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# 1 Identification and Significance of the Problem or Opportunity

The Modus Operandi Team proposes to develop a product enabling on-the-move warfighters to securely send and receive information that can be targeted and tailored for sender-specified geographic regions to rapidly react to changing battlefield conditions and deliver battlefield alerts.

## Executive Summary

**The Problem.** The goal of the research and development effort is to build and demonstrate a software product called Geographically-Aware and Targeted Secure Information Dissemination (GATSID). GATSID will enable on-the-move warfighters, equipped with state-of-the-art wireless information appliances (e.g., handheld, commercially-available or militarized, or wearable computers), to securely send and receive information that can be targeted and tailored for sender-specified geographic regions, sectors, or operating areas. GATSID will enable mobile warfighters to rapidly react to changing battlefield conditions by delivering location-specific time-critical battlefield alerts and advisories. It will implement the following capabilities: 1. A geographically targeted information multicast service that enables an application to securely send data directed at mobile appliances situated within a specified geographic area. The area may be specified graphically (e.g., on a mapping display) or by identification label or geographic coordinates. A minimum of one point with operating radius or two or more points to define outer bounds of the affected area. 2. Range-restricted information dissemination service that delivers data securely to eligible mobile appliances within a given range (say 2 kms) of the information disseminator, where the latter could be a mobile wireless appliance itself. 3. “Banner in the Sky” service that allows information to be “posted” within a specified geographic region. The posted information is then delivered securely to any eligible fixed or mobile appliance entering the region. 4. Adaptation and customization of delivered information based on user’s profile, user’s device, and wireless link capacity. In the GATSID concept, the mobile warfighters are equipped with wireless information appliances such as smart phones that support two capabilities: 1) a position location mechanism (e.g., a Global Positioning Satellite [GPS]); and 2) an (Internet Protocol) IP-based wireless interface for connectivity to the military Internet. All communication to and from the mobile appliances is thus accomplished over IP. A non-GPS-equipped device may be referenced for another known GPS-equipped device(s). GATSID will address a major aspect

of the challenge of delivering “On-demand Information: “What you need . . . When you need it”. It will enable future situational awareness systems where intelligence and tactical sensor data must be exploited to provide customized, location-specific information to the force. The following paragraphs present example scenarios to illustrate the application of GATSID: Example 1: An unmanned aerial vehicle (UAV) operator performing a reconnaissance mission notices what appears to be a suspicious enemy activity in an area where Special Operations Forces (SOF) operations are ongoing. The pilot can use GATSID to send a targeted warning or alert message to all SOF warfighters in the vicinity of the threat. These warfighters will immediately receive this alert on their mobile appliances and can take necessary actions to counter the threat. Example 2: A first responder to an emergency uses his or her handheld device to broadcast a call for help to medical response teams within a 5 mile radius around the site. All medical response teams receiving the message can respond

### Innovative:

- Enhances assured information sharing in network-centric environments.
- Supports data-at-rest security policies while leveraging emerging encryption capabilities.
- Builds on top of a maturing usage management framework for multi-level security environments.

### Sound Technical Approach:

- Based on open standards.
- Leverages UNM’s demonstrated work in usage management.
- Leverages MO’s proven work in knowledge management.

### Qualifications:

- MO Co-PI has significant experience with information assurance and knowledge management systems.
- UNM Co-PI has considerable expertise in information management and security in networked systems.

### Benefits:

- Dynamically and securely share information with properly credentialed users.
- Deliver the power of information to ensure mission success.
- Create an agile enterprise with freedom of maneuverability across the information environment.
- Leverage legacy system investment.

### Commercialization:

- Applicable in any networked environment where fortifying data-at-rest is needed.

back with the ones closest to the site directed to proceed to the emergency scene.

**PHASE I:** Define, determine feasibility and demonstrate a means to collect and identify potential receiving nodes by class, location, or other means. Provide approach to capture the addresses (all modes) of identified receivers to provide multiple redundant alerts to the selected recipients. Provide demonstration using an accepted geospatial display from Sponsor POC (SPOC) recommended system(s).

**PHASE II:** Construct and demonstrate the operation of a prototype system utilizing one or more handheld devices currently approved for use by USAF or SOF warfighters. Demonstrate capabilities to alert nodes to action for response as well as action to head to safety. Working with the sponsor, utilize these capabilities in one or more approved experiments or exercises.

**PHASE III:** Provide usability assessment of Phase II system for final user interfaces that will engage with existing receiver devices (minimum of 4—one sent from air operations center, one sent to/from SOF/embedded Joint Terminal Attack Controller or similar, and other vignette(s) determined in Phase II).

**The Solution Objective.** The Modus Operandi Team, composed of Modus Operandi (MO) and AHS Engineering Services (AHS), proposes to design, prototype and develop <blah blah> methodology, architecture and prototype. The gizmo uses mission-specific knowledge—including mission vocabularies, grammars and ontologies (semantic models)—to help operators:

1. Do one thing;
2. and another;
3. and another;
4. and another;
5. and another; and
6. even this.

**Our Approach.** Our approach to developing the gizmo is to leverage two critical information integration technologies, usage management and ... focusing on the specific threat prosecution test case and dataset to be provided as GFI in Phase I. .

