Automated Vehicle Identification at a Distance using Infrared Ray Tracing: Thin-Film Infrared Barcode Retroreflectors

1. COVER SHEET

(see attached)

2. IDENTIFICATION & SIGNIFICANCE OF THE OPPORTUNITY

The objective of this proposal is to demonstrate the feasibility of developing an infrared ray tracing vehicle identification system that uses invisible barcodes to automatically differentiate between like vehicles at standoff distance using light weight, low power, man portable, and off-the-shelf technology, that can be commercialized and useful in both military and law enforcement applications. Given that a successful implementation is likely, there are a number of commercial applications of the technology: rapid vehicle identification for law enforcement, automated vehicle identification for security gates and toll fees, etc….

An Infrared Ray Tracing Identification (IRTI) system allows for targets to be bar-coded with thin-film infrared substrates coated with highly reflective coatings, and designed as infrared retroreflectors, that can be covered with camouflage or color to match the vehicle, without compromising the identification process. The IRTI system will use an infrared source to illuminate the subject target, and properly tagged vehicles, with an infrared barcode, will reflect the uniquely identifying information, which will then be received by an infrared sensor and used to process the information. The IRTI system will be designed with networking capability in mind, so that many IRTI systems could be used collaboratively to increase the functional range and accuracy of the system.

The use of infrared barcodes for uniquely identifying targets has been demonstrated in the article “Design of a Thin-Film Infrared Barcode on a Flexible Substrate” [3]. A flexible thin-film infrared barcode can be successfully designed using a bilayer composition of titanium and amorphous silicon placed on a pliant piece of Kapton substrate. It has been shown that information encoded on the subject barcode demonstrates a high contrast under infrared light, 8 to 12 mm in wavelength, and the barcode information is concealed under visible light. When viewed under visible light the barcode will appear as a blank metal sheet, thus permitting for camouflage coatings. With the rapid emergence of material science it is now becoming technologically feasible and commercially viable to design, develop, and market an infrared barcode vehicle identification system. The ultimate success of this proposal hinges the systems capability to be used commercially; this is because if the system can be made commercially viable

it will reduce the cost of production and thus make it cheaper and less risky for the military and law enforcement agencies to invest in.
This proposal focuses on developing the technology of infrared barcode identification, with emphasis on using passive retroreflective technology, using the fundamental principles of radiometry and ray tracing to identify a uniquely identifying pattern (radiant exitance) given off by illuminating a target with an invisible infrared barcode. The system design and engineering research will focus primarily on collaborative operation of multiple systems to improve range and accuracy, motion tracking, networking, as well as modular design and independent functionality: subject to mobile operations on tactical vehicles and man portable. The primary target areas of the subject IRTI system design and development are on military, law enforcement, and general commercial applications.

2.1 Background

There is an inherent need for vehicle identification, especially in a dangerous environment where, from an extreme perspective, rapid and accurate recognition could mean the difference between life and death. The ability to identify a vehicle at range and label it friend or foe, and authorized or not, has numerous militaristic applications. The effectiveness and safety of military check points could be improved with the use Infrared Ray Tracing Identification (IRTI) systems, and the safety and effectiveness of monitoring stretches of road could also be improved with systems capable of networking.
The foundation of the Infrared Ray Tracing Identification (IRTI) system is radiometry: the science of measuring light. Infrared light has a larger wavelength than visible light and is not as susceptible to interference from dust, rain, or other environmental obstructions; Infrared light is not visible to the human eye, which presents additional benefits when considering covert applications of the system. Modern infrared technology can be highly portable, durable, and cost effective.
Lightweight, rugged modular design of an IRTI system will allow mobile soldiers and tactical vehicles to identify other vehicles, and even friendly troops in combat environments, thus reducing the chance of friendly fire and improving the chances of positively identifying imposter and enemy vehicles. For automated stationary use, i.e. a vehicle checkpoint, an array of infrared sensors could be used in conjunction with motion detectors to identify a subject target vehicle, then illuminate the target to identify it; the results of the identification process could then be relayed back to a computer hub, correlated to confirm the results, which would then be delivered to the troops on guard. Mobile IRTI applications would utilize modern infrared ray tracing technology to automatically identify a friend or foe during combat situations. The ability to network multiple IRTI systems, as well as use the systems independently, provides a broad scope of applications that would increase the probability of usefulness in military applications and increase

