocket performance. A tracking radar called the AN/FPS-79 was subsequently co-located with the AN/FPS-17 and provided an additional capability for estimating the configuration and dimensions of satellites or missiles and observing the reentry of manned or unmanned vehicles.[5] Figure 6.9 shows the coverage of missile trajectories that the radar obtained.

Figure 6-9   Missile Trajectory Coverage of the AN/FPS-17 Radar
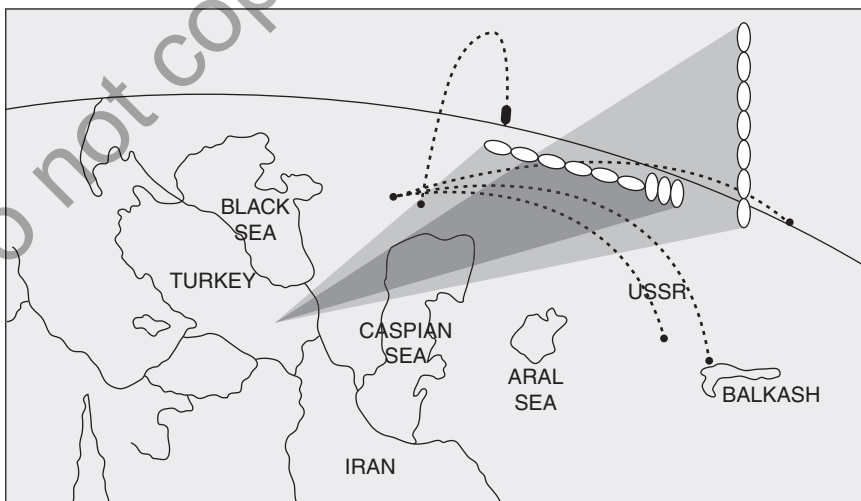
Source: Central Intelligence Agency, "The Diyarbkir Radar," *Studies in Intelligence*, v.8 no.4, https://www .cia.gov/library/center-for-the-study-of-intelligence/kent-csi/vol8no4/html/v08i4a05p_0001.htm

Long-range imaging radars, mostly operating in the microwave band, obtain a unique signature that is used to identify and characterize a target. That signature also is used to identify the target's mission or purpose. These RADINT targets include satellites, missiles, ships, aircraft, and battlefield vehicles.

- The ARPA Lincoln C-band Observable Radar (ALCOR) is located on the Kwajalein Atoll in the western Pacific. It has two missions: monitoring ABM testing by tracking reentry vehicles launched from the United States, and imaging of satellites.
- The Haystack radar, located in Massachusetts, uses its 120-foot diameter X band radar to produce images of satellites.

Laser radars were introduced in the EO MASINT section, in the context of collecting and analyzing the signal from an opponent's laser radars. But laser radars also are used for collection of the reflected signal from a target, and the product is used to identify materials at a distance. Many chemical and biological agents, and spoil from excavations, have characteristic fluorescence spectra when exposed to UV and visible light, so UV or visible lasers are used for fluorescence sensing. One might think of this as a very specialized form of spectroscopy.

Bistatic and multistatic radars have the transmitter and receiver(s) widely separated. Multistatic radars have more than one receiver. The geometry allows MASINT specialists to obtain more information about targets than is possible with a collocated transmitter and receiver. The 440L radar, discussed earlier, was multistatic as well as being an OTH radar. It is also possible create a bistatic or multistatic radar using what are called passive radar techniques—that is, using an existing noncooperative radar in the target area and processing the signals received from targets in the area to obtain intelligence.

SARs were introduced in the GEOINT chapter. Exploitation of the phase history data from these radars today also provide image quality products as well as help to provide evidence of hidden targets and changes detection—that is, what has happened in an area between radar views of the region. This usage of radars was discussed in the GEOINT chapter, but it relies heavily on techniques traditionally associated with MASINT.

Radio Frequency MASINT

RF MASINT, previously known as wideband RF and RINT, depends upon receiving the same frequencies of radio waves that SIGINT uses. But it processes them in unique ways—for example, to determine equipment status; if a computer is powered on; if electrical equipment is operating; or merely if energy is spread across a very broad bandwidth, indicating an impulsive signal in the time domain. RF MASINT concentrates not necessarily on

finding a specific device but on characterizing the signatures of a class of devices, based on their intentional and unintentional radio emissions and in some cases determining their operational status or even fingerprinting them.

Unintentional Radiation

Man-made systems emit electromagnetic energy both intentionally and unintentionally. This component of RF MASINT involves the collection and analysis of RINT or spurious emissions from military and civil engines, power sources, weapons systems, electronic systems, machinery, equipment, instruments, or "leaky" electronic containers. One can, for example, determine the frequency to which a receiver is tuned by detecting the frequency of an oscillator inside a superheterodyne receiver. Truck and tank engines radiate electromagnetic energy from spark plugs. Electrical generators emit a strong signal associated with the generator's rotor movement. These emissions create a signature that can have intelligence use for locating a vehicle, identifying it, and tracking it as it moves. Leaving an opening in an electronic system, such as an open access door in a radar van, can give rise to an unintentional signal with a signal strength and frequency that relate to the size and shape of the opening and the intermediate frequency of the radar, even in standby mode.

Electromagnetic Pulses and Other Energetic Explosions

Another important category of RF MASINT concerns signatures that are obtained from explosions (especially nuclear explosions) and explosive power supplies for DEW. The parts of the RF spectrum where such signatures are obtained are shown in Fgure 6-8. Nuclear and large conventional explosions produce RF energy. The characteristics of the EMP will vary with altitude and burst size. Controlled explosions for generating the power that drives certain classes of pulsed high energy lasers and rail guns is of particular intelligence interest. These energetic explosions can give rise to both EO and RF observables.