**Vision and End-State.** The end state of our Phase I research project will be the production of an <blah blah> methodology, architecture and initial prototype that demonstrate the feasibility of our approach for success during Phases II and III. The methodology and prototype will be developed to support the threat prosecution scenario provided by the government, in which we will demonstrate how operators configure the model to support their missions using the Operator's Tool. We will perform initial tests using the scenario data and measure results based on the usability and detect-to-engagement metrics. Finally, the gizmo requirements, design, tool concept and metrics will be revised based on customer feedback. All results will be reported in the Final Technical Report and summarize in the Final Summary Report. Our vision is to develop an intuitive, high-value gizmo framework that can be integrated into the Air Force's <blah blah>. The specific products we propose to produce in Phase I, include:

- A detailed gizmo methodology and gizmo requirements;
- An open, SOA-based gizmo architecture and framework design that leverages the Wave-EF (unstructured data) and WebTAS (structured data) information integration frameworks;
  - Design of extensions to Wave-EF technology needed to support gizmo innovations;
  - An gizmo Threat Prosecution Knowledge Base consisting of the ontology, vocabulary and grammar needed to extract mission-relevant elements of information from text sources;
  - A Mission-Specific RDF triple store that provides an archive of extracted and inferred knowledge for specific mission instances;
  - An Operator's Tool that allows users to configure ASW F2F with the semantic structures required of their missions, to deploy and execute the software, and to provide human-in-the-loop inputs to the system during execution;
  - Services that provide external applications, such as USW-DSS, with access to ASW F2F services

via a service bus;

- A hybrid reasoning architecture that leverages appropriate statistical methods by data type, such as Bayesian Probability and Dempster-Shafer Theory for large amounts of hard (uncertain) data and inferencing rules (or logic) for soft data;
- An initial, highly focused **gizmo** prototype to prove approach feasibility, identify critical research focus areas for Phase II, identify research issues beyond the scope of this effort, and identify tasks that can be automated and those requiring a human-in-the-loop;
- Metrics to determine operator usability and detect-to-engagement improvements;
- Documentation on the **gizmo** methodology, requirements, architecture, and prototype;
- Required CDRLs, reports, and reviews, as well as professional publications.

## Background and Need

As stated in the topic description, the requirement is to “enable on-the-move warfighters, equipped with state-of-the-art wireless information appliances (e.g., handheld, commercially-available or militarized, or wearable computers), to securely send and receive information that can be targeted and tailored for sender-specified geographic regions, sectors, or operating areas.” [9]

## 2 Phase I Technical Objectives

Our project objectives are motivated by the ASW F2F challenges. Accomplishing these objectives will result in the development of a methodology, architecture and prototype for the ASW F2F analysis process and will chart a clear course for our Phase II work plan.

Our Phase I objectives focus on defining the ASW F2F methodology and architecture, as well as developing an initial prototype based on the government furnished threat prosecution scenario and dataset to demonstrate the technological foundation needed to support ASW F2F framework development in Phase II and subsequent Phase III commercialization. Since a comprehensive solution to the challenges introduced above is beyond the scope of a single STTR project, our overarching goals are to (1) develop the ASW F2F methodology, (2) design the ASW F2F architecture framework and (3) demonstrate the feasibility of evolving ASW F2F over time through the incorporation of new methods, capabilities and tools. Our specific technical objectives for the Phase I effort are discussed next.

## 3 Phase I Work Plan

This Phase I STTR will result in the definition of the ASW F2F technical approach and a prototype to demonstrate the key aspects of our approach. These results will be in sufficient detail to show proof-of-concept and demonstrate feasibility for the Phase II project and Phase III commercialization.

Our work plan is fully responsive to the requirements stated in the N11A-T018 topic. By producing a working proof-of-concept, we will in fact achieve more than the requirements of the topic.

### 3.1 Key Aspects and Innovation

Modus Operandi is an experienced and highly capable STTR/SBIR contractor with a proven record of thorough research and innovation, directed toward solving real problems. MO has been active for over a decade in researching the key technologies required in this effort. The University of New Mexico is a Carnegie Very High Research Activity University, and the Informatics Research Group is highly experienced in the areas of machine learning and hybrid intelligent systems. Our approach integrates proven existing technologies with new innovative approaches. The use and leverage of proven technology provides a sound foundation for our technical approach, reducing technical risk, and providing a platform for our key innovations.

### 3.2 Task Summary and Schedule

The proposed Phase I effort is organized into the tasks shown in the Figure 1. Work will be performed at MO's headquarters in Melbourne, Florida and at facilities in the Department of Electrical and Computer

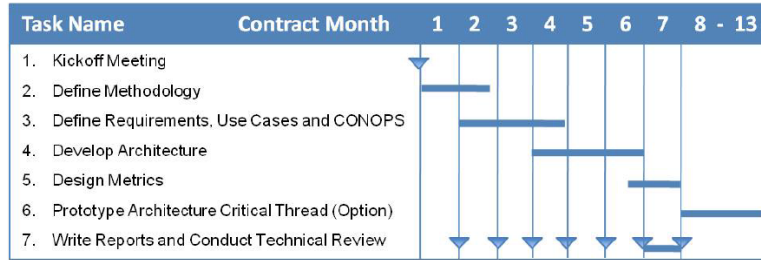


Figure 1: Task and Milestone Schedule.

Engineering at the University of New Mexico in Albuquerque, New Mexico.

- ✓ Innovative <blah blah> Find-to-Forecast methodology for finding “intelligence wheat” and filtering out the “chaff.”
- ✓ Machine learning and hybrid reasoning architecture supports inferencing, statistical processing, and human-in-the-loop inputs.
- ✓ Operator-centric architecture tailors mission-specific information to an AOI.
- ✓ Mission knowledge base to archive and access mission-specific models for enhanced situation understanding that adapts according to previous learning.

