DEPARTMENT OF DEFENSE

MILITARILY CRITICAL TECHNOLOGIES LIST

SECTION 18: SIGNATURE CONTROL TECHNOLOGIES

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Defense Threat Reduction Agency
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PREFACE

The Militarily Critical Technologies List (MCTL) Program provides a systematic, ongoing assessment and analysis of goods and technologies to identify those that are critical to the Department of Defense (DoD). It characterizes the technologies (including quantitative values and parameters) and assesses worldwide technology capabilities.

The MCTL is a compendium of goods and technologies that DoD assesses would permit significant advances in the development, production, and use of the military capabilities of potential adversaries. It includes goods and technologies that enable the development, production, and employment of weapons of mass destruction (WMD). Goods and technologies are considered critical if their acquisition and exploitation by a potential adversary would either significantly negate or impair a major military capability of the United States or significantly advance a critical military capability of the adversary. A leading edge technology that has a high potential for advanced military application can be included even if it is not currently embedded in a U.S. system.

Technologies are identified through the deliberation and consensus of Technology Working Groups (TWGs) whose members are subject matter experts from government, industry, and academia. TWG chairpersons continually screen technologies and nominate items to be added or removed from the MCTL. Working within an informal structure, the TWGs strive to produce precise and objective analyses across the technology areas and to update these assessments periodically.

The legal basis of the MCTL stems from the Export Administration Act (EAA) of 1979, which assigned responsibilities for export controls to protect technologies and weapons systems. It established the requirement for DoD to compile a list of militarily critical technologies. The EAA and its provisions, as amended, have been extended by Presidential Directives.

The MCTL is not an export control list. Items on the MCTL may not be on an export control list, and items on an export control list may not be on the MCTL. The MCTL is designed to be used as a reference for evaluating potential technology transfers and for reviewing technical reports and scientific papers for public release. Technical judgment must be used when applying the information. The MCTL should be used to determine whether the proposed transaction would result in a transfer that would give potential adversaries access to technologies whose specific performance levels are at or above the characteristics identified as militarily critical. It should be used with other information to determine whether a transfer should or should not be approved.

An Index of MTCL Technology Data Sheets is provided with each MCTL section. Separate documents contain a Glossary and a list of Acronyms and Abbreviations.

This document, MCTL Section 18: Signature Control Technology, supersedes MCTL Part I, Section 16: Signature Control Technology, June 1996.

SECTION 18—SIGNATURE CONTROL TECHNOLOGIES

Scope

Highlights

- Low observable technologies strive for balanced reductions across the energy spectrum for land, sea, and air systems.
- New technologies enable both lower signatures and lower maintenance and life cycle costs.
- Counter low observable technologies strive for functions across the energy spectrum.
- International markets for LO and CLO are increasingly sophisticated. Purchasers generally seek:
  - State-of-the-art capabilities.
  - System integration and "how to do it" which are increasingly key to signature control success.

OVERVIEW

This section covers critical technologies in both low observable signature control and counter low observable suites. It also covers systems integration with a signature control emphasis. These technologies reflect many kinds of development programs reaching back to World War II. The technologies are distributed across many U.S. and foreign military systems including retrofits. They are regarded as key to technology superiority for modern warfare. The technologies are subject to special procedures within the Department of Defense. An introduction to these procedures is included in "READ ME" for this section.

BACKGROUND

The theory of signature control has old roots. Basic theoretical understanding is widespread internationally. Using theory and physical insights in military systems has been dependent upon parallel advances in computational power and new techniques and practices for system design. The selection of materials and designs for improved performance and lower cost depends upon the vital iterative development processes between actual hardware, models, and computational analysis. This illustrates the diversity of skills, tools, time and resources required to be successful in both the low observable and counter low observable arenas.

Low observable technology principles have been understood and applied in the military since the 1940s. More recent history (see Figure 18.0-1) has gradually evolved into the basis for a major set of programs applied during and after the Cold War. The purpose was to build a suite of capabilities which, when incorporated in weapons systems, neutralized the Soviet integrated air defense systems and overbounded their huge air defense investment. For various reasons application of LO to land and sea platforms have additional challenges such as interaction with land or water. The technologies were gradually placed into U.S. weapons in an incremental combination of new platforms and modifications to platforms that were not originally designed with emphasis on signature control.

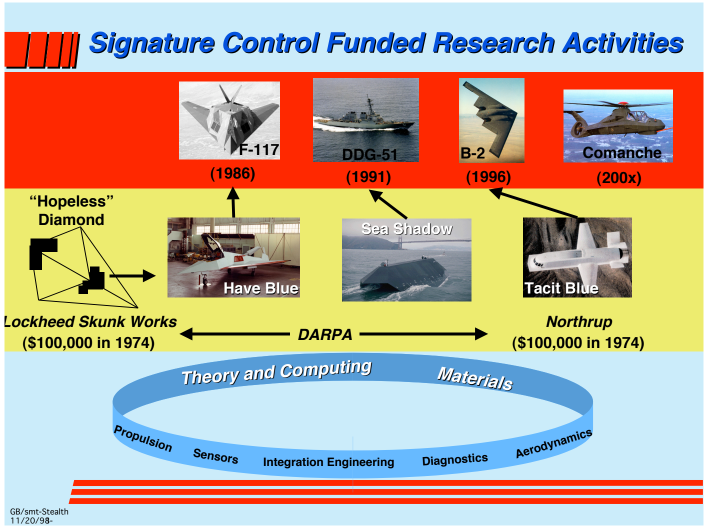

Figure 18.0-1. Technologies-Demonstrators-Systems

An ideal low observable weapons system controls its signature across the entire electromagnetic spectrum, negating sensors in the acoustic, visual, infrared, and radio frequency (RF) bands. However, radar continues to be the most versatile and widespread means to detect objects, even at long ranges and in adverse weather.