Radio Frequency Weapons and Charged Particle Beams

RF weapons, based on the fact that a powerful burst of electromagnetic energy can damage sensitive electronics, have been deployed by a number of military organizations. They are particularly useful for causing missiles to miss their target as well as for such mundane tasks as clearing minefields for advancing troop and armor movements. These directed energy weapons are usually considered tactical in nature, and detecting their testing or use in combat is a mission of RF MASINT. Charged particle beams (CPBs), on the other hand, are considered to be strategic weapons, usually considered for countering ballistic missiles, and would be considered as a technological surprise. Think of a CPB as a controlled superbolt of lightning, following

an ionized path directly to its target. The only way to avoid destruction is not to be in its path. Even the RF signature is somewhat similar to that of a superbolt of lightning. This discussion probably raises the question of neutral particle beams (NPBs), whose use would also constitute technological surprise in a missile defense system. Due to the physics of propagation of a neutral particle beam, their operation must occur in the electromagnetically neutral vacuum of outer space, once a missile rises above the ionosphere of planet Earth. Observations of such a test are more reliable using UV detection rather than RF.

Geophysical MASINT

This subdiscipline exploits both the audible and the very low frequency portion of the acoustic spectrum—that portion below what humans can hear—in order to detect vibrations from operating machinery, underground explosions, or even pressure differences created by opening and closing vault doors.

Geophysical MASINT depends on obtaining one of two signature types:

- Magnetic signatures are obtained by measuring slight variations in the earth's magnetic field, produced either by the presence of ferromagnetic materials such as steel or the presence of a large underground cavity such as a tunnel.
- Acoustic signatures are collected in the air, in the water, and underground, to allow the characterization of air and ground vehicle traffic, ship and submarine movements, and underground explosions. The collection spectrum for these signatures includes audible sound (above 20 Hz) and infrasound (below 20 Hz and usually not detectable by the human ear).

Geophysical MASINT has been defined as involving "phenomena transmitted through the earth (ground, water, atmosphere) and manmade structures including emitted or reflected sounds, pressure waves, vibrations, and magnetic field or ionosphere disturbances."[6]

This is a very broad definition, and it includes several distinct subdisciplines, discussed next.

Underwater Acoustics

ACOUSTINT derived from underwater sound is usually called *ACINT*. ACINT relies on a class of acoustic sensors that detect sound in water. Sound travels much better in water than in air. Underwater sound created by ships and submarines can be detected at distances of several hundred kilometers.

Underwater acoustics depend on the hydrophone, a type of microphone designed to operate underwater. Hydrophones convert sound to electrical

energy, which then can undergo additional signal processing, or can be transmitted to a receiving station for more sophisticated signal processing.

Navies use a variety of passive acoustic sensors in antisubmarine warfare, both tactical and strategic. For tactical use, passive hydrophones, both on ships and airdropped sonobuoys, are used extensively in undersea warfare. They can detect targets even farther away than detection with active sonar but generally will not have the precision location of active sonar. However, passive sonar does have the advantage of not revealing the position of the sensor.

The United States has an elaborate network of such sensors, called the Integrated Undersea Surveillance System (IUSS). It comprises a mix of hydrophone arrays deployed on the ocean floor called the sound surveillance system (SOSUS) and arrays towed behind naval vessels called the surveillance towed array sensor system (SURTASS).

Acoustics in Air

Some acoustic sensors detect sound traveling through the atmosphere or in the ground near the surface and therefore function only at comparatively short ranges (a few meters to a few kilometers). The sounds of powerful vehicular engines can be detected and used to classify if not fingerprint the vehicles and their movements. The intelligence product of such collection is usually called ACOUSTINT.

Seismic and Teleseismic Sensing

The term *seismic sensing* is usually applied to detecting sound that travels through the earth. Seismic intelligence is defined as "the passive collection and measurement of seismic waves or vibrations in the earth's surface."[7]

At short ranges, seismic sensors called *geophones* (microphones emplaced in the earth or in a structure) can obtain a number of signatures of intelligence value. When emplaced in the earth, geophones can detect and often identify specific types of foot or vehicle traffic. The challenge for these seismic sensors often is not so much in detecting people and trucks as it is in separating out the false alarms generated by wind, thunder, rain, earth tremors, and animals. The greatest intelligence value from this specialized microphone typically occurs when the geophone can be placed directly in a building structure; it then can monitor activity in the building or in an underground facility.

One strategic application of seismic intelligence makes use of the science of seismology to locate and characterize nuclear testing, especially underground testing. This special category of seismic sensing is called *teleseismic sensing*. Teleseismic sensing involves the collection, processing, and exploitation of infrasound that travels deep in the earth. Depending on the strength of the source, such infrasound can be detected at distances of thousands of kilometers.

Teleseismic sensors also can characterize large conventional explosions that are used in testing the high-explosive components of nuclear weapons. Teleseismic intelligence also can help locate such things as large underground construction projects.

Since many areas of the world have a great deal of natural seismic activity, teleseismic MASINT requires a continuous measurement process so that the signatures associated with natural seismic behavior are well known and variations from naturally occurring signatures can be identified.

Magnetometry

A magnetometer is a specialized type of sensor used to measure variations in the strength and direction of the magnetic field in the vicinity of the sensor. The measurements from a magnetometer can be used to identify the signatures of vehicles on land and submarines underwater.

Combining Signatures

Many operational MASINT devices make use of different MASINT technologies to obtain a more complete picture of the target. This is especially true for the combination of RF MASINT and geophysical MASINT. An unattended vehicle sensing device, deployed near a roadway, might combine geophysical and radiofrequency MASINT. Acoustic or seismic sensing might allow the sensor to identify the presence of the vehicle, and the RF MASINT signature would allow identifying the vehicle type (such as tank, truck, or automobile) or even the specific vehicle.

Materials Science

Materials MASINT relies on signatures produced by the processing and analysis of gas, liquid, or solid samples. This enables analysts to determine chemical or biological composition of a substance and is critical in defense against CBR threats. The unique signature data of effluents and debris from explosives (such as those used in improvised explosive devices [IEDs]) allows determination of the origin of the explosives. Signatures produced by sampling effluents from missile propellants allow for typing the missile propellant and thus assessing the missile performance.

This subdiscipline divides generally into the two subfields of materials sensing and materials sampling.

- *Materials sensing* makes use of devices that sense chemical or physical changes in the environment immediately surrounding the sensor. These sensors measure phenomena within an object or at short ranges and typically detect such things as temperature, contaminants, nuclear radiation, or electric or magnetic fields.