the chances of success as a commercially available technology. The system identification system under consideration requires no active components on the target side, not unlike a license plate, and thus as a passive system is applicable for everyday law enforcement.
Law enforcement could be drastically changed and roadside stops made safer and highway patrolling more effective with a rapid IRTI system. Current laser radar technology only provides speed information, but with an IRTI system a police officer could access information about the owner of the vehicle: warrants, criminal history, etc… in the same amount of time. The subject IRTI system could revolutionize law enforcement. The research of the subject system if given to due diligence and provided the proper resources could not only prove a great investment for the Department of Defense, but could help reduce the occurrence of violent traffic stops, prevent the unhindered movement of criminals on highways, and ultimately help put more criminals behind bars.
A retroreflector type barcode is sought to be developed in the Phase I of this research project. A retroreflector is a reflective element that reflects light directly back the direction from which the light came, regardless of the angle of incidence. Retroreflector technology has found many uses in the modern world, including applications in communications and security. However some of the most common applications include Currently, retroreflectors are used in high data communications systems in the Czech Republic.
The potential for reliable and secure communication of identification using retroreflector-based communication devices is currently unrealized. The use of retroreflector based IFF systems has the potential to bring reliable and cost-effective security to forces worldwide.
Retroreflectors utilize multiple internal reflective surfaces, or intelligent lensing of light to reflect light in the direction of its source. Modulation or other alterations to the reflected signal can effectively communicate either constant or time-varying data back to a receiver in an intelligent manner. Harnessing of this property can provide both a reliable, low to zero power means of communicating identification or other data.
Retroreflectors possess the unique property of directing a beam of light back along the incident path utilizing simple optics. This technology is currently used extensively by the Dept of Transportation for roadway signs, road reflectors, license plates, etc.

retro reflectors, how they work, briefly how the been successful
Define fundamental principles of radiometry & ray tracing
Mention examples of successful implementation of Infrared technology for identification:
night vision
heat vision
remote controls

From Wikipedia http://en.wikipedia.org/wiki/Forward_looking_infrared
"A forward looking infrared (FLIR) is the North American English term for a camera that takes pictures using the infrared portion of the electromagnetic spectrum.... Often these contain sub-systems known as Thermal imaging common modules or TICM. FLIRs are often described as "infrared cameras". Since FLIRs use detection of thermal energy to create the "picture" assembled for the video output, they can be used to help pilots and drivers steer their vehicles at night, and in fog, or detect warm objects against a cold background when it is completely dark (such as a cloudy, moonless night). Note that a FLIR's wavelength range differs from a night vision camera, which detects wavelengths up to around 1-1.5 micrometers (slightly higher than the human eye can detect).
There are two basic ranges of infrared. 8-12 micrometer cameras (or "far infra-red" or LWIR) can see engine exhaust, or human body heat a few miles away...
FLIRs are often used in naval vessels, fixed-wing aircraft, helicopters, and armored fighting vehicles. In warfare, they have three large advantages. First, the imager itself is difficult for the enemy to detect. Second, they see heat, which is hard to camouflage. Thirdly, FLIR systems can see through smoke, fog, haze, and other atmospheric obscurants better than a visible light camera can."

radar

· refer to thin-film paper for more ideas
· chemical composition
· Ray tracing is a realistic method for rendering images (or frames) constructed in 3D computer graphics environments. It works by tracing the path taken by a ray of light through the scene, and calculating reflection, refraction, or absorption of the ray whenever it intersects an object in the world — hence the name.
en.wikipedia.org/wiki/Ray_tracing
· ray tracing: A graphical or mathematical approximation scheme for determining the propagation of electromagnetic or sound waves by following the path of rays obeying the laws of reflection and refraction. Applications of ray tracing to atmospheric problems include estimating rainbow angles, determining the characteristics of mirages, and mapping the propagation of sound in the atmosphere and oceans.
amsglossary.allenpress.com/glossary/browse

2.1.1 Current Technology

Currently, IFF systems play an important role in ensuring the safety of friendly combatants and civilians in the modern warfare environment. Reliable and accurate identification of friendlies is a necessity to prevent friendly fire incidents.

Current technology uses mainly active radio identification systems, using a challenge and response system to securely verify the identity of a vehicle. These systems require the use of active devices placed in vehicles, and Current automated vehicle identification relies on a signal being transmitted from inside the vehicle to a sensor. (expand on this topic)
Below is a description of United States Patent 5963129
"The instant invention relates generally to identification systems and, more specifically, to a vehicle identification system able to transmit and receive identification or information on a particular vehicle in transit.