The documentation in this section was done in conjunction with discussions of DoD classified and unclassified guidance. Technologies for low observable performance listed in the data sheets are congruent with existing guidelines as of the publication date.

Development of low observable theories since the publication of Maxwell's Equations is shown in Figure 18.0-2. As insights have been refined, the Echo models, Echo successors, and the capabilities of computing platforms have been supportive. The exchanges among new materials, designs, models, and new concepts has been enabling for new generations of LO weapons systems.

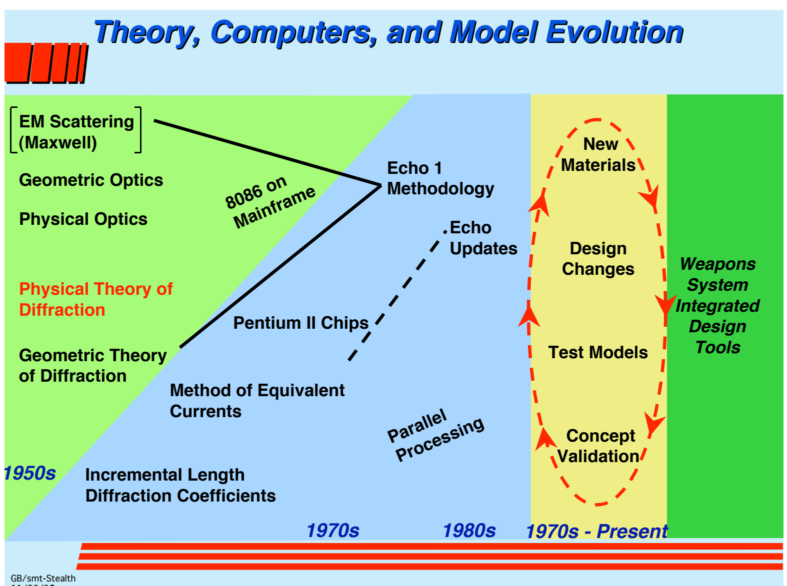

Figure 18.0-2. Development of LO Theory

Reductions achieved in maritime systems must accommodate shifting reflections between the sea and the hull. Requirements for a superstructure, which include many antennas, persist. Salt water corrosion, battle damage repair and the need for repair and maintenance while at sea highlights marine challenges. Figures 18.0-3 and 18.0-4 illustrate approaches to LO surface combatants. The technologies supporting these systems are in their infancy and could progress rapidly.

SA'AR 5

- **Hull and Superstructure Shaped to Reduce RCS**
- **Topside Equipment Shaped or Concealed Behind Bulwark**
- **DRES Ball for IR Treatment**

Figure 18.0-3. Approach to LO Surface Combatant

La Fayette Class Frigate (DCNI)

- Hull and Superstructure Shaped to Reduce RCS
- Topside Equipment Concealed or Eliminated
  - False Foredeck
  - Boat Behind Screen
- Use of Composite Materials
  - Superstructure
  - Foredeck

Figure 18.0-4. Approach to LO Surface Combatant

Counter low observable technologies constitute potent possibility for both U.S. use and for adversary employment. These technologies seek to overcome characteristics of low observability be detecting and characterizing tiny signals in a noisy environment. To date these technologies have been diffuse across many devices and approaches. Sometimes they cascade modest improvements across components used in series (e.g., power supply, transmitter, antenna, receiver). Counter low observable technologies are also spread across existing sensor types to illuminate objects of interest.

Systems integration technologies blend together widely different components to meet overall system requirements. This blending accommodates many components, which can be thought of as both independent and dependent variables. At a high system level both LO and CLO technologies must contribute to the intended mission by integrating considerations of the operating environment, threat, required capabilities, and mission character (e.g., bomb, communicate, suppress).

The best opportunity to use system integration technologies usually occurs when integration of signature control is considered from the beginning of a new system's conceptual design. This provides the best opportunity to find efficient engineering tradeoffs while complying with the overall functional capability budgets for each system trait. Applying single technologies that make discrete contributions to LO or CLO in a system is accomplished differently today since the various disciplines do not function in isolation. Each technical discipline must integrate with every other to transact the required tradeoffs and maintain overall system balance. The LO/CLO features are integrated into each applicable subsystem (structure, avionics, propulsion, etc.) in order to achieve this balance.

SECTION 18.1—LOW OBSERVABLE TECHNOLOGIES

Highlights

- Advances in low observable technology enable new weapons systems to expand the operational envelope of combat air, sea and land vehicles while incorporating low observable features which critically reduce the detectability of the weapons systems.
- A combination of insights and technologies enable the United States to retrofit selected existing weaponry to achieve low observability (stealth). This includes accommodation of external stores and munitions for air platforms.
- Simplification of materials and processes has led to militarily critical reductions in the complexity of maintenance and logistics and enabled low observable systems to be worldwide deployable.

OVERVIEW

The first systems, while operationally capable, were limited in the versatility of their combat features. Improvements in subsequent generations are the result of new or refined critical technologies across the spectrum described in the list of data sheets. Early systems that employed low observable features were maintenance intensive in terms of special training and procedures which resulted in increased costs. Other initiatives have focused on refining the balance in signature reduction across all frequency bands and electromagnetic wavelengths. These technologies and other unconventional approaches will continue to improve and provide opportunity for further reduction in signature and costs across the entire energy spectrum. While civil use for these technologies expands slowly, it is not clear that there is sufficient commercial market to sustain research, development or the industrial infrastructure, which is required by the military.