### 3.3 Task Details and Technical Approach

Due to space limitations in this proposal, we focus our discussion most heavily on Tasks 2 and 4, defining the ASW F2F methodology and architecture, summarizing the other tasks at a higher level, since these other tasks are derived from Tasks 2 and 4 and are therefore somewhat self-explanatory.

#### Task 1: Kickoff Meeting

We will hold a kickoff meeting either at the customer’s site or at MO headquarters, in Melbourne, Florida, based on customer preference. In this meeting, we will review the proposed technical approach and statement of work and firm up optional portions of our proposal.

#### Task 2: Develop ASW F2F Methodology

Operator’s Need. We propose to develop a detailed ASW F2F methodology in Phase I that can help ASW operators to identify mission relevant information, transform it into a normalized knowledge structure, and then correlate mission-specific information to support more effective situational awareness and understanding. The methodology will include operator inputs to the mission models at design time, execution of ASW F2F, and interactions with the system at run-time. By carefully defining this methodology, we propose to (1) document the concept of operation, (2) identify usability issues and technology gaps, (3) significantly reduce an operator’s workload and, (4) improve his situational understanding by presenting filtered, fused, focused situational information that is highly relevant to his mission.

## 4 Related Work

Modus Operandi is highly qualified to successfully perform this effort based on our years of directly related experience in semantic technologies, data fusion, DOD ISR systems, and with enabling technologies such as service-oriented architecture and net-centric computing. AHS Engineering Services and the University of New Mexico’s Informatics Lab are renowned for research in information security, information theory, and machine learning.

## 4.1 Co-Principal Investigators' Related Experience

We propose Dr. Mark Heileman as MO's Phase I Co-Principal Investigator (Co-PI). Dr. Heileman has extensive experience as a research engineer and software system developer. His technological work has focused on applying artificial intelligence techniques and computer modeling to solve real-world business problems. Some of his early work in this area involved the practical application of expert systems and simulation modeling. More recently his work has involved the development of a trust evaluation framework for use in a layered sensing architecture that is intended to produce actionable situational awareness (the notion of trusted sensing is then built into the layered sensing architecture) [17; 18]. He is currently the Co-PI on both the SMASHUP Phase II SBIR project and the Nublu Phase I STTR project. The SMASHUP research project will result in the development of a formal framework that allows integration via mashups of content from various data sources in a secure manner [19; 20]. The Nublu research project will deliver technological innovations to provide assured information sharing (AIS) capabilities using flexible cloud computing based architectures. A summary resume for Dr. Mark Heileman is provided in Section 7.1. We propose Dr. Gregory Heileman as AHS's Phase I Co-PI. Dr. Heileman has over twenty years of experience as a research scientist, and has published over one-hundred peer-reviewed journal articles and conference papers. His research interests are in the areas of information security and multimedia systems, the theory of computing and information, and machine learning. He serves on the Editorial Board for the International Journal of Multimedia Intelligence and Security. Dr. Gregory Heileman is considered an authority on machine learning and information security [8]. He has published extensively in the area of machine learning, including research that dealt with the capabilities of neural networks, and he has proposed a number of neural network architectures and learning algorithms. Some of his early work in information security dealt with the development of secure container technology at the hardware level (see US Patent 6,731,756) [21]. His subsequent work has involved the development of architectural frameworks in support of access and usage control technologies [22; 23; 24; 25], information forensics [26; 27; 28], and semantics-based information valuation [10; 11; 12]. He is currently the Co-PI on the SMASHUP Phase II SBIR project and the Nublu Phase I STTR project; he will be a Co-PI on the ASW F2F Phase II STTR project. Dr. Gregory Heileman's experience is listed in Section 10.

## 4.2 Modus Operandi Related Work

Modus Operandi, Inc., is an advanced software technology firm serving the defense and intelligence community. We are focused on the development and marketing of technology and solutions that speed information discovery, integration, and fusion. We combine innovative semantic technology with defense sector software systems development experience in the Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) domain.

MO's R&D focus is semantic web technologies with emphasis on semantic enrichment of multi-source data, intelligence fusion, unstructured information, reasoning, semantic integration, and migration of legacy systems to SOA. MO has deep expertise in text analytics, knowledge modeling and reasoning with heavy emphasis on open standards such as Extensible Markup Language (XML), XML Query Language (XQuery), RDF, SPARQL (recursive acronym for SPARQL Protocol and RDF Query Language), Web Ontology Language (OWL), and other semantic Web technologies. We pride ourselves on being a service-oriented company, adapting our wide background of in-depth experience to solve an extensive range of customer problems relating to information discovery and exploitation.

### 4.2.1 Related Work – Corporate R&D and Phase III Commercialization

**Wave Exploitation Framework Technology Portfolio**—MO employs a portfolio commercialization strategy under a single brand, called Wave-EF, to achieve maximum payback for our investment in product management, marketing, and sales. An overarching portfolio roadmap and architecture integrates contributions from numerous SBIR/STTR projects, commercialization partners, and internal R&D efforts. Wave-EF components are targeted at the challenges of processing multi-source intelligence for intelligence exploitation. Wave-EF performs “semantic enrichment” via text analysis and machine reasoning within a scalable, component-based architecture.



#### 4.2.2 Related Work – Research & Development

Summarized below are the R&D projects conducted by MO that address the critical technologies that will enable successful <blah blah> R&D.