- *Materials sampling* involves acquiring small quantities or traces of a material and using forensic processes to determine its nature. So materials sampling includes the collection and analysis of trace elements, particulates, effluents, and debris. Such materials are released into the atmosphere, water, or Earth by a wide range of industrial processes, tests, and military activities. Air sampling equipment, carried aloft by reconnaissance aircraft to detect the debris from atmospheric nuclear tests, is an example of such a sampling activity.

Materials sensing and sampling are important for many areas of intelligence interest. They support military planning and operations. They are used to identify nuclear testing, nuclear materials production and movement, and chemical warfare production. In that role, They are critical in defense against chemical, biological, and radiological threats (CBR) or nuclear, biological, and chemical (NBC) as well as more general safety and public health activities. Economic intelligence uses materials sampling to assess factory production. Materials collection can also include sensing or sampling for environmental monitoring, which increasingly is an intelligence concern because some governments and industrial enterprises attempt to conceal their pollution activities.

In intelligence applications, chemical signatures are used mostly to identify effluents from factories to determine what processes are being used in the factory. The most common requirement is to characterize facilities that are suspected of producing WMDs. Such characterization relies heavily on the ability to identify the signatures of chemical effluents from these facilities.

The sensors that detect chemical and biological materials of interest are developed by a number of companies in the United States, but the U.S. Department of Energy (DOE) national laboratories are leaders in this arena. Lawrence Livermore National Laboratory and Sandia National Laboratory, for example, have developed a range of sensors to detect explosives, chemicals, and biological agents.

Nuclear Intelligence

This MASINT specialty covers measurement and characterization of information derived from the nuclear radiation and physical phenomena associated with nuclear weapons, processes, materials, devices, or facilities. These measurements can help to locate storage sites and movements of nuclear materials. They can also glean intelligence from the signatures produced by nuclear testing.

Nuclear signatures are the physical, chemical, and isotopic characteristics that distinguish one nuclear or radiological material from another. Radiological signatures are created by emissions from radioactive material, in the form of alpha and beta particles and gamma rays. The specific combination of particles and rays emitted, along with the intensity of each

type, constitutes a signature that allows for identification of the radioactive source material. The measurements that produce these signatures can be made only at very short ranges.

Nuclear monitoring can be done remotely or during onsite inspections of nuclear facilities. Data exploitation results in characterization of nuclear weapons, reactors, and materials. A number of systems detect and monitor the world for nuclear materials production and nuclear weapons testing.

A definite overlap exists between NUCINT and the nuclear analysis techniques in materials science, discussed earlier. The basic difference is that nuclear MASINT deals with the characteristics of real-time nuclear events, such as nuclear explosions, radioactive clouds from accidents or terrorism, and other types of radiation events. A materials scientist looking at the same phenomenon, however, will have a more microscopic view, doing such things as analyzing fallout particles from air sampling, ground contamination, or radioactive gases released into the atmosphere. So NUCINT divides into two broad categories: remote sensing of nuclear detonations, from the geophysical MASINT subdiscipline discussed earlier, or sensing either at very short ranges or by sampling.

Remote Sensing

Since the 1960s, the United States has operated satellites that are designed to detect nuclear weapons detonations. The sensors on these satellites detect the characteristic optical signature of a detonation, the EMP from a nuclear detonation, the X-rays and gamma rays emitted by the explosion, or all three. As discussed in the section on EO MASINT, beginning in 1963, the United States launched a series of Vela satellites that carried all three sensor types in orbits at approximately 73,000 miles altitude. Project Vela was developed and deployed by the United States to monitor compliance with the 1963 Partial Test Ban Treaty with the Soviet Union.

The DSP satellites replaced the Vela satellites during the 1970s and carried optical, X-ray, neutron, and gamma ray detectors to monitor nuclear events from within the atmosphere and out to deep space. The replacement for the DSP is the SBIRS, which carries sensors for detecting exoatmospheric detonations.

Airborne and Ground-Based Sampling

Above-ground testing produces an abundant amount of radioactive isotopes (called *radionuclides*) that can be detected. But underground testing also releases radioactive substances into the atmosphere. It is very difficult to contain the gases released in a nuclear explosion. If a nuclear test occurs, radioactive particles and gases might be vented at the time of the test or radioactive gases might subsequently seep out through the cracks in the rocks above the explosion.

A number of systems monitor the earth to detect nuclear explosions. In the U.S., this monitoring program dates back to August 1948, when the

U.S. Air Force created the Office of Atomic Energy-1 (AFOAT-1) and gave it responsibility for managing the Atomic Energy Detection System (AEDS). AFOAT-1 identified the first Soviet weapons test in 1949. It also tracked the production of fissile materials such as plutonium, based on atmospheric measurements of krypton-85 gas.[8]

AFOAT-1, subsequently renamed, did extensive acoustic, seismic, and radiological collection with the informed consent of host governments. Sometimes, the host governments could not be apprised of the collection effort, and the Air Force unit conducted unilateral operations. In 1961, it proposed to monitor secretly, from Libyan territory, French nuclear tests in Algeria.[9] Such operations from U.S. embassies and consulates could be conducted without host government approval. For example, a compact air monitoring unit called the B/20-4 was installed in embassies and consulates to measure the levels of gases such as krypton-85, allowing the U.S. to refine estimates of world-wide plutonium production.[10]

After the U.S ratified the 1963 limited nuclear test ban treaty, the AEDS was expanded with the deployment of ground filter units at a number of U.S. embassies, sometimes without the permission of host governments. These units collected airborne particulates that resulted from nuclear tests, and allowed assessments to be made of weapons design, yield, and composition.[11]

The Air Force has conducted airborne sampling missions. In an effort to measure plutonium production by the USSR and China, high altitude air sampling flights were staged by RB-57F aircraft from an Argentine air base in the mid-1960s. Called project CROWFLIGHT, these missions used an Air Weather Service cover. The purpose of the flight was kept secret from the Argentine government.[12]

Another airborne sampling effort by the U.S. Air Force followed the reactor meltdown and explosion at Chernobyl, USSR, on April 25, 1986. A WC-135 departed McClellan Air Force Base in California for RAF Mildenhall Air Base, England, on April 29 and encountered debris from the event north of Scandinavia. It was the first of forty-two air sampling sorties that would be flown all over the globe with WC-135, WC-130, and B-52 aircraft. The first mission encountered a visible cloud of debris about seven miles in diameter and more than 500 feet thick. The cloud gave the flight crew inflight positive readings that normally are encountered only after atmospheric nuclear explosions. Over the next ten days, mission aircraft encountered Chernobyl debris over the Pacific Ocean, Europe, and the Mediterranean.[13]

How MASINT Is Managed

During the past few decades, as discussed elsewhere in this book, the U.S. IC evolved into a functional management structure for the INTs. NSA was designated the functional manager for SIGINT, CIA for HUMINT, DIA for MASINT, and NGA for GEOINT.