BACKGROUND

Low observable features have been driven toward better harmonization with other mission requirements and cost demands. These factors, in combination with international demand and the economic mandate to meet international markets in order to be economically viable are critical developments for the near term future. They will drive entities in the United States, including the government to share more technology to meet the needs of interoperability which are starting to emerge, while keeping the edge needed for superior U.S. weaponry. Simultaneously, international customers demand improved performance from their low observable purchases plus the ability to maintain and operate their systems independent form U.S. support. Key to identification of critical technologies is the ability to discriminate and accurately describe those elements judged to be critical for low observability. Additional references are available to U.S. and foreign participants based upon the nature of their relationships and the technologies under discussion.

LIST OF MCTL TECHNOLOGY DATA SHEETS
18.1. LOW OBSERVABLE TECHNOLOGIES

MCTL DATA SHEET 18.1-1. SHEETS AND THIN FILMS

Critical Technology Parameter(s)	Includes films having controlled resistivity, conductivity or absorption suitable for bonding on or lamination into vehicle structures. Materials generally function when the loading is distributed on the host film or substrate material generally a plastic.
Critical Materials	Loaded Sheets and Films. Indium Tin Oxide on Polymers. Deposited metals on substrate.
Unique Test, Production, Inspection Equipment	Productions of fine tolerance control of materials thickness.
Unique Software	Source codes to optimize resistivity and sputtered materials thickness.
Major Commercial Applications	Limited commercial applications have been found in situations which require rf energy suppression (measurement chambers, areas where antenna patterns should be suppressed, suppression of backlobes from installed antennas).
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-2. MAGNETIC RAM

Critical Technology Parameter(s)	Materials designed to absorb, reduce or direct the radar signature of a vehicle or object. Materials generally function when a magnetic particle is distributed through the host binder, polymer or ceramic materials.
Critical Materials	Carbonyl Iron Powder. Ferrites. Microwave Absorbers. Magnetic Materials.
Unique Test, Production, Inspection Equipment	See Data Sheet on Inspection Equipment.
Unique Software	Source code specifically for optimization of loading amounts or optimization programs to produce desired system signature levels.
Major Commercial Applications	Limited commercial applications have been found in situations which require rf energy suppression except for measurement chambers and areas where radiated signals should be suppressed.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-3. DIELECTRIC RAM

Critical Technology Parameter(s)	Materials designed to absorb, reduce the radar energy, and thereby reduce the radar signature of a vehicle or object. Materials generally function when a dielectric material is distributed through the host binder, a plastic or ceramic material.
Critical Materials	Carbon/Graphite. Resistive Materials and Sheets. Microwave Absorber.
Unique Test, Production, Inspection Equipment	Manual or robotic spray equipment, specifically the spray head, capable of continuous spraying and controlling distribution of material.
Unique Software	Source code specifically for optimization of loading amounts, or optimization programs to produce desired system signature levels.
Major Commercial Applications	Limited commercial applications have been found in situations which require rf energy suppression except for measurement chambers and areas where radiated signals should be suppressed.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-4. RADAR ABSORBING STRUCTURE

Critical Technology Parameter(s)	Components designed to absorb or otherwise manipulate the electromagnetic energy to control the radar signature of vehicles. Generally these are components already a part of the vehicle structure whose design has been modified to integrate stealth additives into the basic structural component design, which can utilize plastic or ceramic structural materials.
Critical Materials	Plastic Foams. Ceramic Foams. Treated/Loaded Honeycomb Core.
Unique Test, Production, Inspection Equipment	See Data Sheet on Inspection Equipment.
Unique Software	Codes to design specific absorber or cancellation designs. Codes which specifically optimize vehicle component design with absorbing characteristics and integrate into vehicle design for optimum signature.
Major Commercial Applications	Limited commercial applications have been found in situations which require rf energy suppression except for measurement chambers and areas where radiated signals should be suppressed.
Affordability Issues	Requirements for DoD is insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, USML Cat XIII.

MCTL DATA SHEET 18.1-5. IR SIGNATURE CONTROL TECHNIQUES

Critical Technology Parameter(s)	Materials, coatings and component integration designed to control the reflected and emitted energy throughout the IR spectrum, generally .7–20 microns. Normally accomplished with coatings, a binder loaded with an additive, which can be added onto a structure.
Critical Materials	Paints/Surface Treatments. Controlled Emissivity/Reflectivity. Appliques.
Unique Test, Production, Inspection Equipment	See Data Sheet on Inspection Equipment.
Unique Software	Source code specifically for optimization of coatings or design of surface treatments. Optimization programs to produce desired system signature levels.
Major Commercial Applications	Limited commercial applications have been found in situations, which require control of IR properties. Some exist in automobile windshields and camera lens coatings.
Affordability Issues	Requirements for DoD is insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-6. VISUAL SIGNATURE REDUCTION

Critical Technology Parameter(s)	Materials and techniques designed to match or blend into the visual (eyeball) background scene. Usually materials are coatings (pigments loaded in a binder) or treatments added onto a structure.
Critical Materials	Multispectral Surface Treatments. Paints. Solar glint reduction.
Unique Test, Production, Inspection Equipment	See Data Sheet on Inspection Equipment.
Unique Software	Source code that optimizes pigment or coating design for signature reduction. Codes that optimize paint colors and their location on vehicles.
Major Commercial Applications	Broad commercial applications of variable visual materials are adaptive architectural glass, camera lens, and eyeglasses.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-7. LASER AND ELECTRO-OPTIC