**Green Wave: Assuring Trust between the Edges Phase I SBIR**—This project dealt with the problem of delivering universal situational awareness to decision makers, and in particular with the problem of providing a means of quantifying the “goodness” of the various pieces of information contained within a layered sensing framework. Layered sensing is characterized by the appropriate sensor or combination of sensors/platforms, infrastructure and exploitation capabilities to generate that situation awareness and directly support delivery of “tailored effects.” During this research effort we created prototype architecture that supported the gathering and propagating (both forwards, for decision making, and backwards, for post mortem analyses) of trust information computed at various nodes in a network. In addition, we computed trust metrics from this information that could be provided to a decision maker. *Contract Completed January 2009. Customer: AFRL/RBTC, Mr. Jong Hwang. (937) 255-4709 x3591.*

**SMASHUP: A Formal Framework for Secure Mashups Phase II SBIR**—The recent development of mashup technologies now enables users to easily collect, integrate, and display data from a vast array of different information sources available on the Internet. The ability to harness and leverage information in this manner provides a powerful means for discovering links between information, and greatly enhances decision-making capabilities. The availability of such services in a DOD environment will provide tremendous advantages to the decision-makers engaged in analysis of critical situations, rapid-response, and long-term planning scenarios. In this research project, we have developed a framework that will allow integration via mashups of content from various data sources in a secure manner. The framework is based on mathematical logic wherein data units are wrapped in policies that provide rules over the manner in which information is collected, aggregated, and rendered in different environments. An advantage of this approach is it provides a formal means for controlling the usage of resources within highly complex secure mashups. *Current Contract Awarded May 2011. Customer: AFRL/RIEBB, Mr. Matthew Shaver. (315) 330-3295.*

**Nublu: Assured Information Sharing in Clouds Phase I STTR**—We are developing an assured information sharing framework for cloud-based systems that leverages our ongoing work in the areas of policy-based usage management and semantic interoperability. The development of this framework will involve the creation of a novel approach to information sharing that treats security as a commodity that can be dynamically provisioned within the cloud, along with other cloud resources. Currently, the security of networked infrastructures tends to be managed statically. That is, security requirements are developed and implemented within the networking environment, and all of the information that traverses the network will have these hard-coded security policies applied to it. The research project addresses this issue by logically separating security policies from security implementations within the network. This approach is vital if the true capabilities of the cloud are to be realized in DOD environments; it naturally meshes with the philosophy behind cloud computing. Specifically, the main advantage of cloud systems is the automatic provisioning of resources according to current demands. In a DOD setting there will be multiple missions currently interacting with the cloud infrastructure, and the proposed framework will allow each mission to do so according to the current security demands. *Current Contract Awarded March 2012. Customer: AFRL/RITB, Ms. Virginia Ross. (315) 330-4384.*

**Anti-Submarine Warfare Find-to-Forecast Phase I STTR**—The ASW F2F Project is focused on extracting situational knowledge from unstructured data sources, specifically tactical communications between Seahawk helicopters and the carrier, to fuse with structured data, such as radar and sonar data. This has involved developing a mission ontology for ASW, building a vocabulary for missions, and building specialized grammars for text parsing, tagging, extraction, and normalization as RDF triples. Phase I Contract awarded June 2011. *Phase II Contract Pending Award. Customer: Office of Naval Research, Mr. David McGrane (360) 315-3531.*



#### 4.2.3 Related Work – Technology Transition, Deployment, and Commercialization Opportunities

This section summarizes the technology transition, deployment, and commercialization opportunities for Modus Operandi efforts relevant to the <blah blah> project. Commercialization Partners are discussed in Section 1.

**WebTHREADS**—MO’s Wave text analytics and correlation technologies were integrated into the Web-based Threat HUMINT Reporting Evaluation Analysis and Display System (WebTHREADS), a web-based system for identifying and classifying intelligence reports used by Air Force organizations including the National Air and Space Intelligence Center (NASIC). Wave-EF uses domain-specific vocabularies, grammars, and ontologies to extract fourteen essential elements of information found in military intelligence reports, such as high-value individuals, locations, or events. MO also developed a tool for measuring the effectiveness of knowledge extraction from text, based on a standard text analysis metric, called F Factor Analysis. We plan to use this approach and these technologies to build up <blah blah> mission vocabularies, ontologies, and grammars for <blah blah> knowledge extraction, transformation, and normalization. *Contract Completed December 2010. Customer: Air Force Electronic Systems Center, 630th Electronic Systems Squadron, Jonathon L. Cozad, Lt USAF, (781) 266-0869.*

**Air Force ISR Agency Semantic Analysis Tool (SAT)**—The AF ISR Agency sought to inject new technology for enhanced exploitation of multiple sources of unstructured data [further details classified]. *Contract Completed December 2010. Customer: AF ISR Agency, Mr. John Gormaley (321) 494-0527.*

**DCGS MC Multi-INT Semantics**—On this US Marine Corps project, Modus Operandi leveraged Wave-EF technology to build a DIB-enabled semantic wiki called Tactipedia. Tactipedia provides analysts with semantically integrated, mission-relevant information extracted from text sources. Links among pages (or semantic content) is based on semantic relations within an ontology, rather than hard-wired hyperlinks. In this way, Tactipedia’s semantic model drives meaningful content integration as well as presentation to users. *Phase II enhancement completed November 2011. Customer: USMC LtCOL Scott Camden, (703) 221-0200.*

### 4.3 AHS Engineering Services Related Work

Summarized below are the research projects conducted by AHS Engineering Services and the Informatics Research Laboratory at UNM that address the critical technologies that will enable successful <blah blah> R&D. As all aspects of science and society become increasingly information intensive, the need to understand, create, and apply new methods for modeling, managing, and acquiring information has never been greater. The UNM Informatics Lab, established by Professor Gregory Heileman, has considerable knowledge in the areas of information security, the theory of information, and information architectures [8]. [1, 2, 3, 4, 7, 8, 5, 6].