For most of the collection INTs, this posed no serious problems because the process—from requirements to dissemination—was structurally within the purview of the functional manager. As discussed in the HUMINT chapter, collection of HUMINT is done by many agencies, but this is a manageable problem.

MASINT, though, had a serious management issue, even with a designated functional manager. Major MASINT subdisciplines always have had to rely on other INTs for collection. So a continuing issue is how to divide management responsibility for the MASINT process. Political and budgetary considerations, rather than technical ones, can therefore shape the definition of MASINT.

There is a natural tendency of any functional manager to define its collection programs so that they do not fall into another manager's realm of responsibility. For example, a HUMINT functional manager responsible for collecting material samples would undoubtedly prefer to have that effort defined as something other than "MASINT." And the Armed Forces Medical Intelligence Center does not treat its medical sampling efforts as MASINT. Yet both efforts fall within the MASINT definition. Not only oversight but also budgets will be affected by such definitions.

This is exactly what happened with the redefinition of GEOINT in 2005, as discussed in the section on the history of MASINT. Traditional MASINT programs that involved imaging radar and imaging EO collection were redefined to be GEOINT if they were currently spaceborne or could be satellite based at some point in the future. Thus, those imagery-derived programs that were not specifically hosted in space—that is, airborne- and surface-based—remained with the MASINT discipline and were usually "owned" by the U.S. military service that operated them. However, this was not a well-known fact.

Nonetheless, the practicality of transferring all space-based responsibility of imagery-derived MASINT was dictated by the need to assign one specific agent as functional manager that could best serve the needs of the most customers. That agent was then given overall funding oversight authority for growing the capability and serving the customer base. NGA was well positioned to do that.

An additional management challenge comes from the tendency of some to describe MASINT as "everything else." Occasionally, IC leaders and former leaders attempting to simplify the explanation of MASINT will say, "If it isn't SIGINT, HUMINT, or GEOINT, then it's MASINT." This simplistic approach may be convenient in dealing with a complex topic, but it can come across as technically vague at best. Not only does it leave too much room for ambiguity but it ignores Open Source Intelligence (OSINT), which is a distinct INT by itself. By omission, it also implies that foreign materiel exploitation (FME) is a subdiscipline of MASINT, although FME is generally considered to be distinct and separate.

Structure

Within the United States, the director of DIA is the functional manager for MASINT. In that role, the director of DIA provides guidance to program managers, recommends a MASINT budget to the DNI, and directly responds to Congress in order to fully explain the utility of MASINT and the intent of the MASINT budget request. In addition, the director of DIA promotes common standards, education, and training; establishes security policy; manages current requirements of intelligence operations; and solicits or validates future community requirements for new capabilities and thus for MASINT plans and program development. MASINT management and oversight is handled by a combination of three organizations, discussed next.

The Board of Governors

This is a senior-level IC group, chaired by the director of DIA. The board is generally populated by the other defense and IC directors. It is charged to formulate guidance for the future direction of the MASINT enterprise, achieve unity of purpose, establish a common vision, and address issues of mutual concern to the MASINT enterprise and its stakeholders.

The National MASINT Office

This is another joint IC–DoD organization, subordinate to the director of DIA, who manages and executes—on behalf of the DoD and the IC—MASINT services of common concern and other MASINT-related activities. The chief of the National MASINT Office (NMO) is dual-hatted as the chairman, MASCOM, discussed next. NMO provides the means and mechanisms to assist the director of DIA in leading the decentralized MASINT community as a fully integrated enterprise. Specific functions executed by NMO include but are not limited to strategy, policy, and programs; mission integration, which encompasses requirements and asssessments; and architectures in its broadest sense.

The National MASINT Committee

This multiagency group serves as an IC sounding board on MASINT issues, and advises the USD(I) and DNI on the status and strategic direction for MASINT capabilities. The National MASINT Requirements Subcommittee of MASCOM validates and prioritizes MASINT collection requirements for the IC. The MASCOM staff is now fully integrated with the NMO, with the chief of NMO dual-hatted as the chairman of the MASINT Committee.

These three organizations manage what is called the U.S. MASINT System. The MASINT System comprises a combination of technology, policies, capabilities, doctrine, activities, people, data, and communities that

are necessary to produce MASINT in an integrated multi-intelligence, multi-domain environment. MASINT System participants include the IC, the Joint Staff, the military departments (to include the Services), the Combatant Commands, and selected international and civil partners. The MASINT System provides the framework for tasking, collection, processing, exploitation, and dissemination (TCPED) and R & D activities that support varied intelligence solutions for national policymakers and the DoD community.

Collection

In the United States, MASINT collection is based on the guidance provided by the National MASINT Requirements System. This is an intranet-based collection management application that supports the creation and submission of MASINT requirements and tracking of user satisfaction. NMO assesses the needs for future collection capabilities based upon shortcomings in the current architecture.

MASINT is not collected by any single intelligence organization—quite the contrary. Collection is performed by military personnel and civilians in separate organizations that often have little or no ongoing relationships. Some MASINT disciplines—materials science and NUCINT, for example—require detailed laboratory equipment and analysis, often taking weeks to reach conclusions that are subsequently documented in lengthy technical reports. At the other extreme, MASINT sometimes relies on relatively unsophisticated sensors with on-board processing that provides immediate indication of an activity of interest—bhangmeters and EMP sensors, for example.

Some MASINT is collected using dedicated systems that are specifically designed to acquire the detailed measurements and signatures required for a particular mission area. In other cases, MASINT is collected by specialized processing of the sensor output from operational or commercial systems that do not have a primary MASINT mission. MASINT, in some cases, includes the specialized processing of sensor data from the SIGINT and GEOINT disciplines.[14] Many MASINT subdisciplines also depend on HUMINT for success—material collection and sensor emplacement being examples.