Critical Technology Parameter(s)	Materials, techniques, and design concepts to absorb, trap, or redirect laser energy impinging of a vehicle or object. This addresses laser energy levels that are not weapon energy levels. Applications include bonded onto or integrated into vehicle structures.
Critical Materials	Materials. Coatings. Paints. LCS Reduction Treatments. Indium Tin Oxide.
Unique Test, Production, Inspection Equipment	See Data Sheet on Inspection Equipment.
Unique Software	Codes to optimize material properties, design concepts and location on a vehicle or object. Codes to optimize broadband performance.
Major Commercial Applications	Safety lens for industries and testing laboratories which employ lasers.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-8. TEST AND INSPECTION EQUIPMENT

Critical Technology Parameter(s)	Measurement equipment, test techniques, and data collection and processing algorithms designed specifically for measuring magnetic and dielectric properties, emissivity-reflectivity-optical properties, major subsystem RF, IR, EO signatures, up to full size vehicle signatures, or components. Includes systems designed for ground measurement of vehicles or components.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Portable or moveable RF and IR/EO measurement equipment. Hand-held measurement equipment.
Unique Software	Any algorithm specifically for controlling measurement of RF and IR/EO properties, collecting the data, and analyzing the data to provide subcomponent or system level signature results. Motion compensation algorithms for data collection as radar moves around target to collect and analyze measurements and normalize data. Algorithms to convert direct property measurements to good/bad (green/red) readout for operator. Software claiming to extract absolute RCS from image data. Software to analyze RCS or RCS image data to determine location and cause of anomalies, can also be used to verify repairs. Image reconstruction.
Major Commercial Applications	There is considerable commercial market for antennas, radar systems and spectrometers. They are used in laboratory and anachoic measurement chambers. Radars have numerous applications to air systems and ground stations.
Affordability Issues	The commercial market place will drive the cost of these classes of equipment. Defense applications will benefit from the commercial segment for the hardware. The defense specialized subsystems and software will still be a costly factor.
Export Control References	WA Cat 1, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-9. RCS PREDICTION CODES

Critical Technology Parameter(s)	Computational electromagnetics (CEM), computer codes designed to compute or closely approximate the radar cross section of a complex object. May also be used to model antenna radiation patterns. There are two classes of RCS prediction codes – asymptotic techniques and first principle codes. Asymptotic technique codes include physical optics (PO), geometric optics (GO), physical theory of diffraction (PTD), geometric theory of diffraction (GTD), and uniform theory of diffraction (UTD) codes. The first principle codes include method of moment (MOM), finite difference time domain (FDTD), finite volume time domain (FVTD) and finite element (FEM) codes. Hybrid codes which mix these various types have also been developed.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Large problems often require the use of high performance computers. Smaller problems may run on workstations or even PC computers.
Unique Software	None (most are FORTRAN based code, some are written in C or C++).
Major Commercial Applications	Limited use in commercial antenna pattern modeling. Potential use in medical imaging.
Affordability Issues	The lack of commercial applications mean that most of the codes developed are funded by the military, military contractor IRAD, or developed as part of academic research in electromagnetics.
Export Control References	WA Cat 21, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-10. IR PREDICTION CODES

Critical Technology Parameter(s)	Computational Electromagnetics (CEM) and Computational Fluid Dynamics (CFD) computer codes to determine the source and contrast Infrared (IR) Signatures of military vehicles including aircraft, ships and tanks. The codes generally contain the LOWTRAN, MODTRAN or FASCODE atmospheric models for modeling of the environment and atmospheric transmission. There are two computational approaches: radiosicity codes as represented by the government sponsored SPIRITS codes and Monte Carlo ray tracing codes as implemented by GSL (SPIRITS) and several DoD contractor codes.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Most IR codes run on PC workstation computers. However, refined plume CFD calculations require very large computers.
Unique Software	None. The codes use all of the popular computing languages.
Major Commercial Applications	None. However, IR Signature codes are related to widely available codes used with thermal imagers for inspection, heat loss sensing, medical imaging and remote sensing.
Affordability Issues	IR codes with limited capabilities are widely available and at modest cost (< $10K). Capable IR signature codes are developed by DoD and their contractors under CRAD and IRAD Funding.
Export Control References	WA Cat 21, MTCR 17, USML Cat XIII.

MCTL DATA SHEET 18.1-11. ACOUSTIC SIGNATURE: NOISE REDUCTION TECHNIQUES

Critical Technology Parameter(s)	Devices, material, features, and/or coatings used in or on components or systems to reduce or limit the transmission of acoustic energy.
Critical Materials	Specialty designed materials, coatings, absorbers, and decouplers.
Unique Test, Production, Inspection Equipment	Vessel noise measurement systems. Sensors capable of measuring acoustic signature.
Unique Software	Test data, techniques and other information revealing effectiveness of acoustic quieting. Specially designed software for analyzing or predicting acoustic signatures. Models to predict acoustic signature of vessel in ocean environment.
Major Commercial Applications	Commercial shipbuilding. Human factors noise reduction.
Affordability Issues	Lack of clear commercial markets means that the development of these technologies will be primarily dependent upon military or developed as a part of academic research in marine technology.
Export Control References	WA ML 9, 17, 21, 22, MTCR 17, USML Cat VI, XIII, CCL Cat 8A, D, E.

MCTL DATA SHEET 18.1-12. ACOUSTIC SIGNATURE: ACTIVE SYSTEMS

Critical Technology Parameter(s)	Treatments and/or devices that reduce the acoustic signature. Includes systems to reduce noise from vibration.
Critical Materials	Specialty designed treatment and/or devices for acoustic reduction.
Unique Test, Production, Inspection Equipment	Vessel noise measuring systems. Acoustic noise measurement, monitoring systems and techniques.
Unique Software	Specially designed software for active component design, placement, and control of the subsystem. Specially designed software.
Major Commercial Applications	Vibration suppression systems for commercial shipbuilding. Human factors noise reduction.
Affordability Issues	Limited commercial applications may help control costs.
Export Control References	WA ML 17, 21, 22, WA Cat 1C, 2E, USML XIII.