A vehicle identification and information system for obtaining information on a plurality of vehicles is disclosed by the present invention. The system includes an identification unit, a remote unit and a central microprocessor. The identification unit is installed in each of the plurality of vehicles and includes a first receiver for receiving information signals containing information regarding the vehicle from the central computer, a display device positioned on said vehicle for displaying information regarding the vehicle contained within the received information signal and an emergency signaling device for transmitting a distress signal to the receiver for display on the display device. The remote unit is positioned in a monitoring station and includes a transmitter for transmitting an information request signal to the central computer, a receiver for receiving an information response signal from the central computer, a microprocessor for processing the information response signal and a device for displaying the information received from the central computer. The central computer includes a database for storing the information regarding the plurality of vehicles and generates an information signal for transmission to both the identification unit and the remote unit."
Below id a description of United States Patent 6778888
"The present invention is a system and method for collecting data from a transportation vehicle and transmitting the collected data upon demand. A telemetry transmitter is mounted to the vehicle and is attached to a service bus by way of an electronic connector. The telemetry transmitter collects relevant data from the vehicle, including but not limited to, identification number, mileage, fuel level, battery charge level, etc. The transmitter communicates with a server, remotely located from the vehicle, where the data can be accessed upon demand. "

There has been extensive exploration of retroreflective systems for use in IFF applications as described in (4-8); however, there has been little to no work in the development of low cost passive IFF systems. Current retroreflector based IFF systems may either modulate or vibrate the retroreflector in order to communicate data back to a receiving station or unit.

2.1.2 Potential Problems with Current Technology

Expensive process. Must put transmitter in each vehicle. Jamming possible. (put in paragraph form)

Current vehicle identification technology uses RFID (Radio Frequency IDentification) "tags," or units, attached to objects that must be identified. These tags may be placed on license plates, or placed inside the vehicle. These tags require a reader within close proximity to read the tag reliably. Confrontations in 21st century warfare make this distance requirement to both dangerous and unacceptable. Current RFID technology is also susceptible to intentional and nonintentional interference from nearby radio transmitters, affecting the reliability of the system. Current systems also require the placement of a complicated transmission device in each vehicle, making deployment expensive.

The retroreflector based bar code system provides better safety, security, reliability and cost effectiveness over current systems. The use of a license plate mounted IRTI system instead of current RFID based systems provides decreased deployment costs, as installation of a license plate is already required on all vehicles. Troops and civilians are better protected from danger as they vehicles can be positively identified as a friend or foe from significantly greater distances. IRTI systems present greater reliability, as optical transmission of identification data is not affected by radio sources that may interfere with current RFID technology.

2.2 Proposed Technique

The number of applications of this technology is large and thus the electronic and software system design options are varied

list types of barcodes

Various systems for the identification of vehicles will be analyzed, utilizing both infrared sensitive bar codes and retroreflector technology to develop an effective IRTI system. The development of Infrared sensitive bar codes applied to licence plates will be the starting point of an investigation into effective techniques for remote vehicle identification utilizing discrete identification devices. Identification numbers encoded as an invisible bar code on a license plate will prove to be an effective form of vehicle identification. Numbers to be encoded may include unique identifiers, such as VIN (Vehicle Identification Numbers) assigned to each vehicle, enabling real-time interfacing with databases providing information on a particular vehicle, such as vehicle registration or criminal records databases. The availability of such data to law enforcement or other personnel will dramatically increase effectiveness in both criminal detection and tracking, and other public safety applications.

An investigation evaluating the benefits of various types of bar codes will be performed, with analysis of both linear and two dimensional bar codes for identification purposes being examined. The benefits of error correction, partial view identification, and visibility at distance will be considered, while

taking into account various possible military, law enforcement, commercial and other applications.
Security of various systems will be analyzed to determine system susceptibility to detection, counterfeiting, and other vulnerabilities.

2.2.1 Various Utilization Methods of Retroreflectors

Incident signal:
Infrared laser mounted or portable. Scope-type laser for portable use.
Retroreflector:
Due to the flexible nature of a thin retroreflective film, a multitude of possibilities exist for product location and implementation. A license plate with a 1-d or 2-d barcode; decals on the doors, hood, trunk, or top of the car; window stickers; bumper stickers; etc.
Detector:
Long-range infrared camera with signal processor to interpret image.
Identification:
Query database for match. Transmit information to whom it may concern.
Generating a Unique Radiant Exitance