### 4.4 Other Related Work

The art and science of multisensor data fusion has emerged as the foundation for the development of next generation net-centric decision support systems, including horizontal fusion systems. These decision support systems require the coordination of service-oriented sensors and fusion components. Distributed coordination-based architectures provide a process-to-process communications infrastructure that supports horizontal fusion services. In this paper, the author discusses architectural considerations for distributed service-oriented horizontal fusion including distributed coordination-based architectures, service access, data transformation, adaption, and end-to-end visualization [29].

Machine learning is concerned with the design and development of algorithms that take as input empirical data, from sensors or databases, and yield patterns or predictions thought to be features of the underlying mechanism that generated the data. A major focus of machine learning research is the design of algorithms that recognize complex patterns and make intelligent decisions based on input data. One fundamental difficulty is that the set of all possible behaviors given all possible inputs is too large to be included in the set of observed examples (training data). Hence the learner must generalize from the given examples in order to produce a useful output in new cases [30]. Numerous approaches have been developed ranging from neural network models to more abstract mathematical manipulations which identify numerical similarities. Never-

theless a common theme amongst the varied approaches is that learning techniques incorporate a strategic component to try and yield the best possible decision or classification. The mathematics of game theory formally analyzes strategic interactions between competing players and is consequently quite appropriate to apply to the field of machine learning with potential descriptive as well as functional insights. [7] authors present a game theoretic chip-fire classifier which is an iterated game that is able to perform pattern classification. [10; 11; 12] authors present a graphical-based model for explicit information valuation. The model caters to the subjective nature of information quality by measuring the impact a candidate piece of information may have on a knowledge base representing the recipient's world view. The model is capable of evaluating information semantically at the statement level and is in effect basing information-valuation on information-understanding. However, information value can be computed and predicted using the causal graph model without requiring full logical inference typically needed for information-understanding.

## 5 Relationship with Future Research or Research and Development

Modus Operandi was founded to address the practical application of innovative technologies. As a result, we are committed to the approach described in this proposal and are enthusiastic about its potential. The results of this program will have a significant influence on the future R&D performed by Modus Operandi. Our work on data fusion, semantic interoperability, and machine reasoning efforts, such as SMASHUP, Green Wave, Nublu, and ASW F2F, provides an excellent technical foundation for the Phase I effort. Phase I will demonstrate the feasibility of our approach and will lay the groundwork for the Phase II development and transition. Specifically, upon successful completion of Phase I, we will have: (1) identified the critical aspects of our technical approach, (2) demonstrated the proof-of-concept, and (3) constructed a roadmap for application to Air Force initiatives such as AF DCGS (which includes identifying the applicable clearances, certifications, and approvals required to conduct Phase II testing). Collectively, the anticipated results from Phase I will provide a solid foundation for Phase II. In Phase II, we will build the full <blah blah> framework and apply it to AF DCGS. Phase III would bring this <blah blah> framework to the marketplace (see Commercialization Strategy below). Our successful realization of our Phase I and II objectives and achievement of Phase III commercialization is expected to provide the following benefits to both Government and private sector customers of <blah blah>:

- Improve situation understanding with method and framework that focus on a specific mission to provide highly relevant results.
- Support machine learning and hybrid reasoning methods with extensible, open SOA architecture.
- Leverage legacy system investment with semantic interoperability.

We are confident of our ability to successfully deliver these benefits. As for future R&D, we will seek out ways to extend the scope of <blah blah> to include more sophisticated machine learning and reasoning capabilities.

## 6 Commercialization Strategy

Our overall strategy for achieving technology transition and commercialization success will be to position <blah blah> as a high-value enhancement to our Wave product and related services, thereby leveraging our existing commercialization momentum and resources. Our three-pronged approach to achieving this strategy is to: (1) transition the <blah blah> technology to AF DCGS, (2) deploy the technology to our other existing defense sector customers, and (3) leverage partnerships with prime contractors and commercial software vendors as channels for broader commercialization. Our overall goal is to build a profitable line-of-business while providing high return-on-investment to our Air Force transition customers.

### Phase III Success Indicators:

- ✓ SBIR/STTR Commercialization Achievement Index (CAI) of 90.
- ✓ Annual corporate investment in commercialization initiatives exceeds \$1 million/year.
- ✓ Winner of \$9.3M Phase III contract with Army CECOM in 2004 and \$9.9M Phase III in 2011.
- ✓ Winner of U.S. Small Business Administration Tibbetts Award, recognizing our innovation, economic impact, and business achievements in the SBIR Program.
- ✓ Government prime contractor partnerships with Lockheed Martin, Northrop Grumman, ManTech, L-3 Communications, Booz Allen, SAIC, etc.