To summarize, MASINT collection is usually under the active management of organizations other than the functional manager—executive agents (direct tasking by the functional manager), other INT managers (negotiated tasking or serendipity collection), or operational forces (cooperative tasking). This is the most difficult to manage, but it clearly builds relationships based on value-added results.

Processing, Exploitation, and Analysis

Each of the six MASINT subdisciplines relies on specialized processing and exploitation technologies that are unique to that subdiscipline. And the expertise required for analyzing the signatures usually differs from one subdiscipline to another.

Even within subdisciplines, separate organizational structures, or "stovepipes," are created based on the specialized expertise and technologies that are needed. Following are two subdisciplines that are typical of this point:

Radar MASINT

Radar processing and exploitation depends heavily on digital signal processing and sophisticated algorithms for extracting signatures from the raw radar data, which may include heavy ground clutter.

- SARs illuminate targets while the radar is moving in a constant stable direction and maintain highly accurate measurements of both amplitude and phase of the returned signal relative to the transmitted signal. This allows for a long "synthetic" aperture the length of their flight path while illuminating the target. The larger the synthetic aperture, the higher the resolution of the image. A number of different advanced processing algorithms have been developed to extract signature data to identify many different characteristics to include the changes in a scene that have occurred since the last images of the scene were taken.
- Precision line-of-sight signature and tracking radars, such as Cobra Judy and its replacement Cobra King, provide a phase one interim product on board its mobile platform; however, the complete data set is dispatched to MIT Lincoln Lab as soon as possible after collection. Detailed processing and analysis can be a lengthy process; however, this in-depth analysis is needed in order to determine small but significant changes in a missile system that may constitute a treaty violation.[15]
- Long-range imaging radars, on the other hand, are usually focused exclusively on space objects and must track the target, usually from horizon to horizon in orbit above them, in order to obtain enough aspect angle change for a reasonable resolution image to be formed. In many respects, this is much like SAR image processing, except the target is moving rather than the SAR radar. These radars typically can transmit waveforms of much greater RF bandwidth than those of the precision LOS tracking radars, thus allowing better spatial resolution of their images. Processing just a single data set equates to "large data processing" in the modern language of advanced signal processing, sometimes requiring the use of supercomputers.
- Over-the-horizon (OTH) radars rely on complex algorithms and Doppler frequency processing to extract targets of interest from the ground clutter. As explained earlier in this chapter, OTH radars always use a portion of the high frequency (HF) spectrum with its longer wavelengths to reflect from the lower side of the ionosphere

and extend the radar's detection range to "over the horizon." This type of data processing and analysis is so uniquely different in appearance that it is often referred to as an art rather than a science by those who are not well schooled in radar signal processing theory.

- Bistatic or multistatic radars depend on special processing algorithms to deal with the complex geometries that are involved. For example, the bistatic radar cross section (RCS) is equivalent to that of a monostatic radar that is located along the bisector of the angle formed by the transmitter-to-target and target-to-receiver lines of sight. Expertise in one of these radar specialties does not readily transfer to another. These were the first types of radars invented and were operationally employed in Europe during World War II.

Geophysical MASINT

In this subdiscipline, the specialties of analyzing magnetic, acoustic, and seismic or teleseismic signatures are separated organizationally.

- Monitoring of seismic and teleseismic events relies on recognizing the physical signatures that are associated with nuclear explosions. These signatures are the basis for (1) concluding that an event has occurred (detection); (2) determining the location of the event (location); (3) discriminating the event from nonexplosive phenomena, such as earthquake activity (identification); and (4) in the case of a suspected explosion, evaluating the yield, its nuclear or nonnuclear nature, and the source of the event (characterization and attribution).
- For geophysical MASINT, natural geological events, such as seismic activity and earthquakes, can serve to increase the noise level in certain regions of the world and thus make it difficult to characterize an event.

Similar observations can be made involving processing of each of the MASINT subdisciplines to some extent.

Dissemination, Storage, and Access

Each subdiscipline, as noted previously, requires different scientific and engineering expertise and uses different technologies. Each also has a different customer base with different requirements, although there may be an overlap in a few cases. So separate management structures also are necessary for disseminating the finished product, storing it, and arranging for searches on the signature databases.

Next, we will continue the previous two examples.

Radar MASINT

Line-of-sight precision radars, OTH radars, long-range imaging radars, SAR radars, and bistatic and multistatic radars all have different targets and different customers. In general, NASIC retains the intelligence databases for all radar, EO/IR, and RF MASINT event collections. All raw data are kept for a relatively short period of time, while event data tends to be kept for a number of years depending upon available computer storage. DIA/NMO specifies the minimum standards for retention. Data and signature products are provided to some customers on a routine basis and to others on an as-requested basis.

Geophysical MASINT

Magnetic signatures and underwater acoustics typically are of interest to the Navy. Acoustic signatures in a battlefield environment have Army customers. Seismic and teleseismic signatures have treaty monitoring organizations as customers for potential nuclear explosions, civil emergency response teams as customers for earthquakes, and military commanders as customers for information about explosions in the battlefield. The Air Force plays a prominent role in this component of geophysical MASINT.

Managing the Transition to Operational Use

The need for talented professionals with technical expertise is a defining characteristic of MASINT. MASINT depends—for its effectiveness—on specialists with a scientific or technical background. It draws heavily on physical, chemical, and electrical expertise. Such scientists and technicians usually are not professionally developed within the IC. They often come from academia and have current scientific knowledge from experimentation and research.[16] This is yet one more reason why the NMO maintains a solid relationship with the two service graduate schools, the AFIT and the NPS. It is also the reason why AFIT has offered a MASINT Certificate Program since 2001 for graduate college credit or for continuing educational units (CEUs) for analysts to maintain MASINT standards for their jobs. In fact, many of the signatures explaining the different subdisciplines (or radar MASINT and EO MASINT) are used as teaching aids for the MASINT Certificate Program usually offered in Dayton, Ohio, but occasionally traveling to the Washington, DC, area so as to be accessible to more students who need the education and training.