3. PHASE I TECHNICAL OBJECTIVES

The subject IRTI system Phase 1 research will focus on the design and implementation of a rapid and accurate low cost, highly portable vehicle identification system, using highly reflective thin-film infrared substrates with off-the-shelf technology. The concentration of Phase 1 research will be partitioned into two homologous tasks: 1) research of the mathematical and physical complexities of the proposed radiometric system, with focus on environmental modeling to emphasize the ramifications of system design and implementation of both military and commercial applications; 2) research on the engineering aspects of implementing the system with focus on the key specifications: plus 500 meter range, low power AC and DC operation, man portable, and rapid processing with networking capability; 3) develop a sound business plan focused on profitable commercialization on the IRTI system. The use of thin-film infrared barcodes retroreflectors in rapid and covert vehicle identification processes holds promise for both military and commercial applications.
The objective of this proposal is to design a vehicle identification method that improves on the current method. The process that will be followed can be enumerated as follows:
1.Characterize the physical properties of various types of retroreflectors.
2.Determine the optimal frequency of the incident signal based on weather, temperature, and time-of-day.
3.Investigate the ideal method of detection for the reflected signal.
4.Process the reflected signal and interface with software.
5.Investigate effective network models and interfaces for use with detector system.

6.Query database for identification.
7.Transmit identification

4. PHASE I - WORK PLAN

Phase I research will be limited to providing a proof-of-concept for retroreflector methods in vehicle identification. A working prototype will be produced in phase II.

4.1 Task 1

A thorough treatise will be given to the mathematical and physical feasibility of successful retroreflection and detection in a variety of conditions. Ray tracing models will be generated to analyze signal paths, scattering, dispersion and detection intensity based on the chosen retroreflecting method. Once the model has been constructed, an analysis of frequencies will occur to determine the ideal signal to be used in all weather and lighting environments. The choice of retroreflector will greatly depend upon the type of signal used. Therefore, the reflectivity analysis will yield the optimum reflective material to be utilized in conjunction with our signal.

4.2 Task 2

- Engineering design. (outline here)
- Retroreflector implementation type
- Detector design
- Software interface with detector
- Software interface with database(s)
- Print capabilities for custom retroreflectors (e.g. DMV needs to process a license plate based on the VIN. Coating is printed and adhered to plate. ref: lamination machine)

More focus will be devoted to the actual implementation and manufacturing methods of a system under Task 2. An effective IFF system will be designed leveraging knowledge acquired as part of Task 1. Materials and methods of manufacture will be examined, with both material and fabrication costs considered for the following elements:

- Retroreflector
- Detector
- Software system
- Network design
- Vehicle attachment options

Reliability analysis will be performed to estimate defect rates and to estimate accuracy and reliability of a field deployment of the solution.

4.3 Task 3

- Develop business plan
- Project cash flows: cost
- plans to apply for a patent

4.4 Reporting

A day-to-day informal “blog” will be updated daily, available to authorized users/viewers only, and used to track project’s progress as well as keep the program monitor updated, at their convenience. Informal and formal email contacts will be made with the program monitor, usually through the Project Coordinator, to address questions or issues that may arise. Conference calls and monthly technical progress reports will be used to update and ensure all stakeholders are satisfied and confident in the team’s progress. Two official Technical Progress reports will be submitted during the 4 month duration of Phase I of the project: one midway through the period and the other at the end of Phase I. Technical documentation and presentation material will be made as necessary for the meetings in Tampa as well as any other meetings that may arise. During the end of Phase I a project website will be made, authorized users/viewers only, to demonstrate and make readily available the progress made with the research funds, and explain the plans going forward with Phase II.

5. RELATED WORK

The Principal Investigator (PI), W.K. Oxford, has been involved with signal detection and methodology at the National Radio Astronomy Observatory (NRAO), Very Large Array (VLA) and New Mexico Tech Observatory. The VLA provided the platform for radio wave detection and recording, with signal processing conducted at the NRAO. At the New Mexico Tech Observatory, his primary duties included constructing an optical system for detection and analysis utilizing off-the-shelf hardware and software. In his current position, the PI is responsible for modeling waves in a variety of background pressures and densities. He is also in close contact with other research and university scientists that possess extensive signal analysis backgrounds, one of which he is currently involved with developing a explosive shockwave simulation model.