**Background.** Modus Operandi's vision is to create solutions that speed information discovery, fusion, integration, and understanding. We combine innovative semantic technology with defense sector software systems development experience in the C4ISR domain. As demonstrated by our SBIR/STTR CAI of 90, we have a track record of successful technology commercialization, particularly with our Wave technology portfolio. Partly as a result of our SBIR/STTR commercialization and technology transfer efforts, our commercial (non-R&D solutions for federal and private sector customers) business base has grown from less than 10% to more than 60% of our company's revenue. The following subsections provide our market analysis and plans for commercialization of <blah blah>.

**Commercialization Strategy.** Our experience has identified two keys to successful SBIR/STTR commercialization: (1) strategic synergy between the SBIR/STTR technology and our core business focus, and (2) strong Phase II/III partnerships. This experience bodes well for the <blah blah> project: first, because of <blah blah>'s direct tie with our strategic focus on the intersection of semantic interoperability and fusion of multi-source information and the needs of the C4ISR community; and second, because the proposed application of the technology directly addresses challenges faced by the Air Force; by our other defense sector customers (i.e., US Army, Marine Corps, NAVAIR, Strategic Operations Command, and Missile Defense Agency); and by our prime contractor (e.g., Northrop Grumman, Lockheed Martin, ManTech, SAIC) and commercial (e.g., Ultra Electronics, Franz, NutraSpace) partners. Our strategy for <blah blah> commercialization will be as an integral part of our Wave product line and associated services. We plan to pursue three paths to commercialization of <blah blah>. All of these paths are already part of our Wave marketing program.

1. Our first path focuses on transitioning the technology to the AF DCGS thereby providing direct ROI for AFRL STTR investment. Our existing knowledge and experience working with the Air Force ISR Agency, the Electronic Systems Center, and the 45-th Space Wing will provide a solid foundation for success in this initiative.
2. Our second path is deployment to our existing DOD customers and prime contractors, leveraging the <blah blah> technology to address both known and anticipated needs they face in the area of machine learning and reasoning.
3. The third path is expanding our business partnerships with prime contractors and commercial software vendors, increasing our market share in the federal sector, and ultimately taking us into the commercial marketplace. We are leveraging our partnership-building experiences to incorporate revenue channel and technology partnerships as a key element in our commercialization strategy.

**Market Need and Size.** Our commercialization strategy consists of two stages. We are currently focused on the first stage, which is establishing Modus Operandi as a premier niche technology solutions provider in the C4ISR market sector. The second stage will be to extend the business partnerships we develop in the first stage to package our Wave technology for the broader federal and commercial markets. We are actively executing a comprehensive business plan which sets forth our strategy and roadmap for our technology, for delivering high value to customers, and for building a successful company. Our first stage market focus is on a niche within the \$16 billion C4ISR market [31]. Although overall defense-related spending is expected to flatten, and likely decline, over the next 10 years, the C4ISR market is projected for continued growth. The overall C4ISR segment is projected to grow at a compound annual growth rate of 2.98% over the next decade [31]. This growth is fueled by the demand for timely intelligence as well as by technology and doctrine factors, particularly the demand for systems interoperability and the emergence of network-centric operations. Within these overall market segments, relevant niche markets for

Table 1: Actual and projected commercialization achievements.

Description	Timeframe	Amount	Comments
Working Capital: Funds Raised	2005	\$450M	Raised in April 2005 through sale of non-core technology to a commercial firm.
Current Working Capital Assets	2012	\$2M+	Existing capital resources.
Customer Investments (USAF 45th Space Wing, AFRL, AFTAC, AF ESC, Marine Corps, CECOM and PEO IEW&S)	2004-2012	\$7.6M	\$4.6M customer/investor funds and \$3M matching/add'l funds and CPP fund on related Phase II SBIRs with USAF and Army.
Modus Operandi IR&D Investment	2012-2015	\$250K	Estimated funds from additional Modus Operandi IR&D investment.
Additional Phase II/III 3rd-Party Investment	2015-2016	\$2-3M	Anticipated from early adopters and business partners.
Ramp-up Period Revenue	2016-2017	\$500K increasing to \$3M annually	A 2-year ramp-up is projected.
Full Scale Sales & Marketing	2018 and beyond	\$3+M annually out of \$20M total	Based on direct sales and co-marketing initiatives. See assumptions below.

Key Assumptions: (1) Revenue includes both product licenses and related services. (2) MO participates as a partner in \$500 million of prime contractor/partner orders annually by 2018. (3) MO's revenue participation averages a minimum of 4% (\$20 million annually by 2017). (4) The revenue share attributable to <blah blah> is 15% (\$3 million annually). (5) Excludes revenue from commercial markets.

Modus Operandi include Big Data, data discovery/integration/sharing, unstructured data analytics, multi-source intelligence analysis, and situational awareness, with concentration on the needs of U.S. DOD and intelligence community. Our preliminary estimate of the size of the MO-addressable portion of this market niche (comprised of R&D, acquisition, and sustainment programs) is \$500-800 million annually.

**Projected Commercialization Results.** Using our three-pronged strategy, we project achievement of the results shown in the Table 1. (Note: Our commercial market potential is not included, and offers the potential to significantly increase these estimates.)

## 7 Key Personnel

Modus Operandi prides itself on teaming superbly qualified personnel for all of our projects.

All key personnel are United States citizens. We propose Dr. Mark Heileman and Dr. Gregory Heileman as Phase I Co-Principal Investigators. Dr. Mark Heileman's biography and résumé are below. Dr. Gregory Heileman's biography and résumé are in Section 10.