Because of this close connection to academic research, MASINT long had more of a laboratory science nature than that of an operational INT. In recent years, though, MASINT has evolved into a mature means of detecting, identifying, and characterizing different threats in an operational environment quickly and efficiently. Its mission areas include supporting

military operations, missile warning, counterproliferation, weapons acquisition, treaty monitoring, environmental activities, counterdrug operations, and counterterrorism.

Challenges to making this transition occur more quickly continue to be both real and perceptual. Consider the following:

- *Budget.* The United States is entering another period of DoD and IC budget reductions and reprioritization toward domestic issues. This will probably remain as the single most concerning issue.
- *Roles and responsibilities.* Those MASINT players with the technical capability do not have the acquisition responsibility of supporting war fighter operations.
- *Title 10 vs. Title 50.* U.S. law often creates stovepipes due to the way funding is appropriated, managed, and overseen by Congress. In this case, Title 10 reflects the manner in which funds supporting military operations may be expended. Congressional oversight is carried out by the Armed Services Committees. Title 50 is the public law dealing with oversight of intelligence activities and resources, and thus congressional oversight is carried out by the Intelligence Committees of the House and the Senate.

During times of tight budgets, these items may present special challenges for funding tightly controlled activities within stovepipes. Since MASINT is particularly useful to COCOMs for support to military operations, this area may require constant attention by the functional manager to define roles and relationships carefully and to sponsor routine exchanges with Congress in order to maximize performance of the U.S. MASINT System.

International MASINT

MASINT collectors worldwide have been developed largely to support military planning and military operations. Most of the MASINT sensors deployed to support four of the MASINT subdisciplines—radar, RF, geophysical, and materials science—have clearly defined tactical military purposes. The EO MASINT and NUCINT collectors are more oriented to strategic intelligence applications.

Only the United States has a distinct MASINT organization. The Commonwealth countries tend to manage their MASINT capabilities via their DoD organizations, with some subtle exceptions. Most other nations who have a capability have combined MASINT with either their SIGINT organization in some cases and in other cases with their GEOINT organization. This usually depends upon whether they are radar centric or imagery centric in their collection capabilities. Since both Russia and China have strong S & T capabilities, it is likely they have organizational focus to fully leverage their

S & T expertise, but these matters are not openly discussed in detail by their news media or on the Internet or in international conferences.

Electro-optical MASINT

Several countries operate imaging satellites that have a spectral sensing capability, including Japan, Taiwan (FORMOSAT), and France (SPOT 5 and Pleiades). Germany's EnMAP satellite is designed to provide hyperspectral imagery.

One country other than the United States has an OPIR satellite capability. The Russian Prognoz satellite has infrared detection capabilities similar to those provided by the U.S. DSP satellite system.[17] The Prognoz program dates from the 1970s with their first generation US-KS (Oko) space-based early warning system. In 1970, the USSR began development of the second-generation early warning system, the US-KMO Prognoz. In contrast to the first-generation system, which was designed to detect only launches of ICBMs from bases in U.S. territory, the US-KMO system was designed to provide coverage of submarine-launched ballistic missles from oceans as well. These satellites are being deployed in geosynchronous orbits, from which they provide coverage of most of the oceans. The US-KMO #8 was launched in 2012.[18]

Radar MASINT

Almost all countries have radar stations that are used for operational purposes—primarily monitoring air traffic. Many of these radars also are capable of providing MASINT worldwide; there exists a wide variety of sophisticated ground-based and seaborne radar systems that can be used for RADINT. And a few countries have developed radars with specific MASINT missions—primarily OTH radars and object identification radars.

Over-the-Horizon Radars

China reportedly developed its first skywave OTH radar back in 1967. Since the 1980s, two further installations may have been added to the inventory, with at least one system looking out into the China Sea area reportedly to track U.S. Navy fleet movements. China also has deployed at least one surface-wave OTH radar, intended to detect surface ship movements and low-altitude air activity beyond the visible horizon, out to about 300 km.[19]

Beginning in about 1970, Australia has developed a network of skywave OTH radars called Jindalee, currently deployed as the Jindalee Operational Radar Network (JORN). JORN comprises two operational radars and a R & D radar located in the Australian interior, providing coverage of ocean areas to the north and west of the continent. The three radars monitor air and ocean traffic in the region.

Russia has a history of building and deploying skywave OTH radars dating back to 1970. The USSR deployed two such radars, called Duga-1, that were intended to provide ballistic missile early warning by detecting missiles launched from U.S. territory during the boost phase. The radars apparently did not succeed in that mission, and subsequently the sites were abandoned.

In recent years, Russia has begun to deploy a new generation of such radars with a more manageable mission: detecting and tracking small aerial vehicles (such as cruise missiles and unmanned aerial vehicles) around the Russian periphery. The first such radar began operational service in December 2013. Called the 29B6 or Podsolnukh-E ("container-E"), the new radar is bistatic (transmitter and receiver stations are separated), as was the Duga-1. The transmitter is located near Gorodets on the outskirts of Nizhny Novgorod, with a receiver located 250 km away at Kovylkino, aligned to monitor the airspace west of Russia. A second 29B6, currently under construction in Russia's Eastern Military District, is scheduled for service entry in 2018.[20]

Object Identification Radars

Russia has developed several generations of missile defense and space tracking radars that have a secondary mission of providing MASINT about these targets. The Dnepr radars, dating to the 1960s, provide orbital information on satellites. The more powerful Daryal radars supplemented the older Dnepr radars during the 1970s. Both radars operate in the VHF frequency band. The newest generation radars are the Voronezh-M (VHF) and Voronezh-DM (UHF) radars that are currently being deployed.

Germany has one of the world's most sophisticated radars for obtaining MASINT on satellites. The tracking and imaging radar (TIRA) is located at the FGAN Research Institute for High Frequency Physics and Radar Techniques, near Bonn. It functions in many ways like the Haystack wideband long-range imaging radar discussed earlier. TIRA obtains radar data at 22.5 cm (L-band) and 1.8 cm (Ku-band) wavelengths and uses the data to produce radar images and perform feature based classification and identification. Features that are measured include orbital elements, satellite motion and maneuvers and orbital lifetimes. TIRA has produced numerous radar images of satellites, of the international space station, and of U.S. space shuttles.