W.K. Oxford is currently working with the Energetic Materials Research and Testing Center (EMRTC), out of Socorro, NM, to develop an accurate close range explosive shockwave model for experimental testing, to be verified with actual explosive tests. The model will simulate the close range dynamics of the explosive shockwave with arbitrary geometry. The model is based on the first-principles of physics and was derived in a purely theoretical manner. His involvement includes the derivation of the arbitrary shockwave divergence and propagation as well as designing the model’s algorithms

Research Scientist, J.C. Hebert, has extensive experience working in government research environment and has been employ

RF NRAO

Telemetric Tracking System

Antenna Design

Another Research Scientist, Baker, to be assigned to this project has been recently involved in the design of a feed for a polarization-steerable aircraft-mounted communications antenna with a team of engineering students. The project is being sponsor New Mexico Tech Electrical Engineering Department and the Big Crow Program Office of the Air Force Materiel Command, out of Kirtland Air Force Base in Albuquerque, NM. This ongoing project has involved extensive simulation, and design analysis using microwave circuit simulation software. The subject microwave circuits under development are specialized feed systems for bidirectional UHF communication. A sound understanding of the fundamental elements of electrical engineering design and test procedures is important to the ultimate success of the project, and

The Project Coordinator,

6. RELATIONSHIP WITH FUTURE RESEARCH OR RESEARCH AND DEVELOPMENT

Development of a new vehicle identification system is necessary in optimizing methods currently in the marketplace. Phase I work will determine the system structure for Phase II construction.

7. COMMERCIALIZATION STRATEGY

The use of vehicle identification has a broad spectrum of applications in law enforcement, toll-way operations, garage door operation, gated communities, gated businesses such as storage facilities, car dealerships, airport security, and a myriad of other fields.

Law enforcement officials will streamline their traffic analysis by scanning vehicles before stopping them on roadways, as well as determining whether the need to stop a vehicle is necessary. Automation of this process will alert traffic officers of potential suspects without the need to manually run the plates of the vehicle. To mirror current traffic light monitoring, the IR/retroreflector system could mail speeding tickets, or warnings, to the offender depending on the seriousness of the infraction. A much more elaborate extension of this idea is to post static systems randomly along roadways to continually scan and monitor speed violators. Implementation of a mobile, or static scanning system would put our roadways in a state of perpetual monitoring.

Toll-way facilities can also scan license plates to determine whether a vehicle has permission to pass a toll-booth without stopping for validation. This system could "piggy-back" off of the Department of Transportation's database referencing capabilities and allow for a unified product among state agencies.

On a smaller scale, garage door manufacturers, gated residential areas, gated businesses, or any other gated facility will be able to automate the pass approval process without delay. This will allow for vehicle inventory

within a gated environment, which will ease inventory control for car dealerships, as an example. Airport security will benefit from this system by scanning vehicles as they enter airport property to determine whether there may be a threat. A series of detectors within the property boundary will allow for vehicle tracking, as well.

8. KEY PERSONNEL

W.K. OXFORD

Principle Investigator

EDUCATION:

M.S, Mathematical Physics, New Mexico Tech, NM 2007

B.S., Mathematics, New Mexico Tech, NM 2001

CURRENT POSITION AND RESEARCH:

W.K. Oxford is a Research Scientist at the Energetic Materials Research and Testing Center (EMRTC) and is the Lead Physicist and co-founder of Dunamai Group LLC. He is currently working with a Lead Scientist at EMRTC to develop an accurate directional wave propagation and reflection in a non-homogeneous medium utilizing geometrical optics and ray-tracing techniques.

RELEVANT EXPERIENCE:

Prior to joining EMRTC and Dunamai Group LLC, W.K. Oxford spent three and a half years working in the physics laboratories for New Mexico Tech. More than two-thirds of his time was vested in studying optics and constructing optical experiments. His experience working for the New Mexico Tech Observatory has equipped him with extensive knowledge of signal detection and processing from both a mathematical and physical perspective. W.K. Oxford's current research with EMRTC has broadened his understanding of wave dynamics: propagation and fundamental behavior of electrical and magnetic waves.

J.C. HEBERT

Research Scientist

EDUCATION:

M.S., Engineering Systems, Colorado School of Mines, CO 2006

B.S., Electrical Engineering, New Mexico Tech, NM 2005

LICENSES:

Engineer in Training (E.I.T.)