MCTL DATA SHEET 18.1-13. PREDICTION MODELS MULTISPECTRAL SURFACE AND SUBSURFACE VESSELS

Critical Technology Parameter(s)	Models to predict acoustic and multispectral signatures in the ocean environment. Models to optimize signature and predict the vessels signature.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Measurement systems specifically for material characterization in marine environment.
Unique Software	Algorithms specially for modeling marine vessels. Empirical data bases and the validated model algorithms.
Major Commercial Applications	Limited commercial use.
Affordability Issues	The lack of commercial applications mean that most of the codes developed are funded by the military, military contractor IRAD, or developed as part of academic research in marine technology.
Export Control References	WA ML 9, 21, 22, USML Cat VI.

MCTL DATA SHEET 18.1-14. PASSIVE MOUNTS AND SUPPORTS

Critical Technology Parameter(s)	Addresses mounts for acoustic isolation and components for vibration isolation. Specifically designed supports or enclosures for underwater noise reduction.
Critical Materials	State-of-the-art materials.
Unique Test, Production, Inspection Equipment	Vessel noise measurement systems. Sensors capable of measuring acoustic signature and/or target strength.
Unique Software	Specially designed software for analyzing or predicting acoustic signatures. Models to predict acoustic signature of vessel in ocean environment.
Major Commercial Applications	Commercial shipbuilding. Human factors noise reduction.
Affordability Issues	Commercial applications could help reduce the cost of the approaches, though the volume is probably not large at this time.
Export Control References	WA ML 9, 17, 21, 22, USML VI, XIII, CCL Cat 8A, 8D, 8E.

MCTL DATA SHEET 18.1-15. ACTIVE SYSTEMS TO REDUCE OR CONTROL MAGNETIC SIGNATURE

Critical Technology Parameter(s)	Devices or techniques specially designed to reduce magnetic signature of marine vessels.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Magnetic field strength measurement systems. Any special magnetic signature precision measuring equipment.
Unique Software	Computer codes to predict specific techniques that will result in an optimized system design performance and the code is validated by test data or contains test data as a means of prediction.
Major Commercial Applications	None identified.
Affordability Issues	Military applications alone are insufficient to maintain an industrial base.
Export Control References	WA ML 9, 17, 21, 22, MTCR 17, USML VI, XIII, CCL Cat 1C, 2E.

MCTL DATA SHEET 18.1-16. PASSIVE SYSTEMS TO CONTROL MAGNETIC SIGNATURE

Critical Technology Parameter(s)	Specially designed materials, structures, coatings or paints to reduce magnetic signature.
Critical Materials	Materials and coatings which reduce magnetic signature.
Unique Test, Production, Inspection Equipment	Magnetic field strength measurement systems. Any special magnetic signature precision measuring equipment.
Unique Software	Computer codes to predict specific techniques that will result in an optimized system design performance and the code is validated by test data or contains test data as a means of prediction.
Major Commercial Applications	None identified.
Affordability Issues	Military specific applications are the dominate use, and will not support a commercial industrial base.
Export Control References	WA ML 9, 17, 21, 22, MTCR 17, USML VI, XIII, CCL Cat 1C, 2E.

SECTION 18.2—COUNTER LOW OBSERVABLE TECHNOLOGIES

Highlights

- Successful development of counter low observable technologies could, if realized, overbound a huge U.S. investment and key strategies.
- Counter low observable technologies are changing and diffusing at a rapid rate, comparable to low observable technologies.
- Often counter low observable technology improvements are integrated efforts in subsystems, components and data processing.
- Unconventional approaches to counter low observable capabilities are being actively pursued in the United States and in foreign countries.
- The most critical and universal CLO technology is real time advanced computational signal processing. This can take many forms.

OVERVIEW

Counter low observable (CLO) technologies span many disciplines and approaches. Imbedded in most efforts are improvements in electric power generation, antennas and electronically scanned arrays, improved signal-to-noise ratios, and fusion of diverse spectral bands (e.g., IR/EO and radar). Prominent are the technologies for high power transmit/receive modules for electronically scanned arrays, advanced signal processing algorithms to detect very low signal to noise ratios, and multispectral / hyperspectral sensor data fusion techniques as applied to counter low observable.

This section covers selected CLO elements that have been clearly recognized as military critical. Less clear are unconventional approaches such as the recently publicized passive coherent location program being explored by multiple contractors in the United States. Considerable attention is being paid to unconventional ways to defeat signature reduction technologies. An emerging element of counter low observable work is in the infrared and electro-optical combined spectrum, now being realized with the advent of multi passive band sensor arrays.

BACKGROUND

The CLO suite of subsystems includes wideband radars, infrared and electro-optical (IR/EO/laser), visual and acoustics components and avionics systems used to detect signature managed, low observable, air, sea and land based targets. Any significant radar investment in high power transmit/receive modules for electronically scanned arrays or advanced infrared search and track (IRST) sensors / signal processing algorithms are potentially used for counter low observable applications in a militarily critical environment. It is difficult to overstate the importance of doing signal processing in very short time, this is a critical capability. Quantum computing, when realized, is likely to contribute dramatically to CLO capabilities.

Subsystems and components include surveillance sensors, fire control sensors, multi-spectral data fusion and kill chain mechanisms (missiles, directed energy systems, etc.) in the detection, tracking, and destruction of enemy low observable weapons and targets. This includes antennas, electronically scanned arrays, radiating elements, radomes, infrared and electro-optical (IR/EO) search and tracking systems, focal plane arrays, deformable mirrors, IR/EO windows, materials and edge/termination treatments. Typical frequency ranges extend from VHF (100 MHz) through W-band (100 GHz) for antennas, arrays, and radomes used in surveillance radar, fire control radar, electronic warfare, and missile warning applications. Typical infrared and electro-optical (3–12 microns up to visible spectrum) wavelengths for passive surveillance and missile attack warning systems.