- ✓ Dr. Mark Heileman has extensive experience as a research engineer and software system developer. He has focused on applying advanced information technology and modeling to solve real-world business problems.
- ✓ Dr. Gregory Heileman is a recognized leader in machine learning and directs the Informatics Lab at the University of New Mexico where he is Associate Provost and Professor in the Department of Electrical and Computer Engineering.

### 7.1 Modus Operandi Key Personnel Biography

**Co-Principal Investigator. Dr. Mark Heileman** is a Senior Scientist at Modus Operandi. Dr. Heileman's over thirty-year career includes engineering and executive positions with Elisar Software Corporation, i2 Technologies, United Space Alliance, Rockwell International, and Harris Corporation. His mission is to focus on the client's challenges and employ a consultative, systems engineering approach to solve complex

business needs. Dr. Heileman is a graduate of the University of Central Florida where he earned a Ph.D. in Industrial Engineering and Management Systems. He is a registered professional engineer in Florida.

## 7.2 Co-Principal Investigator Résumé

**MARK D. HEILEMAN**

**SENIOR SCIENTIST**

### TECHNICAL EXPERTISE:

- Enterprise Information Systems
- Digital Rights Management
- Cyber Security
- Expert Systems
- Data Aggregation
- Simulation and modeling

### SELECTED PUBLICATIONS:

1. Heileman, M., G. Heileman, M. Shaver, P. Jamkhedkar, and M. Gilger. SMASHUP: Secure Mashup for Defense Transformation and Net-Centric Systems. Prepared for SPIE Defense, Security, and Sensing 2011 Conference, Orlando, FL, 25–29 April 2011.
2. Heileman, G. and M. Heileman. Method and Apparatus for Integrating Subjective Trust Measures into Automated Decision-Making Processes. Provisional Patent Application, USA, submitted 19 May 2010.
3. Heileman, M., G. Heileman, and J. Hwang. Integrating Subjective Trust into Networked Infrastructures. Prepared for Systems & Software Technology Conference (SSTC) 2009, Salt Lake City, UT, 20–23 April 2009. Hull, R., K. Bimson, M. Heileman, R. Hyle, and R. Thiebauth. Semantic Service-Oriented Architecture for Range Operations: Evolving the Role of Semantics in the Enterprise. Prepared for SPIE Defense, Security, and Sensing 2009 Conference, Orlando, FL, 13–17 April 2009.
4. Goldstein, H., G. Heileman, M. Heileman, et al. Protecting Digital Archives at the Greek Orthodox Archdiocese of America. Prepared for DRM'03, Washington, DC, 27 October 2003.
5. Linton, D., S. Khajenoori, M. Heileman, J. Bullington, H. Cat, K. Halder, G. Hebert, and S. Sinnappan. “Reporter Object: An Analysis Module Which Aids in Verifying, Validating and Graphically Displaying Results of Simulation Models,” Simulation, Vol. 62, No. 5, May 1994, pp. 313–328.
6. Heileman, M., D. Linton, and S. Khajenoori. “Simulation Study Aids Space Shuttle Flight Rate Planning,” Industrial Engineering, Vol. 24, No. 3, March 1992, pp. 58–59.

### RELEVANT EXPERIENCE:

**Modus Operandi, Inc., 2004–present. Senior Scientist.** A software company serving the US defense and intelligence community by providing technology to speed information discovery, integration, and fusion. Directs the design and development of innovative information system technologies and their application to government and industry needs.

**Elisar Software Corporation, 2001–2003. Vice President, Sales Engineering.** A venture capital financed start-up software company providing digital rights enforcement products and services. Initiated the Sales Engineering function, which had primary responsibility for driving customer and market requirements into the internal development process.

**i2 Technologies, 1997–2001. Senior Solution Consultant.** A business software and services company providing supply chain management solutions to customers worldwide. Provided technical leadership throughout software products sales cycles.

**EDUCATION:** **Ph.D.**, Industrial Engineering & Management Systems, Univ. of Central Florida (1997).  
**M.S.**, Engineering Management, Florida Institute of Technology (1990).  
**M.B.A.**, Business Administration, Florida Institute of Technology (1985).  
**B.S.**, Industrial and Systems Engineering, University of Florida (1980).

**AFFILIATIONS:** Registered Professional Engineer, State of Florida (P.E. #35539).  
 Senior Member, Institute of Industrial Engineers.  
 Member, International Council on Systems Engineering (INCOSE).  
 Security Clearance: DOD Top Secret/SCI/SI/TK/G/HCS.

## 8 Foreign Citizens



We do not expect to involve any foreign citizens on this project.

## 9 Facilities/Equipment

All instrumentation and physical facilities required to carry out the Phase I effort are available at the Modus Operandi headquarters in Melbourne, Florida and at the University of New Mexico facilities in Albuquerque, NM. MOOs 14,500 sq. ft. facility has a fiber optic Internet connection with a dedicated 4-Mbit bandwidth. Engineering laboratories host shared and project-dedicated resources, including two labs dedicated to classified work at the Secret level. These facilities meet all environmental laws and regulations of federal, Florida, and local governments for, but not limited to, the following groupings: airborne emissions, waterborne effluents, external radiation levels, outdoor noise, solid and bulk waste disposal practices, and handling and storage of toxic and hazardous materials.

## 10 Subcontractors/Consultants

Dr. Gregory Heileman, Co-Principal Investigator, is uniquely qualified for this effort. His active involvement will ensure the success in delivering value to the Air Force Research Laboratory.