NM: No. 6340

Amateur Radio Technician: KE5BGB

CURRENT POSITION AND RESEARCH: Jonathan Carter Hebert is currently working as a Consulting Analyst for an international consulting group in the energy market and finance sector. Jonathan' primary areas of practice are related to electrical engineering, analytical modeling, and project development and finance as it pertains to engineering and energy related projects. As the CEO and co-founder of Dunamai Group he has experience

in project management and resource management. He specializes in electronic system and electrical instrumentation design. His recent activities have included extensive work in electricity price modeling for use in electric generation asset valuation, stochastic cash flow analysis in distributed power generation, humanitarian engineering project design implementing renewable energy systems, communication systems, antenna and feed designs, and multi-layer low-noise electrical circuit board designs.
RELEVANT EXPERIENCE:
Jonathan has extensive experience working in government research environments and has been employed by the Department of Interior, Bureau of Reclamation, as an Electrical Engineer and worked for the National Radio Astronomy Observatory for two years under a senior microwave engineer.
National Radio Astronomy Observatory: Years of experience working in a government lab on the multi-million dollar Expanded Very Large Array (EVLA) project; designed LabVIEW virtual instrument to control a cutting-edge multi-channel RF downconverter; designed low-noise multi-layer analog-to-digital converter board and a power regulator board, both to be used in government research facility (VeryLarge Array); designed microwave power splitters, filters, and couplers.
New Mexico Tech: designed circularly polarized spiral antenna and balun feed for 900 MHz weather balloon telemetry communication system;
Colorado School of Mines: designed LabVIEW virtual instrument to read in waveform file and output to spectrum analyzer for communications laboratory development; developed price forecast for electricity and diesel fuel with Geometric Brownian Motion model and used in Monte Carlo simulation to drive cash flow model to value multiple options of distributed power generation; develop humanitarian project to implement a modular solar power system and a renewable pumping system to deliver clean water to a remote village in Nepal.

L.C. BAKER
Research Scientist
EDUCATION:
B.S., Electrical Engineering, New Mexico Tech, NM 2007
B.S., Computer Science, New Mexico Tech, NM 2007
LICENSES:
Amateur Radio Technician: KE5GJP
CURRENT POSITION AND RESEARCH:
Lee is currently a Research Associate at the Institute for Complex Additive Systems Analysis in Socorro, New Mexico, where he works closely with scientist and professors on government funded complex system modeling research. He is currently designing analysis tools for complex networks, and performing research on properties and analysis of scale-free and small-world networks, for use in national security applications.
RELEVANT EXPERIENCE:

L.C. Baker's strong background in hardware and software design makes him a capable researcher in Phase I of this project and Phase II development. has had previous experience in designing a high power aircraft mounted polarization Ku band satellite antenna. He also has experience in the design of autonomous and "swarm" robotics systems. His considerable involvement with both the Computer Science and Electrical Engineering departments at New Mexico Tech has provided him with a wide variety of experience in these and related fields. Mr. Baker will contribute greatly to the networking and engineering aspects of the project.

J.D. HAYES
Project Coordinator
EDUCATION:
B.S., Basic Sciences, New Mexico Tech, NM 2004
CURRENT POSITION AND RESEARCH: Pankow Special Project LP,
RELEVANT EXPERIENCE:

9. FACILITIES/EQUIPMENT

The Dunamai Group has access to a variety of mathematical and software tools useful for analysis of optical and communications systems. Utilizing extensive computing and simulation resources, and most importantly human resources available through New Mexico Tech and the Colorado School of Mines, the Dunamai Group possesses a unique advantage over competitors; this advantage is primarily founded in the close ties that Dunamai Group members have with the faculty and research staff at these institutions. A close connection to the academic environments at these two science and engineering universities enables the development of insightful and innovative solutions. The use of lab facilities and equipment at these institutions has not been ruled out, and will be negotiated following the awarding of the subject contract.

Additional resources shall be required for completion of the contract, to compliment and expand Dunamai Group's computing resources and lab equipment. These elements will be purchased upon award of the contract. A list of these elements and estimates their respective costs are provided in the attached Cost Proposal.

10. CONSULTANTS

No consultants are presently foreseen for the Phase I program. If a need should arise, Dunamai Group has several well known consultants available from the facilities of New Mexico Tech, University of New Mexico, Colorado School of Mines and other local universities and research institutions.

11. PRIOR, CURRENT OR PENDING SUPPORT

Dunamai Group has no prior, current or pending support for a similar proposal.

12. COST PROPOSAL

See attached.

13. REFERENCES

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6.John E. Nettleton et al, US Patent 5422645: Delayed laser retroreflector pulse technique and system
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8.Clifford W. Kelley, US Patent 5355241: Identification friend or foe discriminator
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11. Stephen F. Jacobs., "Experiments with Retrodirective Arrays", Optical Engineering, Vol. 21, pp. 281-283 (March/April 1982)
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