LIST OF MCTL TECHNOLOGY DATA SHEETS
18.2. COUNTER LOW OBSERVABLE TECHNOLOGIES

MCTL DATA SHEET 18.2-1. WIDEBAND RADAR

Critical Technology Parameter(s)	CLO technologies include wideband radars components and avionics systems used to detect signature managed, low observable, air, sea and land based targets. Any significant radar investment in high power transmit/receive modules for electronically scanned arrays, advanced signal processing algorithms to detect a low signal in a very high-to-noise ratio environment and multispectral / hyperspectral sensor data fusion techniques may be used for counter low observable applications in a military critical environment. Encompasses surveillance sensors, fire control sensors, multi-spectral data fusion and kill chain mechanisms in the detection, track, and destruction of enemy low observable weapons and targets. This includes antennas, electronically scanned arrays, radiating elements, frequency selective surfaces, radomes, materials and edge/termination treatments. Typical frequency ranges from VHF (100 MHz) through W-band (100 GHz) for antennas, arrays, and radomes used in surveillance radar, fire control radar, electronic warfare, and missile warning applications.
Critical Materials	High power transmit/receive modules. Low loss, broadband circulators/isolators. Wideband, high power radiating elements. High power, high efficiency microdevices. High-speed A/D and D/A converters. Frequency selective surfaces and radomes. Low noise amplifiers. Millimeter wave sources. Special application CLO waveforms. Methods to rapidly steer phased arrays and tailor radar waveforms for low probability of intercept (LPI) detection and tracking of low observable targets. Examples include agile / adaptive beamforming and nulling; super resolution techniques; etc. Non-cooperative discrimination and rapidly detect identification.
Unique Test, Production, Inspection Equipment	Very fine tolerance tooling techniques for manufacture of dense, compact integrated circuits for T/R modules, monolithic microwave integrated circuits (MMIC), high speed A/D and D/A converters, circulators/isolators, periodic and frequency selective surfaces for radomes, and alignment of phased array radiation elements. Inspection equipment to verify and validate position alignment of array element spacing, T/R modules, circulators/isolators and manufacture of frequency selective surfaces.
Unique Software	Source code to optimize special application counter low observable waveforms, space-time adaptive processing, and non-cooperative discrimination and identification algorithms discussed above.
Major Commercial Applications	The military counter low observable community has technologies that the commercial automotive and civilian truck / bus market wants for collision avoidance radars to detect moving objects at night, beyond human visible range.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA ML 15, 21, 22, WA Cat 3, 6, USML XI.

MCTL DATA SHEET 18.2-2. INFRARED, ELECTRO-OPTICAL AND VISUAL

Critical Technology Parameter(s)	Sufficient CLO technologies include infra-red search and track (IRST), infra-red, electro-optical, and visual components, avionics, or imaging systems used to detect signature managed and low observable, air, sea and land based targets. Any significant IR/EO/Visual investment in focal plane or scanning optical arrays, advanced signal processing algorithms for clutter suppression and to detect low contrast targets, or multi-spectral/hyperspectral sensor data fusion techniques may potentially be used for counter low observable applications in a military critical environment. Encompasses surveillance sensors, fire control sensors and kill chain mechanisms in the detection, track, and destruction of enemy low observable weapons and targets. This includes IR/EO/Visual sensors, windows materials and edge/termination treatments. Typical wavelength ranges utilized are short wave (0.7–3 micron), mid-wave (3–5 micron), and long-wave (8–12 micron) infrared, laser and visual spectral bands.
Critical Materials	High speed electro-optical devices. Specific emphasis on optics not available through commercial sources. High efficiency microdevices or other extremely small devices/components used to feed optical focal plane arrays. High-speed A/D and D/A converters. IR/EO windows . Special application CLO waveforms. Non-cooperative discrimination and identification algorithm.
Unique Test, Production, Inspection Equipment	Very fine tolerance tooling techniques for manufacture of dense, compact integrated mirrors/ optics for advanced IR/EO/visual sensors. High precision techniques and materials for fabrication of windows compatible with high performance aerospace applications.
Unique Software	Source code to optimize special application counter low observable waveforms, multi-spectral or hyperspectral sensor data fusion, and non-cooperative discrimination and identification algorithms discussed above.
Major Commercial Applications	Limited commercial applications have been found in situations requiring conformal windows for reduced aerodynamic drag, reduced weight, and/or reduced prime power levels. The military counter low observable community has technologies that the commercial automotive market wants for collision avoidance and infrared / electro-optical sensors to detect moving objects at night, beyond human visible range.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA ML 15, 21, 22, WA Cat 3, 6, USML XI.

MCTL DATA SHEET 18.2-3. ACOUSTIC SYSTEMS

Critical Technology Parameter(s)	CLO technologies include wideband microphone and acoustic components and avionics systems used to detect signature managed and low observable, air, sea and land based targets. Any significant investment in highly sensitive and directive techniques for scanning microphone arrays, advanced signal processing algorithms to detect low acoustic signal-to-noise ratios, or multi-spectral/hyperspectral sensor data fusion techniques may potentially be used for counter low observable applications in a military critical environment. Surveillance sensors in the detection, track, and destruction of enemy low observable weapons and targets. This includes electronically or mechanically scanned microphone arrays. Typical frequency ranges are in the audible spectrum where motor / engine noise is a discriminate at long ranges.
Critical Materials	High power, high efficiency microdevices or other extremely small devices/components used to feed/steer arrays. High speed A/D and D/A converters. Low noise amplifiers used for wideband receivers for surveillance applications. Special application CLO waveforms. Methods to rapidly steer microphone arrays and low signal-to-noise/clutter algorithms.
Unique Test, Production, Inspection Equipment	Very fine tolerance tooling techniques for manufacture of dense, compact integrated circuits monolithic microwave integrated circuits (MMIC), wideband digital acoustic receivers, high speed A/D and D/A converters.
Unique Software	Source code to optimize special application counter low observable waveforms.
Major Commercial Applications	Limited commercial applications have been found except for long range monitoring of voice conversations in police and special intelligence collection applications.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA ML 15, 21, 22, WA Cat 3, 6, USML XI.