Airborne and Spaceborne Radar MASINT

Airborne and spaceborne SARs primarily are intended to produce imagery, but many of them can produce MASINT. They are capable, for example, of providing change detection and polarization measurements. Germany's SAR-Lupe, TerraSAR-X, and TanDEM-X; India's RISAT; China's Yaogan Weixing SAR; Israel's TecSAR; and Italy's COSMO-SkyMed are all spaceborne SARs that are capable of obtaining MASINT signatures.

Radio Frequency MASINT

Since this subdiscipline is closely aligned with SIGINT collection for military applications, few acknowledge their capability in this area. However, one would assume that all countries with a sophisticated SIGINT capability also have an RF MASINT capability. The principal nonmilitary application is for detection and characterization of lightning. Since many universities around the world are actively engaged in research of this nature and since lightning is the largest natural cause of wildfires in large nations with remote regions, many countries have at least a rudimentary capability to collect wideband radio frequency.

Geophysical MASINT

Acoustic Sensing in Water

The sensing of underwater sound is widely used by naval forces of many countries, primarily for detecting, identifying, and tracking submerged submarines—though it also is used to identify surface ships. Russia, China, and India all have well-developed ACOUSTINT programs for anti-submarine warfare.[22] The British have developed towed sonar arrays that are sold commercially.

Magnetic Field Sensing

Russia, Australia, India, the United Kingdom, China, and France, among others, have deployed magnetic anomaly detectors on antisubmarine patrol aircraft. Several countries also have employed magnetic field sensors for short-range detection of vehicles.

Seismic Sensing

Military forces long have recognized the value of sensing ground vibrations due to foot or vehicle traffic. Sensors that can be deployed to recognize and classify vehicle signatures are increasingly used by ground forces worldwide. A combination of geophysical sensors seems to be the trend; Germany's ground sensor equipment (BSA), for example, uses a combination of seismic (geophone), magnetic, and acoustic (microphone) MASINT sensors for target detection and identification.

Teleseismic Sensing

Under the Comprehensive Nuclear-Test-Ban Treaty, an international network (the International Monitoring System, or IMS) monitors seismic events to detect and geolocate underground nuclear tests. Identification and further analysis of the results is a responsibility of the member states.[21] Russia has had a capability for such monitoring that dates back

to the 1960s. The Borovoye seismic station in Kazakhstan detected underground nuclear explosions at the Nevada Test Site in the United States over the course of three decades, down to a yield of 2 to 5 kilotons. Aided by information from other seismic stations to identify the geological conditions of tests, the Borovoye site could estimate the yield of U.S. explosions with about 20 percent uncertainty.[23]

Materials Science

Many countries worldwide have developed sensors and methodologies for point and standoff detection of chemical, biological, radiological, nuclear, and explosive (CBRNE) materials. The threat of using these materials in terrorist attacks has spurred much of this development. Also, treaties limiting the production, use, and proliferation of such materials have required the establishment of international monitoring regimes.

Nuclear Intelligence

Nuclear sensing at borders around the world is driven by a concern about movement of nuclear materials for proliferation or for terrorist purposes. Several countries have passive gamma and neutron sensors that are intended to detect nuclear materials at choke points (primarily border crossings and ports). Much of this equipment was provided by the United States under the Proliferation Security Initiative. The sensors are capable, at short ranges, of detecting special nuclear materials (the fissile materials Uranium-235, Uranium-233, and Plutonium-239).

Russia has a highly developed NUCINT program that collects samples from nuclear testing.[24]

Treaties such as the Comprehensive Nuclear-Test-Ban Treaty and the Treaty on the Non-Proliferation of Nuclear Weapons led to the deployment of international monitoring networks that operate MASINT sensors. For example, eighty stations worldwide form the IMS Radionuclide Network, and forty of them monitor for isotopes of xenon gas that are diagnostic of nuclear explosions.

The Types of Intelligence Targets
Against Which MASINT Works Best

In general, the MASINT primary value is in characterizing objects and facilities. Like GEOINT, MASINT does not provide access to human thought processes. So it also can't usually provide intent or predictive intelligence.

Following are three general categories that describe the intelligence value of MASINT. It is a primary source for a number of important intelligence issues. For others, it usually is not a primary source but contributes

to the intelligence picture and on occasion becomes a critical source. And for some issues, it is seldom a contributor but may occasionally provide insights.

MASINT as a Primary Source

Situational awareness and missile warning. MASINT provides situational awareness to support national policy decisions, military operations, and law enforcement operations. It is especially useful for providing battlespace situational awareness—that is, identifying the operational status of both friendly and hostile units, monitoring force movements, and for battle damage assessment. Fortuitous or planned collection from areas near underground facilities can provide information on the facility's activity. A particularly important category of situational awareness that MASINT provides is that of indications and warning (I&W), particularly that of missile attacks. OPIR and radar MASINT, for example, have long provided I&W intelligence since ballistic missiles were first developed as major weapon systems capable of carrying explosive warheads. Unattended sensors have long provided situational awareness concerning movement of people and supplies for both military operations and nonmilitary applications, such as smuggling activities.

Arms control and treaty monitoring. MASINT has become increasingly important in arms control and treaty monitoring, particularly treaties meant to limit development of ballistic missiles capable of delivering WMDs. It allows monitoring of transportation of suspect materials from processing sites to disposal areas. It identifies materials that are crossing borders. It provides indications as to whether hazardous materials are being stored safely. It identifies excess production of suspect materials.

Environment and natural resources. MASINT, in conjunction with GEOINT, provides warning of environmental problems such as desertification, climate change, and industrial pollution. It may provide the first indication of natural or man-made water diversion, forest fires, volcanic activity, ash cloud formation, etc. During the 1990s, then senator Al Gore initiated an Environmental Task Force (ETF, later renamed Measurements of Earth Data for Environmental Analysis [MEDEA]) in cooperation with the U.S. IC to examine various intelligence sources using internationally acclaimed environmental experts from U.S. agencies and research institutes. Intelligence remote sensing sources, especially MASINT and IMINT, were found to be most useful. The U.S. Geological Survey (USGS) formed the unclassified Hazard Support Center on Maui along with a more robust classified center in Reston, Virginia. Unfortunately, the U.S. budget and security oversight processes had difficulties maintaining this forward-leaning cooperative relationship.