**CO-PRINCIPAL INVESTIGATOR. Dr. Gregory Heileman** is the Associate Provost for Curriculum and a Professor in the Department of Electrical and Computer Engineering at the University of New Mexico, with over 20 years of experience as a research scientist, and over 100 peer-reviewed journal articles and conference papers. At the University of New Mexico he teaches courses in the areas of algorithms and data structures, software design, theory of computing, learning theory, and information theory. His research interests are in the areas of information security and multimedia systems, the theory of computing and information, and machine learning. He currently serves on the Editorial Board for the International Journal of Multimedia Intelligence and Security. He is the author of the textbook Data Structures, Algorithms, and Object-Oriented Programming published by McGraw-Hill in 1996. During 1998 he held a research fellowship at the Universidad Carlos III de Madrid, and in 2005 he held a similar position at the Universidad Politénica de Madrid. Dr. Heileman is a senior member of the IEEE. He holds a PhD in Computer Engineering from the University of Central Florida.

### GREGORY L. HEILEMAN

### PROFESSOR AND ASSOCIATE PROVOST

#### TECHNICAL EXPERTISE:

- Machine Learning
- Usage Management
- Information Security
- Data Structures and Algorithmic Analysis
- Theory of Computing and Information

#### SELECTED PUBLICATIONS:

1. C. Vineyard, S.J. Verzi and G.L. Heileman. Neurocomputation by a Neural Chip-Firing Game. Proceedings of the 2012 IEEE World Congress on Computational Intelligence, Brisbane, Australia, June 10–15, 2012.
2. C. Vineyard, G.L. Heileman, S.J. Verzi and R. Jordan. Game-theoretic Mechanism Design Applied to Machine Learning Classification, Third International Workshop on Cognitive Information Processing, Baiona, Spain, May 28–30, 2012.
3. C. C. Lamb, P. A. Jamkhedkar, G. L. Heileman and C. T. Abdallah. Managed Control of Composite Cloud Systems. 6th IEEE International Conference on System of Systems Engineering (SoSE), Albuquerque, NM, pp. 167–172, June 27–30, 2011.
4. M. Martinez-Ramon, V. Koltchinskii, G.L. Heileman, and S. Posse. Classification of Multiple Interleaved Human Brain Tasks in functional Magnetic Resonance Imaging, in G. Camps-Valls, J. L. Rojo-Alvarez, M. Martinez-Ramon, editors, Kernel methods in Bioengineering, Communications and Image Processing, Idea Group, 2006.
5. S. al-Saffar and G. L. Heileman. Computing Information Value from RDF Graph Properties. Proceedings of the 12th International Conference on Information Integration and Web-based Applications & Services,



Paris, Nov. 8–10, 2010.

6. T.-T. Quach F. Perez-Gonzalez, and G. L. Heileman. Model-Based Steganalysis Using Invariant Features. IS&T/SPIE Electronic Imaging Science and Technology: Media Forensics and Security XI (Conference EI120), San Jose, CA, Jan. 18–22, 2009.
7. S. al-Saffar and G. L. Heileman. Semantic Impact Graphs for Information Valuation. Proceeding of the Eighth ACM Symposium on Document Engineering, Sao Paulo, Brazil, pp. 209–212, Sept. 16–19, 2008.
8. S. al-Saffar and G. L. Heileman. Semantics-Based Information Valuation. Proceedings of the 4-th IEEE International Conference on Intelligent Systems IS'08, Varna, Bulgaria, Vol. 1, pp. 6–51–6–58, Sept. 6–8, 2008.
9. M. Martinez-Ramon, V. Koltchinskii, G.L. Heileman, and S. Posse. fMRI pattern classification using neuroanatomically constrained boosting. Neuroimage, 31(3):1129–1141, July 2006.
10. S. J. Verzi, G.L. Heileman, and M. Georgiopoulos. Boosted ARTMAP: Modifications to fuzzy ARTMAP motivated by boosting theory. Neural Networks, 19(2):446–468, 2006.

#### RELEVANT EXPERIENCE:

**AHS Engineering Services, 1997–present. Principal.** A consulting firm offering expert engineering services in areas including software engineering and information security.

**University of New Mexico, Department of Electrical & Computer Engineering, 1990–present. Professor, Associate Provost for Curriculum (current position).**

**Elisar Software Corporation, 2000–2003. Chief Executive Officer and Chairman of the Board.** A venture capital financed start-up software company providing digital rights enforcement products and services.

**EDUCATION:**     **Ph.D.**, Computer Engineering, University of Central Florida (1989).  
                           **M.S.**, Biomedical Engineering & Mathematics, University of North Carolina (1986).  
                           **B.A.**, Biology, Wake Forest University (1982).

**AFFILIATIONS:**   Editorial Board, International Journal of Multimedia Intelligence and Security.  
                           Senior Member, IEEE.  
                           Security Clearance: DOD Secret.

## 11 Prior, Current, or Pending Support of Similar Proposals or Awards

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No prior, current, or pending support for the proposed work.

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- [3] P. A. Jamkhedkar, G. L. Heileman, and C. C. Lamb. An interoperable usage management framework. In *Proceedings of the Tenth ACM Workshop on Digital Rights Management*, pages 73–88, Chicago, IL, Oct. 2010.
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- [7] C. C. Lamb, P. A. Jamkhedkar, M. P. Bohnsack, V. Nandina, and G. L. Heileman. A domain specific language for usage management. In *Proceedings of the Eleventh ACM Workshop on Digital Rights Management*, pages 51–62, Chicago, IL, Oct. 2011.
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