MCTL DATA SHEET 18.2-4. PASSIVE COHERENT LOCATION

Critical Technology Parameter(s)	Determine and maintain true location of a target in three-dimensional space to an accuracy of azimuth, elevation and real time track update rate sufficient to allow completion of an accurate kill chain. Practical parameters are on the order of a few hundred meters in azimuth, tens of meters in elevation and subsecond rate of position refresh. Ability to use inputs from disparate sources (e.g. FM, television and cellular phone) drive another parameter for real time fusion of data from multiple sources across a wide range of geometries and signal strengths. This includes specific signal to noise sorting challenges.
Critical Materials	None identified.
Unique Test, Production, Inspection Equipment	Equipment to calibrate antennas and diagnose pattern strength, shape and coverage (reinforcement or cancellation) across different frequencies is key. Computer hardware is readily available and does not require ultimate state of the art capability.
Unique Software	Software for signal processing and integration is the most important feature to making passive coherent location work. Software improvements, coupled with increased hardware speed and capacity support the timely arrival of information at the point of mission execution. Software is both computationally intense and update rate sensitive.
Major Commercial Applications	The technologies for PCL are the same as those used in research in radio astronomy and related fields. Due to the tiny signals in radio astronomy, much of the work needed to support PCL will not be state of the art. There is a potential commercial application in low cost surveillance at small airports.
Affordability Issues	Technologies for the further development of PCL are not expensive. Much of the cost is likely to be borne by unrelated research work. Missile Defense is looking at PCL to support their efforts, and the rate of technical progress is likely to increase as a result.
Export Control References	WA ML 15, 21, 22, WA Cat 3, 6, USML XI.

SECTION 18.3—SYSTEM INTEGRATION TECHNOLOGIES

Highlights

- The United States lead in systems integration is more commanding than in other portions of signature control technologies.
- Systems integration has multiple dimensions of activities that vary as both independent and dependent variables for signature control and constitute “tricks of the trade.”
- Systems integration is a key factor from initial concepts and design throughout the life cycle of LO and CLO systems.
- Systems integration is an exceptionally strong driver for successful adherence to program cost and schedule.

OVERVIEW

Technologies, which integrate LO, and CLO must accommodate considerations of operating environment, threat, required capabilities, and mission (bomb, surveillance, communication suppression, etc.). The integration requires selecting subsystems, which enable satisfactory performance of each mission. Systems integration technologies drive the success of programs in the signature control arena. Defining these technologies is made challenging by their interactive nature. Survivability, logistics and deployability compound the difficulties in accomplishing both generalized and specialized missions. Understanding, description and eventual quantification of integration technologies provides the basis for technology security and for a common understanding of commodities and services which are increasingly important in international trade. This section covers the system integration technologies specifically tailored, developed and/or applied to the world of signature control. These technologies function within an infrastructure of organization and activities, which are, of themselves, integrated at another level of behavior and functionality. No attempt is made to cover the latter. For this section, six functionally related and interdependent technologies have been broken out, in a manner similar to a LO budget tree, which are necessary to achieve and maintain a low system signature through appropriate design, fabrication, test, maintenance and operation of all system elements. They are: planform/outer shape, control surfaces, subsystem apertures, mission equipment integration, propulsion system, and weapons technologies.

BACKGROUND

Combat applications in the last ten years of low and counter low observable technologies have been a fulcrum for U.S. dominance. Capabilities have been so compelling that adversaries have suffered extraordinarily one-sided defeats. In recognition of these results there is an unparalleled worldwide demand for low observable technologies. This demand will increase and the United States will increasingly be driven to share technologies as cost and the need for commonality in coalition operations drive both operational and budgetary concerns. Yet, the ability of the United States to perform systems integration from design to operational support is unique. It is based on some 25 years of accumulated development experience, billions of invested dollars and highly critical analysis of wartime results and costs.

We have not been highly successful at describing and quantifying the technologies for systems integration. A broadly scoped "systems integration" is required to optimize observable, or their opposite, counter low observable systems functions. Systems integration is the complex tasks of both designing in and/or retrofitting LO and CLO technologies and subsystems to a military system be it air, sea, or land. The LO/CLO technologies must become a integral part of the component and system and must function with all other subsystems in the vehicle. While the ideal goal is to optimize the performance of each subsystem as well as the performance of the LO/CLO contributing technologies, classical tradeoffs must be made. The technological advantage held by the U.S. includes the ability to integrate the technologies with subsystems and other systems to achieve maximum performance from all. Using this mix, the U.S. signature control is able to create a potent force mix as demonstrated in the completeness of air superiority during Desert Storm and subsequent operations. Stealth platforms become force multipliers for mixes of forces

Even in retrofitting systems with LO/CLO technologies, the United States has the capability to integrate the technologies without significantly degrading other vehicle performance parameters. We have learned to make the compromises in a manner that maintains the level of basic mission performance for all classes of air, sea, and land systems. There is, however, increasing evidence that foreign nations are investing in integration in a more vigorous fashion. They are trying to understand and apply the insights and knowledge through experience, and are marketing their products.