Humanitarian disaster and relief operations. MASINT provides information about on-the-ground conditions after natural and man-made disasters. It is especially important in identifying chemical spills and pollution subsequent to a disaster. Earthquakes are identified and the epicenter located in real time using geophysical MASINT. The formation of tsunamis can be predicted and monitored after earthquakes in or near large ocean areas. Forest fires, volcano eruptions, and the ash clouds from volcanoes are identified using EO MASINT.

MASINT as a Major Contributor

Agriculture and food security. MASINT, working with imagery, can support crop forecasts and so provide advance warning of food production shortfalls.[25]

Terrorism. Materials analysis is an important part of countering IEDs and the explosives used by suicide bombers. It enables identifying the design of these devices and the composition and source of the explosives used.

Transnational organized crime. MASINT has been a valuable source of intelligence in dealing with the narcotics trade by monitoring opium poppy and coca production using EO MASINT. On one occasion in the late 1990s, the CMTCO loaned a multispectral sensor to the U.S. Drug Enforcement Administration (DEA), who were mapping out coca growth in Colombia. Afterward, the DEA shared their results with the CMO. They had been ordered by the government of Colombia not to overfly government-maintained preserves any longer—since they were routinely finding coca plants flourishing throughout the country.

On another occasion, marijuana growers on the big island of Hawaii fired shotguns at a local helicopter being used by NASIC employees while conducting a MASINT-related ETF experiment in Volcano National Park.

In addition, MASINT sensors have helped to identify narcotics shipments, and materials analysis is used to determine the sources of narcotics. MASINT has demonstrated ship-tracking capabilities, making it very relevant to finding and tracking international smuggling operations.

Biological and chemical warfare development and proliferation. The manufacture, testing, movement, and storage of chemical and biological weaponry can often be identified by the unique signatures associated with such weaponry. MASINT can determine whether biological or chemical warfare weapons are appearing in alarmingly large numbers. It can determine when the materials necessary for the creation of biological or chemical warfare weapons are being manufactured or transported.

Infectious diseases and health. Biological material sampling is used to identify diseases. MASINT technical laboratories have a close relationship with the National Center for Infectious Diseases in Atlanta, Georgia, for the purpose of information sharing.

Missile development and proliferation. Ballistic missile tests are conducted from fixed sites that have unique imagery signatures. During these tests, the performance of the missile—characteristics such as range, accuracy, number, and design of warheads—can be determined by radar MASINT and EO MASINT systems. Cruise missile testing can be monitored by radar MASINT and EO MASINT systems to identify flight profiles as well. Rocket engine test stands can be monitored by several classes of MASINT sensors to reveal rocket engine developments for future ICBMs.

Nuclear weapons development and proliferation. The manufacture, movement, and storage of nuclear materials can often be identified by the unique signatures associated with the materials. Nuclear fuel reprocessing facilities are large complexes with distinct signatures, sometimes emplaced in underground facilities.

Human rights and war crimes. Materials science provides forensic evidence of war crimes, much as it does in law enforcement.

Energy security. Oil and gas drilling, and damage to or disruption of existing extraction or refining facilities, can usually be assessed using MASINT in conjunction with imagery.

Advanced conventional weapons development and proliferation. The production, deployment, testing, and proliferation of conventional weapons can be monitored using MASINT disciplines such as RADINT and EO MASINT. The MASINT products directly support defense acquisition programs, especially MASINT signatures that support the detection, classification, or identification of noncooperative targets beyond visual range. MASINT signatures, along with imagery, are critical to the development and successful operation of modern precision weapons.

Foreign military combat capabilities, operations, and intentions. MASINT can provide some specialized details about weaponry; radar MASINT and EO MASINT can identify artillery fire, direction of fire, and location of active artillery in addition to that of missiles. Increasingly, tactical weaponry relies on the existence of unique signatures for targeting. The F-22 Raptor fighter aircraft, for example, uses infrared signatures to target opposing aircraft and so must maintain a current signature library for rapid identification of both threats and friendly aircraft.

Emerging and disruptive technologies. These technologies generally are assessed using other INTs; however, exotic weapons, such as lasers and DEWs that have the potential to be "game changers" on the battlefield are indeed detectable by MASINT sources and methods. During the Cold War, many technologies and concepts of operations (CONOPs) were developed to remotely detect and characterize DEWs under development and testing in remote locations.

MASINT as an Ancillary Source

Military and civilian infrastructure. MASINT can provide some insights into foreign infrastructure. It finds use in assessing factory production.

Leadership intentions. MASINT sometimes can help in inferring leadership intentions. Clandestinely emplaced acoustic MASINT sensors, for example, can provide warning that combat units such as tanks and missile launchers have left a garrison and are deploying for offensive operations.

Counterintelligence. The primary contribution of MASINT here is in identifying an opponent's denial and deception efforts. Camouflage and dummy weaponry often can be identified using optical or radar MASINT.

Cyber threats. RF MASINT may have application here in special cases.

Political stability. MASINT generally cannot contribute other than to provide situational awareness of civil unrest and violence observable by widespread fires and explosions.

Foreign policy objectives and international relations. Foreign policy planning concerns intent, where MASINT usually does not contribute. However, continued testing of particular classes of weapons that MASINT easily can detect, characterize, and identify does provide inferential evidence that the leadership in a country has an intent to either use or sell those weapons.

International trade. Intelligence to support negotiations on trade typically makes little use of MASINT, although understanding the results of natural and man-made disasters can provide quantitative evidence of loss of capacity or stockpile in certain national industries, particularly agriculture.

Economic stability and threat to finance. Threats to economic stability, responses to sanctions, and similar assessments generally will not have a significant MASINT contribution, although MASINT ability to monitor widespread fires and explosions could provide indications of macro changes in closed societies or third world nations with little free press coverage.

Prisoners of war and missing in action. MASINT generally has not contributed in this area. To do so would require some active participation by the prisoners of war (POWs), such as starting large fires or setting off large explosions in order to draw attention of MASINT sensors that may already be actively engaged in support of search and rescue activities. Airborne SAR and thermal IR specialized processing could provide valuable insight as to whether holding facilities in remote areas are occupied or not. This would be a very specialized support activity that might occur in limited cases only.

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