LIST OF MCTL TECHNOLOGY DATA SHEETS
18.3. SYSTEMS INTEGRATION TECHNOLOGIES

MCTL DATA SHEET 18.3-1. PLANFORM/OUTER SURFACE

Critical Technology Parameter(s)	This addresses the critical area of developing the vehicle shape and the materials/manner of fabricating the exterior surface to meet specific signature requirements and the performance levels expected of the vehicle. It requires a compromise between signature control and system performance. The "know how" to do this effectively is a critical essential factor in designing stealth systems and achieving excellent mission effectiveness. Success requires ability to conduct design, modeling, setup, and production equipment.
Critical Materials	Specific materials and performance parameters are found in Sec 18.1 data sheets. Materials must be selected to maintain electrical continuity control and simultaneously systems requirements throughout the environmental operating extremes of the system.
Unique Test, Production, Inspection Equipment	Precision manufacturing procedures, flush fastener installation techniques. Repair procedures must be developed, which match manufacturing tolerances. In process measure critical electrical and optical parameters.
Unique Software	Tools and source codes to design and shape the vehicle for low observability. Computer source codes and models to design these vehicles. Databases used in the design of low observable vehicles. Source codes that provide the ability to design the alignment fixtures capable of holding cut metal in place while welding. Source codes to convert project designs to optimal plate sizes. Budget codes that define the specific signature levels that each area of the vehicle must achieve, so that the rollup value meets the required vehicle signature level in all categories (IR/EO/RF/etc.). Software to design and fit parts manufacturing that visualizes and checks all processes. Typical software includes modifications and derivatives of special CAD-CAM programs.
Major Commercial Applications	Both composites and metals manufacturing and assembly techniques are well established throughout the industrial community, both domestic and foreign. The precision manufacturing tolerances and flatness requirements are not standard industrial practices and not generally needed for most commercial applications. Unique assembly approaches, driven by these LO needs are not standard in the industrial base.
Affordability Issues	The cost will be driven principally by the industrial production base. Unique fabrication and assembly techniques driven by DoD requirements are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

MCTL DATA SHEET 18.3-2. CONTROL SURFACES

Critical Technology Parameter(s)	This addresses the integration of control surfaces into LO vehicles. While it is probably most critical for air vehicles, similar considerations apply in land and sea vehicles for those external features us similar to air vehicles control surfaces. Successful developers minimize the design compromises between control surface deflections for maneuverability performance and system signature levels through good integration skills.
Critical Materials	Specific materials and performance parameters are found in Sec. 18.1 data sheets. Elastomeric materials, flexible mesh materials.
Unique Test, Production, Inspection Equipment	Precision manufacturing procedures, flush fastener installation techniques. Repair procedures must be developed, which match manufacturing tolerances. In process measure critical electrical and optical parameters.
Unique Software	None identified.
Major Commercial Applications	No commercial applications are known.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

MCTL DATA SHEET 18.3-3. SUBSYSTEM APERTURES

Critical Technology Parameter(s)	This addresses the area of integrating the mission essential equipment and subsystems into the vehicle, performing their function yet maintaining the stealth characteristics of the vehicle. These subsystems control all types of appropriate signatures from the underlying equipment.
Critical Materials	Loaded Sheets and Films. Indium Tin Oxide on Polymers. Deposited metals on substrate. Special attention to materials with electrical properties that eliminate abrupt discontinuities.
Unique Test, Production, Inspection Equipment	Test equipment that measures conductivity/resistivity properties. Inspection equipment that measures same properties.
Unique Software	Unique codes and databases that design optimize electrical interface between components. Codes that quantify desired electrical properties.
Major Commercial Applications	No commercial applications are known.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

MCTL DATA SHEET 18.3-4. MISSION EQUIPMENT INTEGRATION

Critical Technology Parameter(s)	This addresses the area of equipment that is essential to successful operation of various vehicles, and must be properly integrated with the various low observable technologies. Not only must they be integrated into the design, but any special considerations/design features must also withstand operating in air, land, and sea.
Critical Materials	Specific materials and properties are listed in Sec.18.1.
Unique Test, Production, Inspection Equipment	None identified.
Unique Software	None identified.
Major Commercial Applications	No commercial applications are known.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

MCTL DATA SHEET 18.3-5. PROPULSION SYSTEMS

Critical Technology Parameter(s)	Critical to all stealth vehicles is the integration of the propulsion system into the planform, provide all necessary thrust/power, yet maintain overall system signature levels in all categories, especially RF and IR. Many technical disciplines must be integrated together to produce a fully functional, yet stealthy vehicle.
Critical Materials	Specific materials and parameters are found in Sec 18.1.
Unique Test, Production, Inspection Equipment	None identified.
Unique Software	None identified.
Major Commercial Applications	No commercial applications are known.
Affordability Issues	Requirements for DoD is insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

MCTL DATA SHEET 18.3-6. WEAPONS INTEGRATION

Critical Technology Parameter(s)	This addresses the critical area of putting weapons onto or into a vehicle. The signature must be maintained yet the effectiveness of the weapon and accuracy of delivery must not be compromised. Methods to maximize the delivery of weapons with stealth throughout the mission must be designed into the vehicle.
Critical Materials	Material characteristics and parameters can be found in Sec 18.1.
Unique Test, Production, Inspection Equipment	None identified.
Unique Software	Unique software and design techniques/models directly associated with weapons and their integration on various vehicle classes to achieve low signature characteristics.
Major Commercial Applications	No commercial applications are known.
Affordability Issues	Requirements for DoD are insufficient to justify an industrial base adequate to sustain all the desired technical production needed.
Export Control References	WA Cat 8, MTCR 17, USML IX.

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